Paper #46

WHICH RADIOGRAPHIC MEASUREMENTS BEST IDENTIFY ANATOMICAL VARIATION IN FEMORAL HEAD ANATOMY? ANALYSIS USING 3D COMPUTED TOMOGRAPHY AND STATISTICAL SHAPE MODELING

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FDA Status: Not Applicable

Summary: The ability of the alpha angle and head-neck offset measured on the anteroposterior, crosstable lateral, frog-leg, and 45 Dunn views to capture true shape variation between asymptomatic controls and patients with cam FAI was evaluated using statistical shape modeling. Radiographic measurements from the frog-leg view best-captured shape variation, followed by the cross-table and 45 Dunn views.

Alpha angle and head-neck-offset are used to diagnose radiographic cam FAI. There is debate as to which views best identify the cam lesion [1]. Our study quantified the diagnostic strength of radiographic measurements obtained from the anteroposterior, crosstable, frog-leg, and 45? Dunn views to decipher true anatomical variation as derived from 3D statistical shape modeling (SSM).

Computed tomography scans of the proximal femur and pelvis were obtained for 45 screened controls and 28 patients with cam FAI of similar age and BMI. Surfaces of the proximal femur were segmented and input into a SSM software. SSM objectively compares anatomical variation across groups and provides the ability to map each subject's femur relative to the mean shapes to generate a linear discriminant of shape variation [2]. The linear discriminant was used to quantify similarity between each individual femur and mean control or cam femur. This value was then correlated to the radiographic measurements. To reduce errors caused by variations in projection angle across subjects, digitally reconstructed radiographs (DRRs) of the CT scan data were used in-lieu of conventional radiography as described previously [3]. The alpha angle and head-neck-offset were measured on the DRRs using custom software to eliminate measurement bias [3]. Correlations were evaluated using Spearman's rank correlation coefficient. Group measurements were compared using a two-sample Wilcoxon test.

Alpha angle was significantly higher and head-neck offset was significantly lower for the cam group for all views except the anteroposterior view, where only the alpha angle was significantly larger ($p < 0.001$ for all). The highest alpha angle (mean±SD) was observed for the 45? Dunn (68.2±15.4?), with the lowest for the frog-leg (47.7±14.3?). The lowest head-neck offset measurement was obtained for the 45? Dunn (2.5±1.9 mm), with the highest observed for the crosstable (9.4±2.0 mm).

The linear discriminant values from SSM were significantly different between groups ($p < 0.001$). The highest correlations between radiographic measurements and the linear discriminant were observed on the frog-leg lateral view ($r=-0.6061$, $p < 0.001$ for alpha angle, $r = 0.5381$, $p < 0.001$ for head-neck offset). However, the crosstable and 45? Dunn views also showed significant correlations ($r=-0.4349$, -0.4830, respectively for alpha angle, $p < 0.001$ for both; and $r = 0.4417$, 0.3182, respectively for head-neck offset, $p < 0.001$, $p = 0.006$). Measurements from the AP view were not significantly correlated to results from SSM.

Overall, alpha angles were better correlated with overall shape variation than measurements of head-neck offset. However, interestingly, the view with the smallest alpha angle measurement (frog-leg) was actually most strongly correlated to SSM results. This indicates that a higher alpha angle does not necessarily signify greater anatomical variation, and may explain why many asymptomatic individuals have radiographic FAI [4]. In essence, it may be that the alpha angle is not describing true anatomical variation between cam FAI and controls. Thus, SSM may provide a more objective means to assess the severity of cam FAI and to differentiate anatomical features that better describe true anatomical variation.

1. Meyer, *CORR*, 2006, p. 181–5.
2. Harris, *JOR*, 2013, p. 1620-6.
3. Harris, 2014, p. 788-796.
4. Hack, *JBJS*, 2010, p. 2436-2444.