3D CT and the Imaging Approach to Femoroacetabular Impingement Syndrome

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Introduction

Femoroacetabular impingement and tears of the acetabular labrum have recently been recognized as important causes of hip pain in adults(1,2). The common form of impingement, cam-type(3), is caused by abnormal excess of bone on the anterior lateral surface of the femoral head neck junction. This dysmorphic bump is thought to cause mechanical impingement of the acetabular rim during hip flexion(4). The end result of the impingement is a tear and/or detachment of the labrum. In addition, with longer standing labral tears, cartilage injury in the form of delamination is common(4). Surgical approaches to femoroacetabular impingement now include arthroscopic and arthrotomy approaches in order to debride the labral tear and to restore a normal offset contour of the femoral head neck junction.

Preoperative assessment to identify the impingement source is critical to surgical management. Labral tears from diverse impingement sources are clinically present with complaints of groin and hip pains, which commonly radiate to the buttock and inner thigh. Hip impingement is known to result from structurally distinct abnormalities, which include cam type FAI, acetabular retroversion, lack of femoral neck anteversion, and coxa profunda. The clinical presentation of the impingement syndromes is in common with developmental hip dysplasia. Conventional radiography, CT, and MRA have complementary roles in the assessment of the adult with hip pain. In this report, we demonstrate the utility of CT with surface rendering and oblique radial reformation in order to assess the contour of the anterior lateral impingement surface in patients with suspected FAI. Radial reformation along the femoral neck axis is demonstrated using the Aquarius Workstation from TeraRecon, Inc.

Case History:

The patient is a male, aged 30, with a two-year history of chronic left hip pain and sciatica in the right hip. He has had some relief of pain from prior injections in his lower back, but the pain in the groin area eventually defined itself more specifically and became a significant impediment to normal exercise activities. Prior to this onset of pain, he was an active jogger, but had to significantly decrease his sporting activities in order to accommodate his pain. He occasionally took some anti-inflammatory medication. The pain in the hip is mainly through the groin area. He still has some sensation of burning in the back

of his hip and his lower back. He has had no prior hip surgery. He has had no childhood problems and his general health is good. At the clinical assessment, the patient was found to have a positive impingement sign: hip pain elicited by hip flexion, adduction, and internal rotation of the hip. Radiography of the hip was suggestive of a lateral extension of the capital femoral epiphysis along the femoral neck.

Methods:

A CT was performed to assess the contour of the anterior lateral femoral head neck junction. The scan was performed on the Siemens Sensation 16 multidetector gantry at 3 mm slice reconstruction. The scan included the acetabulum to the lesser trochanters.

The data were transferred to the Aquarius Workstation and a 3D surface rendered model was created. After removing the gantry table from the 3D model, the pelvis was then viewed from the side of the (left) symptomatic hip and the model was rotated to look down the barrel of the left femoral neck. The cut plane of the model was restricted to show a narrow zone of the head neck junction. Once the alignment of the femoral head over the neck was approximated, the 2D batch mode for radial reconstruction was selected. The batch was prescribed to create 100 radial reformatted sections using the femoral neck axis as the center of the rotation. The femoral neck axis was determined by aligning the rotation axis along two cardinal points: the center of the femoral head, and the center of the femoral neck at the narrowest portion of the neck.

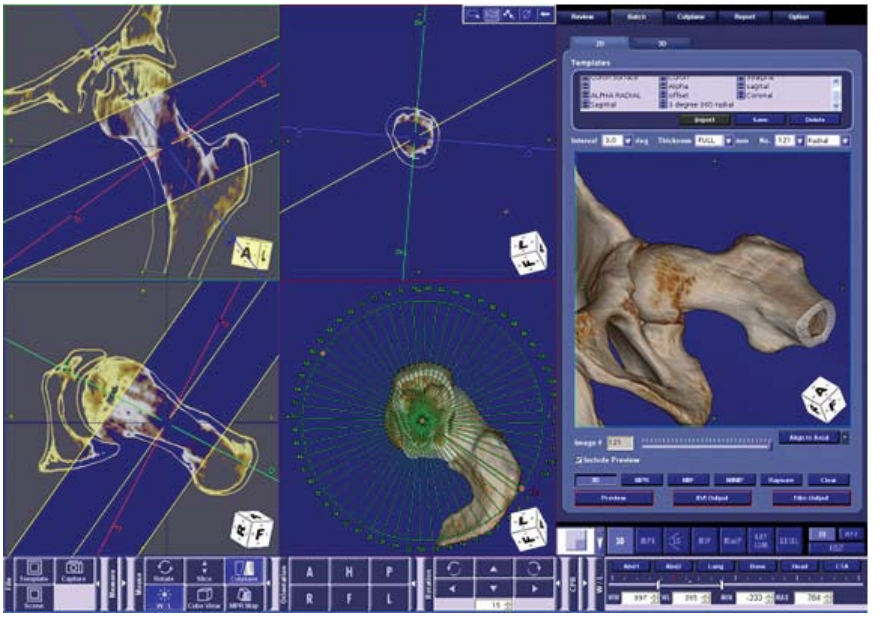

Figure 1 The prescription of the radial reformation of the femoral head and neck is shown. The rotational axis is conceptually along the center of the neck. The axis was determined by using the center point of the femoral head and the center of the neck isthmus as visualized on the para-coronal and para-axial reference images.

The radial reformation prescription was applied using 3D surface rendering technique and 2D Raysum reformation at 20 mm slice thickness.

This reformation technique was also applied to a normal control hip for comparison purposes.

The patient underwent MR arthrography, which included injection of Marcaine given with the gadolinium intra-articular contrast injection. The MRA was performed with the Siemens 1.5 T Symphony scanner. Pulse sequences included para-axial, coronal, and sagittal T1W fat saturated gradient echo images. The patient reported relief of hip and back pain following the Marcaine injection.

Findings:

The anterior lateral offset of the femoral head neck junction was found to be deficient. The anterior offset for the study patient is shown in Figure 2. There is a lack of concavity of the anterior head neck junction as compared with Figure 3. The offset deficiency is better depicted at the anterior lateral surface of the head-neck junction. In Figures 4 and 5, there is a dramatic difference in the bone contour between the control patient and the case example.

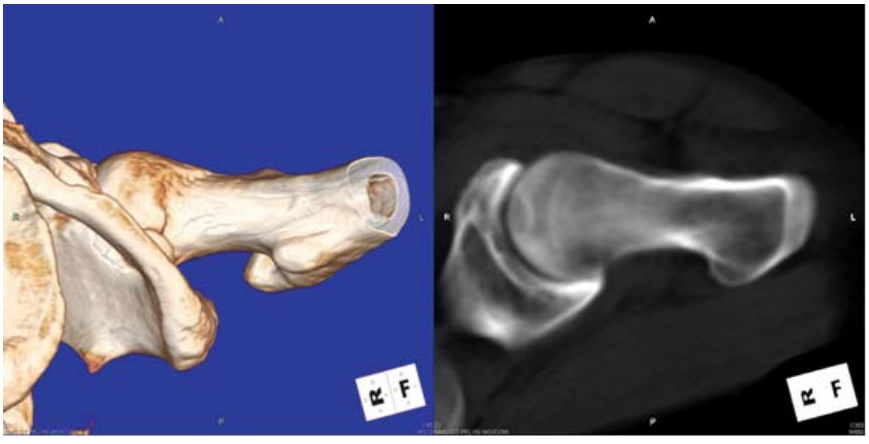

Figure 2 Cam type impingement: 3D surface shaded reformation and MPR are shown side-by-side using the same axis of rotation centered on the femoral neck. Note the flattening of contour along the anterior surface as compared with the posterior surface.

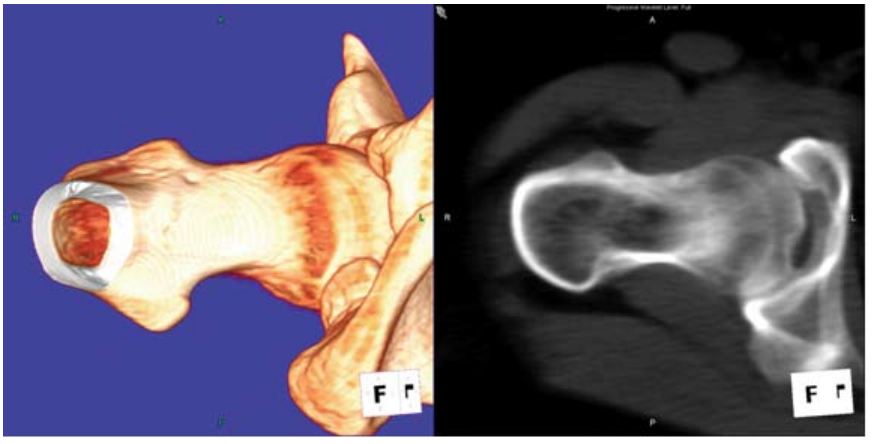

Figure 3 The anterior surface of the femoral neck is displayed in a control patient. Note the anterior surface has a concave appearance that closely mirrors the posterior surface.

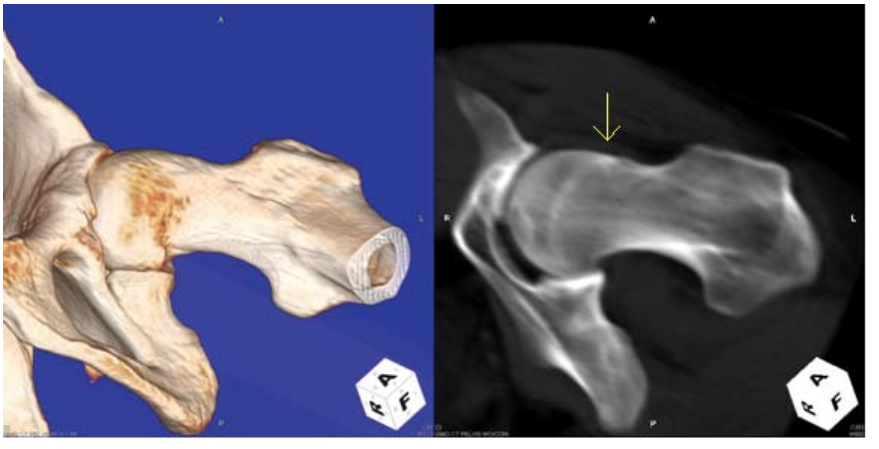

Figure 4 The anterior lateral surface of the femoral head neck junction is shown in the study patient. There is a conspicuous caudal displacement of the epiphyseal scar. The anterior lateral surface demonstrates moderate buttressing. This causes a lack of offset in hip flexion, leading to cam-type impingement. Note the reactive bony sclerosis along the impingement surface (arrow).

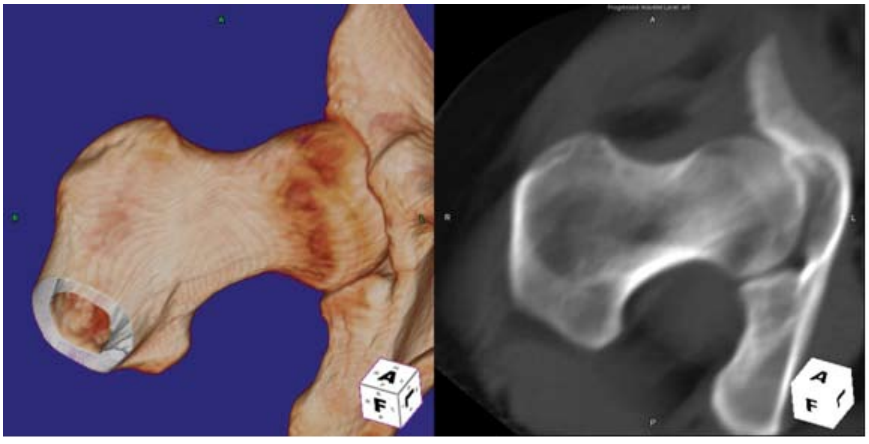

Figure 5 The control patient has a significant set back or offset of the neck in relation to the head. This accommodates the acetabular rim during hip flexion. In this bony morphology, there is no basis for cam type impingement.

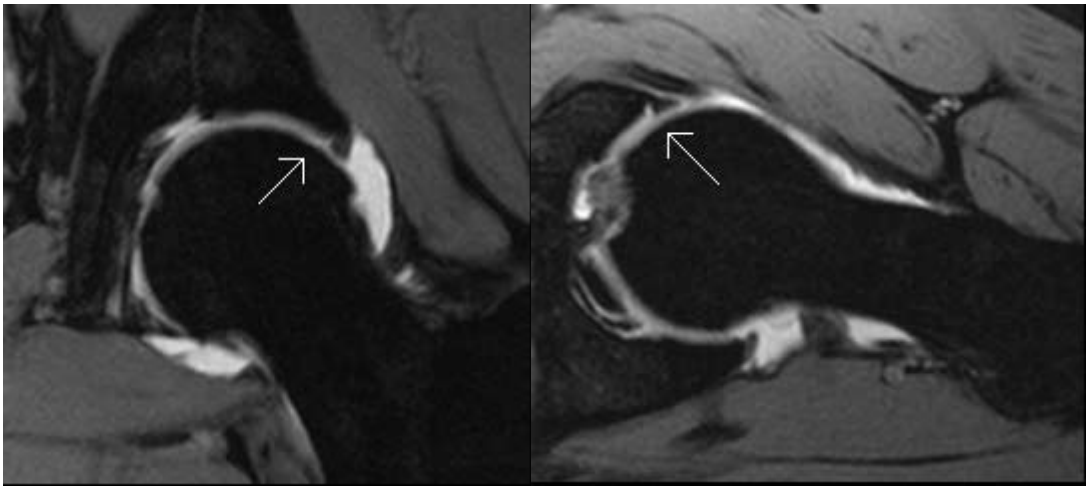

Figure 6 The index patient Gadolinium enhanced MRA confirms a cleft of signal abnormality at the labral osseous junction (arrows), which extended between the 9 and 1O o'clock positions of the acetabulum. The left (coronal) image reveals a chondral defect at the lateral margin of the femoral head (arrowhead).

Clinical Management:

The patient desired a minimally invasive surgical approach. Arthroscopy was performed which confirmed a large anterior superior labral osseous detachment. Because of the cam type impingement demonstrated by the 3D CT evaluation, the patient underwent anterior arthrotomy and osteoplasty of the femoral head neck junction to remove the excess bone at the impingement surface.

Discussion:

Femoroacetabular impingement is a common problem that frequently is unrecognized at initial clinical consultations. Many patients at our practice have suffered painful hips for several months or years. The clinical complaint of groin and hip pain frequently directs initial investigations to familiar problems such as renal calculi, hernias, gynecologic evaluation, and avascular necrosis of the hip. In severe cases, debilitating pain may limit the patient to ambulation on crutches or by wheel chair, prompting orthopedic consultation.

Figure 7 Lateral view of the left hip following osteoplasty of the femoral head neck junction. The anterior surface of the femur was reduced (arrows) to create adequate bone clearance during hip flexion.

Tears of the acetabular labrum have been treated by arthroscopy and by more recent approaches of surgical hip dislocation which have suggested the presence of a primary bone dysmorphism of the proximal femur(4). The premature closure of the capital femoral epiphysis along the anterior lateral margin of the femoral neck is thought to result in asymmetric growth of the femoral head. This leads to a bump deformity and cam type impingement. Confirmation of the femoral dysmorphism has been an elusive goal using radiographic techniques. The impingement surface must be viewed in profile to be conspicuous by radiography.

The ability to apply radial reformation technique to the problem of cam-type impingement has greatly facilitated preoperative visualization of the impingement surface. The ability to preoperatively visualize the size and distribution of the impingement source is of value to the surgeon and the patient when considering treatment options. Radial reformations of the femoral neck have been shown to show quantitative differences from controls using the Notzli alpha angle technique(5,6). The surgical options include arthroscopy, arthroscopy with femoral osteoplasty, arthroscopy with mini-arthrotomy for femoral osteoplasty, and surgical dislocation. Preoperative virtual reality rendering, using advanced 3D rendering tools, has great potential to assist the surgeon in defining the size and position of the impingement surface, particularly when the surgical approach provides limited visualization of the bone contour as may occur when arthroscopic techniques are employed.

In this example, the Aquarius Workstation from TeraRecon, Inc. was applied to provide a standardized method of image reformation for the qualitative assessment of surface contour and the quantitative assessment of cam-type impingement using radial MPR images. The Aquarius Workstation was found to be clinically robust for this purpose for multiple reasons, including the ability to view the rotational prescription in surface shaded 3D mode and MPR without altering the axis of the rotation. This workstation was helpful due to its ability to save the 3D model as a DICOM object, which can be stored by PACS and recalled for interactive review at a later time. The radial reformation tool on the Aquarius Workstation allowed precise adjustment of the axis of rotation by cross-referencing sagittal, coronal, and axial views concurrently. This ability is not universal on other 3D workstations in the market.

Conclusion

While the current case example is designed to illustrate the nature of cam-type impingement using a 3D CT analysis, CT is not mandatory in the assessment of the cam-type impingement patient. These methods can and have been applied to MRA datasets successfully. Once the surgeon, the radiologist, and the technologist understand the technique of 3D reformation, MRA becomes attractive as a preoperative staging tool. MRA lacks the ability to be surface rendered for preoperative virtual reality due to similar fat content of marrow and overlapping soft tissue. The MRA technique is desirable because of its lack of ionizing radiation and its ability to confirm the presence of a labral tear and associated cartilage lesions.

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