Detecting bony deformity in cam femoroacetabular impingement: a new 2D diagnosis graph

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Objective: Cam-type femoroacetabular impingement (FAI) is caused by an aspherical femoral head at the anterosuperior head-neck junction; this typically leads to pain and reduced range of motion. Currently, FAI is typically diagnosed by assessing the alpha angle (Nötzli et al., 2002). However, the alpha angle alone contains little information about the location, size or extent of the bony lesion on the femoral head-neck junction, and there are no widely-used techniques for automatically distinguishing Cam FAI from normal hip joint, though a technique based on assessing 3D images has recently been proposed (Audenaert et al., 2011). The objective of this study was to develop a method based on 3D images for representing the bony shape of the femoral head and neck and visualizing the shape differences between hips with FAI and normal hips; such a method could be used as a basis for diagnosis of FAI and characterization of the deformity.

Materials & Methods: Oblique axial MRI images of the hip joint were acquired from five subjects with diagnosed FAI and four healthy subjects using a 3T MRI scanner at the University of British Columbia MRI Research Centre. The MRI images were segmented using Analyze 10.0 and smoothed in Rapidform to obtain the femur model. Figures 1a and 1b show the generated 3D surface model of the femoral head-neck region of a normal subject and a subject with FAI. The bony deformity is visible in the anterosuperior area.

The surface model was mapped to a spherical coordinate system defined by three landmarks: the hip joint center (HJC), neck center (NC), and femur center (FC). Figure 1c shows the definition of the spherical coordinate system, which is parameterized by the radius r, inclination angle θ, and azimuth angle φ. By projecting directional vectors to the surface and calculating the distance from the HJC to the points of intersection with the surface, a shape map was generated in which distances to the surface are represented as a function of θ and φ. In contrast to Audenaert's approach of fitting simplified geometrical shapes to individual subjects, we obtained a normalized base shape map by averaging the shape maps from three normal hips. A 2D diagnosis graph for a given subject was generated by subtracting the base shape map from that of the subject. Based on the graph, the volume size, surface area, and maximum height of the cam deformity can be readily visualized and calculated.

Results: The cam deformity often occurs in the anterosuperior region which lies approximately in the range of θ=90-150° and φ=0-90°. The location and extent of the cam deformity can be illustrated using the 2D diagnosis graph. Figures 1d and 1e show the 2D diagnosis graph of one normal subject and one with FAI. The colors in the 2D diagnosis graph illustrate the height of the cam deformity, which reflects the severity of the cam lesion.

In the anterosuperior region where the deformity is found (φ=0-90°, θ =90-150°), the mean maximum height of the deformity relative to the baseline normal shape was 4.5 mm (SD 1.8 mm) and ranged across subjects from 2.1 to 6.2 mm. The mean surface area of the detected cam deformities for the five subjects with FAI measured on the 2D diagnosis graph was 296 mm^2 (SD 136 mm^2) and ranged from 169 to 454 mm^2. The mean volume was 504 mm^3 (SD 412 mm^3) and ranged from 130 to 1060 mm^3. The computed alpha angle for the subjects with FAI averaged 60 degrees and ranged from 47 to 71 degrees. The differences between the baseline normal shape and the one reserved normal subject were 1.6 mm in maximum height, 293 mm^2 in surface area and 162 mm^3 in volume.

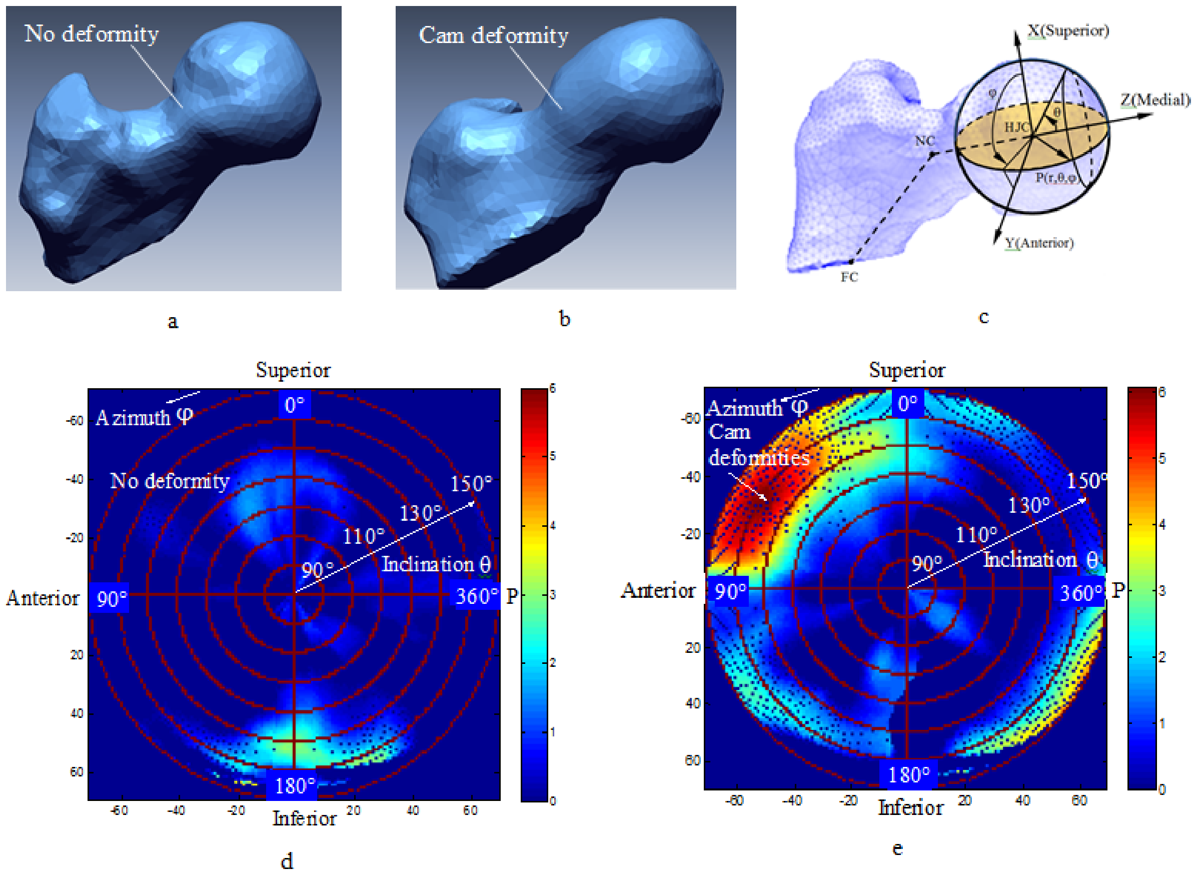

Figure 1: 3D surface model of femurs without (a) and with (b) cam deformities. (c) The definition of spherical coordinate system. 2D diagnosis graph without (d) and with (e) cam deformities.

The 95% confidence limits on Pearson's correlation coefficient (PCC) between the measured alpha angle obtained from an oblique axial view and the detected volume size were -0.44 to 0.98 (mean estimate of 0.72) and between the measured and computed alpha angles were -0.59 to 0.97 (mean estimate of 0.61); these confidence bounds are large due to the limited number of subjects in this pilot study, so we have insufficient data to draw strong conclusions about these relationships.

Conclusions: This paper presented a novel 2D diagnosis graph for the detection and visualization of cam deformities in Cam FAI diagnosis. The shape of femoral head-neck region is represented as a 2D shape map using spherical coordinate system. A normalized base shape map was obtained from subjects without FAI. A 2D diagnosis graph was generated by calculating the shape differences of FAI subjects from the normalized base shape map.

We found results similar to Audenaert's in terms of typical lesion height (4.5 mm in our study vs 3.2 mm in Audenaert's), and surface area (296 vs 326 mm^2). Our estimated PCC value of 0.61 for our computed alpha angle was close to their estimate of 0.60, although, since our confidence interval is so wide, we would not be in a position to detect even relatively large differences from the value they reported.

Qualitatively, our 2D diagnosis graph enabled the cam-type lesions in all five diagnosed patients to be clearly visualized. This visualization tool may help surgeons better characterize cam lesions for diagnosis and develop more precise surgical plans for treatment. A key limitation of this pilot study is the limited number of subjects. More control subjects and subjects with FAI will be investigated to further evaluate the method.

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