SPECTCT imaging of metal hip arthroplasty

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The application of SPECTCT (single photon emission computed tomography combined with simultaneous x-ray computed tomography) imaging in patients with painful hip arthroplasty has been gaining momentum over the past few years. This is reflected by the growing number of papers published in the area. Many of these papers focus on the use of SPECTCT to identify post-surgical complications in the artificial joint. With an increasing elderly population the number of hip replacement operations and SPECTCT studies to investigate complications looks set to rise.

Currently, across England and Wales, approximately 80,000 hip replacements are performed each year. During surgery damaged bone within the joint is removed and replaced with artificial components with the aim of restoring patient mobility and reducing pain. Hip replacement systems consist of a cup, fitted into the acetabulum, and either a replacement femur head or femur cup which is anchored into the femur with a stem (figure 1). Multiple models of replacement hips exist with components made from polyethylene, ceramic or metal. For replacement hips where both components are made of metal the term metal-on-metal (MoM) is used. It is estimated that over 60,000 patients have received MoM implants in the UK.

Complications associated with any joint prosthesis include infection, loosening and malalignment. A notable risk from the use of MoM components is the release of metal ions as the components rub on each other during movement. These ions can trigger a local inflammatory lesion, a pseudotumour which can occur at the bone/implant boundary and may enter the bloodstream leading to raised serum ion levels (figure 2).

The average failure rate for MoM systems has been found to be much higher than other component models. For MoM replacement hips the average failure rate, at seven years, is 11.8% for resurfacing and 13.6% for total hip replacement. The comparable rates for other materials are 3.3%-4.9% with variation between manufacturers.

Due to the increased failure rate of these components the MHRA released guidance in 2010, subsequently revised in 2012. This recommends yearly checks on all implanted MoM hips where the femur head exceeds 36mm. The aim of these yearly checks is to identify any complications at an early stage, enabling more complex surgery on the patients to be avoided.

Patients presenting with a painful MoM hip replacement will undergo clinical examination, blood tests (full blood count, serum ion levels, inflammatory markers) and multi-modality imaging. Imaging options include plain film, ultrasound, MRI, CT and scintigraphy; planar or SPECTCT. No single imaging modality can answer all clinical questions including loosening, infection, pseudotumour or malalignment, but a combination can provide information for appropriate management plans for most patients.

Scintigraphic imaging of painful joint prostheses routinely includes three-phase imaging (dynamic, blood pool and delayed planar imaging) to look for increased blood flow and blood pool which can indicate infection. Increased uptake of Tc-99m labelled phosphorous complexes such as hydroxy-methylene diphosphonate (HDP) and methylene diphostonate (MDP) at bone/prosthesis boundaries has been reported to indicate loosening. More and more centres are combining this planar imaging with hybrid imaging – SPECTCT to provide a more accurate anatomic assessment and localisation of tracer uptake (figure 3).

SPECTCT combines functional information from the uptake of the radioactive tracer with anatomical detail gained from the CT. These studies are also more tolerant to metal implants and artefacts than MRI or ultrasound imaging. However, SPECTCT images are not immune to artefacts. The most obvious image artefact will be streaking artefacts in the CT image around the implanted metal components. CT streaking artefacts can be reduced by using metal artefact reduction (MARs) techniques during reconstruction, or their appearance can be reduced using an extended window scale.

Attenuation correction (AC) within SPECTCT imaging is based on the acquired CT data. PETCT imaging also uses CT-based attenuation correction and studies have found artefacts simulating increased tracer uptake as a result of errors in the CT-based attenuation correction. Similar artefacts arising from CT-based attenuation of SPECT images could be mistaken for component loosening. Literature in this area is limited, although overestimation of the Tc-99m tracer concentration within metal prosthetic components has been observed. It is currently recommended that both non attenuation corrected (NAC) and AC images are reviewed to identify artefacts.

Using a simple phantom we have been investigating whether artefacts simulating increased tracer uptake can arise in AC SPECTCT images of metal prosthetic components. In our initial studies we have acquired SPECTCT images of prosthetic components within a cylindrical water tank filled with a uniformly radioactive background (figure 4). We have observed artefacts that have the same appearance as increased tracer uptake within metal components. Further quantitative assessment of these artefacts is planned which may lead to methods to easily identify artefact occurrence and prevent detrimental impact on clinical reports.

In conclusion, given the increase in numbers of patients undergoing hip replacement, referrals for imaging to investigate post-operative complications are likely to increase. SPECTCT has been demonstrated to be a useful modality to aid identification of the causes of these complications. However, it is important to consider the possible effects of artefacts within images.

References
4. MHRA Updates Advice for metal-on-metal hip replacements. MHRA Press Release 28th February 2012.
5. Hirschmann et al. Clinical value of SPECT/CT for evaluation of patients

Figure 1: Multiple models of replacement hips exist with components made from polyethylene, ceramic or metal. MoM: metal-on-metal.
8, Mirzaei et al. Use of segmented CT transmission map to avoid metal artifacts in PET images by a PETCT device. BMC Nuclear Medicine 2005;5:3.

**Figure 1**
Left hip replacement with metal on metal (MoM) resurfacing system.

**Figure 2**
(A) Right pseudotumour on T2 weighted MRI.
(B) Same pseudotumour on CT component of SPECTCT study.

**Figure 3**
SPECTCT study showing loosening of left MoM hip prosthesis.

**Figure 4**
(A) Diagram of simple phantom containing metal hip component in uniformly radioactive background. (B and C) AC SPECT and SPECTCT images of phantom showing artefact within the metal component mimicking increased tracer uptake.