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Advances in Hip Imaging: 3-Dimensional Computed Tomography, Magnetic Resonance Imaging, and Dynamic Imaging

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Hip preservation surgery has grown tremendously over the past decade in large part because of the improved diagnostic tools and surgical techniques available to treat patients with prearthritic hip pain. The diagnosis of conditions in the prearthritic hip is made through a combination of systematic and stepwise history and physical examination as well as appropriate use of current diagnostic imaging modalities. The purpose of this review is to provide an overview of the advanced imaging techniques that are useful in the diagnosis and treatment of patients with prearthritic hip pain. This article includes a comprehensive review of the imaging modalities used for preoperative planning, intraoperative evaluation, and post-operative rehabilitation of patients with prearthritic hip pain.
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Introduction

Hip preservation surgery is one of the fastest growing subspecialty treatment modalities in orthopaedic surgery. For example, the number of hip arthroscopies performed by the American Board of Orthopaedic Surgery candidates has increased 18-fold from 2003-2009.[1] This is not only because of advancements in our clinical understanding of various hip disorders but also because of the significant improvements in the diagnostic imaging modalities that are currently performed. Pathologies of the prearthritic hip can often be a diagnostic challenge, as the differential diagnosis is vast.[2,3] Evaluation of patients with prearthritic hip pain should begin with a thorough history, systematic physical examination, and appropriate radiographs. In patients with findings suggestive of structural hip disease, the use of advanced diagnostic imaging may be critical to confirm a diagnosis and develop a treatment plan. The objective of this review is to focus on the advanced imaging techniques for the prearthritic hip conditions, such as femoroacetabular impingement (FAI) or dysplasia, including computed tomography (CT), magnetic resonance imaging (MRI), dynamic ultrasound, and intraoperative fluoroscopy.

Computed Tomography

Although plain film radiographs are good for evaluating the morphology of the acetabulum and the proximal femur in patients with FAI, 2-dimensional (2D) and 3D CT scans can provide even more information that is less subject to variable positioning and individual interpretation. Current CT technology with computer software systems also enables clinicians to evaluate both static and dynamic pathomorphologies of the prearthritic hip. Although plain radiographs have traditionally been used to identify acetabular version, there is great variability when evaluating the amount of acetabular coverage secondary to radiographic technique and pelvic tilt.[4] Plain radiographs often overestimate the presence of acetabular retroversion and presence of a crossover sign (Fig. 1).[5] CT also enables clinicians to evaluate the relative relationship of the anterior and posterior acetabular coverage, as well as differentiate between global and focal anterior overcoverage or

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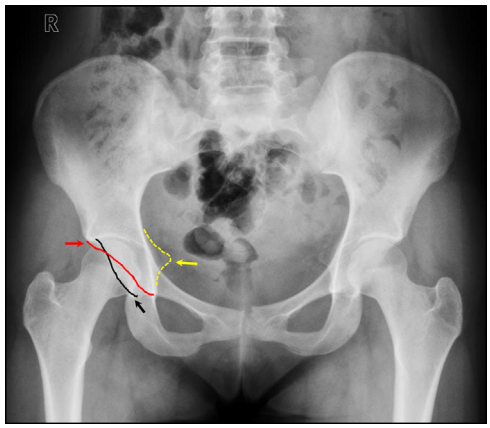

Figure 1 Anteroposterior radiograph of the pelvis with right hip focal anterior overcoverage and acetabular retroversion. The anterior wall (red arrow) and posterior wall (black arrow) form a crossover sign. An ischial spine sign (yellow arrow) is also observed, consistent with acetabular retroversion. (Color version of figure is available online.)

undercoverage (Fig. 2).[6] Conversely, plain radiographs may also underestimate the amount of dysplasia and undercoverage, both situations that may be best treated with a periacetabular osteotomy. Axial CT images may be used to directly measure the acetabular version, which has been described to be 17° (standard deviation [SD] ± 5°) in men and 21° (SD ± 6°) in women, when measured through the deepest part of the acetabula, parallel to the line through the posterior aspect of the acetabula (Fig. 3).[7] Coronal CT reconstructions can be used to calculate the lateral center edge angle, which has been described as 35° (SD ± 6°) in men and 32° (SD ± 6°) in women.[7] However, the overall classification of hip morphology as being undercovered (dysplastic), normal, or overcovered (pincer-type impingement) cannot be made solely from the lateral center edge angle that reflects only lateral coverage. A recent study by Larson et al[8] evaluated the CT scans of 409 asymptomatic hips to define a novel method for calculating the percentage of acetabular coverage of the femoral head. The mean percentage of regional femoral head surface area coverage for the asymptomatic cohort in this study was found to be 40% ± 2% anteriorly, 61% ± 3% superiorly, and 48% ± 3% posteriorly. It was also found that at all clock-face locations, men had more relative retroversion than women had, but there was no difference in the mean global percentage of coverage identified between men and women.[8] This study highlights not only the necessity to evaluate the combined morphology of the proximal femur and acetabulum but also to take into account a 3D measurement such as volume rather than classic 2D measurements such as acetabular version or lateral center edge angle. Additionally, the 3D relationship between the anterior and the posterior acetabular walls can be better defined with CT imaging, further delineating the relatively high prevalence of false-positive surrogates of retroversion such as the crossover and posterior wall signs that are commonly described on plain radiographs and can be seen in the normal population.

In addition to the characterization of acetabular morphology, CT scans also enable surgeons to evaluate the morphology of the proximal femur and the amount of femoral torsion by using the posterior condylar axis of the distal femur. This is critical to determine, as the combined version of the acetabulum and the femur (McKibbin index) should be considered when evaluating a patient with prearthritic hip pain.[9,10] Abnormal femoral torsion may be associated with the

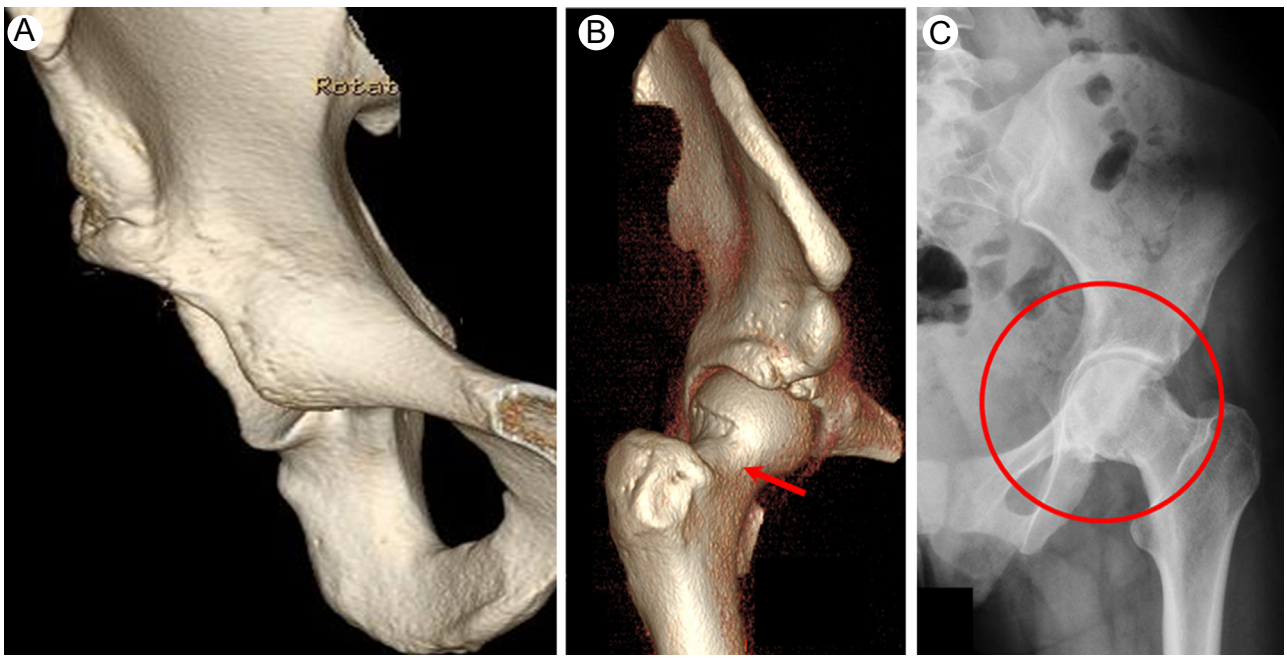

Figure 2 (A) A 3D CT image of the right hemipelvis reveals focal anterior acetabular overcoverage and posterior acetabular undercoverage. (B) A 3D CT image of the right hemipelvis and proximal femur exhibits coxa profunda with anterolateral cam deformity (red arrow). (C) An anteroposterior radiograph of the left hip reveals acetabular protrusion. (Color version of figure is available online.)