AbstractID: 13609 Title: Design and Initial Performance Characterization of a Dedicated Cone-Beam CT System for Musculoskeletal Extremities Imaging

Purpose: High-quality volumetric imaging with isotropic resolution, soft-tissue visualization, and the ability to image load-bearing extremities would be of major benefit to diagnosis and planning in musculoskeletal radiology, orthopaedic surgery, and rheumatology. This paper reports the design and initial performance of an innovative cone-beam CT system under development to address such clinical needs.

Methods: The scanner employs a flat-panel detector (Varian3030+), with source-detector distance of 53 cm, source-isocenter distance of 41 cm, and field of view ~(20x20x20) cm. Gantry orientations (vertical and horizontal) permit imaging of weight-bearing knee and ankle (patient standing) and imaging of tensioned elbow, wrist, or hand (patient seated). Optimization of parameters such as kVp and beam filtration and characterization of detective quantum efficiency, resolution, and required dose levels were performed using cascaded systems analysis. An experimental CBCT bench simulated scanner operation, guided system design, and provided initial assessment of image quality in cadaveric specimens.

Results: Analysis indicates sub-milimeter resolution (~0.3-0.5 mm) and optimal performance for an x-ray technique of ~90 kVp + 0.2 mm Cu added filtration, giving <3 mGy patient dose and requiring ~0.5 kW power. At this dose, signal levels at the detector are ~100 times above the electronic noise floor, giving input-quantum-limited performance and facilitating soft-tissue imaging. Benchtop studies demonstrate exquisite detail in bony trabeculae, and excellent visualization of joint spaces. Soft-tissue visibility approaches that of diagnostic CT (~10-20 HU contrast), with methods for improvement underway in scatter correction and novel reconstruction techniques.

Conclusions: Results indicate that the proposed system delivers low dose, high resolution, volumetric images of the extremities with soft-tissue visualization. The unique characteristic of the design in permitting imaging of loaded extremities is of value in a broad spectrum of applications. A prototype scanner for deployment in clinical trials is now under construction.

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