Sonography-Based Determination of Hip Joint Anterior Alpha-Angle: A Reliable and Reproducible Method

Die sonografische Bestimmung des anterioren Alpha-Winkels des Hüftgelenks: eine verlässliche und reproduzierbare Methode

Authors

Christian T. Schamberger[1], Stephan Stein[1, 2], Gerd Gruber[3], Arnold J. Suda[4]

Affiliations

1 Department of Orthopedics and Trauma Surgery, University Medical Centre Mannheim (36642), Mannheim, Germany
2 Medical Faculty, Ludwig-Maximilians-University Munich, Munich, Germany
3 Private Practice, for Orthopaedics and Trauma Surgery, Heidelberg, Germany
4 Department of Orthopaedics and Trauma Surgery, AUVA Trauma Center Salzburg, Salzburg, Austria

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Correspondence

Prof. Arnold J. Suda
AUVA Trauma Center Salzburg
Department of Orthopaedics and Trauma Surgery, Dr. Franz-Rehrl-Platz 5, 5010 Salzburg, Austria
arnold.suda@auva.at

ABSTRACT

Purpose Femoroacetabular impingement (FAI) is a known risk factor for hip osteoarthritis. The gold standard for diagnostics is X-ray and MRI. The accuracy of hip joint alpha angle measurements obtained using sonography is equal to measurements in MRI for patients with cam impingement of the hip joint.

Materials and Methods Patients with hip pain and MRI and sonography were evaluated between January 2015 and December 2019 in a single center. Musculoskeletal sonography was performed according to the DEGUM guidelines by ultrasound-certified specialists. Measurements were repeated three times by two independent investigators.

Results 285 patients were screened, and 110 patients (49 females, 61 males) met the inclusion criteria. The mean age at time of investigation of 54 left and 56 right hip joints was 54.2 years. 1320 measurements were performed. The mean alpha angle was 50.7° in MRI and 50.4° in sonography with a mean difference of 0.28° ($p > 0.05$).

Conclusion Determining hip alpha angle using sonography is a safe and reproducible method. No statistically significant differences between results in MRI and sonography could be seen. Although this is a retrospective, single-center study including only Caucasian mid-Europeans and with the known limitations of ultrasound imaging, it nevertheless shows that sonography can be used as a simple, cheap, and fast technique to assess the hip alpha angle without losing diagnostic quality.

ZUSAMMENFASSUNG

Ziel Das femoroacetabuläre Impingement (FAI) ist ein bekannter Risikofaktor für eine Coxarthrose. Der Goldstandard in der Diagnostik sind Röntgen und MRT. Die Genauigkeit der sonografischen Bestimmung des Alpha-Winkels des Hüftgelenks entspricht bei Patienten mit Cam-Impingement des Hüftgelenks den Messungen in der MRT.

Material und Methoden Patienten mit Hüftschmerzen und MRT und Sonografie wurden zwischen Januar 2015 und Dezember 2019 in einem einzigen Zentrum untersucht. Die muskuloskelettale Sonografie wurde gemäß den DEGUM-Leitlinien von ultraschallzertifizierten Experten durchgeführt. Die Messungen wurden 3-mal von 2 unabhängigen Untersuchern wiederholt.

Ergebnisse 285 Patienten wurden untersucht, und 110 Patienten (49 Frauen, 61 Männer) erfüllten die Einschlusskriterien. Das Durchschnittsalter zum Zeitpunkt der Untersuchung von 54 linken und 56 rechten Hüftgelenken betrug 54,2 Jahre. Es wurden 1320 Messungen durchgeführt. Der mittlere Alpha-Winkel betrug 50,7° in der MRT und 50,4° in der Sonografie mit einer mittleren Differenz von 0,28° ($p > 0,05$).

Schlussfolgerung Die sonografische Bestimmung des Alpha-Winkels der Hüfte ist eine sichere und reproduzierbare Methode. Es konnten keine statistisch signifikanten Unterschiede zwischen den Ergebnissen von MRT und Sonografie festge-

stellt werden. Obwohl es sich hier um eine retrospektive monozentrische Studie handelt mit ausschließlich kaukasischen Mitteleuropäern und den bekannten Einschränkungen der Ultraschallbildgebung, zeigt sie dennoch, dass die Sonografie als einfache, kostengünstige und schnelle Methode zur Beurteilung des Alpha-Winkels der Hüfte eingesetzt werden kann, ohne dass die diagnostische Qualität darunter leidet.

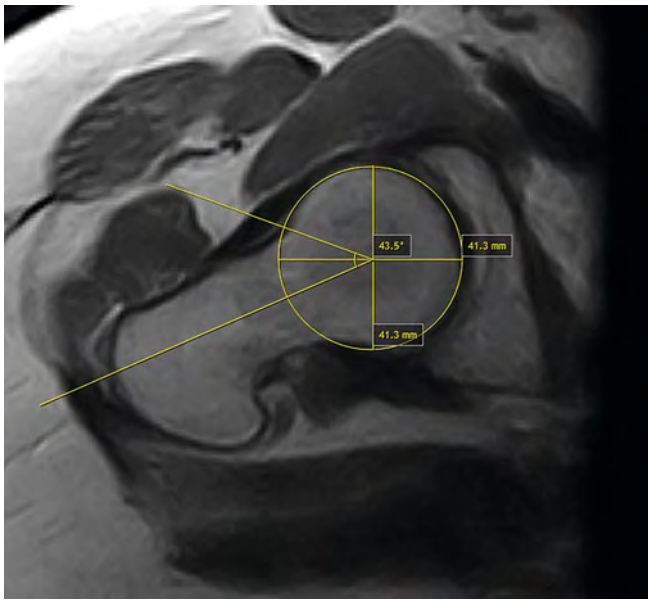
Introduction

Diagnosis of femoroacetabular impingement (FAI) increases in age-independent, hip joint diseases [1]. FAI is defined as pathological contact between the anterior-superior neck-of-femur and anterior acetabular rim with damage of cartilage and labrum. This damage is a known risk factor for osteoarthritis [2, 3, 4]. The number of hip joint arthroscopies because of FAI has recently increased worldwide [1]. For clinical examination and anamnesis, preoperative radiological examination of the hip joint with X-rays in two planes is crucial for further therapy decisions [5]. Determination of the hip alpha angle is a very important tool regarding indication for surgery. This alpha angle is the best-known measurement value for the qualitative description of femoral head form changes [6]. This is the angle between the neck-of-femur long axis and a second line running from the femoral head center to the point where the femoral head shape becomes aspherical. Alpha angles >50° are considered pathological [7]. Usually, the alpha angle is determined using X-rays, computed tomography, or contrast-enhanced magnetic resonance tomography (Arthro-MRI), which can reliably identify cartilage damage and pathological changes of the labrum [6]. The clinical benefit of arthro-sonography in countries with widely used sonographic units is fast, cheap, reproducible, and safe examination without ionizing radiation. In a sonographic assessment of the hip joint, peri-articular changes such as bursitis or pseudo-tumors as well as intra-articular changes such as cortical damage, joint effusion, arthritis, and synovitis can be reliably identified as it follows guidelines and predefined investigation protocols and sectional planes [8]. For the diagnosis of FAI, sonographic assessment compared to MRI has not been evaluated to our knowledge. The aim of this study was to evaluate the reliability of sonographic anterior alpha angle determination compared to MRI in patients with and without cam impingement of the hip joint with the purpose of reducing radiographic examinations and therefore ionizing radiation.

Methods

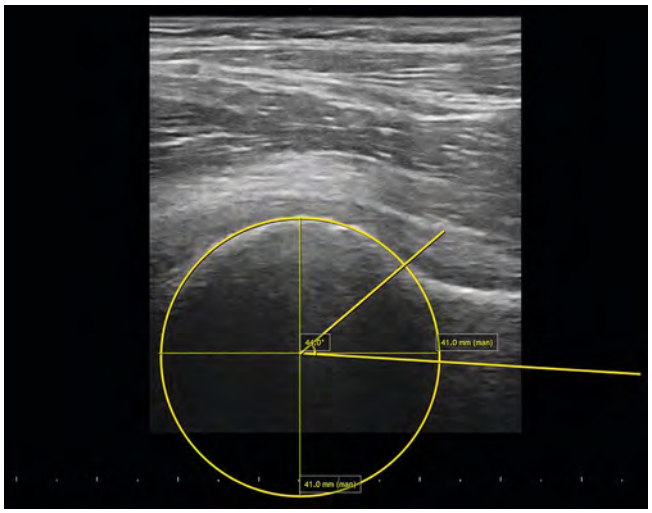
Patients presenting with hip pain who received standardized MRI and sonography of the painful hip joint between January 2015 and December 2019 were included in this study. Exclusion criteria were clear signs of osteoarthritis of the hip in MRI, femoral head necrosis, premature skeleton, recent fractures of femur or acetabulum, presence of hip arthroplasty or any prior hip surgery, anamnestic M. Legg-Calvée-Perthes or epiphysiolysis capitis femoris, and technically insufficient MRI or ultrasound for any reason.

Arthro-MRI of the hip joints was performed using the musculoskeletal MRI 0.3 Tesla S-scan, ESAOTE Biomedica Germany, with standardized layers in TSE- and T1-weighting in coronal, sagittal, and axial planes (▶ **Fig. 1**). Sonographic examination was performed according to the DEGUM (German Society for Medical Ultrasound) guidelines using a linear ultrasound transducer with a

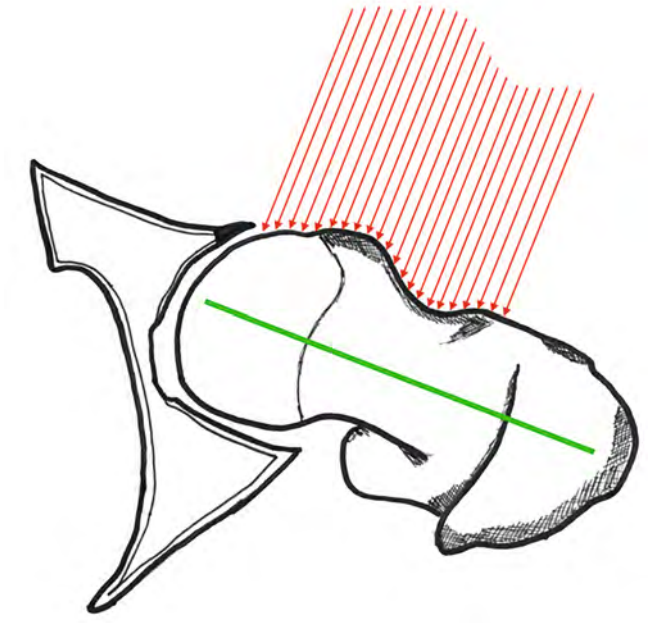


▶ **Fig. 1** Alpha angle determination in MRI, axial view in neck-of-femur axis (T1, 0,25 Tesla, TSE sequence).

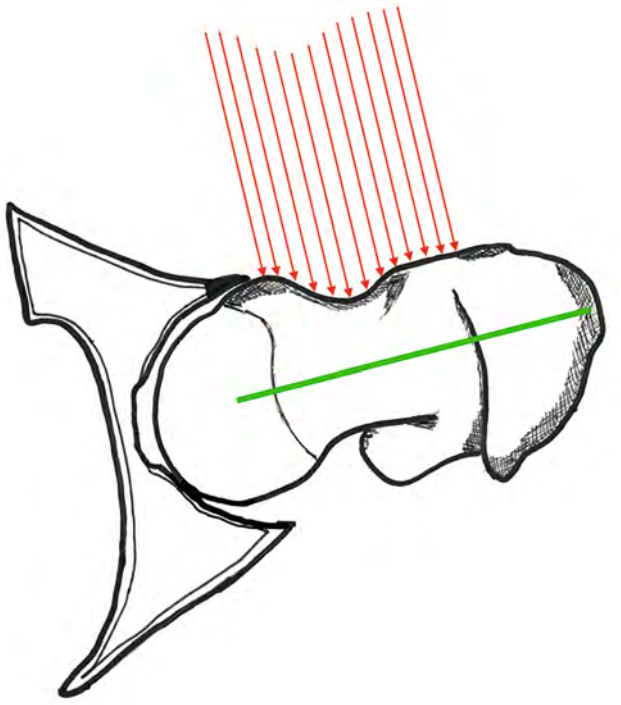
▶ **Fig. 2** Position of patient and transducer in supine position.



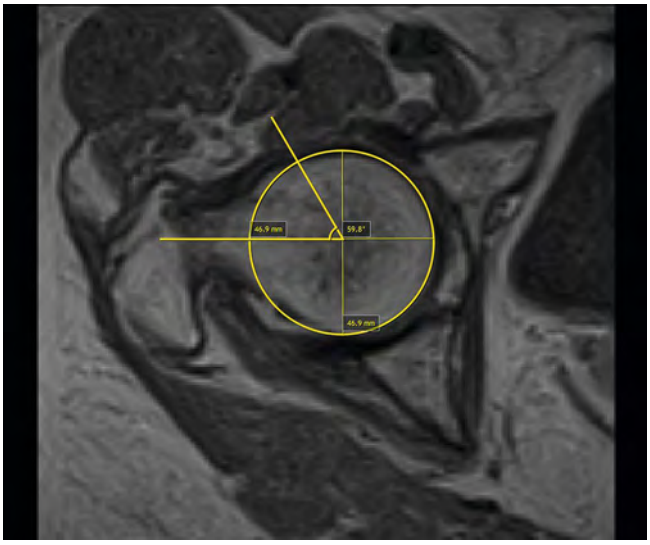
▶ **Fig. 3** Sonographic alpha-angle determination in anterior longitudinal view regarding DEGUM guidelines for the hip joint (supine patient position, 13 MHz transducer).



▶ **Fig. 4** Scheme of cam deformity in axial view and external rotation. Green: neck-of-femur axis, red: ultrasound waves.



▶ **Fig. 5** Scheme of cam deformity in axial view and internal rotation. Green: neck-of-femur axis, red: ultrasound waves.

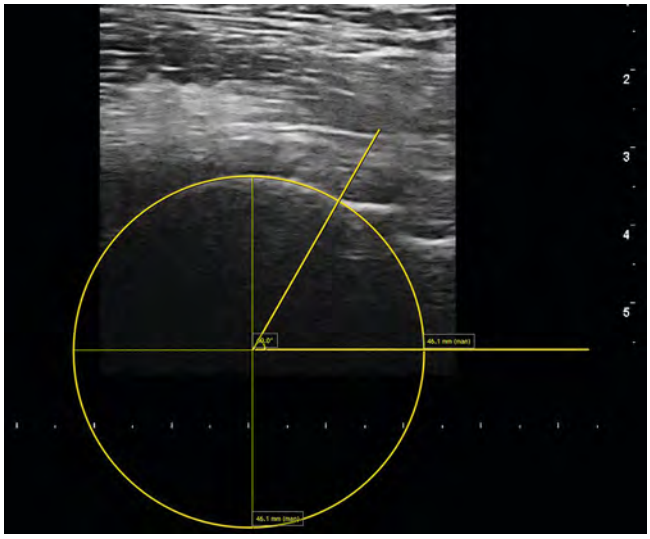


▶ **Fig. 6** Pathological measurement with bump in MRI.

variable frequency of 3.5 to 13 MHz (MyLab Six, ESAOTE Biomedica Germany) [9].

All investigations were performed by a DEGUM-certified specialist in musculoskeletal sonography in 15° external rotation of the hip joint to evaluate the bony bump of the anterior neck-of-femur (▶ **Fig. 2**, ▶ **Fig. 3**, ▶ **Fig. 4**, ▶ **Fig. 5**). The center of the femoral head was defined using circle tools of Syngo imaging software Version VA 26A (Siemens Healthcare, Germany). The first angle side was positioned along the neck-of-femur axis to the center of the femoral head. The second side was positioned at the point where the femoral head shape becomes aspherical, according to Noetzli et al. [7]. The same software and technique were used for the measurement in MRI scan images. The image with largest plain head diameter and the maximum CAM deformity was used for the measurement (▶ **Fig. 6**, ▶ **Fig. 7**).

Evaluation of the measurement results in MRI and sonography was done by two independent investigators, both DEGUM-certified in musculoskeletal ultrasound. Both investigators did time-displaced measurements three times for each MRI scan and each sonogram. Overall, each joint was measured 12 times and the



▶ **Fig. 7** Sonographic image of the hip with bump and angles.

mean of the measurement was used for statistical evaluation using SPSS Version 24 (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY). Using Student´s t-test, $p < 0.05$ was stated to be statistically significant. A power analysis was performed prior to this study with a statistical power of 0.8, a beta of 0.2, alpha of 0.05N> 104 +m according to Green et al. [10]. A positive vote of the regional and institutional ethical committee was obtained.

Results

Between January 2015 and December 2019, 285 patients were evaluated with MRI and sonography for hip joint pain. 110 patients met the inclusion criteria and were included in the study (▶ **Table 1**). The mean patient age was 54.2 years (range: 18 to 81, SD 18.81) with 49 females (44.5 %) and 61 males (55.5 %) in 54 left and 56 right hip joints. 1320 measurements were performed in 110 joints. 45 patients (40.9 %, 17 females = 30 % and 28 males = 45 %) showed pathological hip offset in MRI and 65 patients (59.1 %) did not. The mean alpha angle in MRI was 50.8° (range: 31.3° to 71.5°, SD 8.48), the intra- and interobserver reliability was factual. The mean alpha angle in sonography was 50.5° (range: 31.4° to 69.9°, SD 8.42°). The mean difference in alpha angles in MRI and sonography was 0.27° (SD 1.08°) with a maximal deviation of 3.1° ($p \geq 0.05$). Two outliers could be identified that did not show sphericity in MRI and sonography. Because of physiological joint conditions, the second angle side was difficult to determine, which explains the inaccuracy in these measurements. A Bland-Altman plot shows a high correlation between sonographic and MRI measurement of the alpha angle. Only 6 of 108 measurements (5.5 %) were not found within the default limits. Pearson´s correlation was 0.991 which was statistically significant for both imaging methods. Regardless of the presence of cam deformity, measurements in MRI and sonography showed comparable results. The presence of cam deformity did not influence the accuracy of the measurement, but physiological anatomical conditions with small alpha angles made positioning of the second angle side more difficult compared to aspherical femoral heads as a result of a physical ultrasound phenomenon [9]. Positioning of the legs for measurement is much easier in patients with large cam deformities.

Discussion

In this study, we could show that determination of the hip alpha angle using sonography is a safe and reproducible method. No statistically significant differences between results in MRI and sonography could be seen.

Determination of the alpha angle for qualitative diagnosis of cam impingement is known and widely accepted for therapeutic planning. Barrientos et al. showed in their comparative study of healthy study participants and patients with FAI, that the pathological cut-off point of the alpha angle is 57° and more [11]. A larger angle is casual for pain because of FAI. Smith et al. promoted X-ray in the 45° Dunn technique as a standard procedure to assess cam deformity in FAI in 2018 [12].

Our present study shows that sonography is sufficient to prove cam impingement with qualitative determination of the hip alpha angle without the use of ionizing radiation or expensive MRI. Contrary to the study of Gollwitzer et al. in 2019 with a mean alpha angle of 59° in CT scans, we found a mean alpha angle of 50.3° (50.4° in MRI, 50.2° in sonography) [13]. The reasons remain unknown, but we assume layer thickness, slice axis, or patient bias to be casual for these differences. For FAI diagnosis, MRI and X-rays are accepted as the gold standard. In MRI, small quantifiable differences can be seen [6]. Our current study could show that sonography performed by a certified investigator is also suitable to show these differences around the femoral head and neck and that sonography provides the same measurement results as MRI. There are several advantages of using sonography, such as shorter investigation time, reduced costs, and absence of radiation as well as the fact that the maximum pattern of deformity can be detect-

▶ **Table 1** Alpha angles in MRI and ultrasound (US) examination with differences in degrees.

	N	Mean alpha angle in MRI (°)	Mean alpha angle in US (°)	Mean difference (°)
Male	61	51.4	51.73	0.33 ($p < 0.0001$)
Female	49	49.61	49.42	0.19 ($p < 0.0001$)
All patients	110	50.78	50.51	0.27

ed, whereas there might be a gap between sectional planes up to 3 mm in CT or MRI scans.

In 2016, Lerch et al. published sonographic hip alpha angle assessment compared to conventional hip X-rays [14]. In a small number of patients, the sonographic alpha angle shows a high correlation, as we showed in the current study compared to MRI. Contrary to Lerch et al., we did not use internal hip rotation but rather external rotation for sonographic assessment to provide horizontal neck-of-femur presentation according to DEGUM investigation guidelines of the hip joint, so as to avoid possible false-negative measurement results in FAI diagnosis [9]. Forced internal hip rotation does not lead to better exposure of femoral head asphericity, but rather the bump is more difficult to define because a strict vertical position with respect to the femoral neck cortex of the transducer is needed to enhance ultrasound image quality. Standardized sectional planes according to DEGUM guidelines are mandatory, but 15° external rotation in the hip joint should be ensured.

This study has some limitations:

First, it is a retrospective, single-center investigation including only Caucasian, mid-European patients who were able to present themselves independently. A multicenter/multi-ethnic design could provide larger patient numbers and different results. Second, small labral tears, a relevant Pincer deformity, subchondral tumors, or osteoarthritis grade I cannot be sufficiently visualized using sonography, which could cause misdiagnosis. The purpose of gold standard diagnostics including X-ray of the hip and MRI remains to exclude the diseases mentioned above. Sonography should not replace but rather complement MRI in diagnostics and is an additive investigation, which supports early diagnosis of FAI.

In the current literature, arthroscopic treatment for FAI is recommended after sonographically confirmed diagnosis [1, 15, 16, 17, 18, 19]. MRI detects almost all other pathologies so that native radiography does not show any benefit.

Pincer impingement is rare and occurs in only 7.9 % of cases [20, 21, 22]. Third, patient BMI, body weight, and increased lateral center-edge-angle LCEA were mentioned as risk factors for labral tears, which were not assessed in our study [23, 24]. We are convinced that an influence on measurement accuracy of alpha angle in MRI and sonography is possible, but not relevant.

This study shows for the first time that the hip alpha angle FAI can be reliably determined using sonography. X-rays are not needed, and ionizing radiation can be avoided without compromising diagnostic quality. Sonography should be performed prior to arthro-MRI, if labral tears or cartilage damage is suspected. Standard sonographic assessment of the hip joint is easy to learn and is used widely according to DEGUM standard guidelines for musculoskeletal sonography. Hip joint positioning in 15° external leg rotation is crucial for successful sonographic joint assessment.

We suggest this approach for patients with hip pain (▶ **Table 2**):

1. Clinical examination and anamnesis
2. Sonographic assessment of the hip joint
3. In case of asphericity: MRI
4. In case of normal head-neck contour: radiography

▶ **Table 2** Diagnostic algorithm in the case of suspected FAI.

	Anamnesis, positive clinical findings	
	↓	
	Sonographic assessment of the hip joint	
	↓ ↓	
Asphericity		Sonographic normal head-neck contouring
↓		↓
MRI		Radiography

Because sonography can provide precise asphericity and maximum deformity measurements, radiography should not be the first choice for investigation.

Improvement of sonographic imaging quality will lead to increasing relevance of sonography in FAI diagnostics in the future.

Conflict of Interest

The authors declare that they have no conflict of interest.

Clinical Trial

Registration number (trial ID): DRKS00025175 | Trial registry: Deutsches Register Klinischer Studien | Type of Study: Nicht-interventionell

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