Institute of Medical & Biological Engineering

Investigation of Male and Female Cam Lesions using Radiographic Features and Statistical Shape Models

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Introduction

- Anatomic abnormalities of the proximal femur can be associated with cam-type femoroacetabular impingement (FAI) and where repeated abutment of the cam against the acetabulum during forceful motion, particularly hip flexion occurs, this can cause damage at the chondrolabral junction, leading to the development of osteoarthritis [1].
- Female cams have been reported as smaller and more diffuse than male cams when compared using statistical shape models (SSMs) derived from volumetric computed tomography (CT) data [2].
- It has therefore been hypothesised that some underlying gender related radiographic characteristics may exist in cam-type FAI.

Aim

The aim of this study was to use retrospective volumetric CT data, three-dimensional (3D) patient specific surfaces, and statistical shape models (SSMs) to investigate the hypothesis that male and female cam morphology has different radiographic features.

Materials and Methods

- The study group (n=67) comprised n=41 male and n=26 female patients (mean age 36 years, range 21-63 years), with a clinical diagnosis of cam-type FAI.
- A control group (n=42) with n=22 male and n=20 female participants (mean age 47 years, range 24-76 years), with no existing hip pathology was recruited for comparison.
- Male and female study group participants had been symptomatic for a mean duration of 20±20 months and 23±29 months respectively at the time of their volumetric CT scan.
- Scans were segmented to generate patient specific 3D surfaces of the femurs (n=109) using EndPoint software (ver. 1.2, Imorphics Ltd, UK), with scan and model data only being identifiable using randomly generated numbers to blind researchers to its origin.
- Data was analysed in two stages, with the initial stage being to visually assess each 3D surface in order to identify, and if present, "paint" the area of the cam (Figures 1 and 2).

Stage One

Cams identified on 3D surfaces were "painted" using ProtoMask (Ver. 1, Imorphics Ltd, UK) to indicate their location on the CT scan (Figure 1).

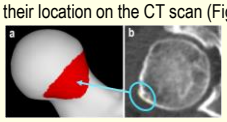

Figure 1: (a) 3D surface with "painted" cam and (b) the location of the cam superimposed onto one slice of the corresponding CT scan.

Surfaces with no obvious cam (e.g. Figure 2) were assumed to be controls and classified as Group 1.

Figure 2: (a) Patient specific 3D surface categorised as Group 1, with the associated CT scan (b).

- Where applicable, the second stage of the analysis involved assessing and categorising the radiographic appearance of the area immediately below the cam on each slice of the corresponding CT scan (Figure 3).

Stage Two

Based on the radiographic appearance on the CT scan, cams identified on the 3D surfaces were categorised into one of three groups, as summarised in Figure 3.

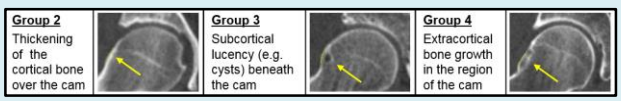

Figure 3: Cam radiographic features for groups 2 (cortical thickening), 3 (subcortical lucency), and 4 (extracortical bone).

- SSMs with anatomically aligned model points [3] were generated for Groups 2, 3, and 4.
- Data was unblinded to assess the accuracy of separating the surfaces into control or FAI study group patients, and before analysing the data for the three cam lesion groups.

Results

- The unblinded results of the classification process (Figure 4) revealed 89% of the patient specific 3D surfaces were placed into the group that they were recruited into.
- Six surfaces (n=3 male, n=3 female) from participants recruited into the FAI group were classified as controls (Group 1), and six surfaces (n=5 male; n=1 female) recruited into the control group were classified as cam-FAI patients.

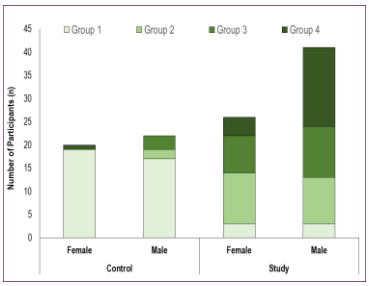

Figure 4: Results following the classification of n=109 patient specific 3D surfaces.

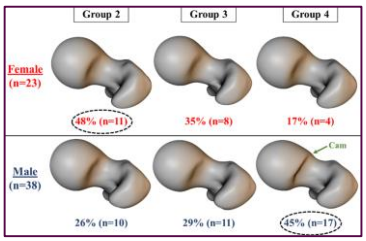

Figure 5: FAI study group results and SSMs following the classification of radiographic features into Groups 2, 3 and 4.

- Visual analysis of the SSMs (Figure 5) confirmed the groups' previous findings that the cams, which were located on the anterosuperior aspect of the femoral head-neck junction, were typically larger and more defined in males when compared with females.
- Larger cams were particularly evident in the Group 4 male SSMs.
- Cams observed on the 3D surfaces of Group 2 patients were generally smaller and less well defined than those of Group 4.
- Of the 3D surfaces correctly classified as FAI patients and categorised based on radiographic appearance, almost half of the female patients (48%) had radiographic features synonymous with Group 2, and almost half of the scans where extracortical bone growth was observed in the cam region (Group 4), were male patients (Figure 5).
- Only 17% (n=4) of females appeared to have Group 4 (i.e. extracortical bone) radiographic characteristics, and evidence of subcortical lucency was observed in ≈48% of CT scans in Group 4, beneath the extracortical bone growth.

Discussion

- The results support the hypothesis, suggesting there may be an association between radiographic features and cam morphology, which differs in male and female patients.
- The key finding was that in the region of the cam, nearly half of the female cohort had thickening of the cortical bone whereas nearly half of the male cohort had evidence of extracortical bone growth. This finding warrants further investigation with larger groups.
- Categorising the surfaces and scan data whilst blinded to group and gender reduced the risk of observer-expectancy bias, and there was no significant difference in the duration of male and female symptoms (*t*-test; p=0.65) in the cam-FAI study group.
- The classification of some FAI group 3D surfaces into the control group and vice versa could be due to clinical diagnosis not being based exclusively on 3D shape, and older control participants having small degenerative changes that were mistaken for cams.

Significance

- The pathogenesis of cam FAI remains poorly understood, however, the results of this study suggesting that the observed differences in the radiographic appearance of cam morphology could be gender related, contributes to the existing knowledge base.
- These results could have important implications for the development of new and effective diagnostic methods and improved treatment strategies, especially in females with smaller cam lesions who may be at risk of being underdiagnosed and treated.

References

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