Emerging Applications in Musculoskeletal CT Imaging

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With the recent advances in technology and software development, the utilization of CT in musculoskeletal (MSK) clinical imaging has undergone tremendous improvements. The most observable changes are the availability of High Definition (HD) CT data acquisition and reconstruction, Gemstone Spectral Imaging (GSI) with monochromatic data, effective metal artifact suppression, and dynamic 4D evaluation of joints and tendons using volume helical shuttle.

In this article, we share some of our early experiences with the new Discovery CT750 HD installed at our hospital.

HD Imaging

The HD scanner can acquire 2.5 times more views per rotation than a typical (non-HD) CT scanner. This results in improved spatial resolution. The images below are acquired with a high definition protocol where both HD standard and HD bone images are reconstructed for analysis for soft tissue as well as for pathologies involving bone and joints (Figure 1).

Comparative images of normal routine bone reconstruction and HD scan and reconstruction (Figure 2) show improved spatial resolution with higher bone details in the HD bone images.

Figure 1. (A) HD standard; (B) HD bone
The HD images clearly demonstrate the comminuted fracture of calcaneus involving the posterior sub-talar joint. The visualization of cortical margins and trabecular pattern is clearly seen in the HD bone image. The spatial resolution of HD images can be up to 230 microns (calculated using 0% MTF).

Using HD imaging in a knee study, we were able to appreciate subtle findings such as a hair-line fracture of the patella in the HD bone image and other soft tissue details in the HD standard images (Figure 3).
Gemstone Spectral Imaging in implant studies

We use dual energy acquisition with fast kV switching enabled by the Gemstone Detector in many of our studies on patients with orthopedic implants. The results were unparalleled and promising. With the GSI technique, we created monochromatic images specific for bone and implants. The projection data based reconstruction technique with metal artifact reduction software (MARs) helps significantly in the reduction of artifacts from high density metal implants and allows the accurate visualization of the underlying bone and adjacent soft tissue.

The 100 keV monochromatic image with MARs was able to show the implosion of implant into the joint space and producing pressure erosion of the articular surface of femoral condyle.

The GSI monochromatic technique with MARs is highly useful in external fixators. Unlike internal fixators, imaging with external fixators involves more challenging issues due to an increase in beam-hardening artifacts that are primarily due to the air gap that exists between the body and the external fixator. We were able to use GSI with MARs to resolve this complex situation (Figure 6).

Figure 4. (A) A routine reconstruction at 140 kV from a GSI scan data shows significant beam hardening artifact from the implant hardware. (B) Monochromatic image generated from the same GSI acquisition at 100 keV demonstrates the subtle reduction of metal beam hardening artifact without significant difference. (C) The same image reconstructed with MARs in which artifacts were completely removed and we were able to assess the implant integrity and adjacent tissue as well.

Figure 5. (A) 140 kV; (B) 100 keV with MARs
CT is often used to rule out vascular injuries in pre-surgical and post-surgical orthopedic patients. GSI with MARs helps us diagnose the presence of vascular injury in these complex cases with a high degree of confidence.

Figure 7 demonstrates the efficacy of MARs in studies involving external fixators by removing beam-hardening effects from the hardware. The 70 keV MARs images show the tibia and the tibial condyles. The margins and cortex of tibial condyle is well visualized compared to the 140 kV standard.

Figure 7. (A) Upper limb angiogram for vascular assessment post external fixation of humerus fracture. Note the extensive beam-hardening artifacts from the metal implants obscuring the visualization of the brachial artery. (B) and (C) illustrate 70 keV monochromatic 3D MIP and 3D VR transparency images depicting the normal patent vessel.

Figure 8. These images show dynamic sequences of the ankle joint from flexion phase to extension phase. This demonstrates movement of the non-united fracture fragment and focal reduction in posterior sub-talar joint space with apposition of the talus and calcaneus.
Kinematic studies in musculoskeletal imaging

Kinematic evaluation of the joints involves the use of the Volume Helical Shuttle (VHS) mode of image acquisition. A special reconstruction algorithm—dynamic pitch reconstruction—is used to help prevent artifacts due to movement. In our facility, we have performed kinematic evaluation of studies for joints including the elbow, wrist, knee, and ankle. Kinematic CT (KCT) is highly useful in evaluating movement of loose bodies into the joint space for assessing instability and predicting development of arthritis.

With the advent of technological developments in CT such as GSI, MARs, and HD, we are able to overcome previous limitations in MSK CT imaging. The use of VHS in orthopedic studies has resulted in the dynamic evaluation of joints. We have used these new techniques very effectively in the evaluation of MSK pathologies with a high degree of diagnostic confidence and accuracy.

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MIOT Hospitals Chennai is a 500-bed, multi-specialty hospital in India founded by a physician. The hospital is recognized as a leading center known for orthopedics and orthopedic research, including joint replacement surgery with 35,000 successful hip and knee replacement and revision surgeries. It is also the first hospital in the Asia-Pacific region and second hospital in the world to have a computer-integrated navigation system for joint replacement surgery. MIOT also has specialized centers for: nephrology, including the largest and most modern nephrology department in the country—performing five renal transplants each month and, in collaboration with Japan, kidney transplants across blood-type groups—and a state-of-the-art dialysis unit; thoracic and cardiovascular care offering endovascular grafting for aortic aneurysm by keyhole surgery procedures and beating heart surgery; neurology and neurosurgery; and pediatric cardiac surgery for treating congenital heart disorders.