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PICTORIAL REVIEW

CT and MRI of hip arthroplasty

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Plain films are the initial imaging method of choice for evaluation of hip arthroplasty. Recent advances in technology and imaging techniques have largely overcome the problems of beam hardening in computed tomography (CT) and magnetic susceptibility artefact in magnetic resonance imaging (MRI). CT and MRI have now become useful imaging techniques in the assessment of hip arthroplasty.

Introduction

Hip arthroplasty is a common treatment for patients with osteoarthrosis and approximately 1.5 million procedures are performed worldwide each year.[1] Although complication rates are low, the large number of hip replacements means that the complications related to hip arthroplasty are common in clinical practice.

Problems that occur after arthroplasty include osteolysis, granulomatous disease, heterotopic new bone formation, dislocation, superficial and deep infection, mechanical aseptic loosening, prosthetic and periprosthetic fracture, and local nerve damage. These problems are a source of morbidity and may require surgical revision.[2,3] Plain films are the initial imaging method of choice for evaluation of hip arthroplasty but are limited in evaluation of complications due to their inability to delineate complex three-dimensional (3D) structures.[4] However, CT and MRI are now also useful imaging tools for assessing orthopaedic implants, as recent advances in technology and imaging techniques have largely overcome the problems of beam hardening in CT and magnetic susceptibility artefact in MRI.[3–12] CT and MRI can detect periprosthetic collections, evaluate osteolysis due to small-particle disease, clearly define the periprosthetic soft tissues, and demonstrate loosening.

This article will describe the optimization of CT and MRI protocols for imaging hip arthroplasties. The role of CT and MRI in contributing to the management of the patient with complications related to hip arthroplasty will be highlighted.

Technical considerations

CT

Beam-hardening artefacts, which manifest as alternating high and low attenuation lines radiating from the prosthesis, are the major cause of image degradation in CT images of metallic implants. The degree of artefact is proportional to the proton density of the metallic implant with cobalt—chrome—steel and stainless steel alloys causing the most severe artefacts.[10,13] These artefacts can be reduced by increasing the signal to noise ratio by increasing the output of the tube (mA and kVp). The exact values will depend on the CT machine and the size of the patient but the mA should be in the region of 350—400 mA on modern

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machines.[12] Using a fast iterative algorithm[14] and an extended CT scale can reduce these artefacts.[15] Soft-tissue or smooth reconstruction filters reduce metal artefact with an inevitable, but acceptable, reduction of spatial resolution.

Viewing the CT images using wide window widths reduces the observer's perception of the artefact. Data acquired with multidetector CT, which is reconstructed with a soft-tissue algorithm and overlapping sections, can be reformatted in any plane, which may further reduce artefact.[12]

MRI

MRI has, until recently, been limited in the imaging of postoperative orthopaedic patients due to magnetic susceptibility artefacts produced by metallic implants. Magnetization of the implant affects the local field gradient, proton dephasing, and spin frequency resulting in signal void, spatial distortion, and spurious high signal. As MRI machines have implemented higher magnetic field strengths, which induce greater magnetization of orthopaedic implants, so the size of the susceptibility artefacts has increased.[2]

MRI parameters can be modified to minimize these artefacts. Increasing the frequency encoding gradient strength decreases the misregistration artefact proportionately. Fast spin-echo techniques refocus spins at a shorter interval than conventional spin-echo techniques and reduce diffusion-related signal intensity loss. Reducing the volume of the voxels (increasing the spatial resolution) reduces diffusion-related signal intensity loss. It also reduces the spatial definition of the signal void, and therefore, leads to reduction in apparent size of the void.[2] Spectral fat suppression is particularly susceptible to metallic artefact and should be avoided in favour of a short tau inversion recovery (STIR) sequence where some of the dephasing of proton spins, due to magnetic field inhomogeneity, is refocused by the 180° inversion pulse. The frequency encoding direction of the image is more susceptible to artefact, because of proton spin dephasing, than the phase encoding direction, and therefore, careful selection of the phase and frequency-encoding directions, in the three principal anatomical planes, will allow superior periprosthetic imaging in the frequency-encoding direction.[2,10] Combining all of these adjustments using metal artefact reduction sequences (MARS) can allow distinction of cortex, marrow, cement mantle, and disease in the region of the femoral stem of the implant (Fig. 1). Positioning the long axis of the prosthesis parallel to the B_0 magnetic field reduces susceptibility, which is why the stem of the femoral component responds better to these refinements than the obliquely oriented neck.

CT versus MRI

MRI offers advantages over CT in assessing many aspects of hip arthroplasty because of its superior differentiation of soft tissues. However, it is still limited in the region of the acetabulum because susceptibility artefact has not yet been completely resolved by current techniques (Fig. 1). It is now possible to image periprosthetic fractures, osteolysis, marrow oedema, collections, extraosseus soft-tissue deposits, and adjacent musculature with routine MRI capabilities.[2,10,16,17]

CT has the advantage of speed. An axial volume acquisition through the pelvis and both femora takes a matter of minutes; multiplanar and surface-shaded reformats can be constructed after the patient has left the department. CT is preferable for imaging the roof of the acetabulum, and is probably superior to MRI for imaging cement, heterotopic ossification, and metallosis.

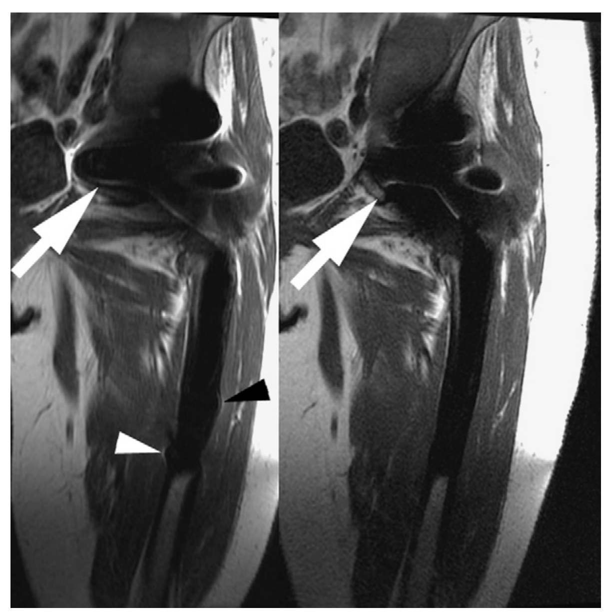

Figure 1 Coronal T1-weighted MRI of a left metal-on-metal total hip arthroplasty. Part (a) was acquired using conventional fast spin-echo parameters and (b) was acquired using metal artefact reduction parameters described in the text. Mismapping of the signal from the femoral cortex (arrowheads) is nearly completely resolved by the MARS where the stem of the prosthesis lies parallel to B_0. The mismapping of the signal from the neck and acetabulum of the prosthesis is reduced so that the superior pubic ramus (arrow) is discernible.