Sonography-based determination of hip joint anterior head-neck offset is reliable and reproducible for CAM deformity assessment

OPEN ACCESS

Authors
Christian T. Schamberger[1], Arnold J. Suda[2], Tobias Grossner[1], Gerhard Schmidmaier[1], Stephan Stein[1]

Affiliations
1 Clinic for Trauma and Reconstructive Surgery, University Hospital Heidelberg, Heidelberg, Germany
2 University Medical Centre Mannheim, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany

Keywords
ultrasound, hip, impingement, MR imaging

received 17.07.2024
accepted after revision 31.12.2024
published online 2025

Bibliography
Ultrasound Int Open 2025; 11: a25377181
DOI 10.1055/a-2537-7181
ISSN 2509-596X

Georg Thieme Verlag KG, Oswald-Hesse-Straße 50, 70469 Stuttgart, Germany

Correspondence
Stephan Stein
Clinic for Trauma and Reconstructive Surgery, University Hospital Heidelberg
Schlierbacher Landstr. 200A
69118 Heidelberg
Germany
stein.nussloch@googlemail.com

ABSTRACT

Purpose Native X-ray, magnetic resonance imaging (MRI), and computed tomography (CT) are standard methods for determining head-neck offset (HNO) in femoro-acetabular impingement (FAI). Our hypothesis was that sonography-assisted determination of the offset in CAM deformity of the hip is a cheap, radiation-free, and reliable alternative to conventional alpha-angle determination.

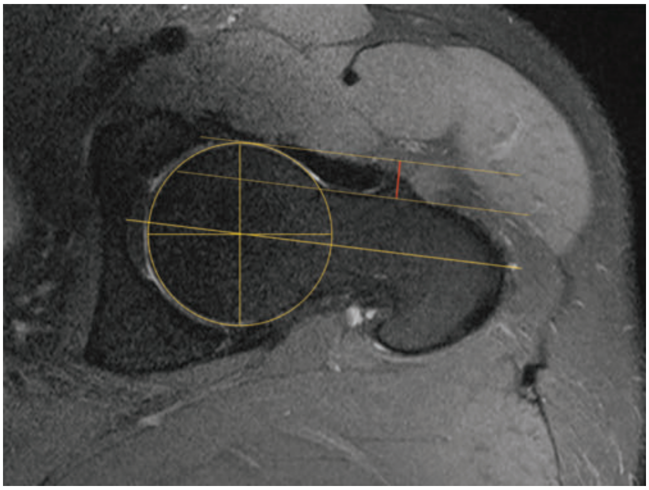
Methods Patients with hip pain and suspected CAM impingement who underwent anterior-longitudinal hip sonography according to DEGUM standard procedures and MRI were included in this single-center study between January 2015 and December 2019. Offset was determined three times on MRI and sonography by two independent investigators.

Results 285 patients were screened and 110 patients (49 females, 61 males) met the inclusion criteria. The mean age at the time of investigation of 54 left and 56 right hip joints was 54.2 years. 1320 measurements were performed. No significant difference in HNO determination between MRI (6.11 mm+/–2.37) and sonography (5.93 mm+/–2.20) could be identified. The mean difference was 0.32 mm+/–0.32 mm ($p > 0.05$) with a maximum deviation of 2.08 mm (outlier).

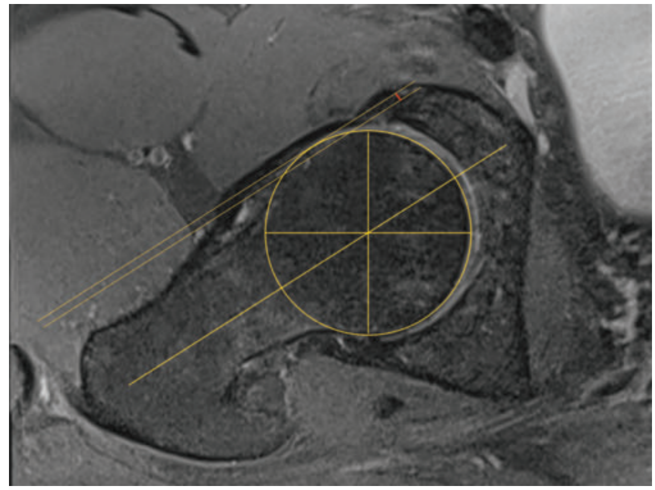
Conclusion Sonography-assisted determination of head-neck offset is a reliable and reproducible method and is not inferior to determination with MRI. Sonography can be used initially as an alternative or additional tool for the qualitative determination of CAM deformity of the hip joint.

Introduction

Determination of the hip head-neck offset (HNO) in patients with suspected femoro-acetabular impingement (FAI) is becoming increasingly important. FAI is known to be a key factor for osteoarthritis of the hip joint [1–3]. In recent years, the indication for FAI-related hip arthroscopy has been increasing [4–7]. Clinical examination, anamnesis, and radiological assessment are crucial for preoperative planning. The HNO is used to quantify the grade of deformity and indication for surgery [8]. The HNO and alpha angle are important parameters for quantitative evaluation of the femoral head [8–11]. The distance between the tangent intersecting the ventral femoral head cortex and a parallel intersecting the femoral cortex where the head contour leaves the head sphericity is measured. Offsets of more than 5 mm qualify as pathologic [1]. The gold standard is to measure the anterior HNO with native X-ray, computed tomography (CT), or contrast-enhanced magnetic res-



▶ **Fig. 1** Offset determination on a MRI on the femoral neck plane with a normal head-neck-offset.



▶ **Fig. 2** Offset determination on MRI on a femoral neck plane with a pathological head-neck-offset.

onance imaging (Arthro-MRI) [9, 10, 12–14]. Arthro-MRI is also able to detect relevant lesions of the cartilage of the hip joint [1, 3].

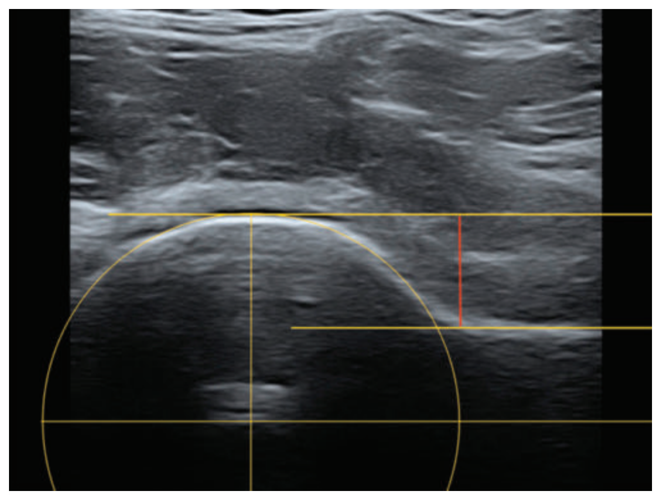
Arthrosonography is widely used in German-speaking countries and is a fast, inexpensive and reproducible examination without radiation exposure that provides diagnostically conclusive results. [15]. Especially in hip sonography, soft-tissue changes such as synovitis, articular effusion, and superficial bone alterations may be identified [15, 16]. According to DEGUM, sonographic planes have been defined [17]. Except for the determination of the anterior alpha angle in femoro-acetabular impingement (FAI), sonography does not play a lead role in HNO diagnostics [15].

The aim of this study was to evaluate the reliability of the sonography-based determination of the femoral anterior head-neck offset (HNO) compared to MRI.

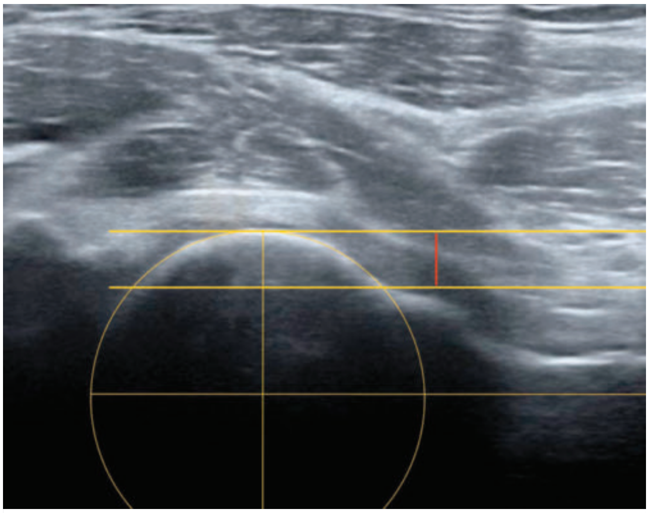
Materials and Methods

Patients presenting with hip pain who underwent standardized MRI and sonography of the painful hip joint between January 2015 and December 2019 were included in this study.

The exclusion criteria were clear signs of osteoarthritis of the hip on MRI, including femoral head necrosis, premature skeleton, recent fractures of the femur or acetabulum, presence of hip arthroplasty or any prior hip surgery, M. Legg-Calvée-Perthes or epiphysiolysis capitis femoris, and MRI or ultrasound examination that was technically insufficient for any reason. Arthro-MRI of the hip joints was performed using the musculoskeletal MRI 0.3 Tesla S-scan device (ESAOTE Biomedica Germany) with standardized layers with PD-fs-weighting in coronal, sagittal, and axial planes. The offset was determined in the axial or the femoral neck plane (▶ **Fig. 1** and **2**). The inclusion criteria were the availability of an MRI examination of the hip joint with PD-fs-weighting and on the axial or the femoral neck plane and a sonographic examination of the same joint on the same day ± 3 days in the modified anterior longitudinal view according to the DEGUM (German Society for Medical Ultrasound) guidelines using a linear ultrasound transducer with variable frequency 3.5 to 13 MHz (MyLab Six, ESAOTE Biomedica Germany): the femoral neck is parallel to the monitor's upper margin, and the bone surface of the femoral neck appears homogenous and hyperechoic [17]. The modified anterior longitudinal view of the hip joint that was used differs from the standard view with a better illustration of the bony bump using a 15 ° external rotation of the hip, and the transducer is strictly placed in an anterior position over the highest point of the femoral head [15–17]. Because of the acetabular rim, the bump cannot be fully seen in the hip's internal rotation, and the measurement of the femoral head cannot be extended to a full circle [15]. First, the femoral neck axis was identified according to Eijer et al. and a parallel tangent to the femoral head's highest point was drawn using Syngo imaging software Version VA 26A (Siemens Healthcare, Germany) (▶ **Fig. 3** and **4**) [9]. That part of the femoral head was extended to a full circle and the point where the femoral head leaves sphericity was determined. Another parallel to the femoral neck axis subtending this point was drawn, and the distance between these two lines was measured:



▶ **Fig. 3** Offset determination in anterior longitudinal section using ultrasound showing a normal head-neck-offset.



▶ **Fig. 4** Offset determination in anterior lingitudinal section using sonography showing a pathological head-neck-offset.

the anterior head-neck offset (HNO) [3, 9, 13, 18]. Evaluation of the measurement results on MRI and sonography was done by two independent investigators, both DEGUM-certified in musculoskeletal ultrasound. Both investigators performed time-displaced measurements three times for each MRI scan and each sonogram. Overall, each joint was measured 12 times (1320 measurements) and the 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. [19]. A positive vote of the regional and institutional ethical committee was obtained.

Results

110 patients (54/49.1 % left joints, 56/50.9 % right joints) with a mean age of 54.2 years (18–81 years, 49/44.5 % females, 61/55.5 % males) fulfilled all criteria and could be included in the study.

On MRI, 87 patients (79.1 %) had a pathological HNO, and 23 patients (20.9 %) had a physiological HNO (36/41.1 % females, 51/58.6 % males). The mean HNO was 6.12 mm (1.19–13.21 mm, SD 2.356; Investigator A: mean 6.13 mm, 1.07–13.50 mm, SD 2.390; Investigator B: mean 6.10 mm, 1.32–12.93 mm, SD 2.324; $p>0.05$).

Using sonography, the mean HNO was 5.94 mm (1.25–11.13 mm, SD 2.204; Investigator A: mean 5.89 mm, 1.22–10.60 mm, SD 2.174; Investigator B: mean 5.97 mm, 1.28–11.66 mm, SD 2.238; $p>0.05$).

Mean difference between measurements in MRI and sonography was 0.18 mm with a maximum deviation of 2.08 mm (SD 0.420).

Using SPSS Statistics (Vers. 27, IBM) homoscedastic independent measures t-test of mean measured values of MRI and sonography showed $p=0.553$ and the difference was not statistically significant. Pearson's correlation coefficient was 0.985, which shows a strong correlation between both methods ($p<0.0001$). Three outliers could be identified: in all three patients, asphericity could be excluded on MRI and sonography, but positioning and drawing of the axis was difficult due to the anatomical nature of the joint, which explains the measurement problems. The Bland-Altman plot shows only 5/110 (4.5 %) of measurements outside the normal limits. Independent of the presence of a CAM deformity, measurements on MRI and sonography showed comparable values. A CAM deformity did not influence the measurement's accuracy. On MRI, there was a tendency towards higher measurement values in 78 patients (70 %), which was a mean value of 0.18 mm and therefore negligible ▶ **Table 1**.

▶ **Table 1** Offsets in MRI and ultrasound examinations with differences in mm.

	N	Mean offset on MRI (mm)	Mean offset on US (mm)	Mean difference (mm)
Male	61	6.06 ± 2.20	5.89 ± 2.03	0.163 ± 0.43
Female	49	6.19 ± 2.42	5.99 ± 2.42	0.206 ± 0.42
All patients	110	6.12 ± 2.36	5.94 ± 2.20	0.182 ± 0.42

Discussion

The results of this study prove that sonography-assisted determination of femoral head-neck offset is a safe and reproducible method compared to MRI. No significant differences in measured angles could be seen between the two methods. The determination of the head-neck offset for qualitative evaluation of CAM impingement is well established for further therapy planning: Eijer et al. evaluated clinical and radiological aspects and showed a cut-off of 7.2 mm as FAI [9]. Smith et al. recommended a 45 ° Dunn-X-ray as the standard procedure for FAI diagnostics in 2018 [20]. In a recently published study, our group showed sonography to be as effective as MRI for CAM deformity detection and reliable for the determination of small changes of the head-neck region, which is similar to the results in our new study [15]. We found a mean head-neck offset of 6.11 mm on MRI and 5.93 mm with sonography, which is different from the results of Jamali et al., who published a mean offset of 8.39 mm on a CT scan [10]. On MRI, even small quantifiable differences can be seen [3, 12–14, 21]. The advantages of sonography are the absence of X-rays, short investigation time, and low costs [15, 22]. Small labral tears or relevant pincer deformities are not easy to illustrate, Nepple et al. showed a coxa profunda as diagnosed with plain X-ray as not suitable for Pincer impingement diagnostics [23]. This study also showed X-ray diagnostic problems in the case of acetabular dysplasia. A subcortical change such as a tumor or cartilage change in osteoarthritis cannot be seen in sonography, whereas X-ray remains an important part of basic diagnostic imaging in hip pain. In 2016, Lerch et al. published sonographic offset determination compared to native X-ray and found a high correlation between the results [24]. Using the sonographic technique described by Lerch et al. in 20 ° internal hip rotation, head asphericity could be missed and the bump is hard to determine. In supine position with minimal (natural, not forced) external hip rotation and transducer's position according to DEGUM, false-negative results due to pseudo-usur phenomenon are minimized [17].

This study has several limitations: First, the retrospective study design – a randomized design could have shown different results. Second, MRI and sonography were performed due to unclear hip pain and not with the aim of CAM impingement illustration in every case. One source of error could be the transducer's position not being above the middle of the highest femoral head point and another source could be the measurements and use of axial MRI views not in the femoral neck axis. In these cases, special software with digital correction was used. This study shows a high correlation with prior published data showing axial MRI views of the femoral neck as a sufficient method for offset determination. Third, Pincer impingement cannot be illustrated because of morphologic acetabular variations with focal or global coverage of the femoral head and impingement. Nepple et al. showed in 2013 that Pincer impingement is rare (7.9 % in 1130 patients) compared to CAM impingement [23].

Several studies identified patient age, weight, and enlarged lateral center-edge-angle LCEA as a risk factor for developing labral tears [12, 21, 25]. Whether there is any correlation between measurement accuracy on MRI or ultrasound and the factors mentioned above remains unclear. Sonographic assessment of CAM impingement of the hip joint should not replace MRI but support FAI diagnostic tools and replace conventional X-ray. The gold standard of FAI therapy is hip arthroscopy [2, 5, 7, 8, 18, 26–30]. For diagnosis, we recommend the following approach in patients with suspected FAI:

1. Anamnesis and clinical assessment;
2. Hip sonography according to DEGUM guidelines;
3. In the case of asphericity or a bump with a pathological head-neck-offset: arthro-MRI with a focus on the labrum and cartilage;
4. In the case of no signs of FAI: X-ray.

Better image definition and quality may increase the relevance of sonographic assessment in FAI in the coming years.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Beck M, Kalhor M, Leunig M et al. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br 2005; 87: 1012–1018. DOI: 10.1302/0301-620X.87B7.15203

[2] Ganz R, Parvizi J, Beck M et al. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res 2003; 112–120. DOI: 10.1097/01.blo.0000096804.78689.c2

[3] Waldt S. Bildgebung des Hüftgelenks beim femoroazetabulären Impingement. Arthroskopie 2019; 32: 86–94. DOI: 10.1007/s00142-018-0254-2

[4] Dienst M, Seil R, Godde S et al. Effects of traction, distension, and joint position on distraction of the hip joint: an experimental study in cadavers. Arthroscopy 2002; 18: 865–871. DOI: 10.1053/jars.2002.36120

[5] Rühmann O, Börner C, von Lewinski G et al. Arthroskopische Behandlung von Verletzungen und degenerativen Läsionen des hyalinen Knorpels, Labrum acetabulare und Lig. capitis femoris. Arthroskopie 2006; 19: 59–66. DOI: 10.1007/s00142-005-0334-y

[6] Clohisy JC, Baca G, Beaule PE et al. Descriptive epidemiology of femoroacetabular impingement: a North American cohort of patients undergoing surgery. Am J Sports Med 2013; 41: 1348–1356. DOI: 10.1177/0363546513488861

[7] Bohnsack M, Hehl S, Börner C et al. Ergebnisse der Hüftarthroskopie. Arthroskopie 2006; 19: 46–50. DOI: 10.1007/s00142-005-0332-0

[8] Lynch TS, Terry MA, Bedi A et al. Hip arthroscopic surgery: patient evaluation, current indications, and outcomes. Am J Sports Med 2013; 41: 1174–1189. DOI: 10.1177/0363546513476281

[9] Eijer H, Leunig M, Mahomed MN et al. Cross-Table Lateral Radiographs for Screening of Anterior Femoral Head-Neck Offset in Patients with Femoro-Acetabular Impingement. HIP International 2001; 11: 37–41. DOI: 10.1177/112070000101100104

[10] Jamali AA, Mak W, Wang P et al. What is normal femoral head/neck anatomy? An analysis of radial CT reconstructions in adolescents. Clin Orthop Relat Res 2013; 471: 3581–3587. DOI: 10.1007/s11999-013-3166-5

[11] Lerch S, Kasperczyk A, Warnecke J et al. Evaluation of Cam-type femoroacetabular impingement by ultrasound. Int Orthop 2013; 37: 783–788. DOI: 10.1007/s00264-013-1844-2

[12] Leunig M, Werlen S, Ungersböck A et al. Evaluation of the acetabular labrum by MR arthrography. J Bone Joint Surg Br 1997; 79: 230–234. DOI: 10.1302/0301-620x.79b2.7288

[13] Heuck A, Dienst M, Glaser C. Femoroazetabuläres Impingement – Update 2019. Der Radiologe 2019; 59: 242–256. DOI: 10.1007/s00117-018-0486-1

[14] Locher S, Werlen S, Leunig M et al. [MR-Arthrography with radial sequences for visualization of early hip pathology not visible on plain radiographs]. Z Orthop Ihre Grenzgeb 2002; 140: 52–57. DOI: 10.1055/s-2002-22122

[15] Schamberger CT, Stein S, Gruber G, Suda AJ. Sonography-Based Determination of Hip Joint Anterior Alpha-Angle: A Reliable and Reproducible Method. Ultraschall Med 2023; 44: 188–193. DOI: 10.1055/a-1663-6085

[16] Konermann W, Gruber G, Gaa J Standardisierte sonographische Untersuchung des Hüftgelenkes. Ultraschall Med 2000; 21: 137–141. DOI: 10.1055/s-2000-13028

[17] Gruber G, Schamberger C, Konermann W. Sonografie in Orthopädie, Unfallchirurgie und Rheumatologie. Springer-Verlag Berlin Heidelberg; 2018. DOI: 10.1007/978-3-662-57659-5

[18] Amanatullah DF, Antkowiak T, Pillay K et al. Femoroacetabular impingement: current concepts in diagnosis and treatment. Orthopedics 2015; 38: 185–199. DOI: 10.3928/01477447-20150305-07

[19] Green SB. How Many Subjects Does It Take To Do A Regression Analysis. Multivariate Behavioral Research 1991; 26: 499–510. DOI: 10.1207/s15327906mbr2603_7

[20] Smith KM, Gerrie BJ, McCulloch PC et al. Comparison of MRI, CT, Dunn 45 degrees and Dunn 90 degrees alpha angle measurements in femoroacetabular impingement. Hip Int 2018; 28: 450–455. DOI: 10.5301/hipint.5000602

[21] Nakashima H, Tsukamoto M, Ohnishi Y et al. Clinical and Radiographic Predictors for Unsalvageable Labral Tear at the Time of Initial Hip Arthroscopic Management for Femoroacetabular Impingement. Am J Sports Med 2019; 47: 2029–2037. DOI: 10.1177/0363546519856018

[22] Gruber G, Schamberger CT, Konermann W et al. Hüftgelenk. Sonografie in Orthopädie, Unfallchirurgie und Rheumatologie: Aktuelle Standardschnittebenen der DEGUM. 2018; 105–123

[23] Nepple JJ, Lehmann CL, Ross JR et al. Coxa profunda is not a useful radiographic parameter for diagnosing pincer-type femoroacetabular impingement. J Bone Joint Surg Am 2013; 95: 417–423. DOI: 10.2106/jbjs.K.01664

[24] Lerch S, Kasperczyk A, Berndt T et al. Ultrasound is as reliable as plain radiographs in the diagnosis of cam-type femoroacetabular impingement. Arch Orthop Trauma Surg 2016; 136: 1437–1443. DOI: 10.1007/s00402-016-2509-6

[25] Maldonado DR, Chen JW, Walker-Santiago R et al. Radiographic and Demographic Factors Can Predict the Need for Primary Labral Reconstruction in Hip Arthroscopic Surgery: A Predictive Model Using 1398 Hips. Am J Sports Med 2020; 48: 173–180. DOI: 10.1177/0363546519887749

[26] Conn KS, Villar RN. The torn acetabular labrum – a hip arthroscopist's view. Der Orthopäde 1998; 27: 699–703. DOI: 10.1007/PL00003455

[27] Farjo LA, Glick JM, Sampson TG. Hip arthroscopy for acetabular labral tears. Arthroscopy 1999; 15: 132–137. DOI: 10.1053/ar.1999.v15.015013

[28] Sadri H, Menetrey J, Kraus E et al. Arthroskopische Behandlung des femoroazetabulären Impingements. Arthroskopie 2006; 19: 67–74. DOI: 10.1007/s00142-005-0330-2

[29] Sampson T. Arthroscopic Treatment of Femoroacetabular Impingement. American journal of orthopedics (Belle Mead, NJ) 2009; 37: 608–612. DOI: 10.1097/01.bto.0000153635.24366.b5

[30] Sozen YV, Hepgur G, Kilicoglu O et al. [The effectiveness of arthroscopic debridement and lavage treatment in osteoarthritis of the hip: preliminary results]. Acta Orthop Traumatol Turc 2004; 38: 96–103