Detection of loosening of total knee arthroplasty prosthesis by ^{99m}Tc HMDP bone SPECT/CT using xSPECT Bone and xSPECT Quant with iMAR

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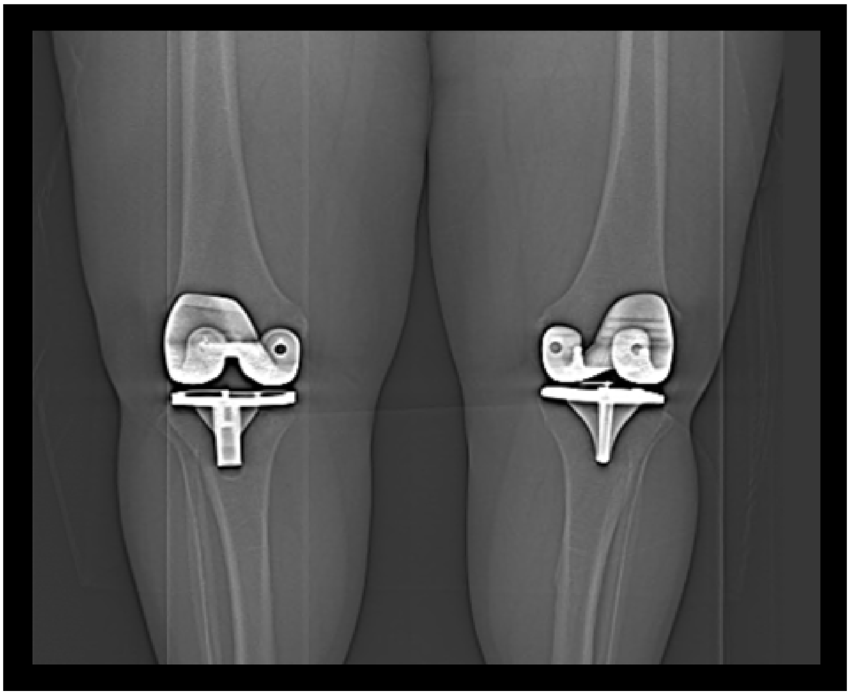
Data and images courtesy of Queen Elizabeth Hospital Birmingham, Birmingham, United Kingdom

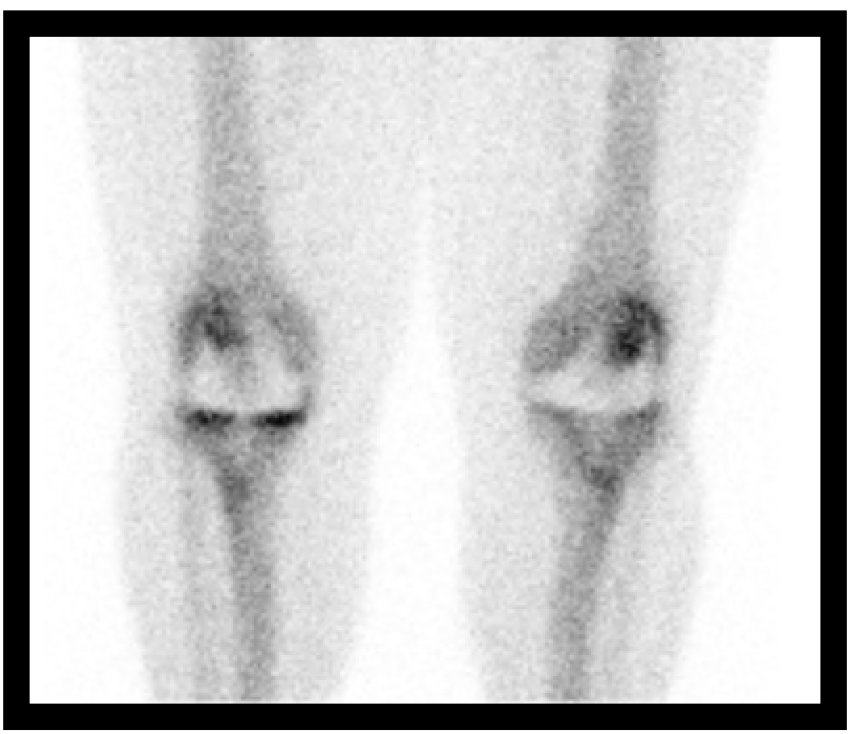
History

An approximately 75-year-old female with history of bilateral total knee arthroplasty (TKA) presented with pain in both knees. X-rays of both knees were unremarkable except for mild radiolucency at the tip of the stem of the tibial component of the right TKA. ^{99m}Tc HMDP bone SPECT/CT was performed to determine the cause of symptoms and the presence of loosening or infection in the prosthetic joints.

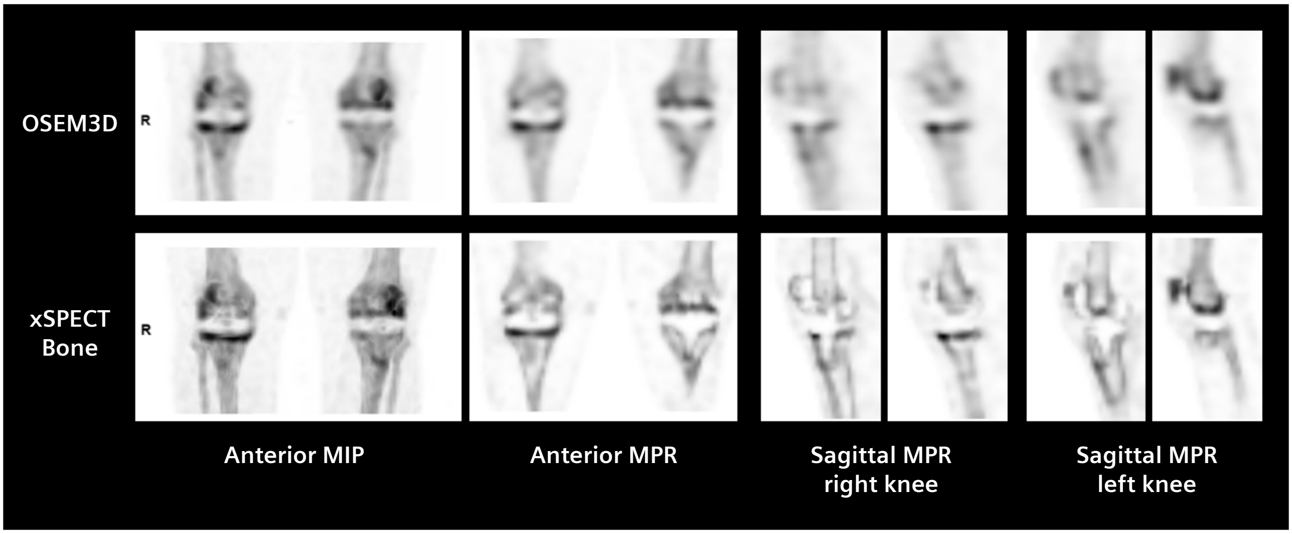
The study was conducted on Symbia Pro.specta™[a] SPECT/CT 3 hours following 15.6 mCi (578 MBq) intravenous (IV) injection of ^{99m}Tc HMDP. Following anterior and posterior planar static acquisitions, a SPECT/CT acquisition of both knees was performed. CT was performed with 110 kV with 181 reference mAs. 1-mm-reconstructed CT slices were obtained for evaluation and fusion with SPECT. Iterative metal artifact reduction (iMAR)[b] was performed on CT using BR44 S3 kernel. Single-bed SPECT was performed with 60 stops per detector and 20 seconds per stop. SPECT was reconstructed using OSEM3D 18i4s with 128 x 128 matrix. Furthermore, xSPECT Bone™ reconstruction was performed using xSPECT™-CG using CT data with iMAR. SPECT/CT data was reviewed using *syngo*®.via.



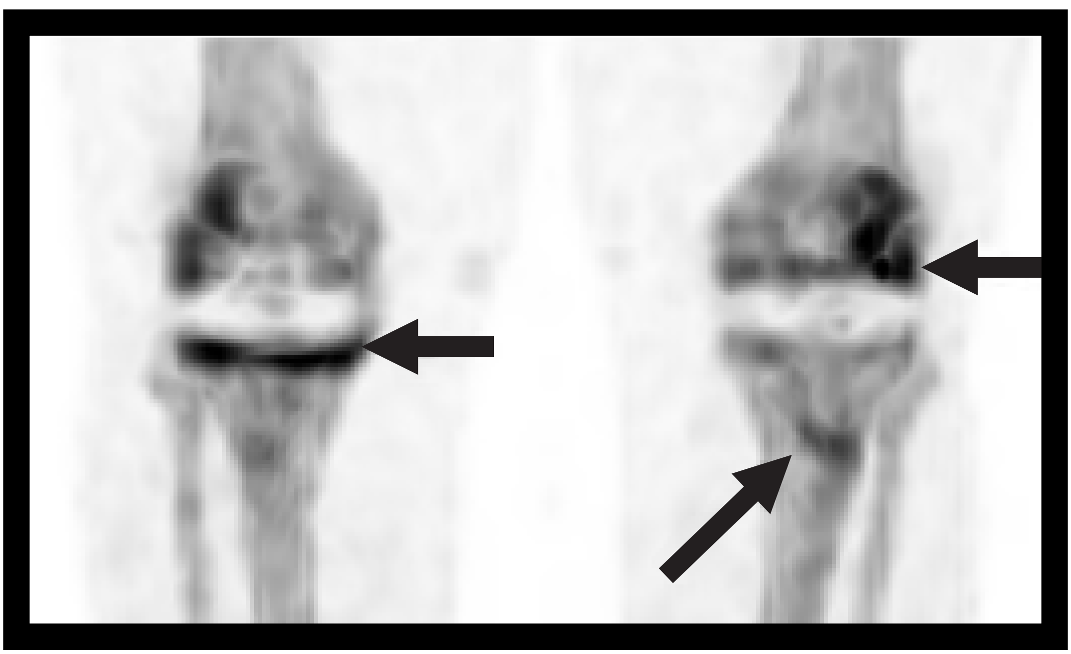
1 Anterior X-ray shows bilateral TKA without any clearly defined lysis around the prosthetic margins. No obvious varus or valgus misalignment visualized.



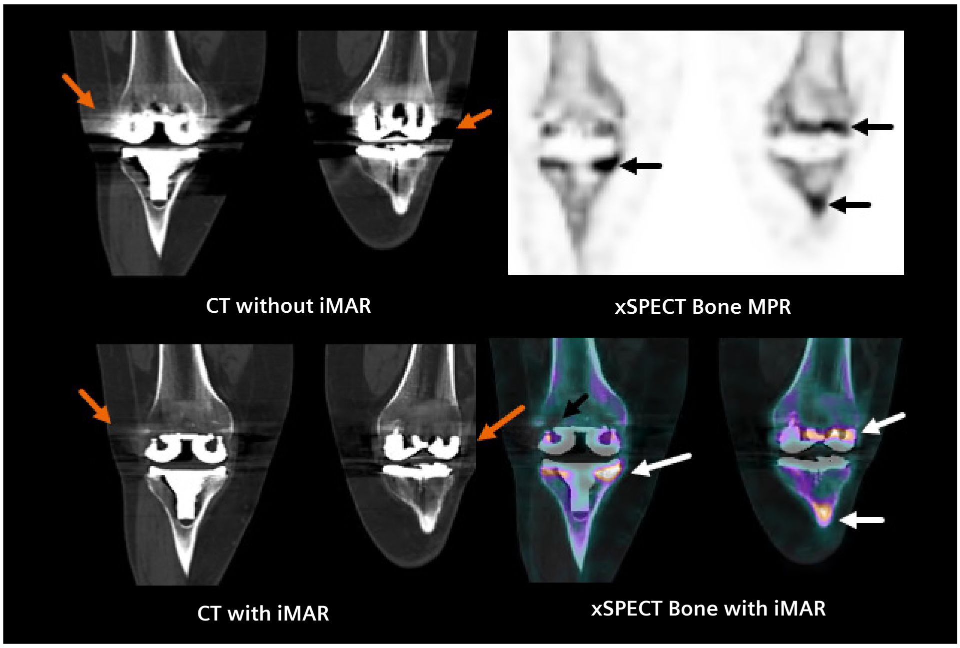
2 Planar anterior static images obtained 3 hours post injection show increased uptake in the left and right tibial plateau on the right knee and in the lateral aspect of the femoral component on the left knee. The left patella also shows increased uptake.



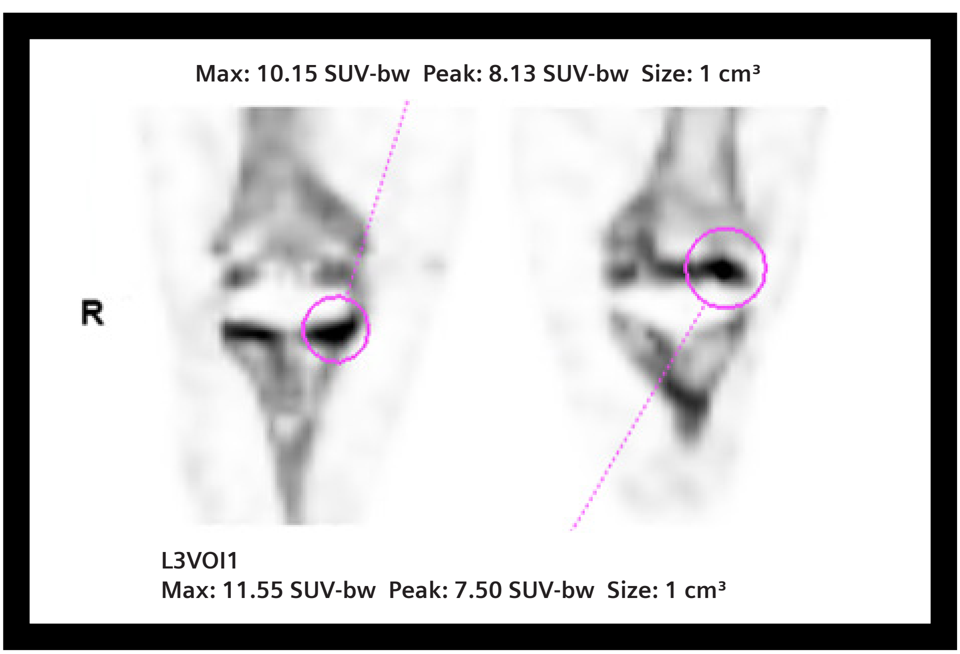
3 **Comparison of OSEM3D and xSPECT Bone maximum intensity projection (MIP) and anterior and sagittal multiplanar reconstruction (MPR) views shows sharp definition of increased uptake at the right tibial plateau and left lateral femoral condyles along with sharper and more prominent visualization of bone-prosthetic margins, especially the tibial stem and patellar margins with xSPECT Bone.**



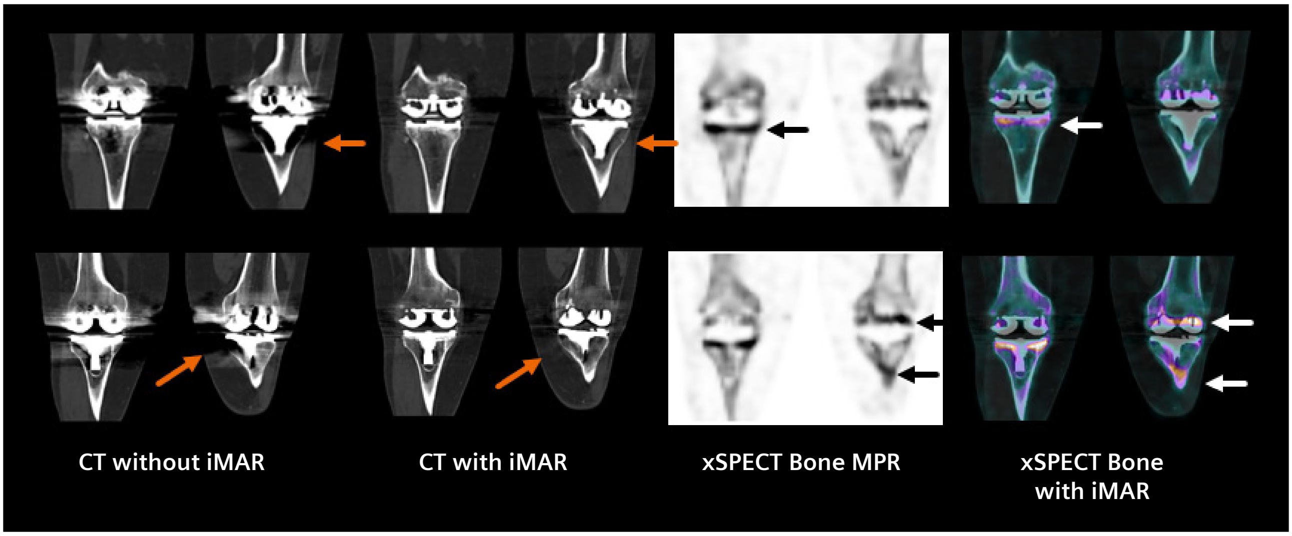
4 **Anterior MIP images of xSPECT Bone of both knees show hypermetabolism at the left and right tibial plateau just below the stemmed tibial plate of the right TKA (arrow). The lateral aspect of the right patella also shows a slight hypermetabolism. The left TKA shows focal hypermetabolism at the lateral aspect of the femoral condyle at the lateral edge of the femoral component (top arrow). The tip of the stem of the left tibial component also shows mild hypermetabolism (bottom arrow).**



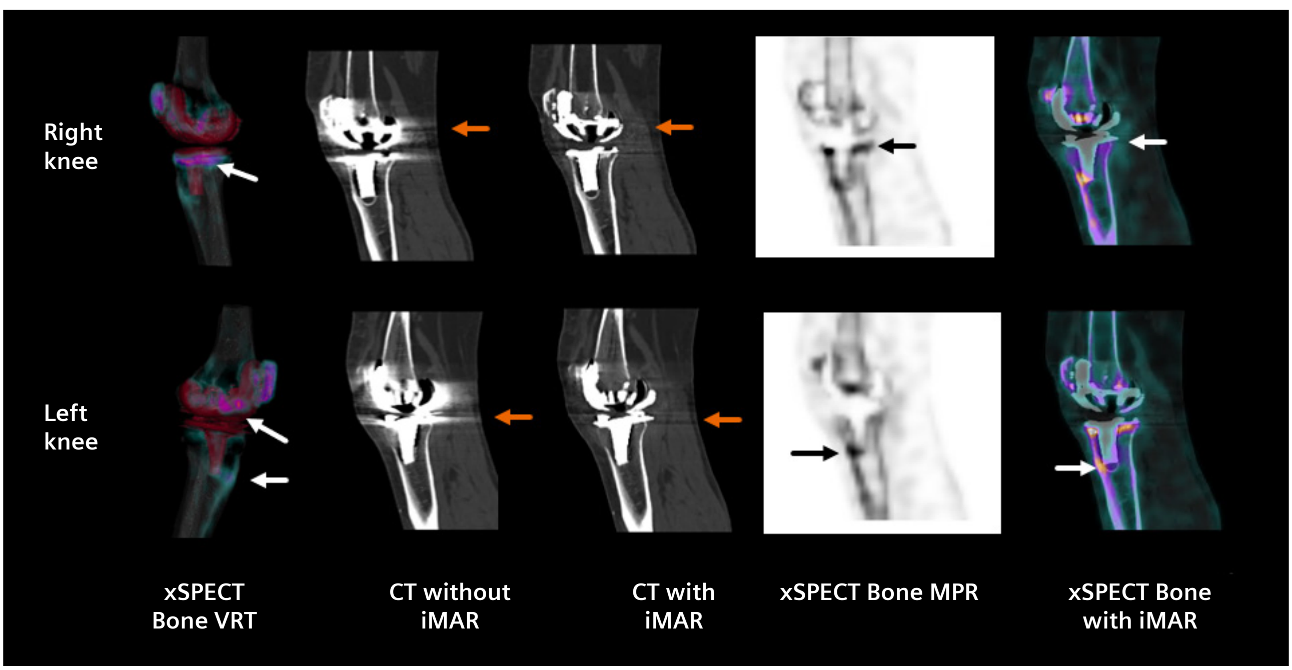
5 CT with and without iMAR with xSPECT Bone and fusion of xSPECT with CT with iMAR through the coronal slice at the mid-knee level showing metal-induced beam-hardening artifacts seen in the standard CT images, especially in the lateral and medial aspects of the femoral condyles (orange arrows), which are significantly reduced using iMAR. xSPECT Bone and SPECT/CT images show focal hypermetabolism in the medial and lateral tibial plateau below the metal tibial plate of the right TKA, which is more prominent on the medial aspect (black and white arrows) suggestive of early loosening. The left TKA shows focal hypermetabolism in the lateral femoral condyle at the bone-prosthesis interface of the lateral femoral component of the TKA (black and white arrows), which also is suggestive of early loosening. The tip of the stem of the tibial component of the left TKA also shows focal hypermetabolism (black and white arrows), which may be related to bone stress due to oblique alignment and impingement of the tip of the tibial stem to the medial tibial cortex but does not appear intense enough to suggest loosening of the tibial component.



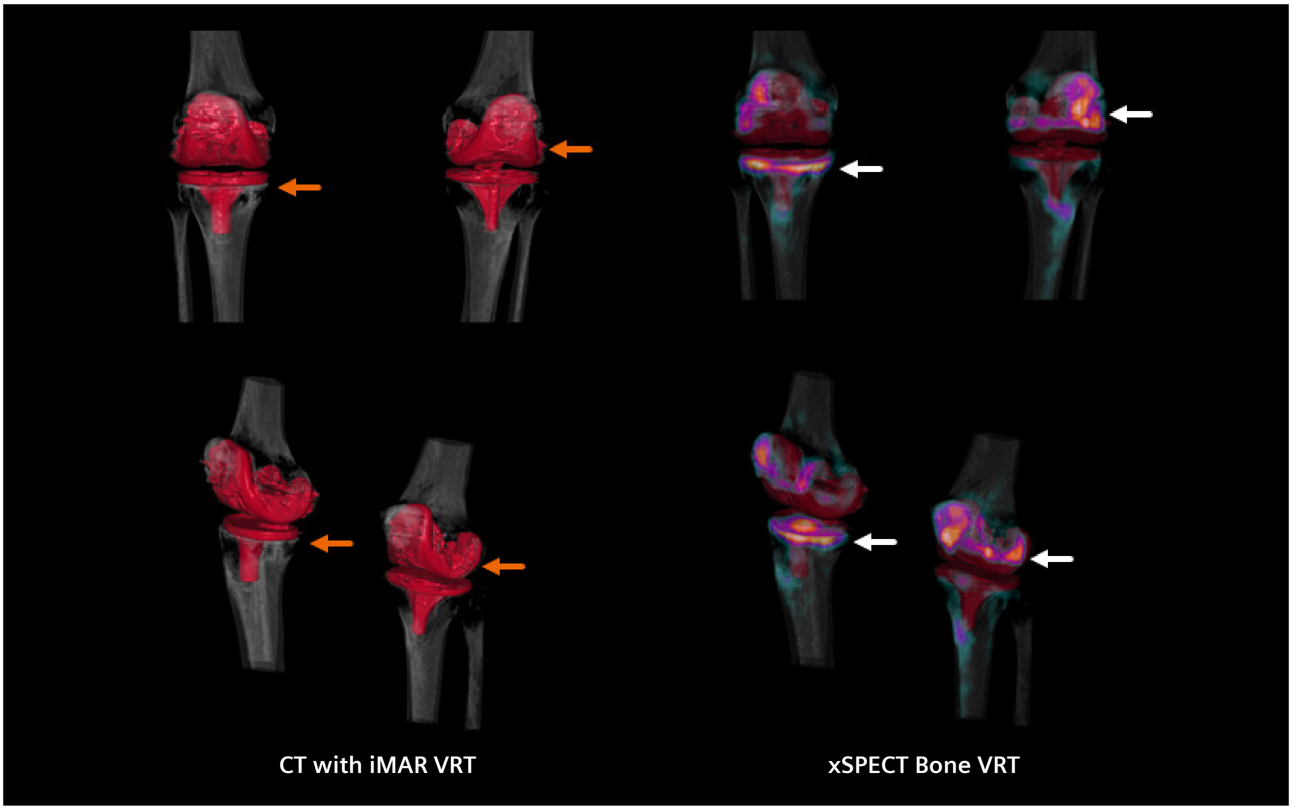
6 xSPECT Quant™ reconstructions obtained as part of the xSPECT Bone show a high standard uptake value (SUV) in the medial tibial plateau of the right knee and the lateral femoral condyle of the left knee. High SUV at these focal hypermetabolic sites at the locations of the bone-prosthesis interface reflects early loosening.



7 CT with and without iMAR at different coronal-slice levels through both TKAs shows the significant beam-hardening artifact seen predominantly medial and lateral to the tibial component (orange arrows) at these orientations with significant improvement following iMAR. xSPECT Bone and with iMAR images at the same coronal orientation show the hypermetabolism at the right tibial plateau and the left lateral femoral condyle and tip of the tibial stem (black and white arrows). These focal uptake sites, especially the right medial tibial plate and left lateral femoral condyle, suggest early loosening.



8 Sagittal CT slices through the left and right TKA show severe beam hardening at the femoral condylar and tibial plate for both sides (orange arrows) with major improvement in visualization after iMAR. xSPECT Bone with iMAR images at the same sagittal slice orientation show focal hypermetabolism at the tibial plate (black and white arrows) of the right TKA. The tip of the tibial stem of the right TKA shows focal hypermetabolism at the point of impaction of the tip to the anterior tibial cortex. There is also lucency around the right tibial stem especially the tip seen on the CT. This lucency reflects possibility of early loosening. The tip of the tibial stem of the left TKA also shows similar focal hypermetabolism at the point of impact with the anterior cortex but with much lower intensity (black and white arrows). However, there is minimal lucency at the bone-metal interface of the left tibial stem, suggesting the focal uptake is probably reactive bone stress rather than loosening.



9 **Volume renderings of CT with iMAR and xSPECT Bone with iMAR show precise visualization of the metallic prosthesis on both knees without any artifact and an exact localization of the focal hypermetabolism—clearly delineating the hypermetabolism related to loosening in the right tibial plateau and the left lateral femoral condyle. The patellar lateral edges of both knees show hypermetabolism likely related to patellar osteoarthropathy at the resurfaced posterior patellar surface.**

Findings

The images clearly define the focal hypermetabolism in the bone-prosthesis interface below the tibial plate of the tibial component of the left TKA. The CT with iMAR clearly shows the lucency below the plates, as well as around the tibial stem of the left TKA, especially at its tip. These lucencies, along with the focal hypermetabolism at the tibial plate and the stem tip, suggest early loosening of the tibial component of the left TKA. The patellar hypermetabolism predominantly at the lateral margin is related to patellofemoral arthropathy related to impingement of the resurfaced patellar articular margin to the femoral component of the left TKA. Thin-slice CT with iMAR was instrumental in accurate evaluation of the bone prosthetic margins and the related lucency and associated bone changes due to the elimination of beam-hardening artifacts. This makes interpretation of the prosthesis-related bone changes and the correct localization of the focal hypermetabolism related to bone stress and prosthetic loosening possible. High-quality CT with thin slices and metal artifact reduction is ideal for orthopedic SPECT/CT as reflected by the artifact-free CT images and ease of interpretation in this clinical example.

The right TKA shows significant metal-related artifacts, especially in the femoral component on the standard CT images, which are significantly reduced with iMAR. The focal hypermetabolism localized to the lateral margin of the lateral femoral condyle at the point of impingement of the lateral femoral component to adjacent bone reflects the possibility of early loosening. The patellar uptake reflects patello-femoral osteoarthropathy due to impingement of the resurfaced patellar articular surface to the underlying femoral component of the right TKA.

xSPECT Bone also provides sharp definition with high contrast of the focal hypermetabolism related to the stress points of the left and right TKA. Improved resolution and higher contrast using xSPECT Bone, along with high-quality, virtually artifact-free CT, is instrumental for accurate evaluation of the intensity of bone stress to attribute focal hypermetabolism to loosening rather than reactive bone changes.

Discussion

Bone SPECT/CT has been established as an accurate and cost-effective modality for diagnosis of TKA loosening and related causes of pain and prosthetic joint failure.[1] Improved visualization and quantification of bone SPECT/CT with xSPECT Bone and xSPECT Quant, along with improved CT visualization with metal artifact reduction on Symbia Pro.specta SPECT/CT, provides an optimum imaging approach for the diagnostic evaluation of TKA-related pathologies.

In this clinical case, early loosening of the tibial component of the right TKA and that of the femoral component of the left TKA were clearly and sharply defined by xSPECT Bone with iMAR. Specifically, iMAR aided in the creation of zone maps that defined cortical bone, spongiosa, soft tissue, fat, and air in order to improve SPECT resolution.

iMAR significantly improved the image quality of the CT in the presence of TKA-related metal artifacts and was instrumental in the proper visualization and localization of the focal hypermetabolism and the related CT findings of periprosthetic lucency. Moreover, the combination of xSPECT Quant with xSPECT Bone provided quantitative indices like SUV_{max}, which further defined the extent of focal hypermetabolism compared to normal bone, with SUV_{max} in the right tibial plateau as high as 10.15. xSPECT Bone has been shown to improve evaluation of skeletal pathology including prosthetic joints.[2] However, the combination of xSPECT Bone with xSPECT Quant using iMAR provides further improvement in diagnostic confidence as shown in a study by Braun et al.[3]

In this study, 22 patients with TKA were evaluated with SPECT/CT on Symbia Intevo™ with xSPECT Bone and xSPECT Quant with iMAR, and the presence or absence of loosening was confirmed during 1-year follow-up. Overall, periprosthetic SUV_{max} was lower with xSPECT Quant (OSCGM reconstruction without CT-based zone map corrections) compared to that of xSPECT Bone combined with xSPECT Quant (CT-based zone map corrections incorporated into quantitative values; mean SUV_{max} ± SD: 9.14 ± 3.31 versus 12.61 ± 4.79). SUV_{max} cut-off values determining uptake levels with the highest accuracy for prediction of loosening were highest with xSPECT Bone using iMAR (cut-off SUV_{max} 13.78 without iMAR and 14.78 with iMAR) but significantly lower for xSPECT Quant without CT zone map (cut-off SUV_{max} 9.40 without iMAR and 9.61 with iMAR). Overall diagnostic accuracy for prosthetic loosening was highest with xSPECT Bone and Quant combination (84.8%) compared to xSPECT Quant (77.4%). The addition of iMAR increased the accuracy of not only xSPECT Bone and Quant combination from 84.8 to 93.9% but also for xSPECT Quant (from 77.4 to 81.8%).

The present case example is thus an ideal combination of xSPECT Bone, xSPECT Quant, and iMAR to provide high diagnostic accuracy. The SUV_{max} of 11.15 at the left tibial plateau, which was deemed the site of loosening of the tibial component, matches the SUV_{max} values associated with the TKA loosening in the study by Braun et al.

Conclusion

iMAR not only provides high-quality CT images for the interpretation of periprosthetic CT changes and localization of hypermetabolism but also improves attenuation correction, the overall image quality of xSPECT Bone, as well as quantitative accuracy from xSPECT Quant. Therefore, the combination of xSPECT Bone, xSPECT Quant, and iMAR available on Symbia Pro.specta SPECT/CT provides the ideal imaging capabilities for the imaging of prosthetic joint pathologies as illustrated by this clinical case study. ●

Examination protocol

Scanner: Symbia Pro.specta

SPECT	
Injected dose	15.6 mCi (578 MBq) ^{99m}Tc HMDP
Post-injection delay	3 hours
Acquisition	1 bed position/30 stops per detector, 20 seconds per stop
Image reconstruction	128 x 128 matrix, OSEM3D 18i4s, xSPECT Bone xSPECT-CG

CT	
Tube voltage	110 kV
Tube current	181 ref mAs
Slice collimation	32 x 0.7 mm
Slick thickness	1 mm

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

References

[1] Van den Wyngaert T, Palli SR, Imhoff RJ, Hirschmann MT. Cost-Effectiveness of Bone SPECT/CT in Painful Total Knee Arthroplasty. *J Nucl Med*. 2018;59(11):1742-1750. doi:10.2967/jnumed.117.205567.

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[3] Braun M, Cachovan M, Kaul F, Caobelli F, Bäumer M, Hans Vija A, Pagenstert G, Wild D, Kretzschmar M. Accuracy comparison of various quantitative [99mTc]Tc-DPD SPECT/CT reconstruction techniques in patients with symptomatic hip and knee joint prostheses. *EJNMMI Res.* 2021;11(1):60. doi:10.1186/s13550-021-00794-7.

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[b] The amount of metal artifact reduction and corresponding improvement in image quality depends on a number of factors including: composition and size of the metal object, patient size, anatomical location and clinical practice. It is recommended to perform reconstruction with iMAR enabled in addition to conventional reconstruction without iMAR.

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