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ORIGINAL ARTICLE

Radiographic Predictors of Hip Pain in Femoroacetabular Impingement

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Abstract The primary diagnosis of femoroacetabular impingement is based on clinical symptoms, physical exam findings, and radiographic abnormalities. The study objective was to determine the radiographic findings that correlate with and are predictive of hip pain in femoroacetabular impingement (FAI). One hundred prospective patients with unilateral FAI symptoms based on clinical and radiographic findings were included in this study. All patients filled out a WOMAC pain questionnaire. Two independent-blinded surgeons assessed antero-posterior and lateral radiographs for 33 radiographic parameters of FAI. Correlations between pain scores and radiographic findings were calculated. A matched radiographic analysis was performed comparing symptomatic versus asymptomatic hips. Radiograph findings were also compared between males and females. Weak positive correlations were identified between increasing pain scores with radiographic findings of posterior wall dysplasia, presence of a shallow socket, and a more lateral acetabular fossa relative to the Ilioischial line. A symptomatic hip had a lower neck shaft angle, greater distance from Ilioischial line to acetabular fossa and larger distance from cross-over sign to superolateral point of the acetabulum when compared to the asymptomatic hip in the same patient. Symptomatic hips in males had more joint space narrowing, femoral osteophytes, higher alpha angles and larger, more incongruent femoral heads compared to females. Females had more medial acetabular fossa relative to the Ilioischial line and smaller femoral head extrusion index. Similar to other musculoskeletal conditions, radiographic findings of FAI are poor predictors of hip pain.

Keywords femoroacetabular impingement · hip pain · hip radiographic analysis

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Institutional Review Board was obtained. Informed consent was given prior to inclusion in this study by all patients. This study was carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA).

Levels of Evidence: III

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Introduction

Femoroacetabular impingement (FAI) is now recognized as a common pathology in young adults potentially leading to osteoarthritis of the hip [2, 7, 13, 14, 18, 19, 21, 27, 29, 31]. Recently, the use of magnetic resonance imaging (MRI) in the evaluation of hip pain has grown increasingly popular [19]. MRI is useful for evaluating the extension of labral tears and particularly for cartilage wear. However, it has been shown that labral tears in up to 87% of cases coexist with radiographic findings consistent with FAI [10, 32]. It is now postulated that these radiographic abnormalities are the causal agents for labral tears and chondral damage [12]. Therefore, plain radiographs are still the first and most important imaging modality in the management and evaluation of patients with FAI [22] and are routinely used

Table 1 Radiographic measurements

Radiographic findings	Abbreviation	Description
Acetabular/labral ossification	OS	0—normal, 1—ossified, 2—fractured, 3—true os
Acetabular cysts	Ace-SC	0—none, 1—small (≤2 mm), 2—large (>3 mm)
Acetabular fossa relative to ilioischial line	AceF-IIL	0 is lateral, 1 is touching, 2 is medial
Acetabular Length	Ace-L	To Shenton's line/teardrop in mm
Acetabular osteophytes	Ace-Oph	0—none, 1—small, 2—large
Acetabular subchondral sclerosis	Ace-ScS	0—no, 1—yes
Alpha angle	Alpha-A	In degrees
AP trochanter-neck offset	AP-TNO	highest of trochanter to piriformis fossa (mm)
Center of rotation relative to the tip trochanter	COR-GT	+ is valgus, − varus (mm)
Congruency of femoral head	Congruency	0<or 1>2 mm of central
Cross-over sign	COS	0—no, 1—yes
Distance from the acetabular edge to COS	Dis-COS	lateral acetabular wall (mm)
Femoral cysts	Fem-SC	0—none, 1—small (≤2 mm), 2—large (>2 mm)
Femoral head diameter	FH-Dia	In mm
Femoral head extrusion index%	FH-Ex-In	Lateral uncoverage/width
Femoral head sphericity, AP and lateral	FH-Sph	0—yes, 1—no
Femoral osteophytes	Fem-Oph	0—none, 1—small, 2—large
Femoral subchondral sclerosis	Fem-ScS	0—no, 1—yes
Head-neck offset, AP and lateral	AP-HNO	In mm
Herniation Pits, AP and lateral	HP	0—no, 1—yes
Ilioischial line relative to acetabular fossa	IIL-AceF	(−) medial, (+) lateral (mm)
Joint space narrowing	JSN	0—none,1—<2 mm, 2—>2 mm
Neck shaft angle	NSA	In degrees
Posterior wall relative to center of femoral head (CFH)	PW_CFH	Medial is minus, lateral is positive (mm)
Posterior wall sign	PW sign	0—PW is lateral or through the CFH, 1—medial
Prominent ischial spine	PIS	0—no, 1—yes
Sharp's angle	SA	In degrees
Tip of PIS to ilioinguinal line	PIS-Ilio	In mm
Tip of PIS to pelvic brim	PIS-BRIM	In mm
Tonnis angle	TA	In degrees
Tonnis scale	TS	0–3
Trough, AP and lateral	Tro	0—no, 1—yes
Wiberg's center edge angle	CEA	In degrees

to determine the severity of the deformity, the risk of progression and the indications for surgery [1, 6].

Recently, an increased number of radiographic parameters are used to measure and describe cam and pincer pathology such as morphology of the femoral head (Table 1); however, it is unclear which of these findings are considered the most critical and useful in diagnosis of FAI and weather they are clinically relevant or have prognostic value related to hip pain. Our objective was to determine the radiographic findings that correlate with and are predictive of hip pain in FAI.

Materials and Methods

One hundred consecutive patients with diagnosis of unilateral symptomatic FAI were included in this study following appropriate Institutional Review Board approval for a prospective study. The diagnosis was made by the senior attending surgeon based on the patients' clinical symptoms such as groin pain, physical exam of the patient including positive impingement test and internal rotation of less than 10°, the radiographic criteria of cam and pincer lesions [3], and MRI findings of FAI, after the exclusion of the extra-articular causes of hip pain. Of the 100 patients, 44 were males and 56 were females (45 left and 55 right hips). Age range was 13–61 years, with a mean of 34.3 (±11.3)years. Body mass index (BMI) range was 16.8–39.4 with mean of 23.1 (±4.1). All patients (200 hips) had two radiographs performed for each hip including antero-posterior pelvis and cross-table lateral. The definition of symptomatic hips was based on the patients' complains of any discomfort such as pain or stiffness. Inclusion criteria included all patients with unilateral groin pain, a positive impingement test (pain with flexion, adduction, and internal rotation of the hip [7]), internal rotation of less than 10°, and radiographic findings consistent with FAI. Exclusion criteria included prior hip surgery, bilateral hip symptoms and morbid obesity with BMI greater than 40.

Thirty-three radiographic parameters (Fig. 1a and b) were identified and measured using digital radiograph computer software (Spectra, Linköping, Sweden). These radiographic measurements (Table 1) included the cross-over sign (COS), prominent ischial spine (PIS), posterior wall sign, neck shaft angle (NSA), head neck offset (HNO), distance from ilioischial line to acetabular fossa (IIL_AceF) [5, 8, 9, 15, 16, 21, 23, 26, 30]. Nine of these 33 measurements were considered to be associated with FAI (five for pincer and four for cam lesions). All the measurements were done by two independent surgeons (ASR, BS), whom were blinded as to which side was the symptomatic side or to any other patient identifiers. Intra-observer

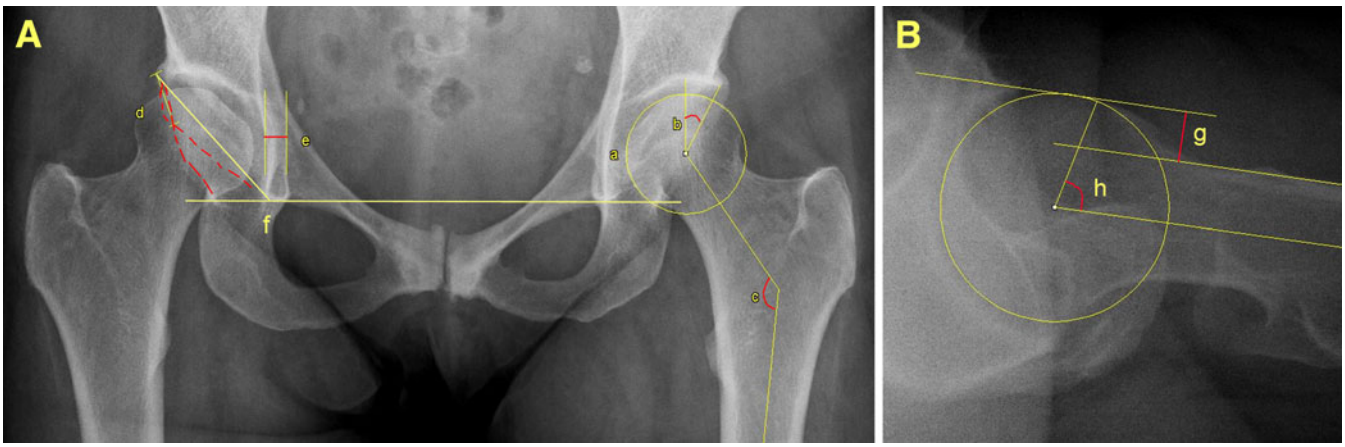

Fig. 1. Sample radiographic measurement of an AP (*1A*) pelvis and cross table lateral (*1B*) radiographs (**a** femoral head sphericity, **b** center edge angle, **c** neck shaft angle, *red dotted line* cross-over sign, **d** distance from the acetabular edge to the cross-over sign, **e** acetabular fossa relative to ilioischial line, **f** Sharp's angle, **g** head-neck offset, **h** alpha angle)

Cohen's kappa was calculated. All patients also completed the Western Ontario and McMaster Universities (WOMAC) pain assessment questionnaire. WOMAC has historically been used for osteoarthritis and now recently been validated for the assessment of FAI [25].

In the first step, correlation between each of the 33 radiographic findings with WOMAC pain scores was calculated using the Pearson's correlation test. Second, a matched radiographic analysis was performed comparing symptomatic versus asymptomatic hips using Student's *t* test or chi-square. Lastly, differences in radiographic presentation of FAI in symptomatic hips were investigated for their relation to gender. All descriptive statistics (mean, SD and mean SE) and calculations (paired Student's *t* test, chi-square, Fisher's exact test and Pearson correlation) were performed with SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Diagnosis of FAI in symptomatic hips included 43 cam, 37 pincer, and 20 cases of combined lesions. The WOMAC pain score ranged from 2 to 86 with mean of 37.5 (±20.7). Ninety-five percent of *n* symptomatic hips had at least one element of FAI in radiographic analysis (14% cam, 23% pincer, and 58% combined). Intra-observer Cohen's kappa was calculated to be 0.8 (range 0.67–1.00, $p<0.001$). We found positive correlations between increasing pain scores with more medial posterior wall relative to center of femoral head (PW_CFH), more lateral acetabular fossa relative to the ilioischial line (AceF_IIL), and presence of posterior wall sign (Table 2).

Several radiographic findings were statistically different between symptomatic and asymptomatic hips. Symptomatic hips present with lower NSA, greater distance from ilioischial line to acetabular fossa and larger distance from the acetabular edge to the cross-over sign compared to the non-symptomatic side (Table 3). Regardless of these differences, none of them was a single strong predictor of pain. Several radiographic findings were significantly present bilaterally, including acetabular sclerosis (75%), joint space narrowing (78%), cyst formation (33%), alpha angle (60%), COS (70%), and PIS (79%).

We found several gender differences in radiographic presentation of symptomatic hips (Table 4). Men presented more frequently with joint space narrowing, femoral osteophytes, non-spherical femoral heads on both antero-posterior and lateral images, larger femoral head diameter, higher alpha angles, and lower center of rotation relative to the tip trochanter compared to females. Femoral osteophytes and herniation pits almost predominantly occurred in male patients. In males, pain scores correlated with more medial PW_CFH and presence of posterior wall sign. Males also reported more pain than females. On the other hand, females presented with smaller Dis_Cos, lower femoral head extrusion index, with more signs of coxa profunda (more medial acetabular fossa relative to the ilioischial line) then males. In females, pain scores correlated with HNO and more lateral AceF_IIL (Table 5).

Discussion

FAI has become recognized as a common patho-anatomical process [2, 7, 13, 14, 18, 23, 28]. While numerous studies document the abnormal radiographic features associated with FAI, it is unclear which of these findings are most important

Table 2 Correlations for pain scores and radiographic findings in symptomatic hips

	Posterior wall relative to center of femoral head (Pearson correlation)	Acetabular fossa relative to ilioischial line (independent *t* test)	Posterior wall sign (independent *t* test)
Pain scores	ρ=0.023 (r=0.226)	ρ=0.01	ρ=0.02

Table 3 Symptomatic vs. asymptomatic hips

Paired *t*-test	Symptomatic side	Non-symptomatic side	ρ Value
Neck shaft angle (degrees)	132.18	133.07	0.005
Ilioischial-line relative to acetabular fossa (mm)	0.23	-0.28	0.022
Distance from the acetabular edge to COS (mm)	20.2	18.5	0.033

Table 5 Correlations with pain scores in males and females

	Males
Posterior wall relative to center of femoral head (Pearson correlation)	ρ=0.001 (r=−0.48)
Posterior wall sign (independent t test)	ρ=0.03
	Females
Head–neck offset (Pearson Correlation)	ρ=0.012 (r=−0.33)
Acetabular fossa relative to ilioischial line (Independent t test)	0.03

and correlate with pain. There is limited data investigating any radiographic differences between symptomatic and asymptomatic hips in a same patient and any gender-specific findings. This prompted our present radiographic analysis to investigate these questions in unilateral FAI patients, compared to their asymptomatic side.

Our data showed weak correlation between pain scores and two findings of posterior wall dysplasia and a relative shallower socket (more lateral acetabular fossa relative to the ilioischial line). These are interesting findings since they are associated with dysplasia and not impingement. It has been documented that patients with symptomatic hips have radiographic findings of both impingement and dysplasia [19]. A potential explanation of this phenomenon may be due to edge loading. Interestingly, our findings suggest that patients with more coxa profunda had less pain. This is different than Reynolds et al. [24] which showed that radiographic evidence of impingement between the femoral neck and anterior acetabular edge, such as a retroverted orientation of the acetabulum, are associated with pain. Another explanation for the lack of a strong correlation is that radiographic abnormalities often do not correlate with symptom severity. This has been shown in hip and knee arthritis and spinal deformities [17, 20]. Djurasovic et al. [4] reported that in the patients who had not undergone prior surgery for spine abnormalities, clinical presentation of symptoms did not correlate with radiographic findings.

Table 4 Radiographic differences in males versus females

Radiographic findings	Male	Female	ρ Value
Presence of Joint space narrowing	29%	11%	0.02
Presence femoral osteophytes	22%	2%	0.002
Number of patients with non-sphericity femoral head in AP or lateral images	25	16	0.006
Femoral head diameter (mm)	58	52	<0.001
Alpha angle (degree)	88°	68.1°	<0.001
Center of rotation relative to the tip of greater trochanter (mm)	−2.0	0.45	0.046
Ilioischial-line relative to acetabular fossa (mm)	1.53	−0.86	0.001
Presence herniation pits in AP or lateral images	18%	2%	0.01
Distance from the acetabular edge to COS (mm)	21.9	17.2	0.039
Femoral head extrusion index	0.17	0.14	0.022
Acetabular length (mm)	75.37	66.64	<0.001
Mean WOMAC pain scores	31.6	42.3	0.009

Although we found several radiographic findings of FAI that were more frequently present in symptomatic hips, all were small differences and none was a single strong predictor for pain. The distance from ilioischial line to acetabular fossa and from the acetabular edge to COS between symptomatic and non-symptomatic hips was 0.51 and 1.7 mm, respectively, which was not clinically significant. The difference in NSA between symptomatic and asymptomatic hips was small and may not seem clinically significant; however, in the setting of a matched pair, this may explain the unilateral nature of symptoms in these patients. Although radiographic findings of bilateral hips may seem similar, we found that symptomatic hips were in more relative varus. In addition, the symptomatic hips had a larger distance from the acetabular edge to the cross-over sign which is potentially indicative of more pincer pathology. Another finding in symptomatic hips was that the acetabular fossa was more lateral to the ilioischial line, which is indicative of releative shallower sockets

In our patient cohort, several radiographic findings were present bilaterally despite unilateral symptoms. These are mostly osteoarthritic finding which includes acetabular sclerosis, joint space narrowing, alpha angle, and cyst formation. Similar to our findings, Allen et al. [1] recently reported 77.8% bilateral radiographic finding of cam-type deformity in a retrospective study of 113 patients, while only 26% had bilateral hip pain. His data showed that most cam lesion although present bilaterally, have unilateral symptoms.

Lastly, we also found several differences in radiographic findings based on gender. Men exhibit more signs of cam characteristics (non-spherical femoral head with larger diameter and higher alpha angle) and females show more signs of pincer (smaller HNO, IIL_AceF and Ace_L). Our findings corroborate with prior studies about gender and FAI [2, 11, 13, 22] and confirms the conclusion made by Allen et al. [1] that men have significantly higher alpha angles than females. We found that femoral osteophytes are almost exclusively present in male patients and significantly correlate with pain, similar to the published data [17, 20]. Neogi et al. [20] demonstrated a strong correlation between presence of osteophytes and knee pain.

There are several limitations to this study which include a limited number of cases, lack of follow-up and no outcome measures. However, our major limitation was that since many of these radiographic findings were rare and subtle, this study may have been underpowered and low intra-observer reliability despite our kappa score. On the

other hand, the strength of our study was the design of a prospective-matched study comparing symptomatic and asymptomatic hips with two independent observers.

In conclusion, there is a poor correlation between pain and radiographic findings of FAI. We did not find a single strong radiographic predictor of pain. There is a unique gender characteristic in FAI radiographic findings.

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