

Case Report

Combined single photon emission computerized tomography and conventional computerized tomography: Clinical value for the shoulder surgeons?

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ABSTRACT

With the cases described, we strive to introduce single photon emission computerized tomography in combination with conventional computer tomography (SPECT/CT) to shoulder surgeons, illustrate the possible clinical value it may offer as new diagnostic radiologic modality, and discuss its limitations. SPECT/CT may facilitate the establishment of diagnosis, process of decision making, and further treatment for complex shoulder pathologies. Some of these advantages were highlighted in cases that are frequently seen in most shoulder clinics.

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INTRODUCTION

Single photon emission computerized tomography in combination with conventional computer tomography (SPECT/CT) pairs a high-resolution anatomical 3D-CT with a functional single photon emission tomography (SPECT).^[1-5] Until recently, registration or image fusion of the functional (SPECT) with structural images (CT) has been difficult due to SPECT's poor spatial resolution (3-10 mm). Another important problem was the poor reproducibility in identifying the anatomical landmarks.^[1,6,7] With the advent of integrated SPECT/CT machines in 1999, where the image data from SPECT are taken in the same coordinate frame as the CT scan, image fusion ceased to be an issue. Furthermore, hybrid SPECT/CT machines now provide superior SPECT data as the CT data can be used to derive the attenuation coefficients of the tissue.^[8] With integrated machines, functional and anatomic information is provided in the same image, supporting diagnostic analysis of diseases where both types of data are vital. SPECT/CT has already proven useful as a

diagnostic tool in areas such as endocrinology, cardiology, and neurosurgery.^[1,9-16] In orthopedics, it has yet to be clinically validated and only a paucity of studies are available.^[1-5,17-19] With the cases described, we strive to introduce SPECT/CT to shoulder surgeons, illustrate the possible clinical value it may offer as new diagnostic radiologic modality, and discuss its limitations.

Technical description

Hybrid SPECT/CT was performed in two centers using either a hybrid system, Symbia T16 (Siemens, Erlangen, Germany) or Hawkeye-4 (GE Healthcare). The systems are equipped with a pair of low-energy, high-resolution collimators and incorporate a dual-head gamma camera with an integrated, 16- or 4- slice CT scanner. Patients were injected intravenously with 10-20 mCi (340-740 MBq) of 99m-technetium-labelled diphosphonate or 99m-technetium-labelled anti-granulocyte antibodies (CIS Bio International Sur Yvette, France). Perfusion images are obtained in the initial 60 seconds post-injection followed by blood pool images 2 to 5 minutes later. SPECT

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was performed at 3 to 5 hours, followed immediately by a CT with the patient in the same position.

CASE REPORTS

Case 1

A 54-year-old male patient sustained a right-sided 4-part proximal humeral fracture, which was treated by open reduction and internal fixation with a Numelock polyaxial locking system (Stryker AG, Switzerland). One month later, he had to be revised due to a superficial wound infection with streptococcus. The infection resolved under antibiotic therapy with augmentin for 6 weeks. The plate was removed four months after initial fracture treatment.

At presentation to our clinic, the patient complained about activity-related pain and stiffness of his shoulder. Anterior-posterior and y-view radiographs revealed a valgus-impacted humeral head fragment. The healing of the fracture was in doubt and at least a partial humeral head necrosis was suspected [Figure 1a]. MRI showed wide intramedullary osteolytic zones, which were attributed either to a pseudoarthrosis or recurrence of infection. In addition, a severe osteoarthritis and a fatty degeneration of the supraspinatus muscle (Goutallier 2) were identified [Figure 1b]. To exclude a persistence of an infection, an anti-granulocyte SPECT/CT was performed. This showed absent tracer uptake of the humeral head fragment which was attributed to a humeral head necrosis. No signs of infection were present [Figure 1c]. The patient was scheduled for total shoulder arthroplasty.

Case 2

A 70-year-old female patient underwent an inverse shoulder arthroplasty (ANATOMICAL 3, Zimmer, Switzerland) due to a cuff arthropathy. Seven months later, she suffered from activity-related pain in her shoulder. Anterior posterior and y-view radiographs showed extensive osteolysis around the glenoid component [Figure 2a]. In SPECT/CT, increased

tracer uptake between the glenoid component and the host bone was present [Figure 2b]. There was no increased tracer uptake around the stem indicating a well-fixed humeral stem component. At revision surgery, the glenoid component was loose. It was revised to a bipolar humeral head (custom-made, Zimmer, Switzerland) and the host bone defect was filled with autologous cancellous bone graft from the ipsilateral iliac crest. The stem was not revised, as it was well fixed [Figure 2c]. At three-month follow-up, the patient had not regained full range of motion, but presented with less in activities of daily living.

Case 3

A 59-year-old male patient underwent a shoulder hemiarthroplasty (EPOCA, Synthes, Switzerland) due to a 4-part proximal humeral fracture. The postoperative recovery was uneventful until 3 years postoperatively when shoulder pain increased. Anterior-posterior and y-view radiographs showed osteolytic zones around the humeral stem indicating aseptic loosening of the hemiarthroplasty [Figure 3a]. Since osteolytic zones and clinical symptoms often poorly correlate in shoulder arthroplasty, a SPECT/CT scan was performed. It showed increased tracer uptake only around the stem in all three phases, which was attributed to mechanical loosening [Figure 3b]. The hemiarthroplasty was revised (GLOBAL, DePuy, Switzerland) and a satisfying recovery was obtained.

Case 4

A 58-year-old patient presented with a painful right shoulder with reduced range of movement and a history of arthroscopy 3 months previously for a stiff painful glenohumeral joint. Given history of the arthroscopy and hence concern for infection, a two-phase bone scan supplemented with SPECT-CT (GE, Hawkeye-4) was performed. Accentuated blood pool activity was found on delayed planar scans with tracer uptake at the right humeral head. Although this finding supported osteonecrosis, the SPECT-CT [Figure 4] localized the activity more specifically at the glenohumeral joint interface. In addition, the CT showed radiographic erosive changes at both



Figure 1a: Anterior-posterior and y-view radiographs of the right shoulder at initial presentation indicating a valgus-impacted humeral head fragment and doubtful partial osteonecrosis of the humeral head

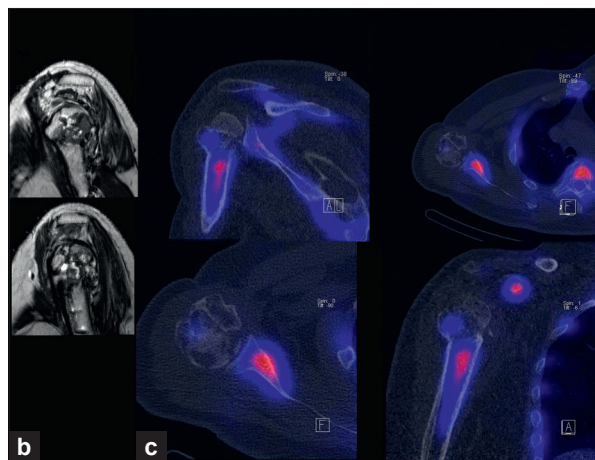


Figure 1: (b) MRI showing extensive cystic changes within the humeral head; (c) 99mTc-HDP-SPECT/CT showing decreased uptake of the humeral head fragment indicating a humeral head necrosis

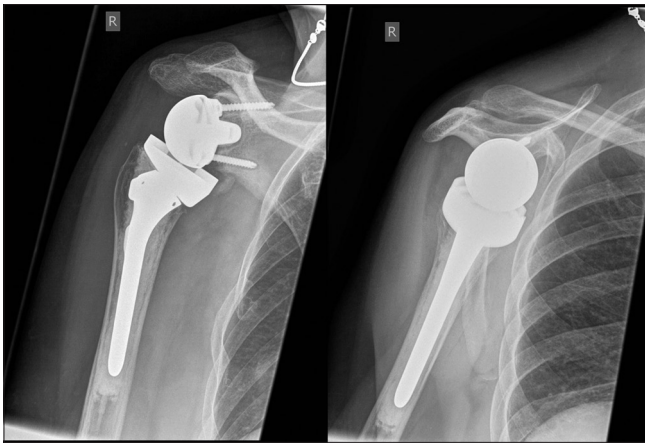


Figure 2a: Anterior-posterior and y-view radiographs of the right shoulder showing wide radiolucent lines around the glenoid peg



Figure 3a: Anterior-posterior and y-view radiographs of the left shoulder indicating radiolucent lines around the humeral stem

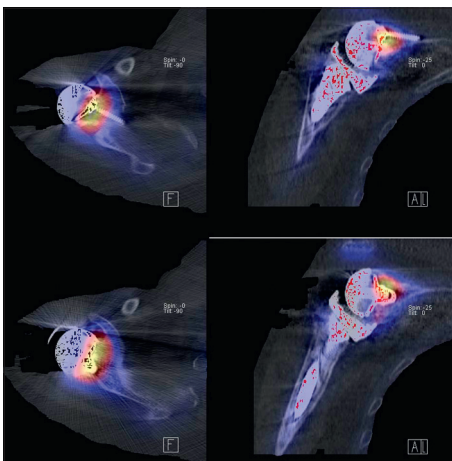


Figure 2b: 99mTc-HDP-SPECT/CT showing increased tracer uptake at the glenoid component-host bone interface, which was interpreted as clear sign for mechanical loosening

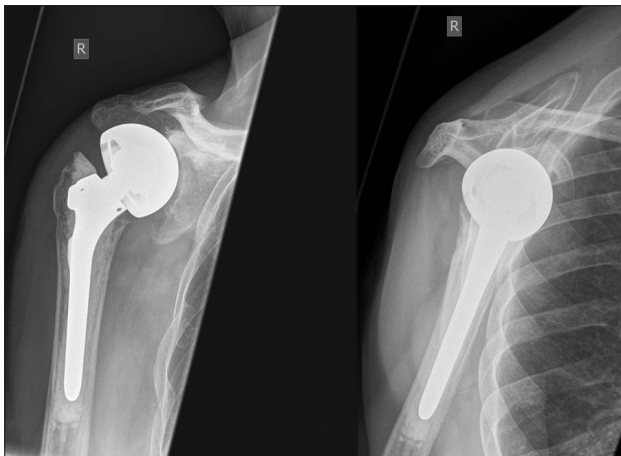


Figure 2c: Anterior-posterior and y-view radiographs of the right shoulder after revision to a bipolar cup prosthesis

subarticular joint surfaces confirming a primary joint-based process [Figure 4]. A total shoulder replacement (TSR) was performed. No bacterial growth was confirmed in culture specimens. After a symptom-free period of 9 months, pain

recurred. On examination, the pain was thought to be of subacromial origin and ultrasound-guided injections of the subacromial bursa brought partial relief. Continuing pain prompted the surgeon to consider prosthetic loosening. A CT scan in a modified position^[20] showed no adverse features [Figure 4]. A SPECT/CT at 14 months after TSR showed no significant early blood pool phase activity mitigating against infection, whilst delayed planar images showed mild periprosthetic activity considered to be in the realm of osseous remodeling after TSR. More focal tracer activity was present at the acromion, raising this site as possible pain generators [Figure 4]. An arthroscopic subacromial decompression resulted in significant pain relief as assessed on clinical follow-up at one-month post-procedure.

DISCUSSION

The most important finding of the present case study was that SPECT/CT may facilitate the establishment of diagnosis, process of decision making, and further treatment for complex shoulder pathologies. Some of these advantages were highlighted in cases that are frequently seen in most shoulder clinics.

In case one, the anti-granulocyte SPECT/CT helped to noninvasively distinguish recurrence of infection from humeral head necrosis. 99m-Tc-labeled anti-granulocyte antibodies are directed against the concomitant infiltration of granulocytes in infected tissues and thereby these are helpful in diagnosing and localizing joint infections.^[13,21] Recently, Graute *et al.* assessed the diagnostic sensitivity of scintigraphy, SPECT, and SPECT/CT. In relation to planar scintigraphy, SPECT/CT substantially improved the sensitivity and specificity for diagnosis and localization of suspected joint infections.^[21] Although the authors only assessed infections of knee and hip arthroplasty, it could be speculated that similar results might be found in patients after shoulder arthroplasty.

The second case illustrates a common problem after shoulder

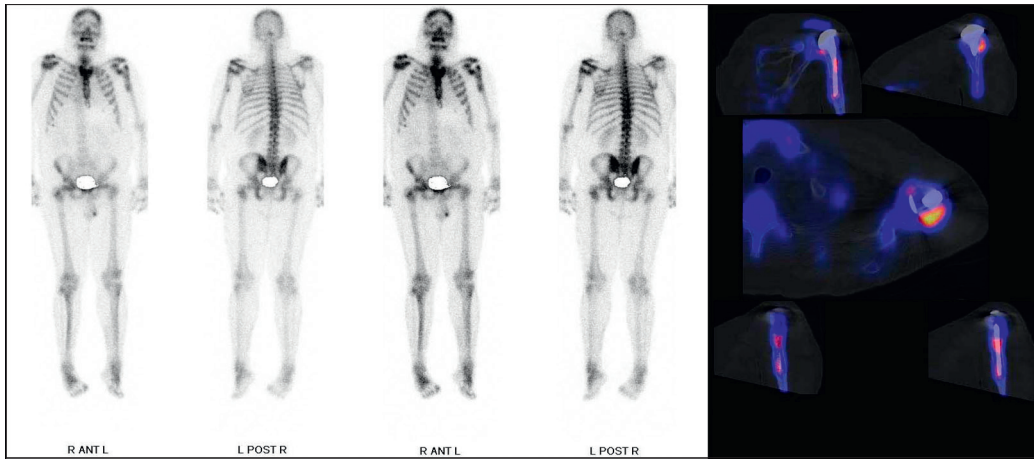


Figure 3b: Planar scintigraphy and 99mTc-HDP-SPECT/CT showing increased tracer uptake around the humeral stem, which was caused by mechanical loosening

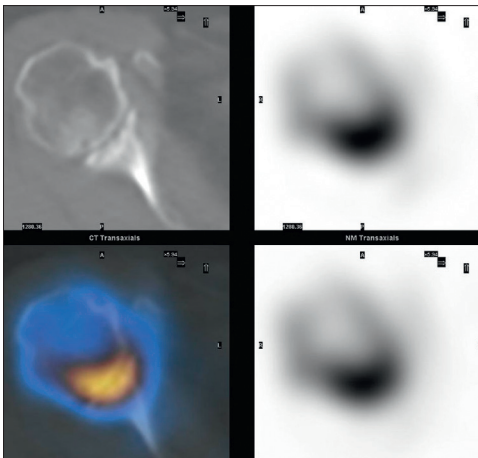


Figure 4a: SPECT/CT showing erosive arthropathy with joint-based tracer uptake

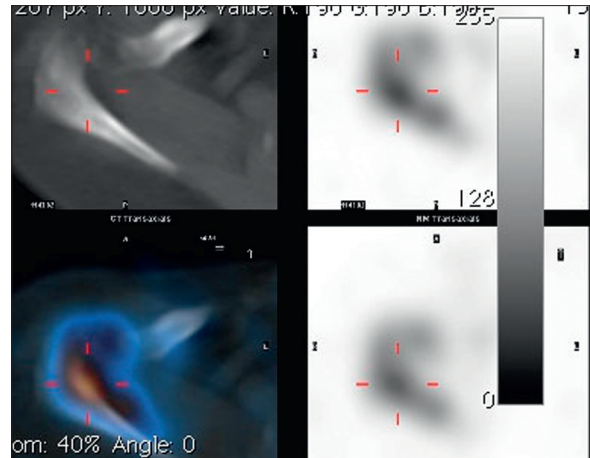


Figure 4b: CT showing no significant periprosthetic lucency; planar scintigraphy indicated normal blood pool activity, delayed moderate periprosthetic tracer activity; SPECT/CT clearly found increased tracer activity of the acromion and acromioclavicular joint

arthroplasty, namely glenoid loosening. In patients after reversed shoulder prosthesis as well as after conventional arthroplasty, glenoid loosening represents one of the most common failure modes causing postoperative pain, limited function, and the need for revision surgery.^[20] To date, detection and monitoring of glenoid fixation failure is considered to be difficult and shows a great inter- and intraobserver variability.^[22] Radiolucent lines, particularly the width, are difficult to interpret in conventional radiographs. This might be due to inaccurate positioning of the patient and anatomical variation in glenoid version and mobility of the shoulder girdle.^[22] Clearly, the radiolucent lines appeared to be smaller when retroversion was 10° or more and when anteversion was 15° or more.^[22]

Nowadays, three-dimensional reconstructions of CT provide the surgeon with a better 3D understanding of patient's anatomy. In addition, the position and orientation of the prosthetic components after shoulder arthroplasty could be assessed in relation to standardized frames of reference. With SPECT/CT, it is not only possible to determine the

width of radiolucencies and the localization of the metabolic tracer uptake, but also assess the orientation of the shoulder prosthesis, in particular the glenoid component. The orientation of the glenoid component has been reported to be a risk factor for early glenoid loosening.^[23]

The potential benefit that SPECT/CT might provide for patients after shoulder arthroplasty is further highlighted by the third case where SPECT/CT identified osteolysis around the humeral stem and metabolic tracer uptake reflecting toggling of the component as cause of the patient's pain. SPECT-CT may be especially useful when MRI is contraindicated, equivocal, or prone to artefacts when metalwork is *in situ*, such as in patients after arthroplasty.

The fourth case highlights the potential clinical benefit that SPECT/CT might offer in patients with shoulder pain. As the shoulder girdle consists of several joints and different anatomical structures within, a small area pain can very often not be localized to distinct structures or joints. SPECT/CT

might help to identify the pain generator, which was shown in the presented case.

Limitations

Using SPECT/CT in orthopedic patients, one should be aware of its limitations. As this was only a small case series, conclusions should be drawn with all due caution. To date, no sufficient information about the natural course of SPECT/CT after shoulder surgery has been established. The sensitivity and specificity of SPECT/CT for establishing the diagnosis in patients with shoulder problems has not been investigated to date as there is only a paucity of studies available in orthopedics.^[2-4,17-19] The cost-effectiveness of SPECT/CT compared with other imaging has not been addressed so far.

CONCLUSIONS

SPECT/CT provides shoulder surgeons with a promising diagnostic tool, which may be particularly helpful in patients with shoulder pain, in which radiological diagnostic possibilities are currently limited, such as painful partial or total shoulder arthroplasty. The clinical value, the sensitivity and specificity of SPECT/CT in patients before and after shoulder surgery should be further investigated.

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