Imaging in Gout and Other Crystal-Related Arthropathies

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INTRODUCTION

The deposition of microcrystals within and around the joint is a common phenomenon. Intra-articular microcrystals are the most frequent cause of joint inflammation in adults. The most common types are monosodium urate (MSU), the cause of gouty arthropathy;

KEYWORDS

- Gout
- Crystal arthropathy
- Calcification
- Imaging
- Radiography
- Ultrasound
- Dual-energy CT
- MRI

KEY POINTS

- Crystal deposits in and around the joints are common and most often encountered as incidental imaging findings in asymptomatic patients.
- In the chronic setting, imaging features of crystal arthropathies are usually characteristic and allow the differentiation of the type of crystal arthropathy, whereas in the acute phase and in early stages, imaging signs are often nonspecific, and the final diagnosis still relies on the analysis of synovial fluid.
- Radiography remains the primary imaging tool in the workup of these conditions; ultrasound has been playing an increasing role for superficially located crystal-induced arthropathies, and computerized tomography (CT) is a nice complement to radiography for deeper sites.
- When performed in the acute stage, MRI may show severe inflammatory changes that could be misleading; correlation to radiographs or CT should help to distinguish crystal arthropathies from infectious or tumoral conditions.
- Dual-energy CT is a promising tool for the characterization of crystal arthropathies, particularly gout as it permits a quantitative assessment of deposits, and may help in the follow-up of patients.

INTRODUCTION

The deposition of microcrystals within and around the joint is a common phenomenon. Intra-articular microcrystals are the most frequent cause of joint inflammation in adults. The most common types are monosodium urate (MSU), the cause of gouty arthropathy;
calcium pyrophosphate dihydrate (CPP), causing CPP deposition disease (CPPD); and basic calcium phosphate (BCP), causing BCP deposition disease (Table 1). In this article, the authors consider the manifestations of intra-articular as well as periarticular crystal deposits. Most cases of crystal deposits are asymptomatic and represent incidental findings at imaging. In case of symptomatic arthropathies, imaging can play an important role in the diagnosis and the assessment of disease progression as well as the extent of crystal deposits. Conventional radiography is the most common imaging modality and still remains essential to the workup. But ultrasound (US), conventional computerized tomography (CT), dual-energy CT (DECT), and MRI all play an increasing role. For example, the new 2015 American College of Rheumatology/European League Against Rheumatism’s classification criteria for gout take into account the radiological signs obtained by standard radiology as well as by DECT and US.1

The authors review typical radiographic features of each of these crystal-induced arthropathies as well as findings that help to differentiate them. The increasing role of complementary imaging techniques will also be emphasized.

CONVENTIONAL RADIOGRAPHY

Radiography remains the primary imaging technique in the diagnosis of crystal arthropathies. Table 2 gives an overview of the imaging features, underlying the main differences to help in diagnosis.

**Monosodium Urate (Gout)**

*Radiographic features of chronic gouty arthropathy*

Deposits of MSU crystals are found in extra-articular as well as intraarticular sites, including cartilage.2 Gouty arthropathy may affect any joint in the body, including the axial skeleton.3 In the acute setting, gout most often affects the first joints of the lower limbs, most typically the first metatarsophalangeal joints.2,4

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**Table 1**

Composition and structure of the common pathogenic crystals in rheumatic diseases

<table>
<thead>
<tr>
<th>Type of Crystal Deposit and Chemical Composition</th>
<th>Size and Shape of Crystals</th>
<th>Detection of Crystals in Synovial Fluid/Biopsy</th>
<th>Common Associated Clinical Conditions</th>
</tr>
</thead>
</table>
| Monosodium urate (MSU) C₅H₃N₄O₃.Na         | 2–30 µm, typically needle shaped | By polarizing light microscopy: negatively birefringent crystals | • Acute gout  
• Chronic gout (tophaceous gout)  
• Urate stones (contain uric acid crystals) |
| Calcium phosphate dihydrate (CPP) Ca₃P₂O₇    | 1–20 µm, rhomboidal shaped   | By polarizing light microscopy: positively birefringent crystals | • Acute CPPD arthropathy (formerly referred to as pseudogout)  
• Chronic CPPD arthropathy |
| Basic phosphate calcium (BCP) Ca₅(PO₄)₃(OH) | 1 nm, 5–20 µm in clumps      | • Difficult to detect by light microscopy  
• Fluorescence microscopy  
• Aspecific alizarin staining on tissue samples | • BCP deposition disease including  
○ Calcific tendinitis  
○ Calcific bursitis |
<table>
<thead>
<tr>
<th>Distribution / in the body</th>
<th>MSU</th>
<th>CPPD</th>
<th>BCP</th>
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</thead>
<tbody>
<tr>
<td>Mostly para-articular structures (tendons, ligaments, bursae)</td>
<td>Most articular tissues (hyaline cartilage, fibrocartilage, synovium, capsule, ligament)</td>
<td>Mostly para-articular structures, in periarticular locations (tendons, bursae, ligaments)</td>
<td></td>
</tr>
<tr>
<td>Intraarticular deposits less prominent</td>
<td>Usually polyarticular</td>
<td>Usually monoarticular</td>
<td></td>
</tr>
<tr>
<td>May be mono-articular or polyarticular</td>
<td>First metatarsophalangeal joints in acute phase, but any joint can be affected, especially in chronic phase</td>
<td>Any joint can be affected, but in decreasing order of frequency: shoulder, hips, elbows, wrists and knees</td>
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<table>
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<tr>
<th>Radiographic aspect</th>
<th>MSU</th>
<th>CPPD</th>
<th>BCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft tissue swelling, joint effusion (acute phase)</td>
<td>Dense</td>
<td>Dense if quiescent, can lose density when resorption occurs</td>
<td></td>
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<tr>
<td>Asymmetric soft tissue nodules that may be faintly hyperdense (tophaceous gout)</td>
<td>Fine, linear, punctate</td>
<td>Homogeneous cloulike, amorphous</td>
<td></td>
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<tr>
<td>Well-defined, punched-out erosion with overhanging edges, with preservation of joint space</td>
<td>Expansive intraosseous erosions</td>
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<table>
<thead>
<tr>
<th>CT</th>
<th>MSU</th>
<th>CPPD</th>
<th>BCP</th>
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<tbody>
<tr>
<td>Denser than soft tissues but lower density than calcified crystals (160–170 HU, with a maximum of 300 HU)</td>
<td>Dense (450 HU or more)</td>
<td>Dense (450 HU or more)</td>
<td></td>
</tr>
<tr>
<td>Nodular extra-articular and intraarticular deposits</td>
<td>Fine, linear, punctate</td>
<td>Homogeneous cloulike, amorphous</td>
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<th>Table 2 (continued)</th>
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<td><strong>MSU</strong></td>
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<td>MRI</td>
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Radiographic signs of chronic gout (also called tophaceous gout) include asymmetric articular, juxta-articular, or periarticular soft tissue nodules, corresponding to tophi. These nodules may be as dense or slightly denser than the adjacent soft tissues but are usually fainter than CPP or BCP deposits (Fig. 1D). MSU deposits can also occur in cartilage, but usually in advanced stages; joint space narrowing occurs late in the evolution of the disease, which is a characteristic feature of this condition (Fig. 2).

Bone erosions are characteristic and present as well-defined intraarticular or juxta-articular lesions with overhanging margins (Fig. 3). They can be expansive, sometimes progressing to a punched-out amputated aspect of bone. Bone erosions are

Fig. 1. 61-year old man with incidental signal abnormalities of the first metatarsophalangeal joint detected on an MRI of the hindfoot for peroneal tendon rupture under fluoroquinolone therapy. These signal abnormalities yielded to complete the study with an MRI of the forefoot, showing incidental asymptomatic chronic gouty arthropathy. Axial T1- (A), axial fat-suppressed enhanced T1- (B) and coronal fat-suppressed T2-weighted (C) sequences show arthropathy of first metatarsophalangeal joint with soft tissue swelling presenting intermediate to low signal intensity on T1-, heterogeneous signal intensity on fat-suppressed T2-, and enhanced T1-weighted images. Note the presence of characteristic areas of low signal intensity on all sequences (arrows), corresponding to crystal deposits and chronic fibrous reactions. Radiograph of the foot (D) shows soft tissue swelling on medial aspect of first metatarsophalangeal joint (asterisk), of similar density than surrounding soft tissues as well as juxta-articular bone erosion (short arrow in [D]).
usually found in the vicinity of tophi, being a direct consequence of their growth into the bone.\textsuperscript{4,9} There is usually no periarticular osteopenia in gout. Bone proliferation is sometimes present, mostly in the form of irregular spicules, best seen on the medial aspect of the first MTP or tarsal joints.\textsuperscript{9} This aspect of bone proliferation is probably also due to the cortical growth of tophi, to be differentiated from the chronic periosteal reactions seen in psoriatic arthritis.

Intraosseous calcifications due to the penetration of calcified MSU deposits in the bone have been described in severe cases of gout and should not be mistaken with enchondromas or bone infarcts.\textsuperscript{10} The differential diagnosis of tophaceous gout is wide and includes rheumatoid arthritis and amyloid arthropathy.\textsuperscript{11} Tophi in some locations, particularly in the axial skeleton, may mimic other inflammatory disorders, such as infectious spondylodiscitis or sacroiliitis.\textsuperscript{3,12,13} For those cases, CT examination is invaluable (see later discussion).

**Radiographic features of acute gouty arthropathy**

In the acute phase, radiographs are normal or they only show soft tissue swelling and joint effusion, which are completely nonspecific findings.\textsuperscript{4} US or CT may be more sensitive in detecting signs of MSU deposits.\textsuperscript{14–16}
Calcium Pyrophosphate Dihydrate Deposition Disease

Radiographic features of chronic calcium pyrophosphate dihydrate deposition disease arthropathy

CPPD can be found in all articular tissues, including hyaline cartilage and fibrocartilage (deposits in the 2 types of cartilage being classically referred to as chondrocalcinosis), synovium and ligaments, tendons, and other soft tissues (Fig. 4).17,18
The sites most often affected are the knee, pubic symphysis, and the wrist. Using radiographs of these joints as a screening test for CPPD, the sensitivity obtained was 100%. However, CPPD can occur in other locations, including the spine (the crowned dens syndrome) (Fig. 5). Typically, CPP deposits present a fine, linear, or punctate pattern, somehow following the fibrillar architecture of the affected tissues, particularly in tendons where CPP crystals deposit between fibers (see Fig. 4). In cartilage, crystals tend to deposit in the middle layer of cartilage, organized in a linear pattern, parallel to the subchondral bone (Fig. 6).

![Fig. 4](image1.png)

**Fig. 4.** An 86-year-old woman with asymptomatic CPPD on radiographs of the knee, showing typical pattern and intraarticular distribution of CPP crystals. Note fine punctate triangular pattern of calcifications in menisci (long arrow in [A]); linear pattern in quadriceps tendon (short arrows in [B]), oriented along the long axis of tendon fibers; and linear pattern of deposits in hyaline cartilage, parallel to the subchondral bone (long arrows in [B]). Deposits can occur in all intraarticular tissues, including hyaline cartilage, meniscal fibrocartilage, tendons (popliteal tendon (short arrows in [A]) and gastrocnemius tendon (asterisk in [B])), ligaments, and synovium.

![Fig. 5](image2.png)

**Fig. 5.** A 62-year-old man with history of CPPD with chronic neck pain. MRI (A–D) shows destructive arthropathy of the atlanto-axial joint, associated with area of low signal intensity on all sequences (T1- [A], fat-suppressed enhanced T1- [B], and T2-weighted sequences [C]), compatible with chronic reactional changes. The correlation with CT (D) confirms the arthropathy with erosions of the dens (black arrow in [D]), associated with calcifications that are compatible with CPP (white arrow in [D]), not visible on MRI (or radiographs, not shown). These features are typical of crowned dens syndrome.
Most cases of CPPD are asymptomatic and are discovered incidentally. The prevalence of CPPD is high and increases with age (prevalence of up to 25% in subjects older than 85 years).21–23 Below 50 years of age, however, idiopathic CPPD is rare; if present, predisposing metabolic disorders should be excluded.1

CPPD may sometimes progress to a destructive arthropathy resembling osteoarthritis (OA). Radiographic features may help to differentiate primary OA and CPPD arthropathy.1,18,24 In case of CPPD, arthropathic changes tend to be more severe and progressive, with extensive fragmentation of bone causing formation of intraarticular osseous bodies as well as prominent subchondral cystic changes. Also very suggestive of CPPD chronic arthropathy is the distribution: non–weight-bearing joints (shoulder, elbow, wrist) can be affected as much as weight-bearing joints (Fig. 7).18

Some sites are particularly suggestive of CPPD, such as the radiocarpal compartment of the wrist, the patellofemoral compartment of the knee (see Fig. 7), the hindfoot, or midfoot.

CPPD can also be associated with other conditions, such as hemochromatosis, hyperparathyroidism, and gout; radiographic features of both CPPD and the associated condition can, therefore, be present simultaneously.25–27 In hemochromatosis, there is more extensive destruction of the MCP joints (including the fourth and the fifth digits), hooklike osteophytes but deposits in the first carpometacarpal joint and scapholunate dissociation are less frequent.27

Finally, it is of note that a potential causative relationship between CPP and BCP deposits and OA is under investigation.1,28,29

Fig. 6. Comparison of US aspect of CPP (A) and MSU (C) crystals in cartilage (different patients). CPP crystal typically deposit within the layer of cartilage (A), forming hyperechoic foci (long arrows in [A]) (see radiograph of same patient in [B] for comparison), whereas MSU crystals deposit on the surface of cartilage, forming the so-called double contour sign (superficial hyperechoic line due to MSU deposits on surface of cartilage and deep fainter hyperechoic line due to subchondral bone) (short arrows in [C]) (MSU deposits in cartilage are not visible on radiographs). Note that on the control US examination performed under appropriate hypouricemic treatment, the double contour sign has disappeared with only one hyperechoic line visible due to subchondral bone, which is now brighter (D).
Radiographic features of calcium pyrophosphate dihydrate deposition disease calcifications in the acute setting

In the acute setting, the diagnosis of CPP is suggested by the presence of the characteristic features for CPPD described earlier. However, the diagnosis can only be proven by crystal identification.\(^1\) The sensitivity of radiography to detect CPPD in crystal-proven cases is weak: only 35.3% of histologically proven meniscal deposits were positive by radiograph in a cohort of 3228 patients.\(^30\) The reported sensitivities vary depending on the joint studied (from 29% to 93%).\(^1\)

Basic Calcium Phosphate

Radiographic features of stable basic calcium phosphate calcifications

BCP calcifications are usually encountered in tendons, bursae, and other peritendinous structures.\(^17\) In descending order of frequency, the shoulder, hips, elbows, wrists, and knees are the most affected sites.\(^31,32\) However, any location can be affected, including unusual ones that often lead to diagnostic difficulties.\(^33–35\)
Typically, BCP calcification in the quiescent phase presents a dense, homogeneous, amorphous, cloudlike appearance (Fig. 8E, F). This aspect might be related to the pathophysiology of the disease: one of the prevailing theories is that dystrophic calcifications form in areas of necrotic changes due to repetitive microtrauma and vascular changes.\textsuperscript{9,17,32}

This pattern allows them to be differentiated from the linear and punctate aspects of CPP deposits. BCP calcifications lack a cortical or trabecular structure, unlike heterotopic ossifications and accessory ossicles (see Fig. 8E, F).\textsuperscript{36}

**Acute manifestations of basic calcium phosphate calcifications**

Acute symptoms provoked by BCP deposits occur typically during the resorption of calcifications. They lose the typical features described earlier and may become faint and irregular (Figs. 9–11). Migration to bursae and adjacent soft tissues can occur (see Figs. 9–11).\textsuperscript{36} As the calcification diminishes and disappears, the acute symptoms improve, typically over the course of a few days or weeks (see Fig. 10).\textsuperscript{36} Repeat

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Fig. 8. A 33-year-old man with pain at the first metacarpophalangeal joint of the right hand. MRI (A–C) shows area of hyposignal intensity (arrows) on all sequences (T1 [A], fat-suppressed T2 [B], and fat-suppressed enhanced T1-weighted [C]), located in articular soft-tissues of the first metacarpophalangeal joint. CT (D) and orthogonal radiographic views (E, F) were ordered to confirm the presence of BCP calcification (long arrow in [D]) with erosion of the adjacent bone (short arrow in [D]), not visible on radiographs (E, F). Note amorphous aspect of calcification on radiographs (arrow in [E]), not to be confused with sesamoid bones (circle in [F]), which present a typical cortico-trabecular pattern of bone, contrary to calcifications.
Fig. 9. Three cases of rotator cuff BCP calcifications, with correlations between radiographs and US. (A, B) BCP calcification in resorptive phase. Radiograph (A) shows slightly blurry contours. US (B) shows multiple hyperechoic fragments visible (arrows). Parts of the fragments are in the subacromial bursa (short arrows). (C, D) BCP calcification that has migrated into the subacromial bursa (arrows). Radiograph (C) shows faint calcification, whereas US (D) shows hyperechoic nodule. (E, F) BCP calcification that is migrating into the bone. Radiograph (E) shows calcification with blurry margins (arrow in E), especially on the inferior aspect. At US (F), a hyperechoic nodule is seen (arrow in F). The continuity of the calcification with bone erosion is clearly depicted. Hyperemic reaction at Doppler imaging is seen. Note that no shadowing is present in any of the cases of resorptive calcifications.
Radiographs can show a change in calcification and help to confirm the diagnosis (see Fig. 10). When the diagnosis is unclear, CT (especially for the spine [see Fig. 11]) or US (for superficial locations) may be useful (see later discussion).

**ULTRASOUND**

In recent years, major technical advances have led to improved image quality and performance of US. It is particularly useful for the diagnosis of crystal arthropathies and has become, along with radiography, one of the main imaging techniques used.

**Monosodium Urate Crystals**

*Ultrasound features of chronic tophaceous gout*

The US features of MSU deposits are the double contour (DC) sign, tophi, aggregates, and erosions. The DC sign is defined as an “abnormal hyperechoic band over the superficial layer of the cartilage, independent of the angle of probe and may be either...
irregular or regular, continuous or intermittent and can be distinguished from the cartilage interface sign” (see Fig. 6C, D). The specificity of this sign for gout has, however, been questioned. The specificity of this sign for gout has, however, been questioned.37,38 Tophi are defined as « circumscribed, inhomogeneous, hyperechoic and/or hypoechoic aggregates, which may be surrounded by a small anechoic rim » (Fig. 12).37 Aggregates are defined as « heterogeneous hyperechoic foci that have a high degree of reflectivity, even when the gain setting is minimized or the probe angle changed ».37 They can have intraarticular or intratendinous locations. Erosions are defined as an « intra- and/or extra-articular discontinuity of the bone surface (visible in two perpendicular planes)».37 Erosions have to be differentiated from normal variations of cortical contour, degenerative, and traumatic changes.40 The inter-reader and intrareader agreement of these signs vary and are higher for the DC sign (kappa = 0.69–96) and tophi (kappa = 0.65–1) than for aggregates.37,41 The diagnostic performance of US for gout depends on several factors, including the duration of the condition. The DC sign has been found in asymptomatic hyperuricemic patients.40,42 When present, tophi and erosions seem to be depicted at US with high sensitivity compared with radiography, MRI, or DECT.41,43,44 Of note, US has been used to assess the efficacy of urate-lowering therapy and can show a reduction in size of tophi as well as the disappearance of the DC sign (see Fig. 6).44–46

Fig. 11. A 56-year-old man with esophageal carcinoma. The PET-CT performed for the staging showed high uptake in the thoracic spine, interpreted as a metastasis (arrow in A). MRI (B–D), performed 10 days after the PET-CT shows inflammatory signal intensity on either side of an intervertebral disc (low signal intensity on T1- [B], heterogeneous signal intensity on T2- [C], high signal intensity on fat-suppressed enhanced T1-weighted sequences [D] (dashed circles)). The pattern (both sides of a disc) and signal abnormality are not compatible with a bone marrow replacement lesion that would be typical of a metastasis. The disc itself does not show significant abnormality except for mild heterogeneous signal. Analysis of the CT examination (E) performed during the PET-CT shows heterogeneous dense calcification in the intervertebral disc (arrow). The calcification has clearly changed aspect when compared with a CT examination (arrow in E) performed 2 weeks prior, on which it appeared more homogeneous. These features are characteristic of a BCP calcification in the resorptive phase, leading to inflammatory reactions. On a follow-up CT performed 5 months later (G), the calcification is less dense at the center and bone erosions (arrowheads) are visible at both vertebral plates, confirming the intraosseous migration of the calcification.
Ultrasound features of acute gout

In the acute phase, the aforementioned signs of gouty arthropathy can be visible. As for all acute arthritic flares, joint effusion and synovitis may be detected on B mode and Doppler but are nonspecific. Synovitis may be heterogeneous with hyperechoic foci corresponding to MSU aggregates. Tophi can become hyperemic during an acute flare (see Fig. 12). Current data do not support the use of US as a replacement for joint fluid examination for the diagnosis of acute gout.

Calcium Pyrophosphate Dihydrate Crystals

Ultrasound features of chronic calcium pyrophosphate dihydrate deposition disease

US is now a well-accepted method for the diagnosis of CPPD, and several criteria have been used to define CPP deposits. In hyaline cartilage, they are described as « hyperechoic, placed within the layer of the cartilage, that can reach large dimensions » (see Fig. 6); in fibrocartilage as « hyperechoic, rounded or amorphous-shaped deposits »; and in tendon as « linear deposits with a the fibrillar texture (multiple or single lines or thick solid band) ».

The sensitivity and specificity of US for the detection of CPP crystal deposits depend on the diagnostic gold standard used: with radiograph as a gold standard, pooled sensitivities/specificities were 0.58/0.84; with synovial fluid analysis, they were 0.87/0.98. The performance also varied depending on the location of CPPD: there was a good accuracy for hyaline and fibrous cartilage, but the performance for tendon lesions was poor. The interobserver agreement varies from 0.55 to 0.81 for hyaline cartilage deposits.

Fig. 12. A 77-year-old man with gout. US of the first metatarsophalangeal joint shows hyperechoic intraarticular mass with a slightly hypoechoic rim (arrow in A). The same patient during an acute flare shows the same image as in (A), with accompanying hyperemia (B).
Ultrasound of acute calcium pyrophosphate dihydrate deposition disease

In the acute phase, the aforementioned signs of CPPD are usually accompanied by a variable degree of synovitis as well as hyperemia on Doppler examination. The value of US as a diagnostic modality was assessed recently. In the absence of any signs of crystal deposit in the symptomatic joint, as well as in knees, ankles, and first metatarsophalangeal joints, CPPD can be ruled out with a negative predictive value of 87%, using synovial fluid analysis as the gold standard. In this study, there was no statistically significant difference between US, radiography, and synovial fluid analysis as a diagnostic tool; but other studies have reached different conclusions.

Basic Calcium Phosphate Calcifications

Ultrasound features of basic calcium phosphate calcification

The main signs are hyperechoic foci with variable acoustic shadowing. The presence of shadowing depends on their structure, the degree of fragmentation of the deposit, and size. Four types of deposits have been described: arc-shaped (an echogenic arc with clear shadowing), fragmented or punctuate (at least 2 separated echogenic spots or plaques with or without shadowing), nodular (an echogenic nodule without shadowing), and cystic. This classification has however not been validated (see Fig. 9).

Ultrasound features of acute basic calcium phosphate calcification

The presence of hyperemia on Doppler and of the features described above seems to correlate with the evolutive stage of the calcification and symptoms. A fragmented appearance is associated with both worsening pain as well as the spontaneous resolution of symptoms. Doppler activity around the deposit and presence of effusion suggest inflammation and are correlated with pain. Migration to surrounding structures (ie, bursae or bone), usually with accompanying hyperemia, can be detected by US (see Fig. 9). Correlation with radiography helps in providing the correct diagnosis.

CONVENTIONAL COMPUTERIZED TOMOGRAPHY

Thanks to its excellent resolution and high contrast, CT is the technique of choice for the assessment and characterization of crystal arthropathies. Crystal deposits are usually hyperdense compared with the adjacent soft tissues. Their density usually helps in differentiating them. Typically, MSU deposits have average densities of 160 to 170 Hounsfield units (HU), with the densest areas around 300 HU. Calcium hydroxyapatite and calcium pyrophosphate deposits typically present densities of 450 HU or more. The latter two types of calcifications are easily differentiated by applying the same semiology as that described for radiography (fine, punctate, linear, oriented along the long axis of fibrillar structures for CPPD vs amorphous, cloudlike for BCP).

CT’s main limitation is radiation exposure. In current clinical practice, CT is an adjunct diagnostic tool to confirm the presence and nature of crystals in difficult cases, especially in locations that are difficult to visualize by radiography. In cases of crystal arthropathies affecting the axial skeleton, CT is particularly useful (see Fig. 11). A typical example of spinal deposit is the crowned dens syndrome, usually due to CPPD but rarely also a manifestation of BCP deposits (see Fig. 5).

The incidental positivity of crystal arthropathies on PET and single-photon emission CT scans has been reported, and careful analysis of the CT examination should avoid erroneous diagnoses of tumoral or infectious disorders (see Fig. 11).
Finally, CT has also been suggested as a quantitative tool to score bone erosions as an outcome measure for chronic gout studies.64

**DUAL-ENERGY COMPUTERIZED TOMOGRAPHY**

More recently, the advent of DECT has opened new perspectives. This technique allows differentiating deposits by their different x-ray spectra, using the principle that the attenuation of tissues depends not only on their density but also on their atomic number Z as well as the energy of the photon beam.65

Along with the characterization of urinary stones, one of the main applications of DECT over the past decade has been the assessment of crystal arthropathies (see Figs. 2 and 3).

DECT shows a high diagnostic performance for the assessment of MSU deposition. Reported sensitivities and specificities vary from 75% to 100% depending on the studies, and there is high interobserver agreement (kappa = 0.87–1).56–70 Compared with US, DECT has shown comparable or higher specificity but lower sensitivity in detecting smaller urate crystal deposits in joints.43,71

Numerous causes of false negatives exist. These causes can be due to less dense tophi with lower crystal concentrations, small size of tophi/crystals (usually not visible at less than 2 mm), or even technical parameters.69,72,73

There are also many causes of false-positive results. Postprocessed color-coded images can falsely mimic the presence of MSU deposits when tissues present similar index values, such as keratin. These false-positive results can be found around nail beds and in the skin but also in regions of beam hardening and metal artifacts or they can take the shape of single pixels scattered around the image, probably related to image noise.58,74 False-positive cases have also been described in cases of severe OA.69 A recent study has found abnormal intensities compatible with extensive deposition of MSU in costal cartilages and intervertebral discs of patients with gout and age-matched controls, suggesting that this finding might represent an artifact, although this would need to be confirmed.75

More work is needed to standardize postprocessing parameters in order to improve the performance of DECT.73 Furthermore, several spectral imaging techniques are used by different manufacturers to obtain DECT.65 Most of the data in the literature were obtained with dual-source scanners, which seem to represent the most robust technique. Results still need to be confirmed using other spectral imaging methods.

One of the main advantages of DECT is to offer automatic volume measurement of MSU deposits, with potential applications not only in clinical practice but also in research.66,67,76,77 Therefore, DECT could serve as a tool to monitor tophus burden as an outcome measure for gout.78 However, the sensitivity of DECT to change in crystal deposit volume still needs to be determined, and measurement errors remain a problem.79,80

**MRI**

MRI is not the modality of choice in the assessment of crystal arthropathies because of its poor performance for the detection and characterization of crystals. In practice, MRI of crystal deposits can be encountered in 2 settings: first, in asymptomatic patients presenting with crystal deposits as incidental findings (see Fig. 1) and, second, in acute crystal arthropathies presenting as inflammation in unusual locations when MRI is requested for diagnostic purposes (see Figs. 5 and 10). In this setting, MR typically shows an intense inflammation in soft tissues and bones, which can be
mistaken for infectious or tumoral conditions. A correlation with radiographs, CT, and US is, therefore, essential to prove the presence of crystals in the inflamed area (see Figs. 5 and 10).36

**MRI Features of Monosodium Urate Crystal Deposits**

MRI features of gouty arthropathy are variable and nonspecific. Tophi usually present intermediate or low signal intensity on T1-weighted sequences. On T2-weighted and gadolinium-enhanced T1-weighted sequences, the signal intensity is heterogeneous (see Fig. 1).40,81 The more inflammatory the tophus is, the higher the signal on these sequences. However, areas of concomitant low signal intensity on both enhanced T1- and T2-weighed sequences, corresponding to crystal deposits and chronic fibrous reactions, are often visible even at the inflammatory stage and can be suggestive of gouty arthropathy (see Fig. 1).5,7

The presence of synovial thickening with low signal intensity on T2-weighted sequences can also be seen in pigmented villonodular synovitis; but in case of MSU deposits, there is no signal attenuation on gradient echo sequences.7,11

**MRI Features of Calcified Crystal Deposits (Calcium Pyrophosphate Dihydrate Deposition Disease, Basic Calcium Phosphate)**

The detectability of calcifications by MRI depends on multiple factors, such as their size, type and level of maturation, as well as the technical parameters that will define contrast, spatial resolution, and potential artifacts, such as magnetic susceptibility.82,83 Signal characteristics of calcifications in the musculoskeletal system are not completely understood. Because of their low proton density and short T2 value, calcifications are often hypointense on most sequences, especially larger ones. However, meniscal calcifications may appear hyperintense on some MRI sequences and be mistaken for meniscal tears.84–86 The cause of this high signal intensity is still controversial. A likely hypothesis is the presence of degenerative tissue around the calcification (Fig. 13).85,86

High T1 signal intensity calcifications have also been described in the intervertebral discs,87 although, in most cases, the high signal intensities are due to the presence of fatty bone marrow following disc ossification.88

![Fig. 13. CT (A) and MRI (B) of a 52-year-old man with tibial plateau fracture showing incidental CPPD. Fine, punctate (arrowhead) or linear (short arrows) calcifications are present in hyaline cartilage and meniscal fibrocartilage. MRI (fat-suppressed proton-density-weighted sequence) (B) shows areas of low signal intensity in cartilage corresponding to calcium deposits (long arrows in [A] and [B]). Calcifications in meniscus are usually not visible (dashed circle in [A] and [B]), but when associated with degenerative tissue changes, areas of high signal intensity can be visible (full circles in [A] and [B]).](image)
One of the key factors influencing the signal characteristics of calcification is their stage of maturation. The signal intensity of BCP deposits in tendons is usually low on all sequences during their quiescent, mature phase (see Fig. 8). Most frequent differential diagnoses for this pattern include the presence of gas related to a vacuum phenomenon, postsurgical magnetic artifact due to intraarticular metallic debris, and pigmented villonodular synovitis.

During the resolution phase of calcific tendinitis, the calcification is no longer compact and the signal intensity of neighboring inflammatory tissues becomes heterogeneous, with areas of intermediate signal on T1- and T2-weighted sequences. During this phase, extensive regional high signal intensities on T2- and fat-suppressed enhanced T1-weighted sequences, due to inflammation, usually prevail. These signal changes are located in the tendon itself and in adjacent tissues where migration of the calcification may occur and should not be mistaken for infectious or tumoral conditions (see Fig. 10).

The detectability of calcifications by MRI also depends on the background tissue. Calcifications in the knee are usually easier to detect when located in hyaline cartilage compared with menisci, which have relatively lower background signal intensity (therefore, creating less contrast with the low intensity calcifications) (see Fig. 13).

Of note, novel MRI techniques are being developed, which have the potential to allow morphologic as well as quantitative assessment of calcifications. More work is needed, however, to shorten their acquisition times for routine clinical use.

SUMMARY

Crystal deposits in and around the joints are common and most often encountered as incidental imaging findings in asymptomatic patients. However, they can also cause chronic or acute arthropathy, generating symptoms. In the chronic setting, imaging features are usually characteristic and allow the differentiation of the type of crystal arthropathy. In the acute phase and in the early stages of the crystal deposition, imaging signs are often nonspecific and the final diagnosis still relies on the analysis of synovial fluid.

Radiography is the main imaging modality for the workup of these conditions. It can confirm the diagnosis and often characterizes the type of crystal arthropathy. In recent years, US has played an increasingly important role in this setting and is a useful tool in superficially located crystal-induced arthropathies. CT nicely complements radiography for deeper sites, especially the axial skeleton. DECT is a promising tool for the characterization of crystal arthropathies, in particular gout as it permits a quantitative assessment of deposits, and may help in the follow-up of patients.

When performed in the acute stage, MRI may show severe inflammatory changes that could be misleading, and correlation to radiographs or CT should help to distinguish crystal arthropathies from infectious or tumoral conditions.

REFERENCES

45. Thiele RG, Schlesinger N. Ultrasonography shows disappearance of monosodium urate crystal deposition on hyaline cartilage after sustained normouricemia is achieved. Rheumatol Int 2010;4(30):495–503.


87. Major NM, Helms CA, Genant HK. Calcification demonstrated as high signal intensity on T1-weighted MR images of the disks of the lumbar spine. Radiology 1993;189:494–496.

