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The Accuracy of Single Photon Emission Computed Tomography/Computed Tomography Arthrography in Evaluating Aseptic Loosening of Hip and Knee Prostheses

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ABSTRACT

Aseptic loosening represents the most common complication associated with hip and knee arthroplasty and is a common indication for surgical revision in the post-arthroplasty population. The optimal imaging methodology in evaluating clinical suspected loosening is not well-defined. Our study retrospectively evaluated nuclear medicine arthrography with hybrid single photon emission computed tomography/computed tomography (SPECT/CT) in 38 patients (21 hip, 17 knee) compared with reference standards of surgical evaluation, spontaneous resolution of symptoms without revision, or a minimum of 1 year clinical and radiographic follow-up. Our study demonstrated a sensitivity of 100%, specificity of 96.0%, PPV of 92.9%, NPV of 100%, and accuracy of 97.4% with this imaging technique suggesting utility of nuclear medicine arthrography with SPECT/CT in the clinical evaluation of suspected aseptic loosening.

Hip arthroplasty and knee arthroplasty procedures are commonly performed surgeries which continue to increase in occurrence. Recent estimates suggest that in the USA in 2009, there were approximately 620,000 knee arthroplasties and 285,000 hip arthroplasties performed [1]. It is projected that by the year 2030, up to 3.48 million knee arthroplasties and 572,000 hip arthroplasties may be performed annually with 6%–12% of these surgeries reflecting revision arthroplasties [2–5]. Aseptic loosening is the most common indication for revision accounting for approximately 40% of revision knee and hip surgeries [2,4].

Up to 44% of patients with a total hip arthroplasty and 27% of patients with a total knee arthroplasty will experience persistent post-surgical pain which can be severe in up to 15% of patients [5]. It is imperative to determine if loosening is present for these patients as revision surgery is indicated in this scenario. Despite the clinical importance of this diagnosis, the available literature evaluating the accuracy of imaging tests in diagnosing aseptic loosening is relatively sparse. Imaging modalities which have been evaluated include radiography, subtraction arthrography, planar bone scintigraphy, and planar radionuclide arthrography with varying levels of reported success. For hip arthroplasty components, the sensitivities for these modalities have been reported in the range of 47%–89% and specificities 50%–80% [6,7]. Literature regarding the evaluation of aseptic loosening of the knee is even more sparse although a 2006 study of knees as well as a very recent study including both hips and knees suggest a sensitivity of 88%–93% and a specificity of 83%–88% for planar radionuclide arthrography in this scenario [8,9]. Overall, a clear algorithm of when and how to image patients with clinically suspected aseptic loosening has not yet been established [10,11].

Single photon emission tomography combined with computed tomography (SPECT/CT) is a recent advancement that has the potential to improve the accuracy of radionuclide arthrography in assessing arthroplasty loosening. The three-dimensional volume acquisition and precise localization should improve the assessment of activity along the bone–prosthetic interface compared with planar techniques. Despite this potential improvement, to our knowledge only a single retrospective series has been published assessing SPECT/CT for this clinical indication [12]. Chew et al [12] assessed 29 hip arthroplasties and 44 knee arthroplasties compared with a gold standard of operative assessment and reported sensitivities/specificities of 73/71% for the acetabulum hip component, 78/90% for the femoral hip component, 75/63% for the femoral knee component, and 86/86% for the tibial knee component. These authors concluded that SPECT/CT had improved accuracy compared

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with planar techniques for all components except the femoral hip component where the accuracies were similar. It should be noted that only those who had surgery were evaluated. As such, there is a potential for referral bias and uncertainty regarding true negative and false negative image evaluation in this report.

The goal of our study was to determine the accuracy of radionuclide arthrography with SPECT/CT in the evaluation of clinically suspected aseptic loosening of hip and knee arthroplasties. In order to optimally assess both the negative and positive imaging studies, the reference standard included both operative findings and a minimum of 1 year clinical and radiographic follow-up in patients who did not have surgery.

Methods

Patient Population

Our institutional imaging database was retrospectively evaluated to identify all patients who had a SPECT/CT arthrogram study to assess for clinically suspected prosthetic loosening (hip or knee) between December 2007 and January 2013. From this cohort, patients were included in the study if they had subsequent surgical evaluation of the prosthesis, spontaneous resolution of symptoms without revision, and/or a minimum of 1 year of clinical and radiographic follow-up. Given the retrospective nature of this study, the parameters for clinically suspected prosthetic loosening were not strictly defined prior to imaging. All patients were referred for imaging by an orthopedic surgeon involved in the patient's routine clinical care. Typically, these patients would have been experiencing unexplained regional post-arthroplasty pain without clear radiographic evidence of loosening.

Image Evaluation

For included patients, all imaging reports from the clinical SPECT/CT arthrogram studies were obtained and reviewed. These were reported by specialists licensed in nuclear medicine and diagnostic radiology with varying levels of experience (range 6–30 years). The images themselves were also evaluated in a non-blinded fashion to ensure the reports matched standard departmental reporting criteria for arthroplasty loosening—the presence of visible activity along the bone/prosthetic interface of the acetabular or femoral stem components (hips) or along the bone/prosthetic interface of the femoral or tibial components (knee). Reports and images from the fluoroscopic tracer injection as well as radiographs obtained during the follow-up period were also reviewed.

SPECT/CT Arthrogram Imaging Procedure

The typical procedure for the evaluation of aseptic loosening with SPECT/CT arthrography at our institution is as follows.

Initially, the patient undergoes fluoroscopic-guided injection of radiotracer into the prosthetic knee or hip joint. This is performed by a diagnostic radiologist with experience in this technique. Typically a 22-gauge needle is directed to the inferolateral margin of the femoral neck component of a hip arthroplasty or subpatellar joint space of a knee arthroplasty under imaging guidance. Once satisfactorily positioned, intracapsular localization is confirmed with the injection of a small amount (2 mL) of water soluble contrast (Omnipaque 300, GE Healthcare, Buckinghamshire, UK). Subsequently, 37 MBq of ^{99m}Tc sulfur colloid in 2 mL sterile saline is injected into the joint space.

The patient is then transferred to the nuclear medicine department. The patient is instructed to ambulate for 30 minutes and then is positioned in a gamma camera for imaging. Initially planar images of the entire arthroplasty region are obtained in anterior, posterior, and lateral projections (low energy high resolution collimator; 128 × 128 matrix; minimum 1,000,000 counts per image or 10 minute acquisition). SPECT/CT of the arthroplasty is then acquired using a 16-slice dual-head gamma camera SPECT/CT system (Philips Precedence, Best, the Netherlands). The SPECT parameters for this are: low-energy, high resolution collimator; 128 × 128 matrix; 1.0 zoom; 20 seconds per frame; and 120 frames at 3° intervals. The CT parameters for this are: 60 mAs, 140 kV, 2 mm slice thickness at 1 mm increments, and 500 mm acquisition length.

All images are processed using the Astonish iterative reconstruction algorithm (Philips Healthcare, Best, the Netherlands) with 4 iterations, 16 subsets, and a uniform start. Decay correction and attenuation correction are both applied. No post-reconstruction filter is applied. The SPECT/CT images are reviewed using Oasis workstations (Segami Corporation, Columbia, MD). The SPECT/CT studies are considered positive for loosening if any activity is visible within the bone–prosthetic interface of any component (Figs. 1 and 2). The SPECT/CT studies are considered negative for loosening if activity is confirmed within the joint space and no activity is demonstrated within the bone–prosthetic interface of either component (Fig. 3). The SPECT/CT study is considered a failed examination if the images demonstrate no activity within the joint space (Fig. 4).

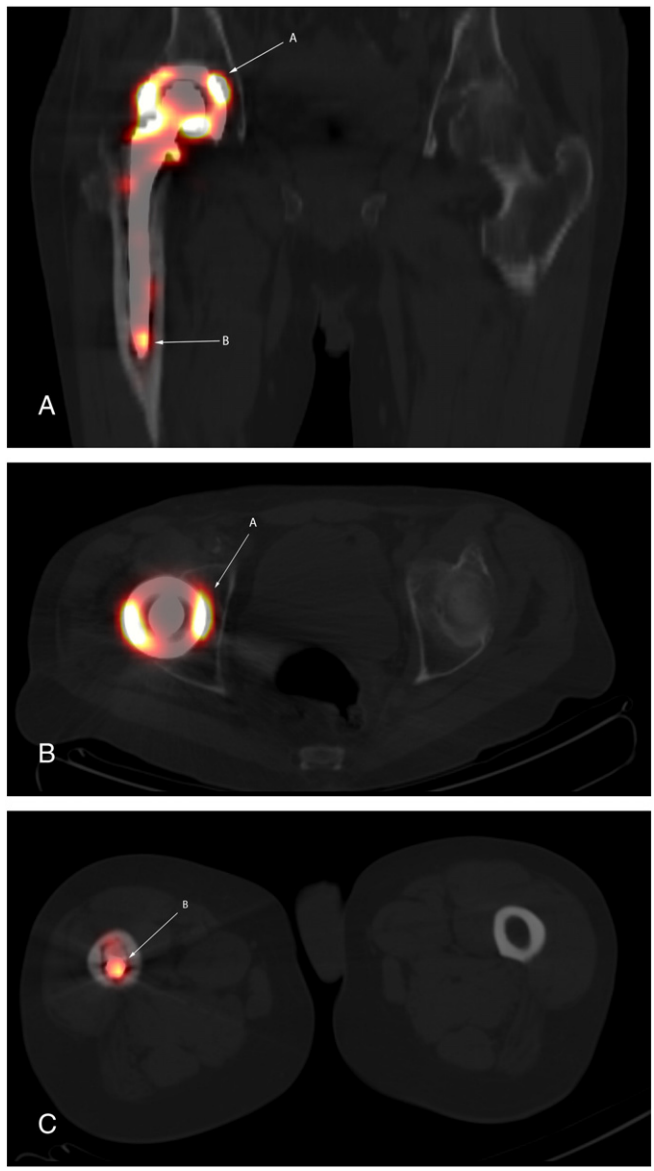

Fig. 1. Loosening of both the acetabular and femoral stem components of a hip arthroplasty. Coronal (A), transverse superior (B), and transverse inferior (C) fused SPECT/CT images demonstrate activity between the bone–prosthetic interface of both the acetabular (arrow A) and femoral stem (arrow B) components.