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Cam impingement: defining the presence of a cam deformity by the alpha angle data from the CHECK cohort and Chingford cohort

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SUMMARY

Introduction: Cam impingement is characterized by abnormal contact between the proximal femur and acetabulum caused by a non-spherical femoral head, known as a cam deformity. A cam deformity is usually quantified by the alpha angle; greater alpha angles substantially increase the risk for osteoarthritis (OA). However, there is no consensus on which alpha angle threshold to use to define the presence of a cam deformity.
Aim: To determine alpha angle thresholds that define the presence of a cam deformity and a pathological cam deformity based on development of OA.
Methods: Data from both the prospective CHECK cohort of 1002 individuals (45–65 years) and the prospective population-based Chingford cohort of 1003 women (45–64 years) with respective follow-up times of 5 and 19 years were combined. The alpha angle was measured at baseline on anteroposterior radiographs, from which a threshold for the presence of a cam deformity was determined based on its distribution. Further, a pathological alpha angle threshold was determined based on the highest discriminative ability for development of end-stage OA at follow-up.
Results: A definite bimodal distribution of the alpha angle was found in both cohorts with a normal distribution up to 60°, indicating a clear distinction between normal and abnormal alpha angles. A pathological threshold of 78° resulted in the maximum area under the ROC curve.
Conclusion: Epidemiological data of two large cohorts shows a bimodal distribution of the alpha angle. Alpha angle thresholds of 60° to define the presence of a cam deformity and 78° for a pathological cam deformity are proposed.

Introduction

Historically, the cause of most hip osteoarthritis (OA) has been defined as 'idiopathic', but recent evidence suggests that development of hip OA is largely influenced by the presence of a cam deformity[1–4]. A cam deformity is characterized by extra bone formation at the anterolateral head–neck junction resulting in a non-spherical cam-shaped deformity[5]. It is forced into the acetabulum during flexion and internal rotation of the hip, a process referred to as cam impingement[6,7]. In time and with repeated movement, the cam deformity might damage the soft tissue structures of the hip, leading to pain, decreased function, and subsequently OA of the hip[1,3,8]. In the prospective CHECK cohort, an odds ratio (OR) of 9.7 (95% CI 4.7–19.8) was found for a large cam deformity (alpha angle >83°) at baseline and subsequent development of end-stage OA after 5 years. Moreover, in a case control study within the prospective Chingford cohort, an OR of 1.05 (95% CI 1.02–1.09) was found for every degree increase in alpha angle at baseline and receiving total hip replacement (THR) within 19 years follow-up.[1,3]

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The presence of a radiographic cam deformity is a common finding with prevalence numbers of roughly 15–25% in males and 5–15% in females[9–11]. The wide range of prevalence reported is mainly due to the inconsistency in the definition of what is a cam deformity. A cam deformity is commonly assessed by the alpha angle, which measures the extent to which the femoral head deviates from spherical[12]. Greater alpha angles increase the risk for development of OA substantially[1,3,13–15]. However, there is neither a validated alpha angle threshold value to define the presence of a cam deformity, nor a pathological threshold that indicates an increased risk for development of OA. As a consequence, threshold values ranging from 50° to 83° have been used in literature, which makes prevalence numbers and associations with subsequent pathology difficult to compare and interpret.[7,12,16]

In order to determine alpha angle thresholds, large cohort studies are needed. For that reason, we combined data of the CHECK cohort and Chingford cohort, both with prospective follow-up. Using these data, the aim of this article is to determine an alpha angle threshold for defining the presence of a cam-type deformity, and to determine a pathological alpha angle threshold based on development of OA at follow-up.

Methods

Study population

The alpha angle threshold values were determined in the CHECK cohort with a current follow-up of 5 years, and in the Chingford study with a follow-up of 19 years.

CHECK is a nationwide multicenter prospective cohort study of 1002 individuals aged 45–65 years (mean 55.9 years) at baseline with symptoms of early OA (pain) of the hip or knee. They had not yet consulted their general practitioner for these symptoms, or the first consultation was within 6 months before entry. Participants with any other pathologic condition that could explain the symptoms were excluded (for hip: other rheumatic disease, previous THR or Kellgren and Lawrence (K&L) grade 4, trauma, dysplasia, Perthes disease, subluxation, osteochondritis dissecans, fracture, septic arthritis, bursitis, tendinitis, or previous hip surgery).[17]

The Chingford cohort is a population-based cohort of 1003 asymptomatic women aged 44–67 years (mean 54.2 years) at baseline. These women were registered at a general practice in London and were invited to participate in a study assessing musculoskeletal disease in the population. Yearly clinic visits were performed, which included; morphometric, clinical, biologic, and radiographic measurements.

Radiographs

In the CHECK study, weight-bearing Anterio-Posterior (AP) pelvis radiographs were obtained from the 11 participating research centers according to a standardized protocol, taken at baseline and at 2 and 5 years follow-up. Feet were positioned such that the medial side of the distal part of the first phalanx touched and a wedge was used to assure 15° internal rotation. In the Chingford cohort, each woman had a standardized supine AP pelvis radiograph, taken at years 2, 8 and 20. A small sand bag under the knees was used to minimize hip rotation.

In both the CHECK and Chingford cohorts, AP pelvis radiographs were scored atlas based and 'blind' to clinical details according to the method of K&L at baseline, and at 5 year follow-up in the CHECK cohort and at year 20 in the Chingford cohort[18,19]. End-stage OA was defined by K&L grade 3, 4, or total hip arthroplasty (THA) at follow-up.

Alpha angle

The alpha angle measures the extent to which the femoral head deviates from spherical. It is measured by first drawing the best fitting circle around the femoral head, then a line through the center of the neck and the center of the head. From the center of the femoral head, a second line is drawn to the point where the superior surface of the head–neck junction first departs from the circle. The angle between these two lines is the alpha angle (Fig. 1).[12]

In both cohorts, the alpha angle was semi-automatically calculated. In the CHECK study, the shape of the proximal femur was outlined by a set of points that were positioned on anatomical landmarks using statistical shape modeling (SSM) software (ASM tool kit, Manchester University, Manchester, UK). From this points set, the alpha angle was calculated using Matlab (V.7.1.0)[1,20]. In the Chingford cohort, the alpha angle was also measured using a validated Matlab based (Matlab R2009b; MathWorks) software package called Hip Morf 2.0. Q3

Reliability of the alpha angle was examined in both cohorts and between both techniques. In the CHECK cohort, interobserver reproducibility was examined by positioning the point set twice in 25 randomly selected hips by three investigators. Intra-observer repeatability was tested for each investigator in 10 randomly selected radiographs. In the Chingford cohort, intra-observer repeatability was assessed by one investigator reading 10 randomly selected blinded radiographs on three occasions. Inter-observer reproducibility was assessed by two further observers reading the same 10 radiographs[3]. Finally, in order to examine interobserver reliability between both techniques, the alpha angle was calculated in 30 randomly selected hips using SSM software and Hipmorf 2.0 (14 hips of the CHECK cohort and 16 hips of the Chingford cohort).

Statistics

Reliability of the alpha angle as a continuous measure was assessed using intraclass correlation coefficient (ICC) and Cohen's kappa indicating agreement for whether a hip was classified as having or not having a cam deformity. A Bland–Altman plot was used to visualize agreement in the alpha angle measurements between the two techniques (SSM and Hipmorf).[21]

Explorative analysis showed a bimodal distribution of the alpha angle in both cohorts, indicating two different populations, one without cam deformity and one with cam deformity. To determine the presence of a cam deformity, the optimal threshold that distinguishes between both distributions was assessed. The alpha angle data of all hips in both cohorts were combined and an optimal fit through the data was determined based on a mixture of normal distributions using Matlab (V7.1.0). The alpha angle corresponding with the minimum of the fit was used as a threshold to define the presence of a cam deformity. The confidence interval was obtained through bootstrapping using 2000 bootstrap samples. Difference in alpha angle between men and women below the found threshold was calculated using generalized estimating equations.

To define a pathological threshold, end-stage OA at follow-up was used as an outcome. The maximum area under the receiver operating characteristic (ROC) curve was calculated for each possible alpha angle threshold. The maximum area under the ROC curve corresponds with the threshold having the highest sum of sensitivity and specificity for development of OA, which indicates the optimal alpha angle threshold to distinguish between hips with and without end-stage OA at follow-up.

As bilateral hips might not be statistically independent, a sensitivity analysis using one randomly selected hip per person was

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