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SPECT/CT delineation of patellar and femorotibial overload after knee arthroplasty

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Data and images courtesy of Engereid Hospital, Bern, Switzerland

History

A 52-year-old woman with a history of right total-knee arthroplasty (TKA) presented with persistent right knee pain. An inconclusive radiographic led to a ^{99m}Tc-MDP three-phase bone scan, which was followed by SPECT/CT imaging to evaluate knee pathology.

After an intravenous injection of 600 MBq of ^{99m}Tc-MDP, the three-phase bone scan was initiated. Initial dynamic planar perfusion images were followed by planar bloodpool images of both knee joints. Delayed-phase planar whole-body images were acquired three hours post injection accompanied by a SPECT/CT of both knees, which was performed on a Symbia Intevo™ 6. CT and fused SPECT/CT images were reviewed together for final evaluation.

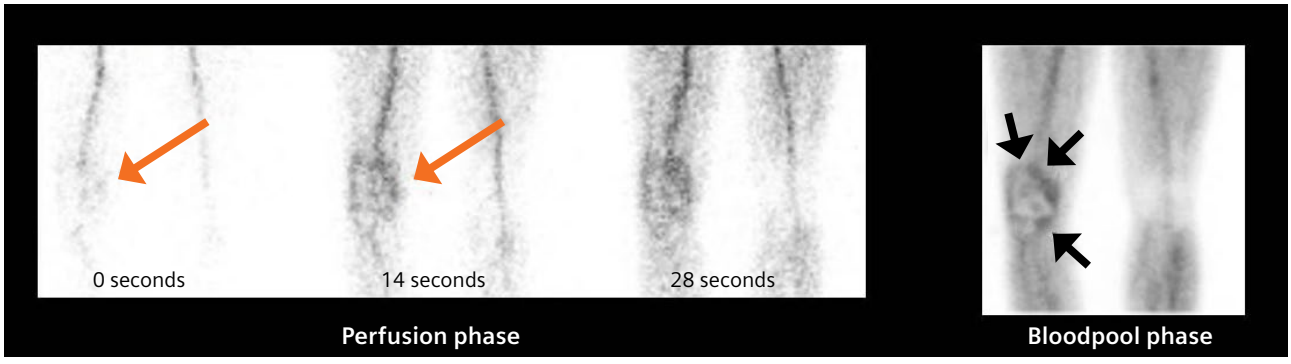
Findings

The prior radiographic information was inconclusive (Figure 1) since there was no sign of loosening (lysis), periprosthetic fracture, or particle disease. In patients with painful joints after arthroplasty, functional evaluation is key to identifying the cause of pain.

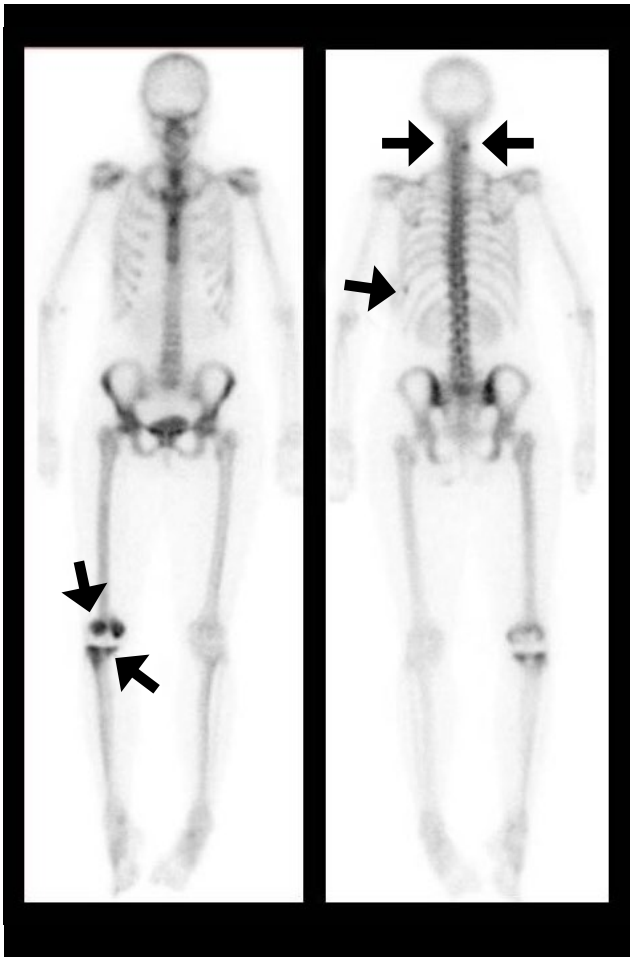
The perfusion and bloodpool images show synovitis and osseous hypervascularization of the right knee, right patella, and medial tibial epipysis (along the medial tibial plateau). In correlation, late-phase planar and SPECT/CT images demonstrate osseous hyper-metabolism in the right patella and the medial femoro-tibial joint reflecting bone stress and bone marrow edema. Varus deformity of the right knee joint with the mechanical axis of the right femur (line between head of the right femur and midpoint between two femoral condyles) is slightly in variance to the tibial shaft axis (line through the tibial shaft). Varus deformity developing following TKA leads to overload stress at various points in the right knee, especially the medial femoral and tibial compartments, as is reflected in the pattern of hypermetabolism.

SPECT/CT delineated the overload stress pattern secondary to a varus deformity delineated on the whole-body planar images. The various orientations of CT and SPECT/CT images (Figures 4 to 7) clearly demonstrate the bony-overload stress in the patella, medial femoral condyle, and medial tibial plateau. The CT images show osteolysis in the patella, medial femoral condyle, and cystic zone of osteolysis in the lateral femoral condyle, reflecting periprosthetic bone loss. There is no visible evidence of prosthetic loosening, misalignment of articular surfaces, or patellar misalignment. The synovitis involving the entire knee joint is reflected in the mild hyperperfusion and hypervascularity seen in the dynamic perfusion and bloodpool images. The Insall-Salvati (IS) ratio, as well as tibial tuberosity (TT)-trochlear groove (TG) distance of the right knee, is within normal limits (Figures 8 and 9), which reflects absence of misalignment of patella and prosthetic articular components. This finding, along with absence of loosening, confirms the mild varus deformity of the right knee to be the principal cause of the patellar and medial femoral condylar and medial tibial plateau overload stress, which are identified as the source of the pain.

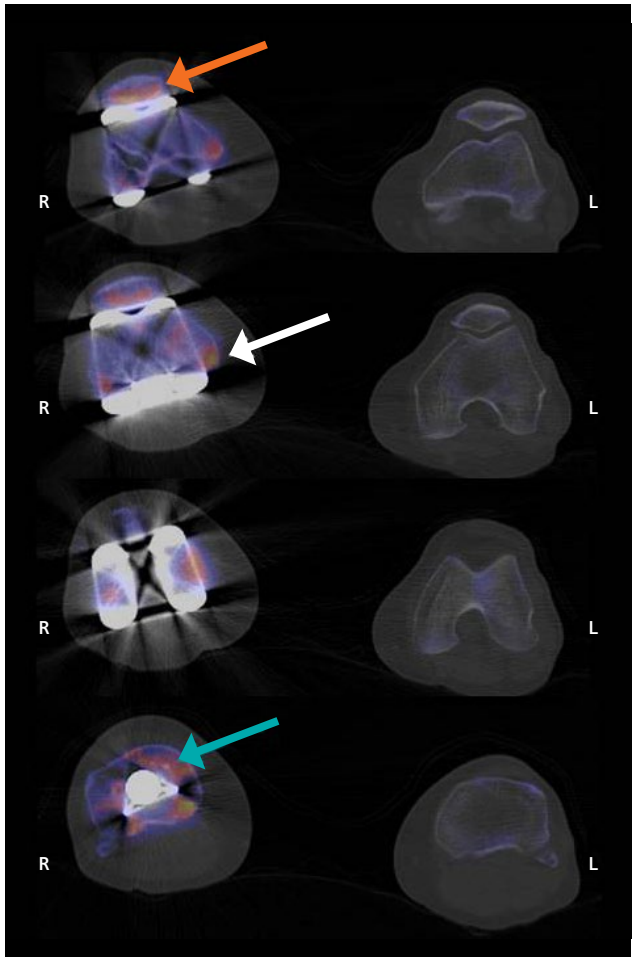
1 Anterior, lateral, and end-on radiographs of the right knee suggest correct axial and vertical positioning of the patella and absence of lysis among the components of TKA, which reflect absence of patellar misload and absence of radiographic signs of loosening or fracture. The periprosthetic femur shows slight radiolucency, which reflects erosion of the bone. The patella is undisplaced with normal concavity of the articular surfaces but shows significant radiolucency, which reflects periarticular bone loss. The radiograph suggest a slight varus mal-alignment when compared to the opposite knee (not shown).



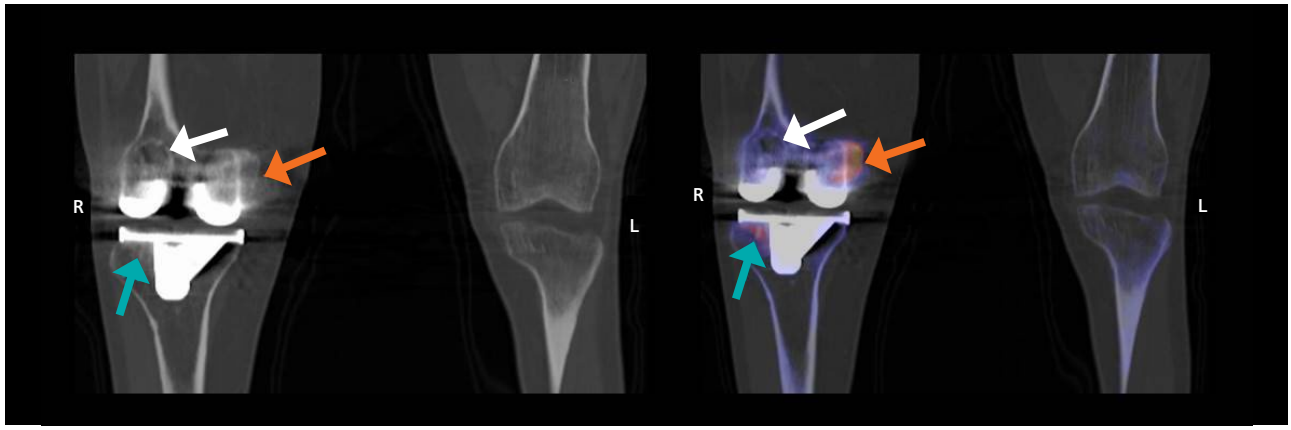
2 Arterial phase and bloodpool images show hypervascularization of bone and soft tissue , especially increased blood flow to the patella as well as the medial part of the knee (orange arrows). The bloodpool images show synovitis in the right knee with hypervascularity in the patella as well as in the medial tibial plateau (black arrows).



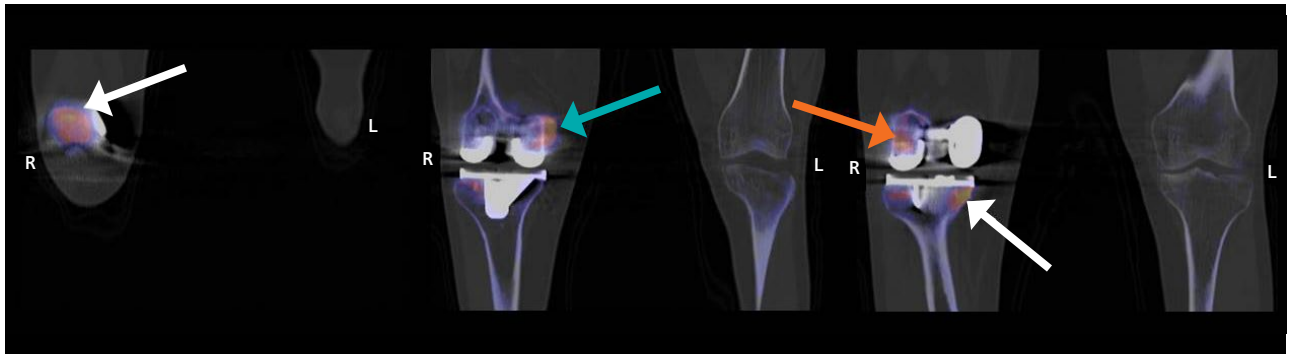
3 Anterior and posterior whole-body planar images show areas of focal hypermetabolism in the right knee joint, especially in the right patella and medial compartment of the tibia (arrows) correlating with the perfusion images. There is a slightly lower level of hypermetabolism in the medial femoral condyle and lateral tibial compartment. These focal areas of increased tracer uptake reflect bone stress related to the right TKA prosthesis. The right knee shows a slight varus deformity with the mechanical axis of the femur not perfectly aligned to the tibial shaft axis. Focal hypermetabolism is also seen in the cervical spine and left 10th rib, which may be related to degenerative changes and trauma. Additionally, there is no active bone stress in the hips or ankle.



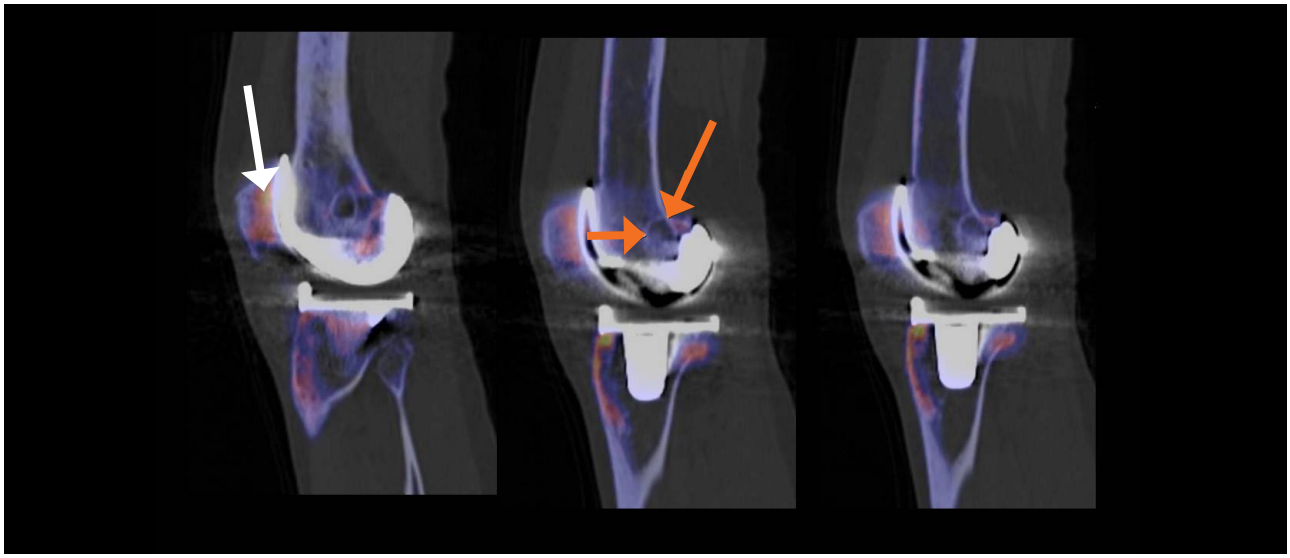
4 Fused SPECT/CT axial images show focal hypermetabolism in the patella, predominantly in the periarticular zone adjacent to the patellar articulating surface articulating with the femoral component of the TKA prosthesis (orange arrow), which reflects patellar-overload stress, secondary to arthroplasty. Focal hypermetabolism in the medial femoral condyle (white arrow), just medial to the prosthesis margin, reflects bone stress. Increased uptake in the medial tibial plateau (blue arrow), just medial to the prosthesis margin, also demonstrates bone stress. There is no evidence of loosening or displacement of prosthesis and the patella appears to be in proper position without misalignment.



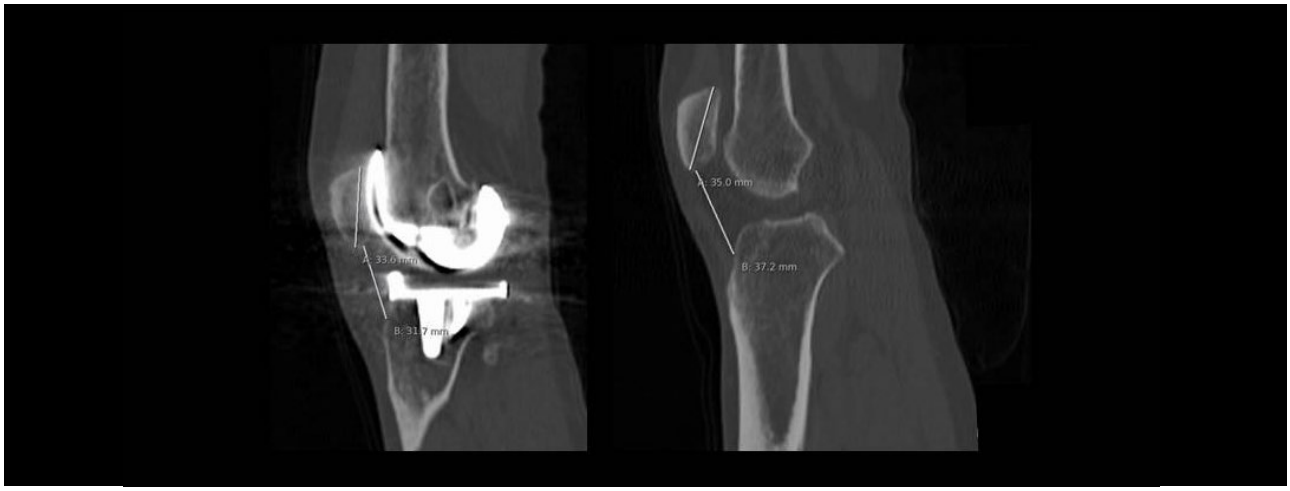
5 Coronal CT and fused SPECT/CT images show increased bone resorption in the medial femoral condyle with corresponding hypermetabolism (orange arrow). This reflects bony stress possibly related to an overload, secondary to slight, varus deformity with alteration of the angle between the mechanical axis of the right femur to the tibial shaft axis, secondary to arthroplasty. The lateral femoral condyle shows a cystic zone of osteolysis (white arrow), which does not demonstrate hypermetabolism. The lateral tibial plateau, just below the prosthetic tibial articular plate, shows minor sclerosis with mild hypermetabolism (teal arrows), which appears reactive in nature but does not appear related to loosening. No gap between bone and prosthetic margins is visualized, which suggests an absence of loosening. Interarticular space is normal with no displacement between the femoral and tibial articular surfaces of the TKA prosthesis.



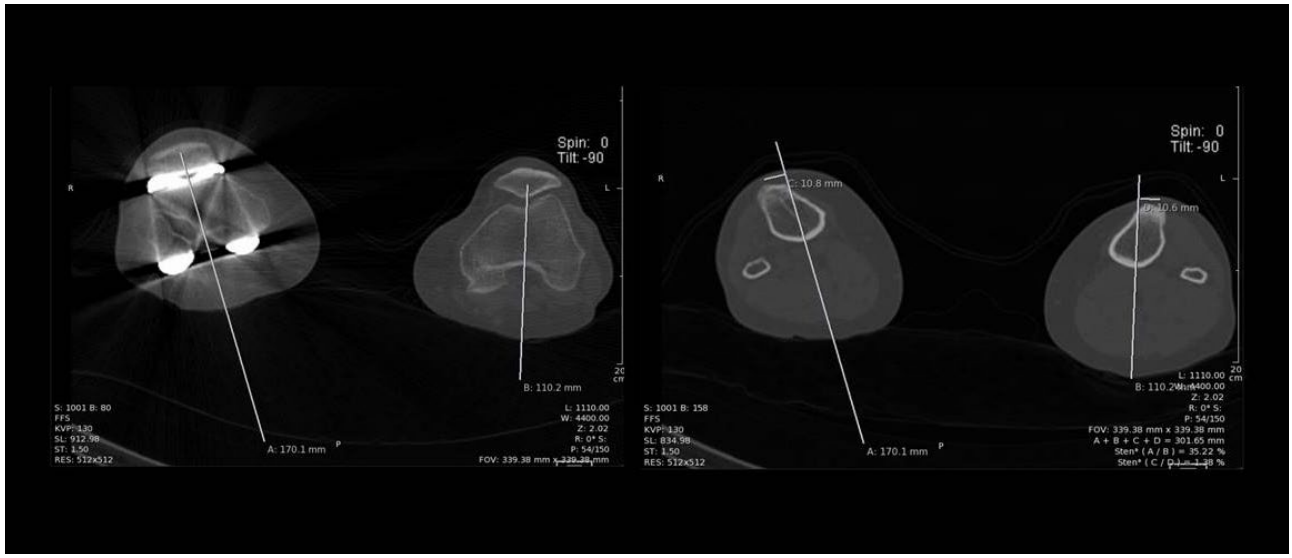
6 Coronal-fused SPECT/CT slices, captured from anterior to posterior, show patellar hypermetabolism (white arrows), bony overload stress in the medial femoral condyle (teal arrow), and hypermetabolism in the lateral femoral condyle adjacent to the prosthesis margin (orange arrow), all of which reflect bone stress. The medial tibial plateau, just below the medial edge of the articular surface of the tibial component of the TKA prosthesis, shows hypermetabolism, which is also related to overload stress related to the slight varus deformity of the right knee following arthroplasty.



7 Sagittal-fused SPECT/CT slices through the right knee joint, from medial to lateral, show patellar hypermetabolism (white arrow) as well as cystic radiolucency in the lateral femoral condyle (orange arrows). As no gap is visible between the prosthetic margin and adjacent bone in either the femoral and tibial component, and there is proper alignment of the prosthetic articular surfaces, these results are suggestive of an absence of prosthetic loosening, misalignment, or displacement of articular surfaces.



8 Sagittal CT slices of right and left (normal) knee joints used for determination of IS ratio of both knee joints. Both knees show normal IS ratio of < 1. Normal IS ratio is 0.8 to 1.2.



9 Axial CT slices through both knee joints at the level of TG of femur (left) and the TT (right), taken in order to measure the distance between the TT to the TG or patellar transition distance. The TT-TG distance in both knees is 1.1 cm and is within normal limits (< 15 mm).

Discussion

The most frequent cause of pain and implant loosening in arthroplasty patients is overload/misload of periprosthetic bone and patella, which is reflected as hyper-metabolism related to bone stress on bone SPECT/CT. In this case this was instrumental in accurately defining the focal areas of periprosthetic bony stress in the right knee joint as related to overload stress caused by mild varus deformity secondary to TKA in absence of any prosthetic loosening, malalignment, or articular displacement or periprosthetic fracture. Bony stress-related hypermetabolism in the medial femoral condyle and medial tibial plateau delineated on SPECT/CT correlates with varus deformity visible on the planar whole-body and coronal SPECT/CT images, which causes atypical stress to the medial compartment of the right knee joint. The level of hypermetabolism is lower than that of the patella and is likely not the principal cause of pain. The patellar hypermetabolism in absence of any patellar misalignment, malrotation, or displacement suggest patellar overload secondary to genu varum deformity. The normal IS ratio and TT-TG distance in the right knee also suggests stable patella with proper position of patellar articular surface in the trochlear groove of the femoral component of the TKA prosthesis. This rules out patellar malalignment or maltracking as a cause of the patellar hypermetabolism, thereby confirming patellar overload stress caused by varus deformity of right knee.

Patellar overload without malposition is most likely due to scarring of the patellar ligaments, the likely reason for acute pain. The CT shows perfect alignment of the prosthetic margins with periprosthetic bone without any gap—which rules out loosening. Even without loosening, the osseous overload of medial part of the tibial component with genu varum deformity is likely to be the biomechanical reason for eventual loosening. The reasons for patella overload are frequently axial patella shift (medial or lateral), high or low riding patella, and tibial malrotation to the femur that leads to patella maltracking) or scarring of the patella ligaments. Various measurements in the SPECT/CT images show the orthopedic surgeon how to correct the mal-positioning. Comparison with the other side (knee) is essential because knee alignment, patella positioning, and tilt varies from patient to patient. Measurements of patella shift, tilt, vertical position, and TT-TG are key to explain the reasons for overload. Chronic stress to the arthroplasty will eventually lead to loosening with CT evidence of lysis, which reflects instability caused by a moving prothesis. in such situations the management decision is between waiting until the arthroplasty becomes loose or earlier realignment of the joint. This depends on the pain profile of the patient.

Conclusion

Since focal bony stress may be associated with changes visualized on CT, like focal lysis or sclerosis (which are non-specific), evaluation of bone metabolism in the joint—with correlation to evidence of instability, deformity, malalignment, or loosening using bone SPECT/CT—is vital for proper evaluation of post-arthroplasty pain or movement restriction. Although an MRI can delineate bone edema related to focal bone stress, it is often difficult to interpret in the presence of a prosthesis. As shown in this particular case study, SPECT/CT with accurate co-registration of bony metabolic abnormalities to joint and prosthetic morphology can be of vital clinical value. The high-quality CT, combined with the high-resolution SPECT provided by the Symbia Intevo are key to diagnostic accuracy and confidence. ●

Examination protocol

Scanner: Symbia Intevo 6

SPECT		CT	
Injected dose	600 MBq ^{99m}Tc-MPD	Tube voltage	130 kV
Acquisition	30 frames, 20 seconds per frame with Flash 3D reconstruction	Tube current	25 mAs
		Slice thickness	3 mm

The outcomes achieved by the Siemens customers described herein were achieved in the customer's unique setting. Since there is no "typical" hospital and many variables exist (e.g. hospital size, case mix, level of IT adoption) there can be no guarantee that others will achieve the same results.

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