



RADIOLOGY—ORIGINAL ARTICLE

Protocol for CT in the position of discomfort: Preoperative assessment of femoroacetabular impingement – how we do it and what the surgeon wants to know

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Introduction

Femoroacetabular impingement (FAI) has been found to cause premature osteoarthritis of the hip, especially in young and active adults.¹ It has been described that certain morphological abnormalities of the femur, acetabulum or both can result in abnormal repetitive impingement between the proximal femur and acetabulum during hip motion, especially flexion and internal rotation. Two impingement mechanisms of FAI have been described, but most FAI is a combination of both processes. Pincer impingement is the acetabular cause of FAI and is characterised by acetabular overcoverage, leading to conflict between the acetabulum and the femur. Cam impingement is the femoral cause of FAI and occurs when a non-spherical femoral head abuts against the acetabulum, usually with hip flexion. Repetitive abutment results in chondral and labral damage, leading to early degenerative changes of the hip joint. Early recognition and identification of the

Abstract

Introduction: The use of computed tomography of the hip in a position of discomfort (CT-POD) in combination with 2D and 3D surface rendering is a technique increasingly used to aid in the assessment and confirmation of femoral and acetabular bony abnormalities related to femoroacetabular impingement. The purpose of this article is to describe this dynamic method of assessment.

Methods: Patients referred by orthopaedic surgeons for assessment of femoroacetabular impingement as part of preoperative planning and patients who required postoperative assessment of residual bony abnormalities were selected.

Results: This article describes the CT-POD technique and the information required by the referring surgeon.

Conclusion: CT-POD is a new technique that provides valuable preoperative and postoperative information to the surgeon.

Key words: computed tomography; CT POD; FAI; femoroacetabular impingement; musculoskeletal; position of discomfort.

type of FAI is important, as surgical management is different for each type.

Surgical treatment of FAI aims to remove the mechanical obstruction or impingement between the proximal femur and acetabular rim, thus allowing an impingement-free range of motion.² This is achieved either by open surgical techniques or arthroscopically. For cam impingement, excision osteoplasty of the non-spherical portions of the femoral head and neck junction can be performed to restore the normal head–neck offset. Surgical treatment of acetabular retroversion involves resection of the prominent anterior overcoverage. Labral and chondral lesions are also addressed during surgery.

Conventional radiography, magnetic resonance imaging (MRI) and computed tomography (CT) have complementary roles in the assessment of FAI. MRI and MR arthrography are effective in assessing labral, cartilage and some FAI lesions but not in determination of the exact position of the impingement process or overall visualisation of the bony contour. More recently,

CT has been applied, allowing two-dimensional (2D) and three-dimensional (3D) images with surface rendering, permitting excellent visualisation and assessment of bony impingement, contour, size and location of the FAI lesions. Patients are typically scanned supine with neutral hip position, including the problematic hip.

CT scanning with the hip in the position of discomfort (POD) is a variation of the standard CT protocol where the affected hip is positioned in flexion, internal rotation and adduction; it is being increasingly used by orthopaedic surgeons for preoperative planning.

The intent of this article is to describe our approach to CT-POD. Included are descriptions regarding patient selection, image acquisition, reconstruction parameters, analysis techniques and radiology reporting, with emphasis on information required by the referring surgeon.

Methods

Patient selection

In our current practice, CT-POD is performed as part of preoperative planning on patients referred by an orthopaedic surgeon who have a history of persistent hip pain and

clinical suspicion or examination findings of FAI with no prior intervention. MRI is generally also performed to identify labral and chondral abnormalities and exclude other underlying causes. Post-surgical patients referred for follow-up of residual bony abnormalities also receive CT-POD.

Description of the POD protocol and image processing

The POD protocol combines two scans: the first for femoral neck version measurements, the second for a detailed imaging of the affected hip.

For the femoral neck version scans, patients are positioned supine, feet first. The legs are straight and the pelvis is not rotated. An anteroposterior and a lateral scout are acquired from iliac crests to below knees (Fig. 1a). Three single 5-mm low-dose slices through femoral head, femoral neck and femoral condyles are acquired (Fig. 1b). Scanning parameters are 120 kVp and 120 mA with 5-mm slice thickness with a 5-mm interval on a bone algorithm. Field of view and x and y coordinates are the same for all scans, allowing the images to be superimposed for measurement purposes. The three low-dose images are superimposed (Fig. 1c).

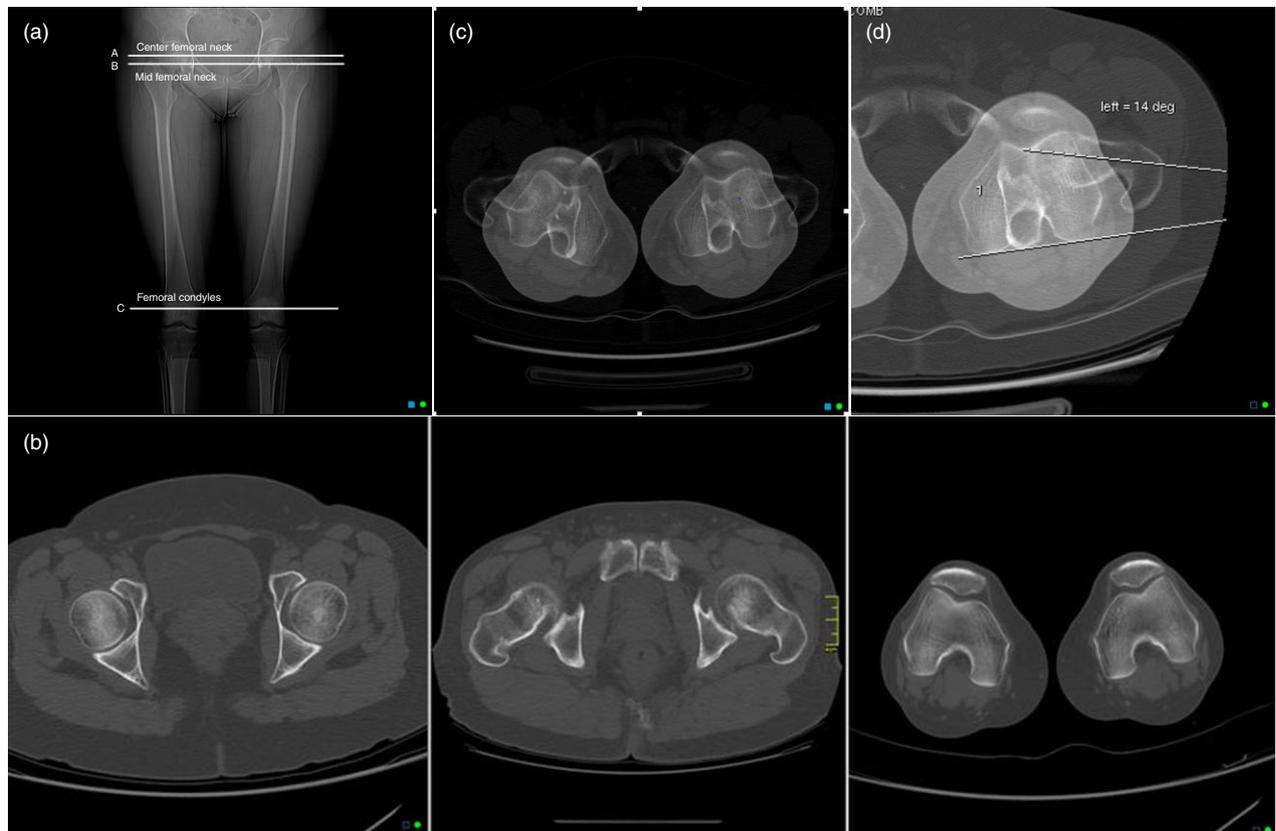


Fig. 1. (a) Femoral neck version scanogram, anteroposterior scout. (b) Axial CT slices through the femoral head, neck and condyles to determine femoral neck version. (c) Femoral neck version calculation. Femoral condyles are superimposed on the femoral neck. (d) Femoral neck version calculation.



Fig. 2. Anteroposterior CT scout view of both hips with the right hip in position of discomfort (right hip flexion and adduction).

Femoral neck version is determined by measuring the angle between the femoral neck and the femoral condyles (Fig. 1d).

For the second detailed scan of the hip, the patient's hip is placed in the POD. The patient's hip is flexed, adducted and internally rotated (Figs 2,3). The combination of flexion and adduction leads to the approximation of the femoral neck and the acetabular rim. The degree of flexion and adduction is determined by the patient and the ability to fit the patient in the gantry. It is important to ensure the hip is in the isocentre of the gantry to maximise image quality and minimise radiation dose. An anteroposterior and a lateral scout are acquired, and the scan is performed from the anterior inferior iliac spine to the lesser trochanter. Scanning parameters are 140 kVp, 380 mA (with smart and auto mA) and rotation time of 0.8 s.

If both hips are to be assessed for FAI, both hips are scanned at the same time (to keep radiation dose as low

as possible), with the more symptomatic hip in the POD and the less symptomatic hip in a neutral position.

Helical CT (GE LightSpeed, 16-slice; GE Healthcare, Little Chalfont, UK) with 0.65 mm collimation and a 0.5-mm reconstruction interval are performed on bone and soft-tissue algorithm for reconstruction and 3D surface rendering. Images are transferred to a GE workstation and loaded to create 3D surface-rendered images with and without the acetabulum and pelvis.

Post-processing

Multiplanar reconstructions are created and filmed in axial, sagittal and coronal planes relative to the femoral neck, with non-contiguous 2-mm slice thickness with an interval of 0.4 mm to optimise bony detail.

Three-dimensional surface-rendered images of the hip with and without the acetabulum are generated to best demonstrate the femoral neck, femoral cam lesion and acetabular rim.

Radiation dose

Radiation dose is determined by patient size, the length of the scan range and the image quality. Decreasing the radiation dose will decrease the image quality owing to an increase of noise. This noise increase will particularly affect the spatial resolution of 3D images. At our clinic, a dose-length product of 500 mGy/cm is typical. With advances in recent scanners, it is expected that the dose could drop by as much as 32–65% with no loss in image quality.³

Radiologist's report

Information required in the report is summarised in Table 1. The femoral neck cam lesion's location and size (mild, moderate, severe) are documented. The femoral neck fibrocystic change location and size are described. Femoral neck version is also calculated.

The hip joint is inspected for joint space loss. The joint space loss location is described as anterior, antero-superior, superior, posterosuperior or posteroinferior.

Fig. 3. (a) Photograph of a patient with the affected hip placed in the position of discomfort. (b) Axial CT with the right hip in the position of discomfort.

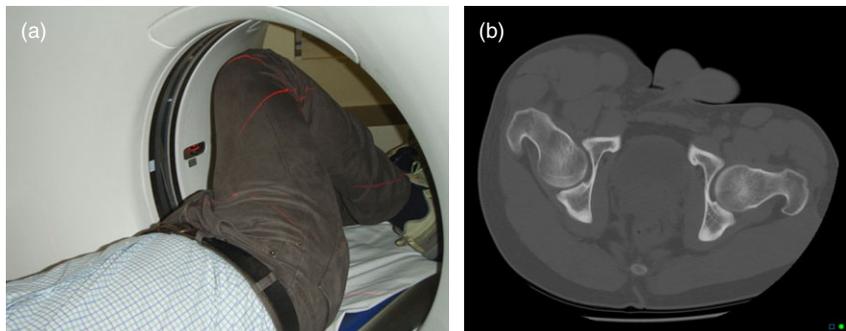


Table 1. Information obtainable from CT in position of discomfort that should be included in report

Femoral cam lesion	Location Size
Femoral neck cystic change	Location Size
Joint space narrowing	Location Severity
Acetabular rim abnormalities	Fragmentation Cyst formation Os acetabuli
Effusion	
Acetabular overcoverage	Anterior coverage Coxa profunda Protrusio acetabuli
Femoral neck version	Anteversion Retroversion
Post-surgery	Size of osteoplasty Size of residual cam lesion

The presence of a hip joint effusion is reviewed on the soft-tissue windows. Any calcified or ossified intra-articular bodies are documented.

Acetabular rim bony abnormalities such as fragmentation and cyst formation are described. The presence of a separated acetabular ossicle (os acetabuli) is indicated.

An assessment of the acetabular morphology is undertaken for either focal or diffuse acetabular overcoverage. Review of the 3D images provides an excellent overview of the hip.

In post-surgical patients under consideration for surgical revision, the femoral and acetabular surgical sites are reviewed. The size of the femoral neck osteoplasty is assessed, and any residual cam lesion is documented.

Discussion

Femoroacetabular impingement is a recognised pathological cause of hip or groin pain and restricted range of motion, usually occurring in young, active individuals.¹ Repetitive microtrauma and abnormal stresses from the impingement process, which is due to certain abnormal morphological features of the acetabulum, femur or both, result in progressive labral and articular cartilage damage, which are precursors to osteoarthritis. Early identification and intervention are therefore essential in the delay and prevention of premature osteoarthritis.⁴ Preoperative imaging assessment will include a combination of plain radiograph, MRI/MR angiography and/or CT.

The CT-POD technique presented in this paper provides a simple, dynamic method to demonstrate FAI in the provocative impingement position. This technique is an advancement on the evaluation for FAI previously described by Beaulé *et al.*, which uses 2D and 3D CT in the neutral position.⁵ With CT-POD, the patient is

scanned in the impingement position, removing the need for a virtual computational model or software to simulate the impingement process. CT-scanning the patient's symptomatic hip in the POD and applying 3D reformations and virtual surface-rendering techniques considerably assists in the preoperative visualisation of the impingement process (specific points of impingement) and location of the FAI lesions for both the surgeon and patient. Advanced degenerative osteoarthritis and extensive articular cartilage damage (joint space narrowing) are relative contraindications for FAI surgery because of the increased risk of poor post-surgical outcomes.^{6,7} Thus, an advantage of CT-POD is the demonstration of the degree of loss of joint space.

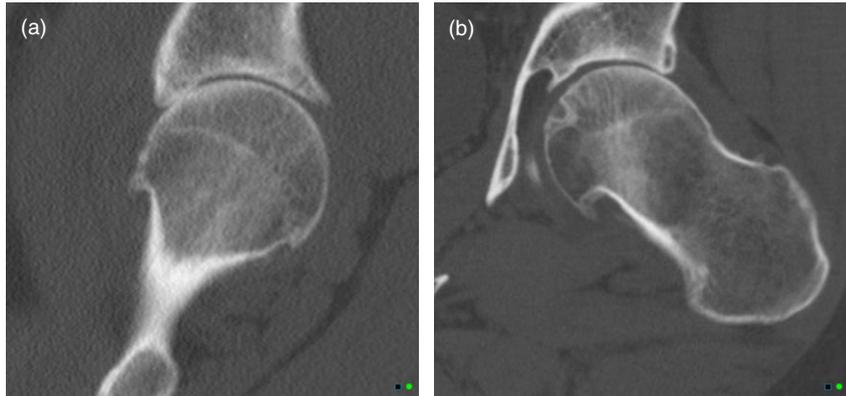
With CT-POD, loss of the joint space associated with acetabular rim lesions can be seen between the femoral head and acetabulum in the position of impingement. The size and extent of rim lesions has also been demonstrated to be an important prognostic indicator in determining the likely outcome of arthroscopic FAI surgery.⁸ The additional information gained with CT-POD with respect to loss of joint space can be used preoperatively to give a more informed estimate of the degree of improvement that might be expected following surgery. This is similar to the improved demonstration of decreased joint space seen with weight-bearing radiographs of the knee. We have observed that the commonest site for this loss of joint space is located anterosuperiorly (Fig. 4), which corresponds to the findings of an MRI study performed by Pfirrmann *et al.*⁹ Figure 5 demonstrates the benefit of scanning a patient in POD rather than a neutral position: CT-POD clearly shows the reduction in joint space and location of impingement, which is usually not well appreciated in neutral position.

Less commonly, with a CT-POD scan, loss of joint space can be seen posteroinferiorly (contre-coup cartilage lesion); this is seen in one-third of patients with pincer FAI^{1,10} and is also a poor prognostic sign (Fig. 6).

Identification of the abnormal femoral head-neck junction is critical in treating patients with cam-type impingement and is well demonstrated in the CT-POD protocol (Figs 7,8). If only the labral and cartilage abnormalities are identified and treated, the underlying cause of impingement will remain present, likely resulting in persistent pain, further cartilage and labral damage, and, potentially, further acceleration of degenerative change.¹¹ Cam-type impingement is treated with femoral neck osteoplasty with removal of the non-spherical portion of the head, thereby improving the head-neck offset and creating clearance for flexion and internal rotation.¹

Pincer FAI is the result of a linear contact between the acetabular rim and the femoral head-neck junction. This acetabular morphologic deviation may be characterized as a generalized overcoverage in patients with a deep acetabular socket (coxa profunda or protrusio acetabuli)

Fig. 4. Fifty-year-old patient with left hip pain and cam-type femoroacetabular impingement. Sagittal (a) and coronal (b) CT images demonstrate anterosuperior joint space loss with bone on bone appearance.



or as localized anterior overcoverage, which may be due to acetabular retroversion or elongation of the anterior acetabular wall. With pincer impingement, the CT-POD scan can be used to plan how much of the acetabular overcoverage to reduce by an acetabular rim resection. This is achieved by correlating the position of impingement of the femoral neck with the acetabulum (Fig. 9). In FAI, CT-POD allows direct visualisation of the dynamic impingement location, enabling the surgeon to adequately plan the volume of acetabular resection and femoral neck osteoplasty.

The presence of cysts (fibrocystic change) in the anterosuperior femoral head-neck junction is seen in some 33% of patients with FAI.¹² It is postulated that fibrocystic change may be caused by repetitive abnormal contact between the femoral head and acetabular rim. Acetabular rim fragmentation and os acetabuli are also frequently seen in patients with FAI¹³ (Figs 7,8).

Femoral neck version is defined as the angular difference between the long axis of the femoral neck and transcondylar axis of the knee. Femoral neck version is a physiological factor, with variations in degrees depend-

Fig. 5. Impingement lesion viewed in a neutral position (a) and in the position of discomfort (b) in the same patient.

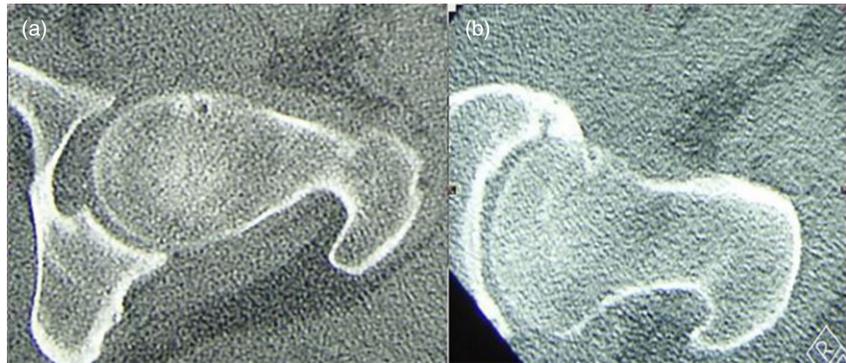
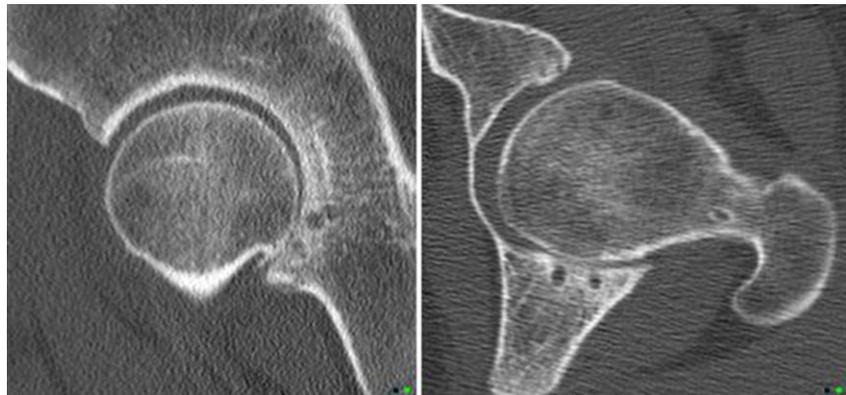


Fig. 6. A 34-year-old woman with bilateral acetabular protrusio. Sagittal CT in position of discomfort shows posteroinferior joint space loss with subchondral cysts in position.



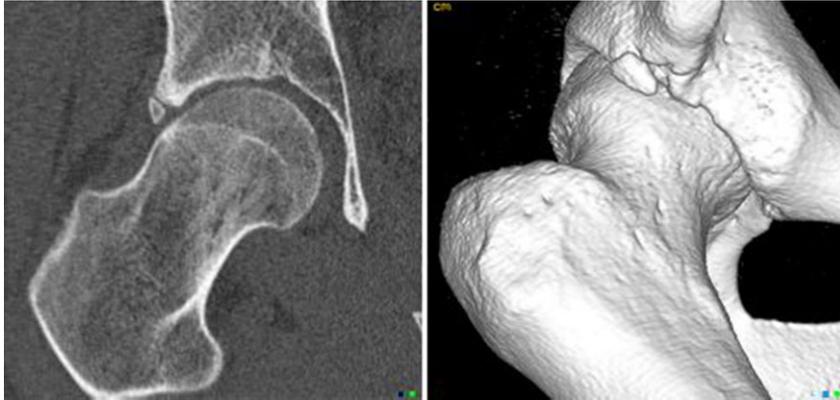


Fig. 7. A 19-year-old with left hip pain and cam-type femoroacetabular impingement. Coronal CT in position of discomfort and 3D reconstruction show cam deformity with os acetabuli.

ing on the age and sex of the person. If the axis of the neck is inclined upwards with respect to the transcondylar axis, it is called anteversion. If the axis is tilted downwards or below the transcondylar axis, it is called retroversion. In adults, anteversion ranges from 5 to 15 degrees,¹⁴ with an average 8 degrees in men and 14 degrees in women¹⁵ (Fig. 3). Femoral neck version is an important factor when diagnosing and treating hip problems, as excessive version can compromise hip stability or range of motion or lead to component impinge-

ment or subluxation/dislocation following reconstruction. An increased femoral neck version necessitates an adjustment to the angle of portal entry of the arthroscopic needle. For example, if there is increased femoral neck anteversion, the surgeon will need to direct the needle slightly more in line with the anteversion angle.

Finally, CT-POD is useful in revision cases. One of the commonest reasons identified for revision hip arthroscopy is an inadequate femoral osteochondroplasty.¹⁶ With a POD scan and a 3D reconstruction, an assessment

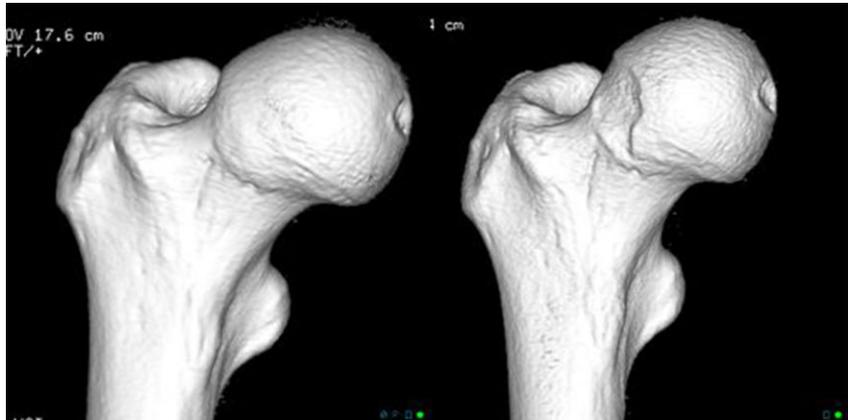


Fig. 8. A 17-year-old boy with hip pain and cam-type femoroacetabular impingement. Coronal CT in position of discomfort and 3D reconstruction show cam deformity and os acetabuli.

Fig. 9. A 20-year-old with left hip pain. Coronal CT in position of discomfort and 3D reconstruction show femoroacetabular impingement with focal pincer.



Fig. 10. Three-dimensional reconstructions before and after cam osteoplasty.



of the primary bony resection can be made, and any further bony resection can be planned accordingly (Fig. 10).

One of the disadvantages of using the POD scan is the radiation dose compared with MRI. MRI and MR arthrograms are useful for assessing early damage to the labrum and the adjacent cartilage, which frequently is not detectable on conventional radiographs. More recently, dynamic MRI using an open-magnet-bore configuration to allow flexion of the hip during imaging has been described.¹² Although this option negates radiation exposure, it does not provide a 3D reconstruction image that can be used in preoperative planning for the bony resection.

The CT-POD technique has limitations with regard to maximum achievable hip flexion, adduction and internal rotation. These are limited by patient discomfort, patient height and/or the CT gantry aperture. If maximal impingement cannot be achieved, the imaging still provides valuable information to the surgeon.

Conclusion

The use of CT-POD of the hip in combination with 2D and 3D surface rendering is a technique increasingly used to

aid in the assessment and confirmation of femoral and acetabular bony abnormalities related to FAI, the degree of joint space loss and the impingement region. The technique provides valuable preoperative and postoperative information to the surgeon, and radiologists should be aware of the key information to be documented in the radiology report.

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