Radiology of the crystal-associated arthritides

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Introduction

Appreciation of the role and effects of crystals in arthropathy is advancing and changing rapidly. Three substances—namely, sodium biurate, calcium pyrophosphate dihydrate, and hydroxyapatite—are recognised to have acute and/or chronic radiological articular manifestations.

I will describe the pure radiological features of each of these crystal associated arthritides but it is essential to appreciate that they may occur in any combination or they may coexist with another arthropathy such as rheumatoid disease. The effect of each on the other has not been fully assessed, although a modifying influence of pyrophosphate arthritis on rheumatoid disease has been seen.¹

Gout

The principal radiological features of gout are due to the presence of tophi in or around bone. As chemotherapy is designed to prevent the formation of such tophi many patients with gout have either no abnormal appearances at radiology or entirely non-specific features. The individual radiological signs of primary and secondary gout are identical, though in secondary gout an atypical joint may be primarily affected or established features of bone erosion may be present in patients seemingly sustaining their first clinical attack.

The initial radiological description was made soon after the discovery of x-rays² and has been followed by fuller descriptions.³ In *acute gout* the metatarsophalangeal joint of the great toe is affected in 80% of cases and ill-defined soft tissue swelling may be appreciated, although less readily than on clinical examination. Calcification is absent and there are no features to permit a specific diagnosis. Osteoporosis may occur but is not

juxta-articular or periarticular in distribution as in rheumatoid disease, nor is it as extensive as that seen in regional migratory osteoporosis.

In *chronic gout* there is characteristically an asymmetrical polyarticular arthropathy predominantly affecting the metatarsophalangeal joints of the great toe (Fig. 1). Overall, the distribution of joints affected is predominantly peripheral, the feet, hands, wrists and elbows being the major sites. Sacroiliac, acromioclavicular and sternoclavicular joint disease are less common. Distribution in the hands is the inverse of that found in rheumatoid disease, with major involvement of the terminal interphalangeal joints and least of the metacarpophalangeal joints. The soft

Fig. 1 *Tophaceous gout in metatarsophalangeal joint of great toe. Note considerable soft tissue swelling and relative preservation of joint space width. Well defined erosions are present adjacent to joint. Bone density is normal.*

Fig. 2 *Gross gout of ring finger. Note extensive asymmetrical soft tissue swelling and well defined erosions. An overhanging margin sign is present (arrow).*

tissue abnormality is eccentric asymmetrical soft tissue swelling, present once tophaceous deposits have exceeded about 5 mm. Soft tissue tophi are principally present around the joints of the hands (Fig. 2), ankles, and elbows. Those at the elbow may be mistaken for rheumatoid nodules, while those at the tendoachilles insertion may mimic xanthomata. Soft tissue swelling about the dorsum of the foot and os calcis is particularly characteristic. Calcification of purely soft tissue tophi is unusual and is thought to indicate either coexisting pyrophosphate or hydroxyapatite deposition, calcium dysmetabolism, or infection. Ossification of tophi, though rare, has been reported on occasions and typically is found in the hands.³

The bony manifestations of urate depositors are typical although not diagnostic. Lesions in the soft tissues

adjacent to bone induce areas of pressure erosion with wasting or indentation of cortical outline creating sharply defined sclerotic margins (Figs. 1, 2). There is no change in overall bone density. Lesions in the periosteum or cortex produce expansile corticated, sharply defined defects typically in a periarticular position. The cortex is not usually intact over the lesion and this hook-like appearance, or overhanging margin of Martel (Fig. 2), is a well recognised feature.⁴ Lesions within the medulla are typically round or oval in the bony long axis with sharply defined sclerotic margins. Size normally varies from 1 to 3 mm, although frequently exceeds 5 mm. The sharply defined nature of the bone erosion, with, at this stage, the preservation of hyaline cartilage width, is in sharp contradistinction to rheumatoid disease. Indeed, despite substantial erosion cartilage width is preserved late into the disease. Multiple

Fig. 3 Established joint disease with subchondral collapse of subarticular cysts and secondary osteoarthritis at metacarpophalangeal joints. Note new bone formation (arrows) not present in rheumatoid disease.

Fig. 4 Typical meniscal chondrocalcinosis. Note coarse granular quality and absence of any other abnormality.

Fig. 5 Gross capsular and ligamentous chondrocalcinosis at knee calcification extends along popliteal bursa and into superior tibiofibular joint (arrows).

subarticular radiolucencies eventually coalesce and may be shown arthrographically to communicate with the joint space like rheumatoid geodes. Subsequent subchondral collapse occurs with degenerative joint disease (Fig. 3). Osteoporosis only occurs as the result of disuse. Fibrous ankylosis is relatively common, whereas bony ankylosis is reported only occasionally, predominantly in the hands, particularly between carpal bones. Incidence of chondrocalcinosis is no higher in those with gout than in a control population.

Gout is also associated with bone proliferation (Fig. 3) especially at the entheses particularly with the formation of organised calcaneal spurs and bridging syndesmosphytes in the

thoracolumbar spine. It is not clear, however, whether this is a manifestation of gout or a reflection of a broader dysmetabolism embracing obesity and diabetes mellitus. Urate crystals in urine produce non-opaque calculi with secondary obstructive uropathy.

The differential diagnosis of acute gout includes either of the other two acute crystal arthritides, septic arthritis and seronegative spondyloarthropathy. In established disease the important differential diagnosis rests with psoriatic arthritis, because of the relative preservation of bone density; the asymmetry of lesions; the presence of bone proliferation; and the predominantly peripheral involvement, particularly the terminal interphalangeal joints in

Fig. 6 *Pyrophosphate arthropathy. Gross new bone formation is most pronounced at patellofemoral joint. There are apparent loose bodies in suprapatellar pouch.*

the hands. Patchy sacroiliac involvement is reported in both arthritides. Inflammatory osteoarthritis, particularly erosive osteoarthritis, must also be considered as a differential diagnosis. The preservation of the width of joint space in the presence of well defined erosions in gout is seen also in multicentric reticulohistiocytosis and, in a single joint, of pigmented villonodular synovitis.

Calcium pyrophosphate deposition disease

Calcium pyrophosphate deposition disease (CPPD) has been recognised for nearly 20 years but there is still appreciable difficulty in its terminology. Precise methods of establishing the diagnosis are beyond

the scope of this paper, but it is essential to specify three distinct facets. Firstly, the presence of calcification radiographically—chondrocalcinosis; secondly, the occurrence of acute clinical attacks or episodes of arthritis—pseudogout; and, thirdly, the development of a destructive joint disease—pyrophosphate arthropathy. The principal radiological features of chondrocalcinosis and pyrophosphate arthropathy have been reviewed⁵⁻⁷ but the relationship between them may prove difficult both radiologically and clinically.

Radiologically, chondrocalcinosis is an age-related phenomenon with a peak incidence of about 30% in elderly institutionalised patients.⁸ The presence of chondrocalcinosis may not necessarily indicate calcium pyrophosphate dihydrate as it may be

due to calcium phosphate dihydrate, hydroxyapatite, or, occasionally, brushite. When the features of pyrophosphate arthropathy are present the correct specific diagnosis may be inferred, but if, for example, there has been total hyaline cartilage attrition chondrocalcinosis may not be seen.

CHONDROCALCINOSIS

The detection of small quantities of chondrocalcinosis requires a meticulous radiographic technique with optimal resolution.⁶ In most cases, however, careful routine radiography will suffice. Radiological examination of the knees (in the anteroposterior projection) gives a 90% detection rate for chondrocalcinosis, 98% with anteroposterior views of the knees and hips, and 100% if the wrists are also examined.⁷ Chondrocalcinosis most commonly occurs in fibrocartilage or hyaline cartilage, typically the menisci of the knee joint (Fig. 4), triangular ligaments of the wrists, and the acetabular and glenoid labrae. Less usually the annulus of the intervertebral discs and other fibrocartilaginous structures are affected. The calcification is typically coarse and granular in fibrocartilage, whereas in hyaline cartilage it is usually discrete, well defined, and linear, paralleling the underlying articular bony cortex. Calcification also occurs in the synovium, particularly at the wrists, knees, metacarpophalangeal joints and metatarsophalangeal joints and is characteristically ill defined and hazy. Gross calcification with joint disruption may present a tophaceous appearance.⁹ Calcification also occurs in the joint capsule, particularly around the elbows, knees, (Fig. 5) and metatarsophalangeal joints. Calcification at tendon insertion into bone, particularly the tendoachilles, is common and is typically linear and extensive compared with the more discrete and focal involvement seen in hydroxyapatite deposition states. Occasionally calcification may occur in bursae when an ill-defined cloud-like quality may be observed.

PYROPHOSPHATE ARTHROPATHY

The structural joint changes of pyrophosphate arthropathy most

Fig. 7 Pyrophosphate arthropathy with very extensive joint disruption, resembling a charcoal joint.

closely resemble those of osteoarthritis. There are, however, major differences. Pyrophosphate arthropathy affects more unusual sites, particularly the radiocarpal, metacarpophalangeal, trapezio-scaphoid, elbow, and the glenohumeral joints. The distribution within individual joints is also different—for example, the patellofemoral joint of the knee is predominantly affected (Fig. 6). Formation of new bone is variable and may be excessive with exuberant or massive osteophytes when compared with osteoarthritis. Large masses of trabeculated osteophytes develop (Fig. 6) and may appear separate from the underlying bone, suggesting loose bodies. Indeed, isolated fragments of cartilage are also more common, giving rise to genuine sepa-

rate intra-articular loose bodies. Unless they become substantial in size, however, these are distinguished by the absence of bony trabeculae on x-ray. Formation of osteophyte varies considerably; while in most patients considerable bone production occurs, in others it is virtually absent with merely smooth eburnated articular surfaces. The extent of this subchondral sclerosis and the associated subarticular radiolucencies is far more pronounced in pyrophosphate arthropathy than in osteoarthritis. There is also a predilection for severe destructive changes in pyrophosphate arthropathy and the likeness of these joints to neuropathic joints has been emphasised (Fig. 7).¹⁰ Though this may be observed in the hip and knee joints, proximal row col-

lapse of the carpus associated with scapholunate diastasis is typical. The severe destructive nature of the arthropathy also produces severe facet degenerative disease in the lumbar spine, often with degenerative spondylolisthesis.

Pyrophosphate arthropathy predominantly affects large joints, particularly the knees, hips, and glenohumeral joints. Severe deformity of the knee joint may cause stress fractures of the upper tibia requiring joint replacement. Indeed, careful analysis of most cases of deforming knee disease requiring total knee replacement shows undoubted features of pyrophosphate arthropathy.

Clinical and radiological correlation is, however, fraught with difficulty. There is no definite relation between clinical arthritis and the presence of chondrocalcinosis or pyrophosphate arthropathy. For example, extensive radiographic abnormality may be present in entirely asymptomatic joints. Furthermore, there is no definite relation between symptoms and the type of calcification present. Calcification may be ephemeral or never seen although crystals may be clearly demonstrated from joint aspirate. There is no definite progression from chondrocalcinosis to pyrophosphate arthropathy.

It is unclear whether pyrophosphate arthropathy and/or chondrocalcinosis are specifically related to any particular predisposing factor. Only primary hyperparathyroidism and haemochromatosis (both primary and secondary) have such a proved causal relationship.¹¹ Indeed, apart from very minor variations 'primary' pyrophosphate arthropathy often cannot be distinguished on purely radiological grounds from that associated with other diseases.¹ Subtle distinctions between primary pyrophosphate arthropathy and haemochromatosis have been emphasised in a meticulous study of hand involvement (D Resnick, paper presented at the International Skeletal Society Meeting, San Francisco, 1982). Joint space narrowing at the ring and little finger metacarpophalangeal joints and crumbling of articular surfaces but with relative preservation of the radiocarpal joint and larger hook-like osteophytes on the

Fig. 8 *Pyrophosphate arthropathy and rheumatoid disease. Note normal bone density, patchy involvement, and absence of fresh erosion. Radiocarpal joint disruption is consistent with either pyrophosphate arthropathy or old rheumatoid disease with superadded degenerative disease.*

metacarpal heads were found to be more common in haemachromatosis. Scapholunate dissociation and chondrocalcinosis of the thumb carpometacarpal joint were, however, commoner in pyrophosphate arthropathy.

There is mounting evidence that pyrophosphate arthropathy has a modifying effect on other non-crystal arthritides and in a recent series of patients with chondrocalcinosis patients with rheumatoid proved by ARA criteria had extremely modified

radiographic features.¹ This difficulty in distinguishing between rheumatoid disease and pyrophosphate arthropathy has also been noted by others.¹² In most patients with rheumatoid disease and pyrophosphate arthropathy there are only occasional erosions with the preservation of normal bone density and an asymmetry of involvement (Fig. 8). The relationship between pyrophosphate arthropathy and degenerative joint disease is ill understood, but it is clear that chondrocalcinosis occurs more often in previously traumatised joints as, for example, after meniscectomy,¹¹ and that the degree of associated pyrophosphate arthropathy in these patients is worse in those patients who have evidence of osteoarthritis elsewhere—for example, in the terminal interphalangeal joints of the hands.¹³

Calcium hydroxyapatite deposition disorders

EXTRA-ARTICULAR

The presence of foci of calcification related to the shoulder joint is well recognised and although the supraspinatus tendon (Fig. 9) is by far the commonest affected numerous other foci are now acknowledged. These include the wrists (flexor carpi ulnaris, less commonly flexor carpi radialis and extensor carpi ulnaris); adjacent to the metacarpophalangeal joints of the fingers and the metatarsophalangeal joints of the feet, especially the great toe (Fig. 10); the elbow, particularly the common flexor and extensor insertions; and at the hip joint, particularly the gluteal insertions into the greater trochanter. Recently, involvement of the longus colli with prepharyngeal soft tissue swelling has also been recognised. The bursa may be affected on occasions, and this calcification may not be seen in radiographs.

The condition is usually detected in a single joint, but when multiple joints are affected the onset is simultaneous in about one third and successive in two thirds of cases. Typically, the patient is aged between 40 and 70 and the initial radiological features are ill-defined soft tissue swelling adjacent to a joint, corresponding to the acute inflammatory episode. Calcification is almost always observed on the first

Fig. 9 Extensive hydroxyapatite periarthritis of shoulder. There is amorphous calcification extending from supraspinatus tendon into subdeltoid bursa and over humeral head (arrows). Irregularity and sclerosis of supraspinatus insertion and focal osteoporosis are present (open arrows).

examination and is initially ill defined and poorly localised. The supraspinatus is most common of the rotator cuff tendons to be affected and is best seen on a film in external rotation, whereas the infraspinatus and teres major may be seen on internal rotation posterior to the humeral head and the subscapularis anterior. When calcification is ill defined symptoms can usually be relieved by aspiration under fluoroscopic control, with injection of local anaesthetic and steroid. With

time the calcification becomes more localised, homogenous, and more dense, with a linear or circular configuration. Around the shoulder this may persist for many years and is resistant to needle aspiration. A sudden change in the clinical signs is often associated with apparent rupture and shedding of the calcification either into the shoulder joint or, more commonly, into the adjacent subdeltoid bursa from the supraspinatus tendon. If there is extensive involvement of the tendon

Fig. 10 Acute hydroxyapatite periarthritis of great toe. Note ill-defined soft tissue swelling and discrete, dense calcification adjacent to metatarsal head.

rotator cuff instability may then develop, manifested by cephalic migration of the humeral head with excavation of the inferior aspect of the acromion. Though no abnormality of bone is observed on initial presentation with chronic disease there is usually bone resorption, sclerosis, and cyst formation at rotative cuff insertions.

When multiple joints are involved both shoulders usually demonstrate the abnormality. However, there is undoubtedly an incidence of non-symptomatic calcific disease.

The calcification needs to be distinguished from other causes of soft tissue calcification in a periarticular distribution, particularly that associated with calcium dysmetabolism (especially secondary hyperparathyroidism and renal osteodystrophy) and in connective tissue disorders such as Ehlers-Danlos syndrome.

INTRA-ARTICULAR

Since Dieppe *et al.* found minute dense opacities within joints of patients with severe and destructive changes,¹⁴ hydroxyapatite has been associated with osteoarthritis,

Fig. 11 Advanced 'Milwaukee' shoulder. The acromium, coracoid process, and outer third of the clavicle are all destroyed. There is glenohumeral osteoarthritis. Calcification (arrow) is present in region of former rotator cuff.

particularly of the knee. It has also become clear that calcification of hyaline cartilage (chondrocalcinosis) may also be due to hydroxyapatite¹⁵ and be associated with a pronounced inflammatory arthropathy. Similarly, a progressive and destructive arthritis occurs at the shoulder joint, radiologically representing the severe end stage of rotator cuff instability (Fig. 11) (the 'Milwaukee shoulder').¹⁶ In this condition there is considerable synovial swelling with gross excavation and attrition of bone, particularly the acromium, the lateral end of the clavicle, the coracoid, and, latterly, the glenoid fossa. These appearances, when pronounced, are probably characteristic and entertain no serious differential diagnosis; they are usually bilaterally symmetrical. It is becoming clear that these patients also have destructive arthritis of other joints, particularly the knee (Fig. 12), and that hydroxyapatite deposition disease needs to be considered in the presence of severe Charcot-like knee and shoulder joints.

Hydroxyapatite deposition occurs both in joints and adjacent joints in mixed connective tissue disease and

scleroderma,¹⁷ though the relevance of this calcification in the pathogenesis of both arthritides is unclear. An erosive arthropathy with associated calcification should allow a specific diagnosis of mixed connective tissue disease rather than rheumatoid. In all of the hydroxyapatite deposition diseases there is evidence scintigraphically of considerable metabolic activity in the calcification site.

Conclusion

It is clear that the understanding of the crystal-associated arthritides has advanced considerably in the past decade. Many radiological features that would have been dismissed as degenerative changes or osteoarthritis are now known to be manifestations or modifications of osteoarthritis as a result of the influence of crystal deposition. Although the three principal crystal arthritides may be distinguished radiologically there is an appreciable overlap between them and there are no exclusive pathognomonic hallmarks to allow an absolute diagnosis.

Fig. 12 Left knee of same patient as Fig. 11. Extensive sclerosis and attrition of bone in lateral compartment suggests an atypical osteoarthritis. There is possibly chondrocalcinosis (arrow). Hydroxyapatite crystals were isolated from joint fluid.

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