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SPECT/CT in the Postoperative Painful Knee

Wouter van der Bruggen,[*] Michael T. Hirschmann,[†] Klaus Strobel,[‡] Willm Uwe Kampen,[§] Torsten Kuwert,[‖] Gopinath Gnanasegaran,[¶] Tim Van den Wyngaert,[#,**] and Frédéric Paycha[††]

This review summarizes the role of SPECT/CT in patients with a painful postoperative knee and describes typical diagnostic criteria in these patients. Pain after knee surgery is common and is influenced by the underlying pathology, the type of surgery, and the patient. Knee joint-preserving surgery includes osteotomy, ligament reconstruction, meniscus surgery, and cartilage repair procedures, often used in combination. Knee arthroplasty procedures consist of unicondylar, patellofemoral, and primary or revision total knee prosthesis. In patients with pain after knee joint-preserving surgery, MRI remains the reference standard. After ligament reconstruction, CT can evaluate postoperative tunnel positioning, and bone SPECT/CT can contribute by assessing overloading or biodegradation problems. After meniscal or cartilage surgery, SPECT/CT can be particularly helpful to identify compartment overloading or nonhealing chondral or osteochondral lesions as cause of pain. SPECT/CT arthrography can assess cartilage damage at an early stage due to altered biomechanical forces. After corrective osteotomy of the knee, SPECT/CT can reveal complications such as overloading, nonunion, or patellofemoral problems. After arthroplasty, conventional radiographs lack both sensitivity to detect aseptic loosening and specificity in differentiating aseptic from infectious loosening. Secondly, hardware-induced artifacts still hamper CT and MRI, despite improving and increasingly available metal artifact reduction techniques. Bone scintigraphy is a proven useful adjunct to conventional radiography and MRI to reveal the pain generator and is less hampered by artifacts from metallic implants compared with CT and MRI. Nevertheless, the optimal imaging strategy in evaluating complications after knee arthroplasty is still a matter of debate. Although the evidence of the use of BS SPECT/CT is still limited, it is growing steadily. In particular, recent data on specific uptake patterns in tibial and femoral zones after total knee arthroplasty and the impact of integrating biomechanics into the assessment of SPECT/CT appear promising, but more research is needed.
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*Department of Radiology and Nuclear Medicine, Slingeland Hospital, Doetinchem, The Netherlands.
†Department of Orthopaedic Surgery and Traumatology, Kantonsspital Baselland (Bruderholz, Liestal, Laufen), Bruderholz, Switzerland.
‡Department of Radiology and Nuclear Medicine, Lucerne Cantonal Hospital, Lucerne, Switzerland.
§Nuclear Medicine Spitalerhof, Hamburg, Germany.
‖Clinic of Nuclear Medicine, University Hospital Erlangen, Erlangen, Germany.
¶Department of Nuclear Medicine, Royal Free London NHS Foundation Trust, London, United Kingdom.
#Department of Nuclear Medicine, Antwerp University Hospital, Edegem, Belgium.
**Faculty of Medicine and Health Sciences, University of Antwerp, Wilrijk, Belgium.
††Department of Nuclear Medicine, Hôpital Lariboisière, Assistance Publique-Hôpitaux de Paris, Paris, France.
Address reprint requests to Wouter van der Bruggen, MD, Department of Nuclear Medicine, Slingeland Ziekenhuis, Kruisbergseweg 25, Doetinchem 7009 BL, The Netherlands. E-mail: W.van.der.Bruggen@slingeland.nl

Introduction

The knee joint consists of three articulations: the medial and lateral tibiofemoral joint, the patellofemoral joint, and the tibiofibular joint. It is the largest joint in the human body, which permits flexion and extension in the sagittal plane, internal and external rotation in the transverse plane, and varus-valgus in the coronal plane, resulting in a "six-degrees-of-freedom" range of motion.[1]

Establishing the true cause of postoperative knee pain is mandatory to guide optimal treatment. Often it is difficult, however, to achieve a comprehensive understanding of the reasons for persistent, recurrent, or newly onset postoperative knee pain. In addition to the patient's history and a detailed clinical examination, radiological and radionuclide imaging (RNI) complement the diagnostic workup in this challenging group of patients.

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This review aims to report the current evidence-based imaging strategy in patients with a painful postoperative knee. It emphasizes on the current value of bone scintigraphy using technetium-99m-hydroxymethylene diphosphonate ([^{99m}Tc]-HDP) or technetium-99m-methylene diphosphonate ([^{99m}Tc]-MDP), both hereafter called bone scan (BS). The evidence of the use of SPECT/CT over planar imaging and directions how to achieve optimal image quality will specifically be discussed in depth. For all indications, its relation to radiological techniques (conventional radiographs, MRI, and CT) is discussed. In addition, the role of technetium-99m-sulesomab and technetium-99m- and indium-111-labeled leukocytes will be addressed and compared with that of FDG-PET, fluorine-18-sodium fluoride-PET, and conventional radiological techniques.

There is no single imaging modality to date (both in the field of radiology or nuclear medicine) that is able to diagnose all possible knee disorders with satisfying accuracy in one visit. A combination of modalities will therefore remain necessary in many cases. This review presents the most common clinical diagnostic problems in patients with knee pain and provides solutions for an optimal imaging strategy in text, pictorial examples, and flowcharts.

Knee Surgery and Arthroplasty

When nonoperative treatment for knee pathology fails, knee surgery might be carefully considered. One can differentiate between knee joint-preserving surgery and knee arthroplasty, which resurface the worn parts or the entire knee joint. Knee joint-preserving surgery includes osteotomy aiming for alignment correction, ligament reconstruction, meniscus surgery, and cartilage repair procedures.[2] Often a combination of the aforementioned procedures is used.[2] Knee arthroplasty includes partial replacement, such as unicondylar knee arthroplasty (UKA), patellofemoral joint arthroplasty, or total knee arthroplasty (TKA).[3] In terms of TKA, primary and revision total knee prostheses should be distinguished.[1]

Ligament Reconstruction

Repair or reconstruction of the anterior cruciate ligament (ACL) is one of the most frequently performed surgeries in orthopedics. Estimates of ACL reconstruction vary widely, but the population-adjusted estimated rate of ACL reconstructions within the US increased by 37% from 86,837 in 1994 to 134,421 in 2006.[4]

Torn ACLs might be repaired using suture devices or more often reconstructed using autografts or allografts. Repair of the ACL has been reintroduced in the last decade using sutures and novel fixation and stabilization devices.[5] ACL reconstruction partly or entirely removes the torn ACL, drills bone tunnels, introduces a variety of different autografts or allografts, such as bone-patellar tendon-bone ACL reconstruction. It aims to replace the torn ACL by a transplant.[6] Persisting knee pain and instability after ACL reconstruction are reported in 15%-20% of patients. Most frequent causes are graft impingement, tunnel widening, malposition of bone tunnels, and graft or fixation failure.[7] With the use of biodegradable fixation devices, degradation problems are seen.[8]

Reconstruction of the posterior cruciate ligament (PCL) is less frequently necessary, as isolated PCL tears often heal with nonoperative treatment. However, if multiple ligaments are torn—as in a knee dislocation—PCL reconstruction, as well as reconstruction of all other involved ligaments, is indicated.[9] These ligaments include the medial collateral and lateral collateral ligaments and the posterolateral and posteromedial corner structures. Chronic knee pain and instability are common and are due to graft impingement, tunnel widening, malposition of bone tunnels, and graft or fixation failure.[9] Reconstruction or repair of peripheral knee ligaments is prone to the same technical considerations, problems, and complications as ACL or PCL surgery.

In cases with persistent patellofemoral instability, reconstruction of the medial patellofemoral ligament is often indicated.[10] Reefing of the medial retinaculum has not stood the test of time. Reconstruction of the medial patellofemoral ligament can be done using gracilis or quadriceps tendon autograft or allograft. The most commonly used graft is the gracilis tendon. The graft is used as a free graft and fixed at the patella and femur using different types of fixation devices. When using the quadriceps tendon, the graft remains attached to the patella and is redirected and then fixed at the femoral insertion using an interference screw. The most common reasons for persistent pain and limited range of motion are malposition of the graft or associated cartilage degeneration.[11]

Osteotomy

Coronal alignment (varus-valgus) significantly influences loading of the different knee compartments.[12] In a varus aligned knee, around 70%-90% of the loading runs through the medial compartment.[12] In a valgus aligned knee, the lateral compartment is significantly more loaded.[12] This mechanical loading results in increased joint forces and wear of the affected knee compartment.[12]

In patients with early osteoarthritis (OA) or overloading symptoms, alignment might be corrected by osteotomy of the femur, the tibia, or both.[13-15] The most commonly performed osteotomy is the high tibial osteotomy aiming for correction of a proximal tibial varus alignment. Two techniques are used, the medial opening-wedge or lateral closing-wedge osteotomy. The medial opening-wedge technique is current standard of care.

Another osteotomy, which is mainly used in valgus aligned knees, is the distal femoral osteotomy, which is a reliable procedure to reduce the loading within the lateral knee compartment.[13] Valgus malalignment may also be attributable to tibial deformity.[14]

Most common problems after osteotomy surgery are persistent pain within the unloaded knee compartment due to insufficient correction, loss of correction, pseudarthrosis, overloading of the other increasingly loaded compartment, malposition of plate or screws, intraoperative fractures, change of patellar height, altered rotational alignment, and neurovascular complications.[15] Subsequently, an osteotomy may cause osteoporosis because of the stress-shielding effect.[16]