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REDEFINING OSTEOARTHRITIS THROUGH IMAGING: FROM *MAGNETIC RESONANCE IMAGING* TO *GENICULAR ARTERY EMBOLIZATION*

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ABSTRACT
Osteoarthritis is traditionally perceived as a disease of "wear and tear", often diagnosed through radiographic findings such as joint space narrowing and osteophyte formation. However, this structural approach often delays diagnosis until irreversible joint damage occurs. Contemporary understanding of OA now recognizes it as a biologically active process involving synovitis, neovascularization, cartilage degeneration, and subchondral bone remodeling. This shift demands a redefinition of diagnostic and therapeutic strategies, with radiology playing a central role in both. Objectives to review the evolving role of advanced imaging modalities in osteoarthritis (OA), including Magnetic Resonance Imaging (MRI), Ultrasonography (US), and Computed Tomography (CT), and to evaluate the emerging therapeutic role of Genicular Artery Embolization (GAE) as an image-guided, non-surgical option for knee OA. MRI allows early detection of bone marrow edema, cartilage softening, and synovial inflammation. Advanced techniques such as T2 mapping, T1ρ, and delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) provide quantitative evaluation of cartilage integrity. US enables dynamic, bedside assessment of synovial hypertrophy and vascularity, particularly using Doppler imaging, making it valuable for monitoring active inflammation. Dual-energy CT enhances visualization of subchondral bone changes and urate deposition. These modalities also support patient selection and post-procedural monitoring for GAE, a minimally invasive, imageguided intervention that targets abnormal periarticular neovessels to alleviate pain and inflammation. GAE has shown promising results in patients with moderate knee OA, particularly those who are not candidates for surgery. Modern imaging does more than confirm osteoarthritis; it reveals its pathophysiology, progression, and therapeutic targets. Radiologists are no longer passive observers, but active contributors to OA care. By integrating MRI, US, CT, and interventional radiology techniques such as GAE, radiology is reshaping both diagnosis and treatment in this era of robust technology and multidisciplinary excellence.

Keywords: dual-energy computed tomograph; genicular artery embolization; magnetic resonance imaging; osteoarthritis; ultrasound

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INTRODUCTION

Osteoarthritis (OA) is the most common degenerative joint disease and a leading cause of chronic pain, functional disability, and reduced quality of life in adults and the elderly. Early identification of structural joint changes plays a crucial role in preventing OA progression and optimizing therapeutic strategies. Historically, OA was viewed as a purely mechanical " *wear and tear* " process resulting from chronic loading on cartilage, with conventional radiographic detection only identifying structural changes such as joint space narrowing, osteophytes, and subchondral sclerosis at an advanced stage (Piccolo et al, 2023; Roemer et al, 2022). The current paradigm identifies OA as an active biological process involving synovial inflammation, pathological neovascularization, cartilage matrix degradation, and subchondral bone remodeling, which occurs from a subclinical phase before radiographic abnormalities are detected (Thoenen et ak, 2022). In line with this

understanding, advances in imaging technology have shifted the diagnostic paradigm of OA, from merely detecting radiographic abnormalities at an advanced stage to a comprehensive assessment of morphological and biological changes in the joint from an early stage. Advanced imaging modalities such as Ultrasonography *(* US *)* , *Computed Tomography* (*CT*), and *Magnetic Resonance Imaging* (*MRI*), as well as minimally invasive interventions such as *Genicular Artery Embolization* (*GAE*) have a strategic role not only in early diagnosis and monitoring of progression, but also as a therapeutic approach that specifically targets the pathophysiological mechanisms of OA (Piccolo et al, 2023).

The aims of study to a comprehensive understanding of the development of the role of advanced imaging modalities in osteoarthritis (OA), especially *Ultrasonography* (*US*), *Computed Tomography* (*CT*), and *Magnetic Resonance Imaging* (*MRI*), as well as examining the therapeutic role *of Genicular Artery Embolization* (*GAE*) as a minimally invasive intervention based on imaging guidance. The objective of this study is to review the evolving role of advanced imaging modalities in osteoarthritis (OA).

METHODS

This research was a case study that describing about advanced imaging modalities in osteoarthritis (OA) techniques to provide a comprehensive assessment. Various imaging modalities can be used to assess osteoarthritis, each with its own advantages, limitations, and specific indications (Table 1). Selecting the optimal modality requires consideration of diagnostic accuracy, facility availability, cost, examination time, and patient safety (Piccolo et al, 2023; Roemer et al, 2022; Thoenen et ak, 2022).

Table 1.
Advanced imaging methods that can be used in the evaluation of osteoarthritis (Piccolo et al, 2023; Roemer et al, 2022; Thoenen et ak, 2022).

No	Modality Types	Superiority	Limitations	Role in Osteoarthritis	Role in *GAE*
1.	*Ultrasonography* (*US*)	• No radiation • Cheap • *Real-time* • *Bedside*	• *Operator-dependent* • Limited to bones • Limited penetration into deep intra-articular structures	• Detection of synovitis • Detection of joint effusion • Intra-articular injection guide	• *GAE* monitoring
2.	*Computed Tomography scan* (*CT*)	• High spatial resolution for bones • Evaluation of complex deformities • *Dual energy* : Identification of vein crystals	• Radiation exposure • Less sensitive to soft tissue • *Dual energy* : Limited cost and availability	• Detailed bone structure evaluation • *Dual energy* : OA, gouty arthritis • Surgical planning	• Intervention planning • *Dual energy* : Comorbidity evaluation
3.	*Magnetic Resonance Imaging* (*MRI*)	• No radiation • Comprehensive high-resolution visualization of soft tissue and bone • Detection of early changes in cartilage, synovium and subchondral bone. • Quantitative techniques	• High costs • Long duration • Contraindications in patients with certain implants	• Early diagnosis • Progress monitoring	• Patient selection • *GAE* evaluation

No	Modality Types	Superiority	Limitations	Role in Osteoarthritis	Role in *GAE*
4.	*Genicular Artery Embolization (GAE)*	• Minimally invasive therapy • Targeting pathological neovascularization • Reduces pain and inflammation	• Requires special expertise (interventional radiology) • Limited availability • Risk of vascular complications	• Refractory OA pain therapy in non-operative patients	-

RESULT

Ultrasonography (*US*)

Ultrasonography (*US*) is an imaging modality that allows real-time evaluation of intra-articular structures, the synovium, and periarticular tissues, and has high diagnostic value in detecting active synovitis. Integration of *US* with *Doppler* or *contrast-enhanced ultrasound* (*CEUS*) has been shown to improve the accuracy of detecting mild synovial inflammation (Nevalainen et al, 2023).

In a study of 57 patients with advanced OA, the accuracy *of US* in detecting femoral cartilage damage was comparable to that found on conventional radiographs for joint space narrowing. *US* proved reliable in detecting tibiofemoral osteophytes, effusion/synovitis, and meniscal protrusion, with the highest accuracy in the medial compartment (Figure 1). [5] Several inflammatory manifestations of knee OA, such as joint effusion or Baker's cyst, synovial thickening, and increased vascularity , can be identified well by *US* (Figure 2) and are associated with pain intensity and disease progression. Furthermore, *US plays an important role in guiding intra-articular aspiration or injection procedures, as well as in post- genicular artery embolization* (*GAE)* monitoring in assessing the inflammatory response (Nevalainen et al, 2023; Valerio et al, 202).

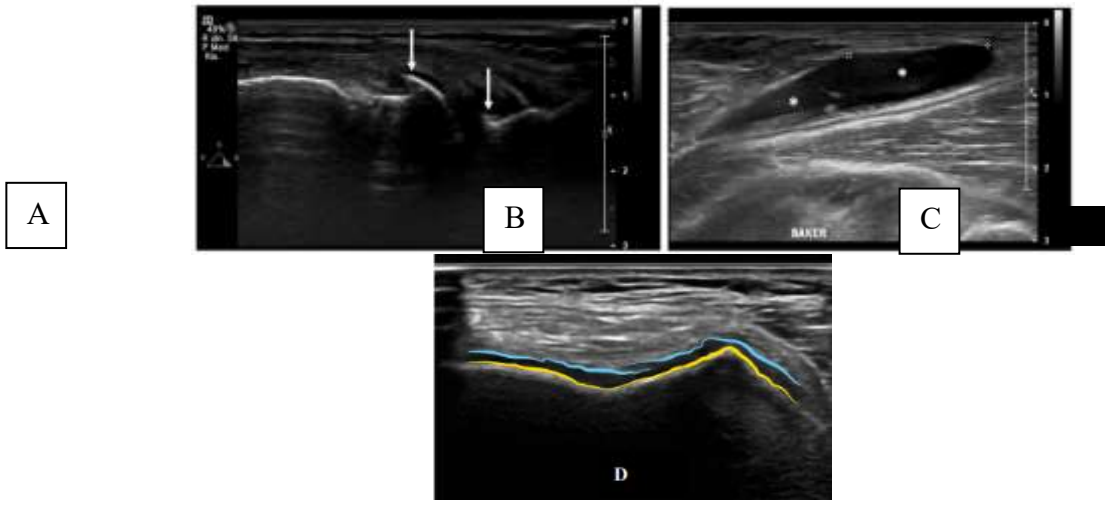

Figure 1. A. *US* image (B-mode) longitudinal section of the medial side of the knee showing early signs of osteoarthritis, in the form of small osteophytes on the epiphyses of the femur and tibia (indicated by arrows). B. Baker cyst seen in the posterior longitudinal section on the medial side of the popliteal fossa as a collection of fluid (*) between the medial head of the gastrocnemius muscle and *the semimembranosus tendon sheath* . C. Evaluation of the trochlear cartilage of the femur by US in an axial longitudinal section in the knee flexion position (light blue = superficial layer of cartilage, yellow = cortical bone of the trochlear groove).

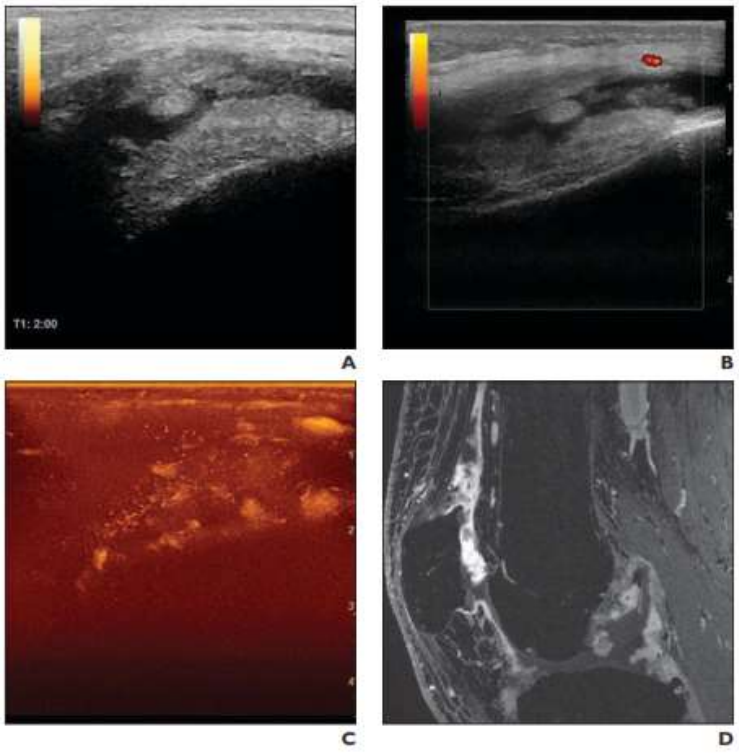

Figure 2. Figure 2. Ultrasound and contrastenhanced MRI findings in a patient with Kellgren-Lawrence grade 3 radiographic osteoarthritis and severe synovitis. A. Longitudinal grayscale ultrasound of the suprapatellar recess shows convex distension of the joint capsule by synovial fluid and hyperechoic synovial tissue. B. Corresponding Doppler ultrasound shows fewer than three color signals. C. Corresponding contrast-enhanced ultrasound depicts the total representation of detected contrast agent microbubbles. D. Sagittal contrastenhanced MRI shows severe

***Computed Tomography scan* (*CT scan*)**

Computed tomography (*CT*) offers superior visualization of subchondral bone structures and osteophytes, with high spatial resolution and optimal multiplanar reconstruction capabilities. In knee OA, *CT* excels in detecting osteophytes, subchondral cysts, bone sclerosis, joint effusions, and periarticular cysts (Figure 3) (Thoenen et al, 2022). *Dual-energy CT* (*DECT*) allows differentiation of material composition, including identification of urate crystal deposition that can contribute to *OA pain* , as well as mapping bone density and subchondral lesions specifically. The knee *CT protocol* includes thin slices (≤1 mm), multiplanar reconstruction, and bone algorithms to optimize resolution . *Arthrography* can be used to measure cartilage thickness, detect meniscus tears and ligament injuries, and evaluate cartilage-bone interactions through subchondral mineral density assessment (Valerio et al, 202).

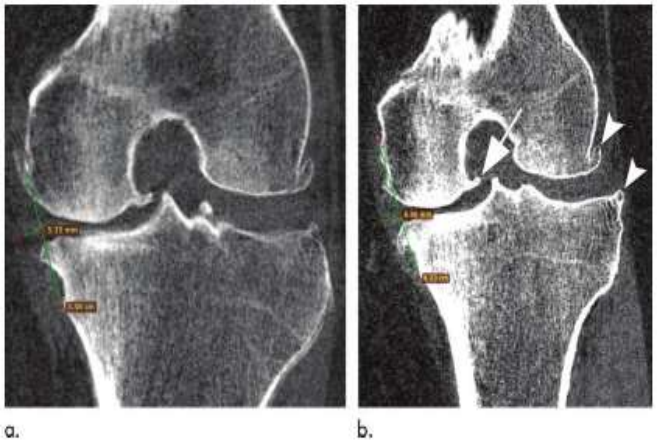

Figure 3. Coronal cone-beam CT images of a 58-year-old man in the non-weight-bearing (a) and weight-bearing (b) positions. Medial meniscal extrusion is observed, measuring 5.35 mm in the non-weight-bearing position and increasing to 6.86 mm under weight-bearing conditions. Both images also demonstrate characteristic osseous features of osteoarthritis, including a lateral marginal osteophyte (arrowhead) and a large osteophyte at the

***Magnetic Resonance Imaging* (*MRI*)**

Osteoarthritis of the knee is the most common form of OA, characterized by biomechanical, cellular, and biochemical changes in hyaline cartilage. This cartilage consists of three collagen zones: a surface zone with parallel fibers, a transition zone with random arrangement, and an inner radial zone with fibers perpendicular to the joint surface (Roemer et al, 2022; Thoenen et ak, 2022). The initial damage process is characterized by a decrease in proteoglycans and glycosaminoglycans (GAGs) and an increase in water content, followed by progressive and irreversible collagen tissue destruction. In advanced stages, OA affects all joint components, including the subchondral bone,

synovium, and menisci. In OA, *MRI* detects abnormalities such as *bone marrow lesions* (*BMLs*), synovitis, joint effusions, meniscal tears, and cartilage degeneration long before they are visible on plain radiographs (Figure 4). Conventional *MRI* is particularly useful for assessing joint morphology due to its high soft tissue contrast resolution (Mallio et al, 2022). Meanwhile, quantitative MRI (*QMRI*) techniques such as *T1ρ* , *T2 mapping* , and *dGEMRIC* allow the detection of biochemical changes in cartilage before structural damage is visible by quantitative evaluation of proteoglycan and collagen content in cartilage (Ehmig et al, 2023). *QMRI* has the potential to be an imaging biomarker for early diagnosis, predicting the risk of progression, and monitoring the effectiveness of preventive or regenerative therapies before surgical intervention is required. *MRI procedures* for knee OA include supine positioning, use of a specialized knee coil, T1, T2, *PD fat-suppressed* , and *STIR sequence protocols* , and administration of gadolinium for *dGEMRIC* when needed. This examination can predict OA progression and guide patient selection for therapies such as *GAE* (Mallio et al, 2022).

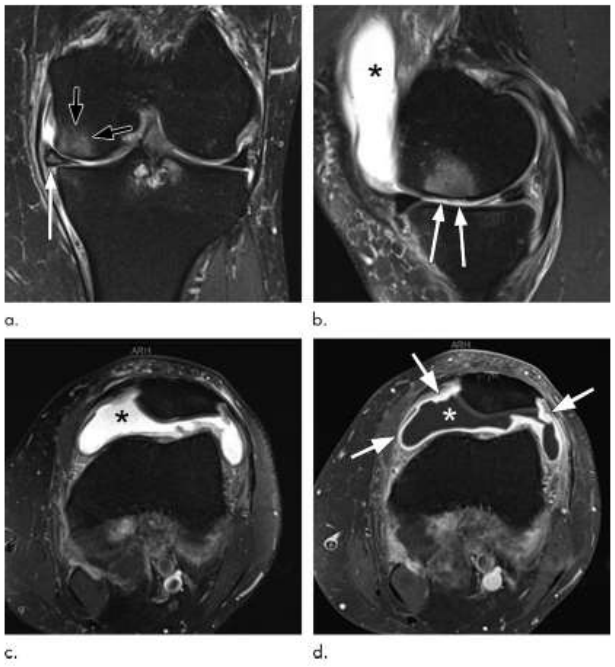

Figure 4**.** Contrast-enhanced knee MRI in a 71-year-old woman with osteoarthritis (OA). (a) Coronal fat-suppressed intermediate-weighted image showing a signal resembling bone marrow edema (black arrow) and meniscal extrusion (white arrow). (b) Sagittal fat-suppressed intermediateweighted image confirming femoral cartilage thinning (arrow) and demonstrating an intraarticular joint effusion. (c) Axial fat-suppressed intermediate-weighted image showing a joint effusion with high signal intensity within the synovial cavity. (d) Fat-suppressed T1-weighted image following intravenous contrast administration revealing a thickened, high-intensity synovial lining (arrow), while the joint fluid

T1ρ mapping

T1ρ mapping is a spin-lock MRI- based imaging technique that produces T1ρ relaxation time maps, depicting spin-lattice relaxation in a rotating skeleton. This parameter is sensitive to low-frequency interactions between mobile water and macromolecules in the extracellular matrix, particularly proteoglycans and glycosaminoglycans (GAGs). Loss of proteoglycans/GAGs is an early sign of cartilage damage, leading to increased T1ρ values (Figure 5) (Ehmig et al, 2023). Compared to T2 mapping , T1ρ has higher sensitivity and dynamic range, allowing it to detect small changes in cartilage with greater accuracy. Studies have shown that T1ρ can differentiate cartilage composition in asymptomatic individuals with focal abnormalities, and its value correlates with the severity of osteoarthritis (higher in advanced stages). Its advantages include no special preparation, contrast agents, or additional hardware, and relatively short examination time. However, it requires MRI with a special radiofrequency pulse sequence that increases the specific absorption rate (SAR) (Roemer et al, 2022; Ehmig et al, 2023).

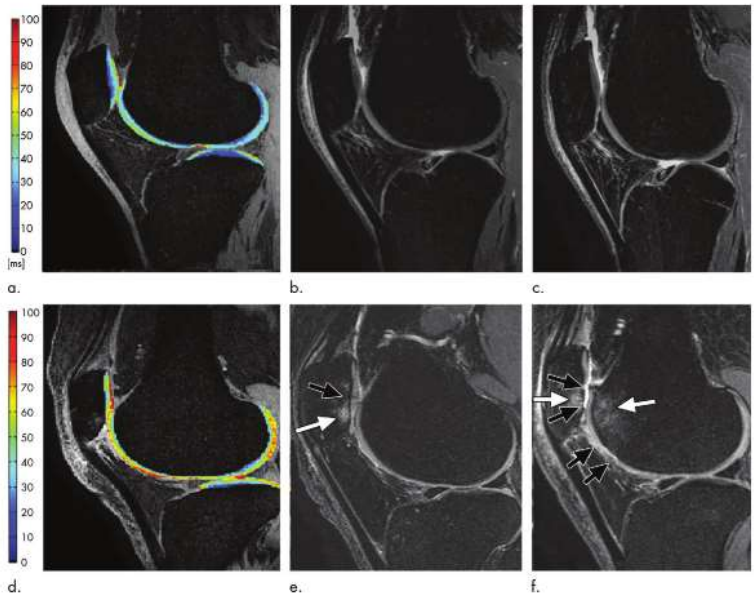

Figure 5. Baseline T1ρ maps and knee MRI images showing the difference in cartilage degeneration progression between a patient without progression (top) and a patient with progression (bottom) over 2 years. In the progressive case, baseline T1ρ values were higher, and after 2 years, severe thinning to complete loss of cartilage was observed, accompanied by an increase in subchondral bone marrow lesions (Ehmig et al, 2023).

T2 mapping

T2 mapping is one of the most widely studied quantitative MRI methods, producing color or grayscale T2 relaxation time maps that can indicate early biochemical changes in the pathological process of cartilage degeneration. T2 values reflect spin-spin relaxation times and are sensitive to the anisotropic movement of water molecules in the fibrous collagen network of the cartilage matrix. In articular cartilage, T2 values are inversely proportional to the regularity of the collagen network and directly proportional to water content. Loss of collagen network integrity accompanied by increased water content and mobility (which occurs in the early phase of cartilage degeneration) will prolong the T2 relaxation time (Ehmig et al, 2023). Several studies have shown that T2 mapping can detect premorphological changes in the early stages of OA, predict future OA risk, and monitor the effectiveness of various cartilage repair techniques over time (Figure 6) (Thoenen et al, 2022; Ehmig et al, 2023).

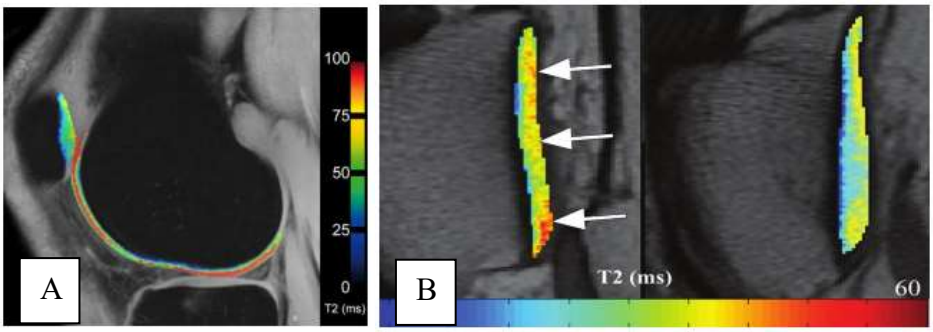

Figure 6. A. *T2 maps* of the femoral and patellar cartilages, *the colorbar* on the right indicates *the T2 relaxation time. B. T2* color maps based on *sagittal T2 multiecho spin-echo* sequences of the patellar cartilage of a 61-year-old man with diabetes mellitus (left) and another without diabetes mellitus (right). The patellar cartilage in both patients appears morphologically normal, but the T2 value appears diffusely increased (arrow) in the individual with diabetes mellitus compared to the age-matched control without diabetes (Ehmig et al, 2023).

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Delayed Gadolinium-Enhanced MRI of Cartilage (dGEMRIC)

dGEMRIC is a T1 mapping technique used to indirectly evaluate glycosaminoglycan (GAG) levels in cartilage by measuring the distribution of gadolinium-based contrast agents (GBCAs). After intravenous injection, negatively charged GBCAs are pushed away from negatively charged GAG chains and accumulate more in areas of cartilage with low GAG levels (damage), so that GAG levels are inversely proportional to GBCA concentration . Because GBCAs accelerate T1 relaxation, damaged cartilage areas will show increased signal on post-contrast T1 images . This technique has

been shown to be sensitive and specific for early detection and prediction of osteoarthritis severity, although there are limitations such as the need for contrast injection, long procedure duration (±90 minutes after injection for diffusion and penetration), and the need for physical activity before scanning (Figure 7) (Roemer et al, 2022; Ehmig et al, 2023).

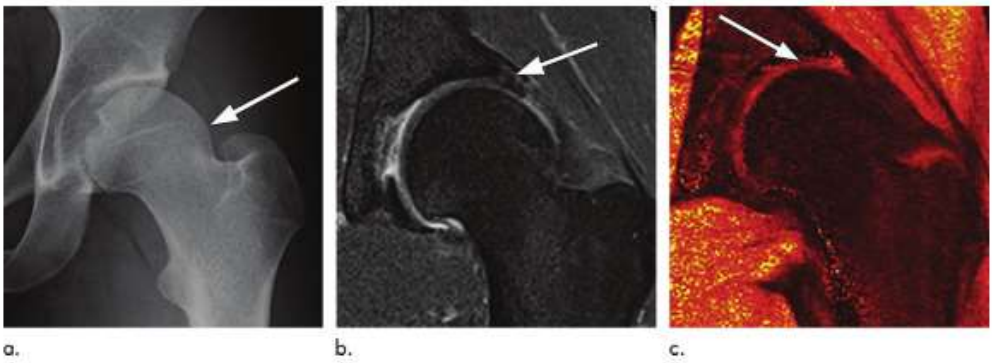

Figure 7. Delayed gadolinium-enhanced MRI of cartilage (GEMRIC) of the left hip joint of a 22-year-old female gymnast with clinical symptoms of femoroacetabular impingement (Roemer et al, 2022).

(a) Anteroposterior radiograph shows a cam-type deformity at the superolateral femoral head-neck junction (arrow). The joint space is preserved and no marginal osteophytes are visible. (b) *Intermediate-weighted* coronal image with fat suppression shows normal surface morphology of the femoral and acetabular cartilage, with mild labral degeneration (arrow). (c) Color coronal *dGEMRIC image* shows a focal decrease in *the dGEMRIC index* characterized by a fine dark line in the acetabular cartilage (arrow), indicating possible early cartilage degeneration.

Genicular Artery Embolization (GAE)

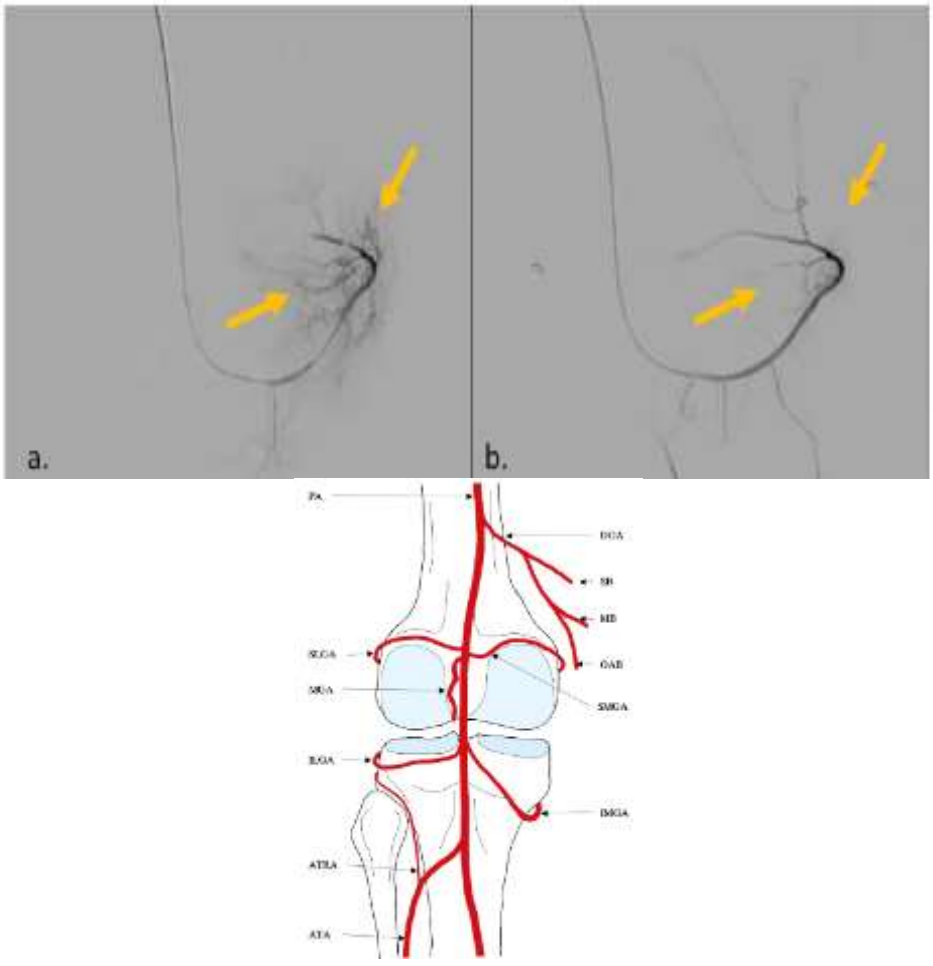

Figure 8. Embolization of the inferior lateral genicular artery (left). a. Pre-Embolization-Angiography shows synovial hyperemia and neovascularization. b. Post-Embolization-Angiography shows reduced neovascularization (pruning) and a significant decrease in synovial hyperemia. Schematic illustration of the classic arrangement of the genicular artery anastomosis from the posterior view of the left knee (right). Collateral vascular supply includes: popliteal artery, descending genicular artery (with saphenous branch, muscular branch, and articular branch), superior medial genicular artery, superior lateral, middle genicular artery, inferior medial, inferior lateral, anterior recurrent tibial artery, and anterior tibial artery (Shami et al, 2025; Brown et al, 2025).

Inflammation and angiogenesis play a crucial role in the pathogenesis and progression of OA, contributing to endochondral injury, ossification, and synovitis. Synovial angiogenesis is triggered by inflammation, primarily through macrophage activation, with the involvement of proangiogenic factors such as vascular endothelial growth factor (VEGF), β-nerve growth factor , and neuropeptides. These factors not only promote new blood vessel formation but also facilitate neoinnervation. The growth of new nerve fibers, coupled with hypoxic conditions and mechanical stress, triggers nerve sensitization that exacerbates pain. GAE is a minimally invasive radiological intervention that targets abnormal neovascularization in the synovial membrane and periarticular tissues of OA (Figure 8). This procedure works by occluded the arterial supply to the synovial membrane, thereby reducing perfusion to the hyperemic tissue, suppressing inflammation, and interrupting the transmission of pain signals. GAE is recommended for patients with knee OA with refractory pain who do not respond to intra-articular injections or conventional non-surgical therapies (Brown et al, 2025; Shami et al, 2025).

The procedure begins with local anesthesia and femoral artery access using the Seldinger technique, followed by selective catheterization of the genicular artery using a microcatheter with a diameter of ±0.6 mm. Superselective catheterization allows precise targeting of the genicular artery, minimizing the risk of non-target embolization. Embolization is performed with 100–300 μm microsphere particles until devascularization of the target area is achieved. Fluoroscopy Digital Subtraction Angiography (DSA) is used to visualize the vascular anatomy in real time and identify areas of synovial hyperemia and confirm successful occlusion. Recent studies have shown GAE to be effective in reducing pain scores by 50–70% over 6–12 months, with a good safety profile. Side effects of GAE are generally mild and transient, with skin mottling reported in 11.6% of cases. Other complications include knee pain (1.2%), hematoma at the access site (0.6%), and focal skin ulcers (0.3%) (Shami et al, 2025; Femia et al, 2024).

DISCUSSION

The evolving concept of osteoarthritis (OA) as a disease involving inflammation, cartilage degeneration, and subchondral bone remodeling has increased the need for imaging techniques that can detect changes beyond conventional radiographic findings. Each modality provides complementary information.

Ultrasonography (US)

Ultrasonography (US) provides real-time assessment of the knee joint, synovium, cartilage surfaces, and periarticular soft tissues. Its main advantage in osteoarthritis (OA) is the evaluation of inflammatory manifestations, particularly synovial hypertrophy, joint effusion, and increased synovial vascularity. Doppler or contrast-enhanced ultrasound (CEUS) may improve detection of mild synovial inflammation, which is associated with pain intensity and disease progression (Nevalainen et al, 2023; D'Agostino et al, 2024). US can also demonstrate marginal osteophytes, meniscal protrusion, and superficial cartilageabnormalities, particularly in the medial compartment. Despite limitations in evaluating deep intra-articular structures and operator dependency, its accessibility, lack of ionizing radiation, and real-time capability make it useful for assessment and

follow-up. US also facilitates image-guided aspiration and intra-articular injection and may help monitor inflammatory changes following genicular artery embolization (GAE).

Computed Tomography (CT)

Computed tomography (CT) provides high spatial resolution for evaluating osteophytes, subchondral sclerosis, cystic changes, and complex osseous deformities associated with OA. Multiplanar reconstruction facilitates assessment of articular surfaces and subchondral bone, particularly when detailed bone morphology is required for advanced disease or surgical and interventional planning.Dual-energy CT (DECT) can differentiate materials and assist in identifying urate crystal deposition, which may contribute to joint symptoms. However, radiation exposure and limited soft-tissue contrast remain important limitations compared with MRI (Piccolo et al, 2023; Thoenen et al, 2022).

Magnetic Resonance Imaging (MRI)

MRI plays an important role in assessing OA as a disease involving multiple joint tissues and biological processes. Unlike conventional radiography, MRI can detect abnormalities of cartilage, synovium, menisci, ligaments, and subchondral bone at earlier stages. Bone marrow lesions (BMLs), synovitis, joint effusion, meniscal abnormalities, and cartilage degeneration may be detected before substantial radiographic changes become apparent. Cartilage degeneration begins with extracellular matrix changes, including loss of proteoglycans and glycosaminoglycans (GAGs) and increased water content, preceding collagen disruption and morphological cartilage loss. Conventional MRI provide s detailed assessment of cartilage and associated abnormalities such as BMLs, synovitis, effusion, and meniscal extrusion (Ehmig et al, 2023; Roemer et al, 2022).

Quantitative MRI

Quantitative MRI (QMRI), including T1ρ mapping, T2 mapping, and delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), provides information on biochemical and compositional cartilage changes that may precede morphological abnormalities. T1ρ mapping is sensitive to proteoglycan and GAG loss, with increased values associated with early cartilage degeneration and OA severity. T2 mapping reflects collagen organization and cartilage water content; increased T2 values may indicate early matrix degeneration. dGEMRIC indirectly evaluates cartilage GAG content through the distribution of gadolinium-based contrast agents and may detect early cartilage damage. However, its use is limited by contrast administration, prolonged examination time, and the need for standardized physical activity before imaging.Overall, QMRI may provide imaging biomarkers for early cartilage injury, disease progression, and treatment response before irreversible structural damage develops (Ehmig et al, 2023; Roemer et al, 2022).

Genicular Artery Embolization (GAE)

Inflammation and pathological angiogenesis are important components of OA pathophysiology and provide a biological rationale for genicular artery embolization (GAE). Synovial inflammation promotes angiogenesis through mediators such as vascular endothelial growth factor (VEGF), β-nerve growth factor, and neuropeptides. Abnormal neovascularization and neoinnervation may contribute to peripheral nerve sensitization and persistent OA-related pain.GAE is a minimally invasive procedure targeting abnormal periarticular and synovial neovascularization. Selective embolization reduces perfusion to hyperemic synovial tissue, aiming to decrease inflammation and pain. It may be considered in patients with refractory knee OA pain who do not respond adequately to conventional non-surgical therapies.Angiographic assessment and superselective catheterization allow precise targeting of abnormal vascularity and may reduce non-target embolization. Recent studies have reported pain reduction of approximately 50–70% over 6–12 months, with generally favorable safety profiles. Appropriate patient selection and detailed knowledge of genicular arterial anatomy remain essential (Femia et al, 2024; Shami et al, 2025).

Integrating Imaging and Intervention in OA Management

The multifactorial nature of OA highlights the complementary roles of different imaging modalities. US is useful for assessing synovitis, effusion, and vascularity; CT provides detailed evaluation of osseous morphology; and MRI offers comprehensive assessment of cartilage, menisci, synovium, and subchondral bone. QMRI adds information on early biochemical cartilage changes (Piccolo et al, 2023; Roemer et al, 2022; Ehmig et al, 2023). These modalities also contribute to treatment planning and monitoring. MRI may assist in characterizing disease phenotype and selecting patients for advanced therapies, while US enablesdynamic assessment and follow-up. CT and angiographic imaging may provide additionalinformation for procedural planning. The integration of advanced imaging with GAE illustrates the expanding role of radiology in characterizing disease activity, identifying therapeutic targets, and supporting image-guided treatment (Brown et al, 2025; Shami et al, 2025)

CONCLUSION

Advances in imaging technology have shifted the paradigm of OA diagnosis and management from a structural approach to a biological and functional one. *MRI* , *ultrasound* , and *CT* not only detect anatomical changes but also map the underlying pathophysiological processes of OA, enabling early diagnosis, therapy monitoring, and personalized patient management. Radiological interventions such as *GAE* expand the role of radiologists from diagnostic to therapeutic. The integration of advanced imaging technology with minimally invasive interventions will be a crucial pillar in OA management in the era of precision medicine.

REFERENCES

Brown, J. M., Vandeveer, Z. T., Cadoret, D., Morrison, J. J., & Jahangiri, Y. (2025). Genicular artery embolization: A technical review of anatomy, pathophysiology, current experiences, and future directions. Journal of Clinical Medicine, 14(6), 2106.

D'Agostino, V., Sorriento, A., Cafarelli, A., Donati, D., Papalexis, N., Russo, A., et al. (2024). Ultrasound imaging in knee osteoarthritis: Current role, recent advancements, and future perspectives. Journal of Clinical Medicine, 13(16), 4930. https://www.mdpi.com/2077-0383/13/16/4930

Ehmig, J., Engel, G., Lotz, J., Lehmann, W., Taheri, S., Schilling, A. F., et al. (2023). MR-imaging in osteoarthritis: Current standard of practice and future outlook. Diagnostics, 13(15), 2586.

Femia, M., Valenti Pittino, C., Fumarola, E. M., Tramarin, M., Papa, M., Giurazza, F., et al. (2024). Genicular artery embolization: A new tool for the management of refractory osteoarthritis-related knee pain. Journal of Personalized Medicine, 14(7), 686.

Mallio, C. A., Bernetti, C., Agostini, F., Mangone, M., Paoloni, M., Santilli, G., et al. (2023). Advanced MR imaging for knee osteoarthritis: A review on local and brain effects. Diagnostics, 13(1), 54.

Nevalainen, M. T., Uusimaa, A. P., & Saarakkala, S. (2023). The ultrasound assessment of osteoarthritis: The current status. Skeletal Radiology, 52(11), 2271–2282.

Piccolo, C. L., Mallio, C. A., Vaccarino, F., Grasso, R. F., & Zobel, B. B. (2023). Imaging of knee osteoarthritis: A review of multimodal diagnostic approaches. Quantitative Imaging in Medicine and Surgery, 13(11), 7582–7595.

Roemer, F. W., Guermazi, A., Demehri, S., Wirth, W., & Kijowski, R. (2022). Imaging in osteoarthritis. Osteoarthritis and Cartilage, 30(7), 913–934.

Shami, S. M. U., Hata, N., & Epelboym, Y. (2025). Genicular artery embolization and nerve ablation: Interventional radiology solutions for osteoarthritis related knee pain. Osteoarthritis Imaging, 5(2), 100271.

Thoenen, J., MacKay, J. W., Sandford, H. J. C., Gold, G. E., & Kogan, F. (2022). Imaging of synovial inflammation in osteoarthritis, from the AJR special series on inflammation. American Journal of Roentgenology, 218(3), 405–417.