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Project : MARS analysis of calcium and gout crystals
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Introduction :
Gout is a painful form of arthritis caused by an accumulation of monosodium urate (MSU) crystals in the joints and periarticular soft tissues. With delayed or no treatment, gout can further lead to formation of tophi (MSU deposits + inflammatory tissues), chronic synovitis and joint damage. Hence, a fast and non-invasive method of detecting these MSU crystals found in early stage of gout can reduce disability and improve patients' quality of life. In this project, we tested the performance and sensitivity of the MARS pre-clinical scanner in detecting MSU crystals.
The MARS spectral scanner is a new imaging modality developed in Christchurch that allows the characterisation of materials based on X-ray attenuation differences at different energy levels. It was hypothesised that having more energy levels than currently available dual energy CT (DECT), MARS will have superior sensitivity in detection and characterisation of MSU crystals at lower concentrations.

Aim :
To determine the sensitivity of MARS scanning for MSU crystal detection.
To differentiate MSU crystals from other tissues.

Impact :
The prevalence of gout is increasing. Better methods to identify if and what crystals are causing arthritis will allow rapid diagnosis to ensure the appropriate therapy is provided. Better and timely management of gout can reduce disability and reduce the need for amputation.

Method :
A comparative study of MARS and DECT was conducted using an amputated gouty finger specimen. The MARS scanner's tube potential was set at 80 kVp with the detector setting at energy levels 20, 30, 40 and 50 keV. A second scan with the same parameters was then performed on a calibration phantom comprised of several concentrations of MSU, bone, water and oil equivalent basis. Using mass X-ray attenuation values calculated from the spectral response of each materials and their concentrations as reference, the black and white CT images were materially decomposed into spectral image with different materials highlighted in different colours.
The DECT scan was performed using the tube potentials 80 and 140 kVp. Material selective image was produced using a commercial software programme ('Gout', Syngo.via Workstation, Siemens Medical Systems). Lastly, a biopsy of the finger was done to validate the presence of crystals in the area where MSU was detected in MARS.

Results :
Both MARS and DECT images depicted tophi around the damaged joint of the gouty finger. Importantly, MARS scan revealed small deposits of MSU crystals in lower portion of the finger which DECT has failed to detect. This indicates that MARS is capable of detecting lower concentrations of MSU crystals as we hypothesised. Furthermore, MARS showed superior spatial resolution to that of DECT and showed better delineation of bone surface and the affected joint. Biopsy results confirmed the presence of MSU crystals in the area where MSU was detected in MARS. This suggests that MARS imaging may be capable of providing outcome measures, such as change in tophus volume, for monitoring the response to urate-lowering therapy.

Conclusion :

This prospective study shows MARS imaging holds promise as a practical tool for diagnosing gouty arthritis in a non-invasive manner in patients suspected of having gout. From our results, MARS has an advantage in diagnosing gout owing to its higher sensitivity in detecting crystal compared to DECT. This further implies that MARS may be able to provide early diagnosis of gout which means faster treatment can be provided for the patient.

One of the challenges that we faced was finding a suitable range of MSU calibration for identifying MSU crystals in the MARS image. Our material decomposition software appears to be greatly dependent on the concentrations of materials used in calibration. Further work on finding the optimal MSU calibration may improve the material decomposition process and the image quality.