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Developments in imaging methods used in hip arthroplasty: A diagnostic algorithm

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Abstract
Background: Several imaging modalities can be used to diagnose complications of hip prosthesis placement. Despite progress in these imaging techniques, there are, as yet, no guidelines as to their respective indications.
Methods: We formed a panel of experts in fields related to prosthesis imaging (radiology, nuclear medicine, orthopedic surgery) and conducted a review of the literature to determine the value of each modality for diagnosing complications following hip replacement.
Results: Few recent studies have investigated the benefits related to the use of the latest technical developments, and studies comparing different methods are extremely rare.
Conclusions: We have developed a diagnostic tree based on the characteristics of each imaging technique and recommend its use. Computed topography was found to be the most versatile

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and cost-effective imaging solution and therefore a key tool for diagnosing the complications of hip replacement surgery.

Over the last 10 years, the frequency of joint replacement surgery has steadily increased due to population aging and the effectiveness of such implants in alleviating pain and restoring joint function [1,2]. Despite the improved life span of prosthetic implants, the growing life expectancy of the population has resulted in an increased number of prosthesis-related complications, and hence a global increase in the number of revision surgeries [3]. Prosthesis-related complications are diverse, and depend largely on the type of prosthesis used. They can involve the implant itself, the bone in which the implant is placed, as well as the joint and surrounding soft tissue.

A more accurate and earlier detection of some of these complications has recently become possible owing to recent progress in imaging techniques. The use of such techniques has quickly spread due to the concern raised by the high rate of complications associated with resurfacing implants, and has most probably led to an excessive number of diagnostic imaging examinations, particularly magnetic resonance imaging (MRI) [4—6].

Most reports in the literature focus on a single modality and have not attempted to compare its best performance with other imaging techniques. We therefore deemed it necessary to summarize recent developments for each imaging technique and propose a diagnostic tree that takes into account the cost, performances and availability of each modality. In the absence of sufficiently supported scientific data, the recommendations presented in this paper were reached by consensus of a multidisciplinary panel of orthopedic surgeons, radiologists and nuclear medicine physicians specialized in musculoskeletal disorders. The aim of this article was not to describe the clinical semiotics of prosthesis-related complications, which have previously been extensively described in the literature.

Review of existing literature and development of the diagnostic algorithm

Existing literature was reviewed prior to algorithm development. The aim of this review was notably to identify recent studies comparing the performances of various imaging techniques for diagnosing hip prosthesis-related complications. The review was carried out by two radiologists experienced in bone and joint disorder diagnosis using the PubMed research engine with the following MeSH terms: ''hip replacement'', ''hip prosthesis'', ''hip implant'', and ''metal artifact reduction''. Three studies were identified in 2014 and 2015 that compared the performances of different imaging modalities, using their most recent technological improvements, for diagnosing prosthesis-related complications. They all dealt with the complications of metal-on-metal hip prostheses. Two of the studies compared the performances of ultrasound and MRI in diagnosing pseudotumors, and the third compared computed tomography (CT) and MRI for the diagnosis of periacetabular osteolysis [7—9].

The radiologists, nuclear medicine physicians and orthopedic surgeons who contributed to the development of the diagnostic algorithm were all experts in their subject matter, used imaging techniques in their everyday practice and were experienced in prosthesis-related complications. The technical platform included single photon emission computed tomography (SPECT-CT) scanners, positron emission tomography (PET)-CT scanners, a scanner with a metal artifact reduction algorithm (SEMAR, Aquilion One, Toshiba Medical Systems, Tokyo, Japan) and a MRI with metal artifact reduction sequences (STIR MAVRIC-SL, Discovery MR750w, General Electric Healthcare, Milwaukee, WI, USA). All images were available for viewing in the Picture Archiving and Communication System (PACS) (Fuji Medical Systems).

The experts were asked to provide feedback on various situations that are typically diagnostically challenging: suspected component fracture or malposition, periprosthetic fracture, aseptic loosening, particle disease, infection or septic loosening, iliopsoas impingement, muscle/tendon injury, and monitoring for bone sarcoma at the proximal end of the implanted femur. An initial algorithm was developed and submitted to the group's members, then iteratively corrected until consensus was reached.

The different imaging techniques

Various imaging techniques can be used to assess prosthetic joints. The recent technical improvements that reduce or compensate metal artifacts have changed the way they are used. Each imaging technique can be characterized by its cost, ease of use, performance and availability in medical imaging centers (Table 1).

Conventional radiography

As for all initial bone and joint investigations, conventional radiography is still the first imaging examination to be performed with patients who have undergone hip replacement surgery [10—16]. Conventional radiography alone may suffice to diagnose the complications and provide therapeutic indications. Both implant components and position can be visualized via radiography, as can bone cement and bone status.

Nevertheless, this technique has serious limitations. The overlay of various implant/bone components can hide abnormalities, bone lesions are underestimated and soft tissue damage is not at all visible. In addition, the intra- and inter-observer reproducibility of radiolucency analysis is

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