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Imaging of the Painful Hip Arthroplasty

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Abstract

The incidence of complications following total hip arthroplasty is low, but due to the frequency of the procedure, they are quite commonly encountered and require appropriate investigation. Complications include aseptic loosening, infection, foreign body granulomatosis (osteolysis), adverse reactions to metal debris, periprosthetic fracture, heterotopic ossification, hardware failure, and a range of soft tissue complications, all of which may result in pain. Relevant imaging findings are illustrated and the role of various imaging modalities is reviewed. A suggested approach for the radiological investigation of each potential complication is outlined, based on our experience at a specialist referral unit.

Résumé

En dépit d'un taux d'incidence faible, les complications résultant d'une arthroplastie totale de la hanche sont assez courantes et exigent la tenue d'examens appropriés en raison de la fréquence de cette intervention. Ces complications, qui sont toutes susceptibles de causer des douleurs, englobent le descellement aseptique, l'infection, la réaction granulomateuse à corps étranger (ostéolyse), les effets indésirables causés par les débris métalliques, la fracture périprothétique, l'ossification hétérotopique, la rupture de l'implant et diverses complications touchant les tissus mous. L'étude présente des aspects d'imagerie pertinents et examine le rôle de diverses modalités. Elle propose aussi une approche pour l'examen radiologique de chaque complication potentielle, fondée sur notre expérience au sein d'une unité de consultation spécialisée.
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Total hip arthroplasty (THA) is most frequently performed for advanced osteoarthritis (OA) of the hip, with >1 million estimated procedures undertaken worldwide annually. It provides significant reduction in pain, restoration of function and improvement in quality of life for the vast majority (>89%) of patients [1−3].

The incidence of complications is low, but due to the frequency of the procedure, they are quite commonly encountered and require appropriate imaging and interpretation. A painful THA may relate to a variety of general complications, however specific complications also exist in relation to the various different commercially available implant types.

The articulation between the femoral and acetabular components (or bearing surfaces) may incorporate "hard-on-hard" surfaces (eg, metal on metal [MoM], ceramic on ceramic) or "hard-on-soft" surfaces (metal or ceramic on polyethylene) [4]. In addition, the stem of the prosthesis may be modular, with modular head-neck or neck-stem junctions, or nonmodular, which is uncommon. The resulting configuration of bearing surfaces and modular junctions can influence specific wear-related complications that may occur [2,5−8].

Not all complications result in pain however and the aim of this article is to review complications giving rise to a painful THA, along with a suggested approach to imaging and interpretation.

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Imaging Modalities

A range of imaging modalities may be used in the investigation of painful THAs, with each modality providing complementary information.

Plain radiographs are readily available, suffer from effectively no metal artifact and are the usual initial investigation of choice for any painful THA. Component positioning is readily assessed on plain radiographs. The vertical and horizontal centres of rotation are important to evaluate; if the component is positioned too high there will be resulting muscle laxity. Conversely, a low placement results in stretch of the muscles and resulting spasm. Femoral stem alignment is also easily assessed; varus positioning of the stem, where the distal stem is directed towards the lateral endosteum, may pose an increased risk for loosening [9]. Periprosthetic fractures, hardware failure, and osseous complications are often visible although may occasionally be radiographically occult. Soft tissue complications are however poorly characterized on plain radiographs.

Computed tomography (CT) provides excellent evaluation of bone texture and morphology whilst providing useful soft tissue information. Hardware is generally well assessed although beam hardening and streak artifacts may obscure the relevant anatomy. In recent years, dual-energy CT (DECT) has been shown to reduce metal artifacts compared with conventional CT imaging and provide superior diagnostic value in implant evaluation with no additional radiation [10–12]. The dose of ionizing radiation is an important consideration with CT and DECT and dose-reducing protocols or software algorithms should be utilised where possible. CT is however often required as a preoperative planning tool for complex revision surgery.

Ultrasound (US) is widely available and has the benefit of dynamic assessment. Its use in evaluation of painful hip replacements is typically aimed at relatively superficial soft tissue assessment including tendons, muscles, soft tissue collections, and the joint capsule.

Nuclear medicine has a complementary role in investigation of suspected infection although in our institution this is less commonly utilised than in the past, with more emphasis now being placed on tissue sampling from the joint in such cases. Single-photon emission computed tomography (SPECT-CT) imaging may also be beneficial in specific complex cases, including chronic fractures and poorly positioned prostheses.

Magnetic resonance imaging (MRI) remains the cross-sectional modality of choice for the investigation of a painful THA with its combination of excellent soft tissue contrast resolution as well as its ability to demonstrate marrow oedema. Conventional MRI pulse sequences can be used, however the presence of metal requires careful parameter modification to limit susceptibility artifact. This includes using an increased bandwidth, use of fast spin-echo sequences with long echo train lengths, reducing voxel size, increasing the number of excitations, using inversion recovery fat suppression instead of frequency selective fat saturation and scanning at 1.5-T rather than 3-T [2,13]. Specialized metal artifact reduction sequences (MARS) have been shown to improve visibility of synovium as well as the bone and soft tissues structures immediately adjacent to a THA, including at 3-T [14,15].

Complications

Aseptic Loosening

Noninfective, mechanical, or aseptic loosening is considered one of the most common causes of chronic THA failure and subsequent revision surgery. Up to 60% of revision cases have been attributed to loosening and as such it is an important diagnosis to make correctly [7].

Loosening is defined as motion of the implant detected by mechanical manipulation during surgery [16]. Mechanical stress and movement can promote migration of synoviocytes into the interfaces of the THA with surrounding bone and/or cement. There may be cytokine release from these synoviocytes but also formation of a fibrous or synovial-like membrane, which can precede the onset of loosening [4]. The lysis of periprosthetic bone critically loosens the prosthesis at the metal-bone or cement-bone interface and eventually results in complete loss of implant fixation [8,17,18].

In practice, radiographs play the primary role in the initial evaluation of THAs in the postoperative period and provide baseline imaging for subsequent surveillance. They provide an accessible and inexpensive means of accurate hardware evaluation without being subject to the metal-related artifacts encountered in CT and MRI [6–8,19].

The criteria for the firm diagnosis of loosening have been defined as the migration of any of the prosthetic components over time, cement mantle fracture, and also osteolysis, which surrounds 50%-100% of the cement mantle [8].

Recognition of arthroplasty migration and subsidence requires careful assessment of serial radiographs. Early loosening may be more difficult to detect; a periprosthetic 1-2 mm lucent layer, which appears to be new, can be a result of loosening. To help describe the site of involvement, the femoral prosthesis is traditionally divided into zones defined by Gruen and the acetabular component into zones according to DeLee and Charnley (Figure 1).

For noncemented acetabular components, migration or lucency that appears to be new or is seen to progress over a 2-year period, or found to be >2 mm has been shown to be 95% sensitive and 100% specific for loosening (Figure 2A) [7]. For noncemented femoral components, subsidence (a change in the distance from the greater trochanter to the lateral shoulder of the femoral component) is suggestive of loosening if >2 mm, as is endosteal scalloping or migration of the prosthesis [4,6].

For cemented THAs, the correlation between radiographic lucency and mechanical loosening appears to be more reliably related to its extent and location. Periprosthetic lucency confined to acetabular zone I is associated with only a 7% chance of finding mechanical loosening at surgery, while this

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