Dual-Energy Computed Tomography for the Evaluation of Gout and Calcium Crystal Deposits

MAYO CLINIC

Black DF[1], Glazebrook K[1], Bongartz T[2], Matteson EL[2], Manek NJ[2], Leng S[1], Fletcher JG1, McCollough C[1]

CT Clinical Innovation Center, Department of Radiology[1] and Division of Rheumatology[2], Mayo Clinic, Rochester, MN

Objectives

1. To describe the use of dual-energy (DE) CT scanning of the extremities for the demonstration of uric acid and calcium crystal deposition.
2. To describe the clinical application of this technique and its benefit to patients with atypical inflammatory arthropathies.
3. To show case examples of patients imaged with this technique.

Background

- Demonstration of uric acid crystals within joint fluid remains the gold standard for the diagnosis of gout.
- At times clinicians base the diagnosis on secondary criteria like hyperuricemia, response to colchicine, or a typical natural history.
- Diagnostic accuracy may be limited, as invasive techniques like synovial fluid aspiration may not reveal uric acid crystals in the acute setting and laboratory accuracy has been shown to vary [1].
- Up to 42% of patients with gout have normal serum uric acid levels. Bony alterations occur only years into the illness and even then only 45% of patients have radiographic findings [2,3].
- Hyperuricemia may also be present in patients without gout.
- Thus, non-invasive techniques to accurately diagnose uric acid crystals within joints are needed to identify gout in patients with atypical inflammatory arthropathies and rule out gout as a diagnostic possibility in others.

Early diagnosis is important

- Early and intensive therapy with urate-lowering medications can play a major role in preventing eventual functional impairment [4].
- Utilization of imaging studies in order to accurately diagnose, monitor progression or treatment response, and assess clinical outcomes is increasing rapidly [5].

Evolution of imaging for gout

- Historically, radiographs have been the mainstay of imaging, but only demonstrate chronic (irreversible) changes.
- More recently, CT, MRI, and ultrasound techniques have been applied, primarily to assess severity and change over time, or as outcome measures in randomized clinical trials.
- CT is the best modality to demonstrate bony change, while MRI excels at depicting soft tissue (synovial) inflammation.
- While ultrasound does not expose the patient to radiation, is less expensive, and more useful for procedures, it has a small field of view, is operator dependent, and cannot always reliably differentiate gout from other inflammatory arthropathies.

Protocol

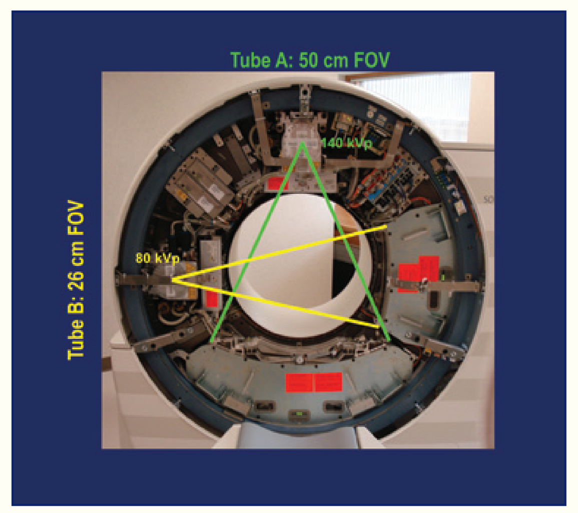
- 55 DECT scans were performed on 54 patients who were either clinically diagnosed with or suspected of having gout.
- This study was IRB approved.
- MSK subspecialist radiologists interpreted each CT.

Dual Energy CT

Principles

- The degree of attenuation of incident x-rays depends on the atomic number "Z" of the material and the energy spectrum to which its exposed.
- By measuring the difference in attenuation using two different energy spectra, the composition of a material can be determined [6].
- By exploiting the x-ray energy dependent attenuation of different materials, DECT has been shown to accurately differentiate uric acid kidney stones from stones of various other materials such as calcium oxalate, cysteine, or struvite [7,8].
- A Siemens SOMATOM Definition dual source CT scanner was used to acquire images on all patients.
- This scanner has two orthogonally positioned X-ray tube/detector array pairs.
- Data acquired simultaneously with two different beam energies allows dual energy material decomposition analysis.

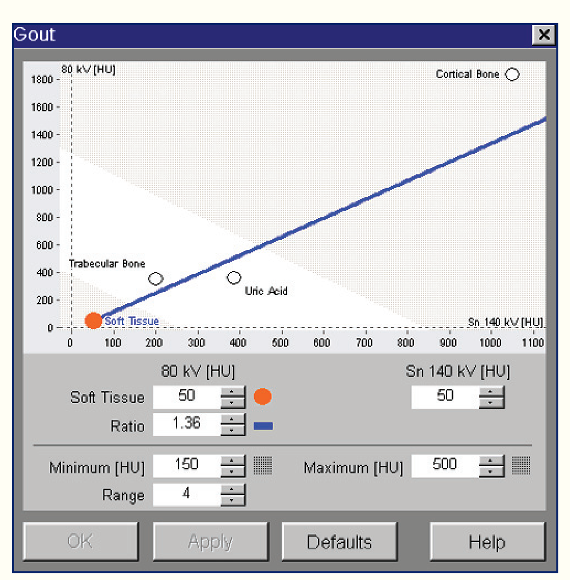
Dual Source CT Scanner with DECT capabilities



- A different kV was selected for each x-ray tube (80 and 140 kV) to exploit the kV-dependent nature of CT attenuation.

Imaging Processing

- Commercially available dual-energy CT analysis software was used to classify a voxel as either tissue, uric acid, or calcium/bone.

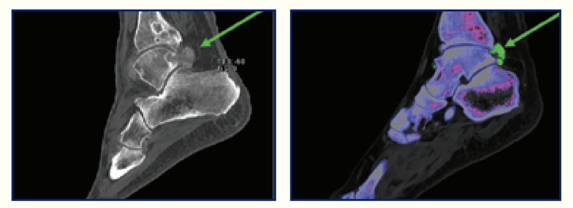


- Uric acid crystals were color coded as green, calcium as purple, and soft tissue was not colored.
- The volume of uric acid crystal was measured using commercial software.
- Thus far, only two other studies of DECT use in gout have been reported [9,10].

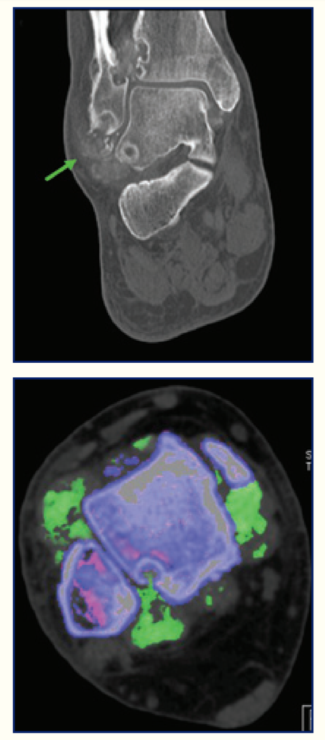
Patient Examples

Positive Case - #1

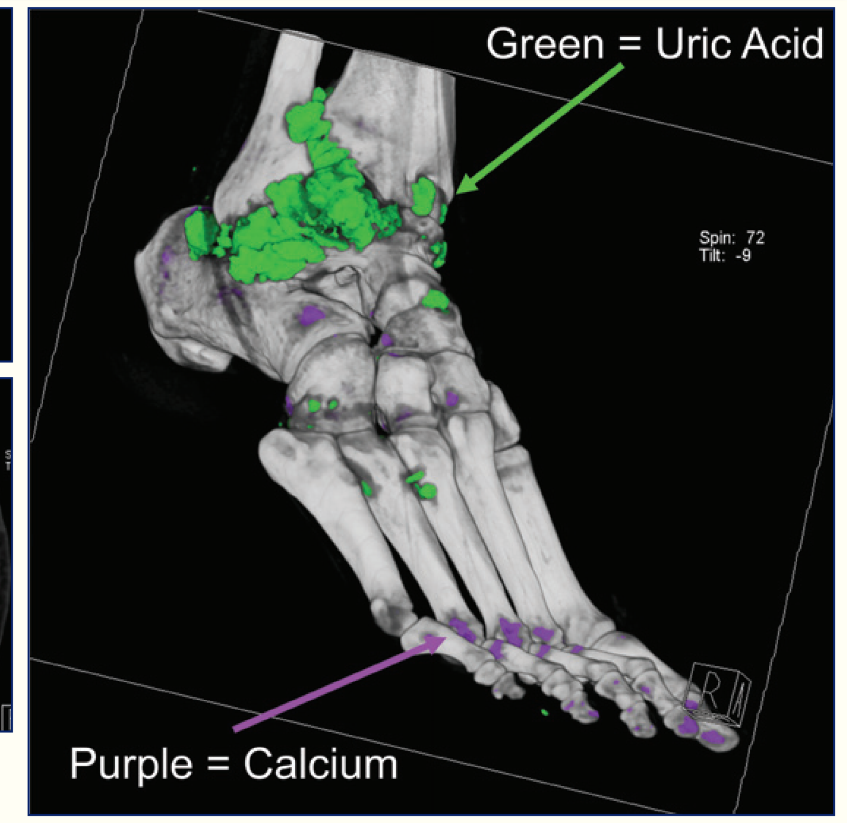
Lateral radiograph of the right ankle shows well corticated large erosions of the distal tibia and lateral malleolus with high density effusion or synovitis in the right ankle.



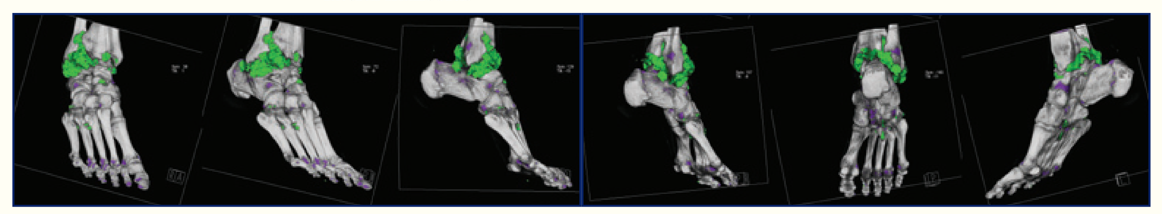
2D sagittal images without and with decomposition algorithm. High density material in soft tissues within and surrounding joints consistent with tophaceous deposits.



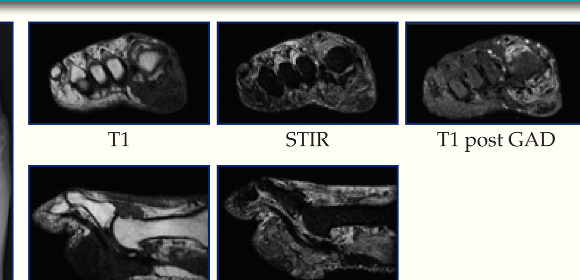
Top images: Coronal CT scan at the level of the ankle joint shows high density soft tissue mass within the ankle joint, extending into the well corticated erosions within the talus, distal tibia and lateral malleolus



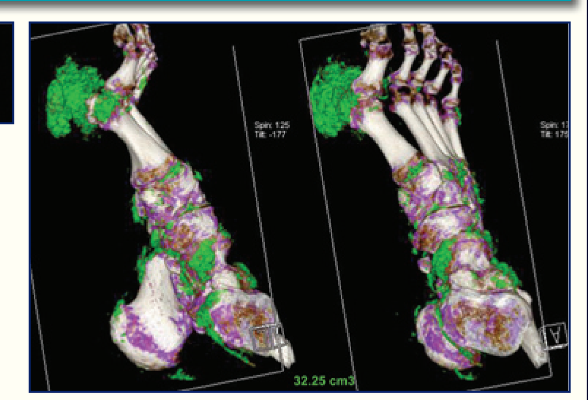
3D reconstruction clearly conveys uric acid quantity and distribution.



Positive Case - #2



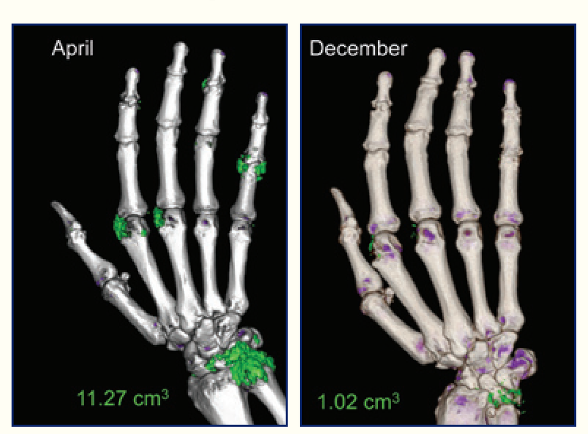
T1 STIR T1 post GAD



- One patient had been told at an outside institution that he would need a forefoot amputation for "some type of tumor" in his plantar soft tissues.
- DECT demonstrated this "tumor" was simply tophaceous gout.

Positive Case - #3

- Only one subject had repeat DECT scans, eight months apart, which demonstrated a dramatic reduction in uric acid burden. This corresponded with clinical improvement after treatment initiation.

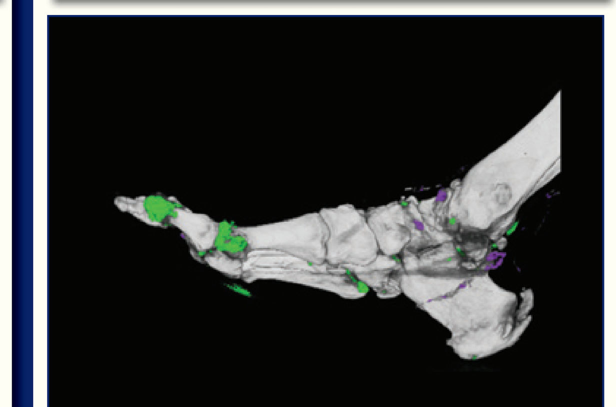


Images acquired eight months after receiving multiples infusions of rasburicase demonstrate a 90% reduction in uric acid volume (11.27 → 1.02 cm³), providing a quantitative measure of treatment response.

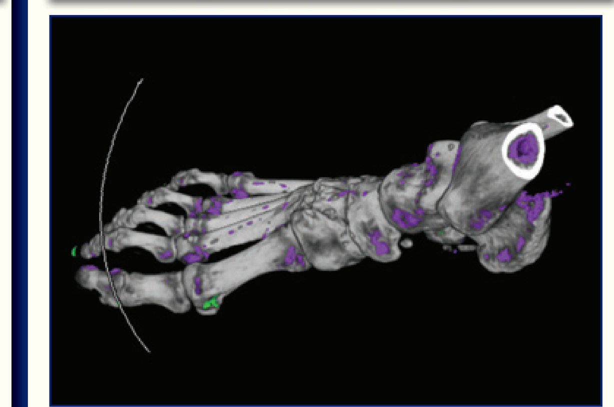
Positive Case - #4

- Uric acid deposition about multiple joints and tendons, depicted in green. The accompanying CT without post-processing (left image) demonstrates erosion with overhanging edges.
- Plain film (left) and 3D DECT image depicting typical changes of gout, with green uric acid demonstrated within the tendons on the DECT image.

Positive Case - #5

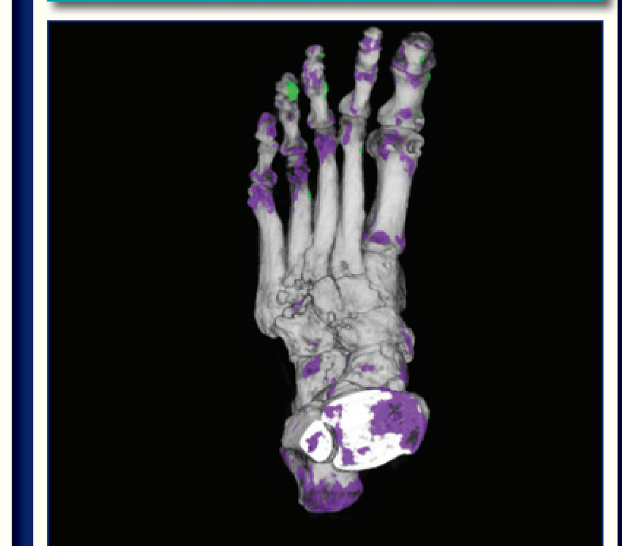


Positive Case - #6

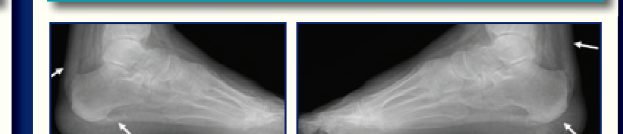


Positive Case - #7

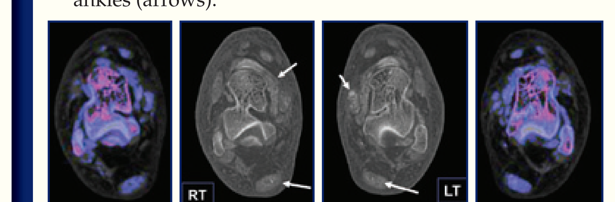
Positive Case - #8



Negative Case - #9

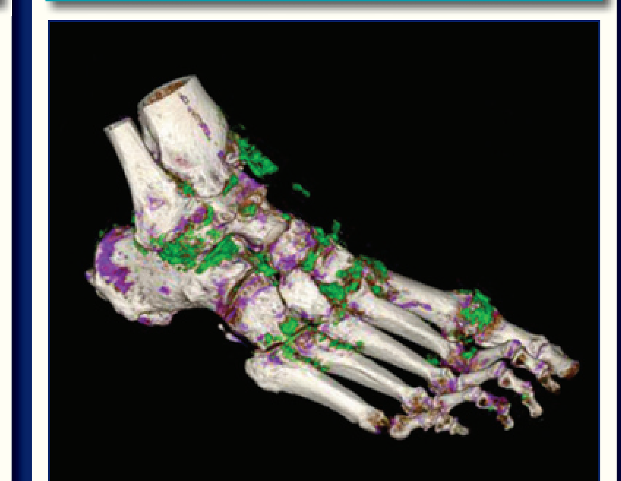


38 y. o. patient with chronic renal failure. Extensive calcification within soft tissue and tendons about both ankles (arrows).



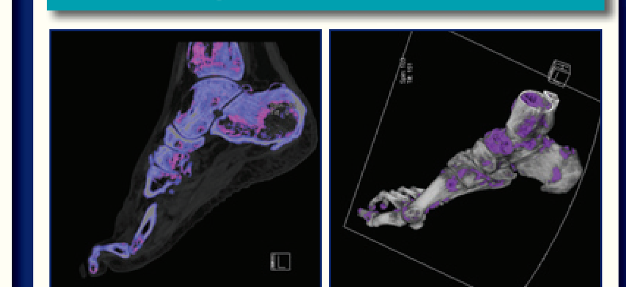
Extensive high density material bilaterally in the tendons and soft tissues (arrows). No evidence of uric acid deposition on DECT which correlated with the clinical impression of CPPD and calcification due to chronic renal failure.

Positive Case - #10



Scattered periarticular uric acid deposition within the tendons.

Negative Case - #11



Degenerative arthritis between the medial and middle cuneiform bones. Diffuse subcutaneous edema. No uric acid deposition.

Negative Case - #12

Erosive changes involving the distal radius, ulna, and carpal bones without evidence of uric acid deposition. Final clinical diagnosis was rheumatoid arthritis.

Positive Case - #13

A negative plain film and only subtle uric acid deposition seen on DECT in a patient with less severe symptoms.

DECT Artifacts

Occasionally, dense skin such as calluses are mistakenly characterized as gout. These artifacts occur at the skin surface. Green voxels located in unusual places can be identified using a surface rendered image to show the skin's surface.

Results

- 26/54 subjects had DECT positive for uric acid deposition.
- Compared with final clinical diagnosis:
  - No False Positives
  - No False Negatives

Conclusions

- DECT scanning provides a noninvasive means of:
  - Diagnosing gout by demonstrating uric acid deposition
  - Differentiating gout from other inflammatory arthropathies
  - Quantifying and depicting distribution of MSU in multiple joints
  - Monitoring disease progression or response to therapy
  - Easily conveying distribution and disease burden to non-radiologists
- Further studies will be required to determine the sensitivity, specificity, and threshold concentrations required to diagnose gout using DECT.
- Limited initial availability will likely confine the role of DECT to those individuals with diagnostic uncertainty or access to larger imaging centers.
- DECT may produce color-coded artifacts which localize in regions not typically associated with uric acid deposition in gout (e.g. nail bed or calloused skin) and thus are easily distinguished from true findings.

References

1. Schlesinger N. Diagnosis of Gout: Clinical, laboratory, and radiologic findings. Am J Manag Care. 2005; 11:S443-S450.
2. Schlesinger N, Baker DG, Schumacher HR Jr. Serum urate during bouts of acute gouty arthritis. J Rheumatol. 1997:325-341.
3. Brower AC, Flemming DJ. Gout. In: Arthritis: In Black and White. 2nd ed. Philadelphia, Pa: WB Saunders; 1997:325-341.
4. Dalbeth N, Collis J, Gregory K, Clark B, Robinson E, McQueen FM. Tophaceous joint disease strongly predicts hand function in patients with gout. Rheumatology online 11/ 3/2007 doi:10.1093/ rheumatology/kem246
5. Perez-Ruiz F, Naredo E. Imaging modalities and monitoring measures of gout. Curr Opin Rheumatol 2007;19:128-133.
6. Johnson TRC, Kraub B, Sedlmair M, Grasruck M, Bruder H, Morhard D, Fink C, Weckbach S, :Lenhard M, Schmidt B, Flohr T, Reiser MF, Becker CR. Material differentiation by dual energy CT: initial experience. Eur Radiol. 2007; 17:1510-17.
7. Primak AN, Fletcher JG, Vrtiska TJ, Dzubak OP, Lieske JC, Jackson MR, Williams JR Jr, McCollough CH. Noninvasive differentiation of uric acid versus non-uric acid kidney stones using dual-energy CT. Acad Radiol. 2007; 14 (12):1441-7.
8. Graser A, Johnson TRC, Bader M, Staehler M, Haseke N, Nikolaou K, Reiser MF, Stief CG, Becker CR. Dual energy CT characterization of urinary calculi: Initial in vitro and clinical experience. Invest Radiol. 2008; 43:112-119.
9. Johnson TRC, Weckbach S, Kellner H, Reiser MF, Becker CR. Dual-Energy Computed Tomographic Molecular Imaging of Gout. Arth & Rheum. 2007; 56:2809.
10. Choi HK, Al-Arfaj A, Eftekhari A, Munk PL, Shojania K, Reid G, Nicolaou S. Dual energy computed tomography in tophaceous gout. Ann Rheum Dis. Online 9 December 2008. doi:10.1136/ard.2008.09913.

© 2009 Mayo Foundation for Medical Education and Research

11/19/09 3:09:03 PM