Bone erosions in patients with chronic gouty arthropathy are associated with tophi but not bone oedema or synovitis: new insights from a 3 T MRI study

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Abstract

Objectives. Bone erosion has been linked with tophus deposition in gout but the roles of osteitis (MRI bone oedema) and synovitis remain uncertain. Our aims in this prospective 3 T MRI study were to investigate the frequency of these features in gout and determine their relation to one another.

Methods. 3 T MRI scans of the wrist were obtained in 40 gout patients. Scans were scored independently by two radiologists for bone oedema, erosions, tophi and synovitis. Dual-energy CT (DECT) scans were scored for tophi in a subgroup of 10 patients.

Results. Interreader reliability was high for erosions and tophi [intraclass correlation coefficients (ICCs) 0.77 (95% CI 0.71, 0.87) and 0.71 (95% CI 0.52, 0.83)] and moderate for bone oedema [ICC = 0.60 (95% CI 0.36, 0.77)]. Compared with DECT, MRI had a specificity of 0.98 (95% CI 0.93, 0.99) and sensitivity of 0.63 (95% CI 0.48, 0.76) for tophi. Erosions were detected in 63% of patients and were strongly associated with tophi [odds ratio (OR) = 13.0 (95% CI 1.5, 113)]. In contrast, no association was found between erosions and bone oedema. Using concordant data, bone oedema was scored at 6/548 (1%) sites in 5/40 patients (12.5%) and was very mild (median carpal score = 1, maximum = 45). In logistic regression analysis across all joints nested within individuals, tophus, but not synovitis, was independently associated with erosion [OR = 156.5 (21.2, >999.9), P < 0.0001].

Conclusion. Erosions were strongly associated with tophi but not bone oedema or synovitis. MRI bone oedema was relatively uncommon and low grade. These findings highlight the unique nature of the osteopathology of gout.

Key words: gout, MRI, bone oedema, DECT, tophi.

Introduction

Joint damage in gout is a consequence of chronic inflammation, bone erosion and deposition of monosodium urate (MSU) crystals as tophi [1]. Chronic gouty arthropathy is associated with disability and work loss, and has important social as well as health consequences for affected patients [2, 3]. The mechanisms leading to bone erosion in gout have been studied in vitro and there is evidence for enhanced osteoclastogenesis [4, 5]. Numerous osteoclast-like cells are present within and adjacent to the tophus [6] and are likely to mediate erosion [7]. In addition, increased RANK ligand (RANKL) and M-CSF could contribute to a pro-erosive cytokine milieu, while reduced viability and function of osteoblasts suggests disordered bone homeostasis [7]. There has been recent interest in the imaging of gout as three-dimensional (3D) modalities such as CT scanning, US,
MRI and dual-energy CT (DECT) offer new opportunities to improve diagnostic accuracy and guide patient management [8]. Advanced imaging techniques are also powerful tools to help elucidate disease pathways in vivo [4, 9]. Studies using high-resolution CT scanning have extended previous observations from plain radiography (XR) in gout, demonstrating that XR frequently underestimates the burden of erosions and tophi [10]. A CT study by Dalbeth et al. [11] showed that 82% of erosions were associated with adjacent tophi, implicating tophus infiltration as a dominant mechanism leading to erosion. DECT imaging is another new modality that can accurately detect MSU crystals present within tophi [12]. DECT images are acquired using two X-ray tubes with different voltages that are aligned at 90° to one another. It allows uric acid to be very specifically identified (on the basis of its atomic number) and differentiated from calcium in bone and soft tissues [12]. DECT has been shown to be highly sensitive and specific for identification of urate deposits when compared with the gold standard of positive joint aspirates [13, 14].

Although powerful for identification of bone erosion and tophi, radiographic techniques including CT and DECT cannot reveal inflammation within soft tissues or bone. In contrast, MRI can capture all the major components of gout pathology, including inflammation, damage and tophi [1], and may have applications in gout diagnosis and monitoring responses to urate-lowering therapy (ULT) [15]. As a 3D modality, MRI can access all relevant anatomical regions, including complex areas such as the ankle/foot as well as the wrist/hand, that are not fully accessible to other modalities such as US [4]. Bone oedema is a specific MRI appearance that occurs in many settings and indicates pathology affecting bone beneath the joint [16]. Bone oedema is an important imaging feature of RA, where it occurs in up to 60% of patients and represents osteitis as revealed by comparative imaging/histopathological studies [17, 18]. Bone oedema in RA is frequently associated with neighbouring erosions [19] and has adverse prognostic implications. Patients with active osteitis are at increased risk of developing erosive joint damage [20, 21] and long-term disability [22]. Bone oedema also occurs in the spondyloarthropathies, both peripherally and axially [23], and when identified at the sacroiliac joints it is a forerunner of erosions [24]. Bone oedema has been identified in gout in case reports [25–27] and a recent retrospective series from our institution examined its prevalence in patients with severe tophaceous gout over a 10 year period [28]. It was relatively rare and mild, occurring in a severe form in only 8% of those with uncomplicated gout compared with 93% where gout was complicated by osteomyelitis [28]. However, a recent short report comparing MRI scans of the hand/wrist in RA and gout suggested that bone oedema was equally common in both conditions [29].

The aims of the present study were to use MRI scans to explore associations between bone erosion, bone oedema, synovitis and tophi in gout with a view to clarifying the processes underlying bone erosion and joint damage. We used high-field 3 T MRI scanning to provide optimal images and prospectively studied patients of Polynesian ethnicity who frequently exhibit florid gout pathology [30]. In a subgroup we compared 3 T MRI with DECT scanning for tophus detection.

Patients and methods

Patient recruitment and clinical assessments

Forty patients with gout were recruited to the study from rheumatology outpatient clinics within the Auckland region. This study was approved by the Northern X Regional Ethics Committee and all participants provided written informed consent according to the Declaration of Helsinki. Inclusion criteria were a history of gout based on the ACR diagnostic criteria [31] and willingness to undergo imaging investigations. Acute gout was not a specific criterion for inclusion and patients were scanned during the intercritical phase. Clinical assessments at enrolment included disease duration, co-morbidities, medications, Health Assessment Questionnaire Disability Index (HAQ-DI) score [32], 36-item Short Form Health Survey (SF-36) [33], flare frequency and pain score. Examination included swollen and tender joint counts and subcutaneous tophus counts. Laboratory investigations included measurements of serum urate, creatinine and CRP.

Imaging—MRI scans

MRI scans of the dominant wrist were performed according to the following protocol: scans were obtained on a 3 T scanner [Philips Achieva 3 T, Philips Electronics (Healthcare), The Netherlands]. An eight-element sensitivity-encoded (SENSE) phased array coil (receive) was used. The dominant hand was fitted snugly by the patient’s side in a wrist coil, palm facing the body, thumb anteriorly. The field of view extended from the distal radioulnar joint to the metacarpal bases (dimensions 86.4 mm × 86.4 mm). MRI operational parameters were as cited [34], including a median slice thickness of 2.1 mm and matrix 400 × 307. Images were reconstructed in 3D for viewing at a matrix of 1024. The following turbo spin echo sequences were used: T1-weighted and T2-weighted sequences with fat suppression (FS) using Spectral Adiabatic Inversion Recovery (SPAIR) in the axial and coronal planes and proton density (PD) coronals including an ultra-high-resolution sequence. T1-weighted FS axial and coronal sequences were obtained after i.v. gadolinium diethylenetriamine pentaacetic acid given at a standard dosage of 10 ml [Omniscan (Gadodiamide); 5.0 mmol/10 ml or 2.87 g/10 ml; GE Healthcare, Princeton, NJ, USA].

Imaging—DECT scans

DECT scans of the dominant wrist were performed in a subgroup of 10 patients on a dual X-ray tube 128-detector-row scanner (Somatom Definition Flash, Siemens Medical, Erlangen, Germany). Patients were selected from those with tophaceous disease who were willing to return for reimaging. Patients were positioned prone with arm outstretched. Helical axial scans from the mid-metacarpal region to the distal radius and ulna were

10 ml or 2.87 g/10 ml; GE Healthcare, Princeton, NJ, USA].
acquired. Scanning time was 26.9 s. Scans were performed with the same image protocol, with acquisition at 40 mm × 0.6 mm and a pitch of 0.7. X-ray tube A was operated at 80 kV/260 mA and tube B was operated at 140 kV/130 mA. The images were reconstructed on a bone algorithm, 512 matrix, to 0.75 mm slices with a 0.5 mm increment. Additional reconstructions were done on a soft tissue algorithm, 512 matrix, also to 0.75 mm slice with a 0.5 mm increment. Reconstructions used the parameter ratio of 1.55 (Siemens software gout algorithm). Images were viewed as 0.75 mm slices and reconstructed 3 mm slices on a picture archiving and communications system. DECT scans were performed a median of 7 months after the MRI scans (range 4–18 months).

MRI scoring

Scoring of MRI scans was performed by two radiologists experienced in musculoskeletal imaging (A.D. and Q.R.). Scans were scored for bone erosions and bone oedema at 15 sites within the wrist, including the individual carpal bones as well as the metacarpal bases (1–5), as described for the Rheumatoid Arthritis MRI Scoring (RAMRIS) system [35]. Tophi were defined as discrete areas of altered signal that may be adjacent to bone, tendon or soft tissue with homogeneous low-signal intensity on T1-weighted images and heterogeneous signal intensity on T2-weighted images. Different morphological patterns and variable contrast enhancement were recognized as described [36]. Scoring for synovitis used the same sites at the wrist (including the distal radioulnar joint, radiocarpal joint and intercarpal-carpometacarpal joints) as outlined in the European League Against Rheumatism (EULAR)-OMERACT atlas [37]. All MRI scores were obtained independently and without review of clinical or XR data. Intraobserver reliability for MRI scoring was obtained for one reader (A.D.) who reviewed 10 scans, 12 months after the first scoring, without access to previous scores.

DECT scoring

This was performed by a rheumatologist (N.D.) with experience in scoring DECT scans [12]. Urate deposits were scored as either present or absent at the same sites assessed for MRI bone erosion and bone oedema. The rheumatologist scoring the DECT scans was blinded to the clinical characteristics of the patients and the MRI scores.

Statistical analysis

Interobserver reliability (two readers, Q.R. and A.D.) for each feature was assessed using intraclass correlation coefficients (ICCs). Concordance for the presence/absence of erosions and tophi was calculated and reliability presented as the kappa coefficient. Intraobserver (A.D.) reliability was calculated in a subset of 10 randomly selected patients. Scores from each reader were averaged and analysed as ordinal variables using a multinomial model. Since joints were nested within patients, a generalized estimating equations (GEE) approach was employed to adjust for the correlation of scores within a patient. The odds of tophi being present at the same bone sites as erosion, or tophi/erosions being adjacent to regions of synovitis, were modelled using GEE. Logistic regression analysis was used to determine whether synovitis and tophus were independently associated with erosion. Analyses were performed using SAS (version 9.2; SAS Institute, Cary, NC, USA) and results are presented with 95% CIs or as median (range) as appropriate. Tests were two-tailed and P < 0.05 was considered significant.

Results

Patient demographics are shown in Table 1. The group had a range of disease severity (50% of patients had tophi detected on examination). Most were male (97%) and with a median age of 56 years. Many patients were of Pacific or Maori ethnicity (70%). Patients were receiving medications (Table 1), including ULT [allopurinol 90%, uricosurics (probenecid and benzbromarone) 22.5%]. The median serum urate was 0.39 mmol/l (0.20–0.69). A subgroup of 10 patients who were similar to the main group had DECT imaging at the same wrist (Table 1).

MRI scoring reliability

Reliability was high between MRI readers for scoring bone erosion and tophus size [ICCs 0.77 (95% CI 0.71, 0.87) and 0.71 (95% CI 0.52, 0.83), respectively] and was moderate for assessment of synovitis and bone oedema [ICCs 0.62 (95% CI 0.34, 0.80) and 0.60 (95% CI 0.36, 0.77), respectively]. Reader 1 (A.D.) scored 10 scans again, 1 year after the first score, and intraobserver reliability was very high: bone erosion ICC 0.95 (95% CI 0.83, 0.99), bone oedema 0.92 (95% CI 0.74, 0.98), synovitis 0.97 (95% CI 0.9, 0.99), tophus size 0.97 (95% CI 0.90, 0.99). Concordance between readers for erosions was 82%, for all tophi was 85% and for tophi >5 mm was 93%. These results are summarized in Table 2.

MRI validated against DECT scanning for tophus detection

Further validation against DECT was performed in a subgroup of 10 patients. Compared with DECT, two-reader MRI (readers concordant) had a specificity of 0.98 (95% CI 0.93, 0.99), sensitivity of 0.63 (95% CI 0.48, 0.76), positive predictive value (PPV) of 94% and negative predictive value (NPV) of 84% for detecting tophi [k = 0.66 (95% CI 0.53, 0.79)]. One-reader MRI (A.D.) vs DECT had a specificity of 0.92 (95% CI 0.85, 0.96), sensitivity 0.69 (95% CI 0.54, 0.581), PPV of 81% and NPV of 85% for detecting tophi [k = 0.63 (95% CI 0.50, 0.76)]. Fig. 1 shows a composite image, revealing a large tophus over the dorsal radioscaphoid joint and another tophus extending into the soft tissues ventrally at the wrist, clearly delineated on MRI and also registering signal on DECT scans.

MRI bone oedema is mild in gout and not associated with erosion or tophus

Bone oedema was scored as positive by one radiologist in 30% of this cohort and by the other in 55%. However,
Scores were frequently very low and in 52/600 sites there was discordance between radiologists, where one scored the site as a minimum 1 and the other scored the site as 0. For this reason, data were reanalysed to include only bone oedema scores where radiologists were concordant.

Bone oedema was scored at 6/548 (1%) of concordant sites in 5/40 patients (12.5%) and was very mild (median score = 1, maximum possible = 45). In the only patient with significant bone oedema (score 7.5), there was rupture of the triangular fibrocartilage complex (TFCC) and ulno-lunate impaction, probably contributing to bone oedema within the lunate. On a site-by-site analysis using the full data set of 600 sites, no association was found between bone oedema and erosions or tophi. In comparison, MRI synovitis, tophi and bone erosion were common: 65% of patients exhibited bone erosions, 28% tophi (25% had tophi >5 mm) and 64% synovitis. Summary scores for these MRI features of gout are shown in Table 3. Fig. 2 shows MRI scans revealing extensive carpal erosions but no bone oedema in a typical patient.

MRI bone erosions are associated with tophi

Site-by-site analysis revealed that MRI bone erosions were strongly associated with tophi with an odds ratio (OR) of 13.0 (95% CI 1.5, 113) when sites were treated as independent and 2.9 (95% CI 1.6, 4.2) when the patient effect was factored in. In some situations tophi overlapped several sites, so we also assessed the association between erosion and tophus according to joint region. This revealed extremely strong associations, with ORs ranging from 61.8 (95% CI 7.4, 516.9) (P < 0.0001) at the distal radius/ulna to 2128.0 (P < 0.0001) at the proximal carpal row. Fig. 3 shows

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**Table 1** Demographics, medications and disease activity for gout patients

<table>
<thead>
<tr>
<th>Clinical features</th>
<th>Total group (n = 40)</th>
<th>DECT group (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (range), years</td>
<td>55.5 (29–70)</td>
<td>61 (42–69)</td>
</tr>
<tr>
<td>Gout duration, median (range), years</td>
<td>17 (1.25–42)</td>
<td>19 (10–39)</td>
</tr>
<tr>
<td>Male:female</td>
<td>39:1</td>
<td>9:1</td>
</tr>
<tr>
<td>Aspirate positive for MSU crystals</td>
<td>19 (48)</td>
<td>4 (40)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>11 (28)</td>
<td>2 (20)</td>
</tr>
<tr>
<td>Maori or Pacifica</td>
<td>28 (70)</td>
<td>7 (70)</td>
</tr>
<tr>
<td>Filipino</td>
<td>1 (3)</td>
<td>1 (10)</td>
</tr>
<tr>
<td>Gout medications (dose range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allopurinol (100–600 mg/day)</td>
<td>36 (90)</td>
<td>9 (90)</td>
</tr>
<tr>
<td>Colchicine (0.5–1.0 mg/day)</td>
<td>24 (60)</td>
<td>8 (80)</td>
</tr>
<tr>
<td>Probenecid (500 mg–2 g/day)</td>
<td>5 (13)</td>
<td>2 (20)</td>
</tr>
<tr>
<td>Benzbromarone (100–150 mg/day)</td>
<td>4 (10)</td>
<td>2 (20)</td>
</tr>
<tr>
<td>NSAIDs</td>
<td>16 (40)</td>
<td>2 (20)</td>
</tr>
<tr>
<td>Prednisone (6–40 mg/day)</td>
<td>2 (5)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Disease activitya, median (range)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tender joints (68)</td>
<td>1 (0–63)</td>
<td>4.5 (0–63)</td>
</tr>
<tr>
<td>Swollen joints (66)</td>
<td>0 (0–9)</td>
<td>1.5 (0–6)</td>
</tr>
<tr>
<td>Pain score, VAS 100 mm</td>
<td>20 (0–74)</td>
<td>9 (0–63)</td>
</tr>
<tr>
<td>Tophus count</td>
<td>3.0 (0–64)</td>
<td>10 (2–64)</td>
</tr>
<tr>
<td>Frequency of flares (past 12 months)</td>
<td>8 (0–52)</td>
<td>7 (1–52)</td>
</tr>
<tr>
<td>Urate, mmol/l</td>
<td>0.39 (0.2–0.69)</td>
<td>0.38 (0.24–0.59)</td>
</tr>
<tr>
<td>Creatinine, mmol/l (normal range = 60–105)c</td>
<td>90 (63–219)</td>
<td>88 (63–165)</td>
</tr>
<tr>
<td>CRP, mg/l (normal range = 0–4 mg/l)</td>
<td>2.4 (0.5–22)</td>
<td>1.5 (0.5–5.9)</td>
</tr>
<tr>
<td>HAQ-DI</td>
<td>0.32 (0.2–2.25)</td>
<td>0.50 (0.2–2.25)</td>
</tr>
<tr>
<td>SF-36 physical functioning scale</td>
<td>75 (0–100)</td>
<td>55 (0–95)</td>
</tr>
</tbody>
</table>

Results are n (%) unless stated otherwise. aNZ Maori (7), Pacific = Samoan (15), Tongan (4), Cook Island Maori (6), Nueean (2), Tokelauan (2). bPatients were scanned during the intercritical phase. c37.5% with impaired renal function. VAS: visual analogue scale.

**Table 2** Reader reliability for scoring MRI scans in gout (n = 40)a

<table>
<thead>
<tr>
<th></th>
<th>ICC (95% CI)</th>
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<tbody>
<tr>
<td>Interreader reliability</td>
<td></td>
</tr>
<tr>
<td>Bone erosion</td>
<td>0.77 (0.71, 0.87)</td>
</tr>
<tr>
<td>Tophus size</td>
<td>0.71 (0.52, 0.83)</td>
</tr>
<tr>
<td>Bone oedema</td>
<td>0.60 (0.36, 0.77)</td>
</tr>
<tr>
<td>Synovitis</td>
<td>0.62 (0.34–0.80)</td>
</tr>
<tr>
<td>Intrareader reliability</td>
<td></td>
</tr>
<tr>
<td>Bone erosion</td>
<td>0.95 (0.83, 0.99)</td>
</tr>
<tr>
<td>Tophus size</td>
<td>0.97 (0.90, 0.99)</td>
</tr>
<tr>
<td>Bone oedema</td>
<td>0.92 (0.74, 0.98)</td>
</tr>
<tr>
<td>Synovitis</td>
<td>0.97 (0.90, 0.99)</td>
</tr>
</tbody>
</table>

aInterreader reliability for MRI scores (n = 40) and intrareader reliability for MRI scores (n = 10).
typical examples of tophi adjacent to bone erosions in gout, revealing low signal on T1-weighted images and enhancement post-contrast.

Relationship between tophi, synovitis and erosions
We investigated whether there was an association between tophi and synovitis in gout. As tophi sometimes overlapped two bone sites, they were classed into three groups: group A sites within the distal radius or ulna, group B sites within the proximal carpal row and group C sites within or adjacent to the distal carpal row/metacarpal bases. These were examined for associations with synovitis at the distal radioulnar joint or radiocarpal joint, the intercarpal joints and the carpometacarpal joints, respectively. This analysis revealed associations that were significant for group A [OR 3.9 (95% CI 1.2, 12.9), \( P = 0.020 \)] and group B sites [OR 2.3 (95% CI 1.3, 4.2), \( P < 0.0001 \)] and a trend towards significance for group C sites [OR 2.9 (95% CI 0.8, 10.0), \( P = 0.088 \)]. We also investigated for an association between bone erosions and synovitis. At those bone sites with erosion, there was adjacent synovitis in 34% of cases and not in 66.1%, however, if there was no erosion, there was adjacent synovitis in 14.2% of cases and not in 85.8% of cases, giving an OR for the association between erosion and synovitis of 3.1 (95% CI 1.8, 5.2) \( P < 0.0001 \). In logistic regression analysis across all joints nested within individuals, tophus but not synovitis was independently associated with the

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**Fig. 1** Tophi are easily visualized on MRI scans and coincide with DECT deposits.

(A) Coronal T1-weighted MRI scan revealing extensive tophi dorsally at the radioscaphoid joint (circle). (B) Volume-rendered DECT scan shows same tophus (circle). (C) Axial T1-weighted MRI—tophus extends ventrally (arrow). (D) Axial DECT image shows same tophus (arrow) at the level of the scaphoid. (E) Adjacent to the radius.

**TABLE 3** Total scores and percentage of patients affected for MRI features of gout at 15 sites at the wrist in 40 patients

| MRI feature (possible range) | Total carpal score | Patients affected | | |
|-----------------------------|--------------------|------------------|---|---|---|
| Bone erosion (0–150)        | Reader 1 | Reader 2 | Reader 1, % | Reader 2, % | 2-reader MRI, % |
| Bone oedema (0–45)          | 6.2     | 3.8     | 77          | 68          | 65          |
| Synovitis\(^a\) (0–45)      | 3.1     | 5.6     | 61          | 89          | 64          |
| Tophus diameter, mm         | 11.4    | 15.2    | 33          | 43          | 28          |

\(^a\)\(\text{n=28}\) (only assessed in those receiving i.v. contrast; this was contraindicated in some patients because of renal impairment). \(^b\)Concordant sites only.
The presence of erosion; odds of erosion with synovitis 1.7 (95% CI 0.9, 3.4) (P = 0.10) and after adjustment for tophus presence 156.5 (95% CI 21.2, >999.9) (P < 0.0001).

**Discussion**

This is the first comprehensive, prospective, 3 T MRI study of patients with chronic gouty arthropathy. The aims were to characterize the MRI features of gout and explore underlying mechanisms leading to bone erosion by looking for associations between bone oedema, erosions, tophi and synovitis [28, 29]. We also assessed the diagnostic accuracy of MRI for detecting tophi using DECT as a gold standard. Most gout studies have imaged the feet or large joints such as the knees, but we have experience with MRI at the wrist in other inflammatory arthropathies [34] and used a similar protocol, employing sequences that provide excellent image quality.
and clarity. Another advantage is that the carpal joints are not weight-bearing and there may be less contamination from concomitant osteoarthritic change, although this is likely to occur in some sites, such as the first carpometacarpal joint, and may be associated with bone oedema on MRI [38]. We enrolled patients with chronic and frequently tophaceous gout so that we could examine all features of gouty arthropathy using MRI scanning. We recognize that this group presents a severe clinical phenotype and that our findings relate only to the intercritical phase and not to the acute gout attack. Polynesian and Maori men in their fifth or sixth decade have an extremely high prevalence of the acute gout attack. However, it is interesting that a large number of patients (64%) did show evidence of synovitis on their scans, suggesting low-grade chronic inflammation was present.

We then looked for associations between bone oedema and erosion in gout. In RA, bone oedema has been shown to represent a lymphoplasmacytic infiltrate [44] that is strongly linked to later bone erosion in a site-specific manner [20]. We found no evidence for such a link in these patients with gout, suggesting that the bone oedema lesion may have a different pathological basis.

Little information is available regarding bone histology in gout because of the difficulty in obtaining tissue and there are no comparative MRI/histology studies. It seems likely that mechanical derangement of the wrist joint with, for example, rupture of the TFCC or ulnocarpal abutment could contribute to bone oedema at the lunate or distal ulna, and an arthroscopic study has suggested that TFCC rupture is very common in gout [45]. Therefore the osteopathology of bone oedema in gout remains to be determined but seems more likely to resemble that of OA than RA [46]. Although the usual assumption is that bone oedema can only be detected using MRI scanning, Pache et al. [47] recently described a technique whereby calcium can be virtually subtracted from DECT images, allowing abnormal soft tissue-like attenuation in the bone marrow to be detected. A comparison with MRI in a group of patients with post-traumatic bone oedema at the knee (bone bruises) revealed that this virtual non-calcium DECT technique had a sensitivity of 86% and a specificity of 95% for detecting bone oedema. It would be of great interest to apply this technique to patients with inflammatory arthritis, including gout and RA, and studies are awaited.

We have also confirmed the relationship between tophi and erosions using MRI. We previously investigated this using CT scanning [11] and found that 95% of CT erosions >5 mm were associated with tophi [11]. The mechanism of this association has been explored in vitro using peripheral blood mononuclear cells (PBMCs) from patients with severe erosive gout and is likely to involve enhanced osteoclastogenesis [5]. The current MRI study confirms and extends these observations. Again we have found erosions to be strongly associated with tophi, especially with larger tophi, probably indicating that very small lesions can be false positives. The association was strong, but with wide CIs when all sites were considered independently (OR=13), and remained significant (OR=2.9) when the patient effect was factored in. We also examined joint regions instead of individual bone sites and found the association to be extremely strong for this analysis, which allowed for situations where large tophi overlapped several carpal bones.

MRI synovitis was common in this group of gout patients who were not specifically scanned at the time of an acute attack, and was detected in 64%. Thus the results are not directly comparable with those of Cimmino et al. [29], who identified wrist synovitis in 8/8 patients with acute gout. We investigated associations between tophi and synovitis and found the presence of a tophus within
the distal radius or ulna to be four times more likely to be associated with synovitis in the same region than not. This gives new insight into links between urate deposition and joint inflammation in gout and emphasizes the ability of MRI scanning to explore the interplay between these different aspects of pathology. We also investigated associations between synovitis and erosion and found that bone sites affected by erosion were three times more likely to lie adjacent to regions of synovitis than not, but when tophi were taken into account this effect lost significance. Taken together, these results suggest that the erosive process in gout is determined predominantly by tophus deposition, but due to limited numbers of patients who received contrast and in whom assessment of synovitis was possible, further longitudinal studies are required to explore the influence of synovitis.

To summarize, new data from this prospective MRI study indicate that bone oedema is low grade in gout during the intercritical phase and not associated with erosion, confirming the findings of a previous retrospective 10-year observational study and emphasizing the differences in bone pathology between gout and RA [28]. Tophus, but not synovitis, was independently associated with erosion, shedding further light on the links between inflammation, crystal deposition and joint damage in this condition. The specificity of 3 T MRI for the detection of tophi approximates that of DECT scanning, suggesting a possible role in gout diagnosis.

**Rheumatology key messages**

- MRI scanning confirms that erosions are strongly associated with tophi in gout.
- MRI bone oedema is relatively mild and uncommon in gout and not associated with bone erosions.
- Synovitis is common in chronic gout but has no association with erosion independent of tophi.

**Acknowledgements**

The authors gratefully acknowledge the assistance of the technicians and nurses at Specialist Radiology and MRI, Greenlane, at the Department of Radiology, Starship Children’s Hospital and the Department of Radiology, Greenlane Clinical Centre for their assistance in performing MRI scans, DECT scans and X-rays in these patients. The authors also wish to thank the patients themselves and their referring rheumatologists from the greater Auckland area.

**Funding:** Funding for this study was provided by the Auckland Medical Research Foundation, which is a charitable body providing funds for medical research in the Auckland area of New Zealand. All other authors have declared no conflicts of interest.

**References**

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