A New Approach to Quantitative CT (QCT) Bone Densitometry with Asynchronous Calibration

Gabriel Bodeen, J. Keenan Brown, and Alan Brett

Objectives
Quantitative Computed Tomography (QCT) bone densitometry, a common diagnostic aid for osteoporosis, has conventionally relied for its accuracy and precision on scanning a calibration phantom simultaneously and co-extensively with the patient anatomy. Asynchronous calibration methods for QCT promise to permit more convenient patient scanning and both dual-use and retrospective extraction of QCT measurements from other abdominal and pelvic CT procedures. In this study we assess systematic and random measurement differences between a commercially-available, conventional QCT device and a prototype QCT device using asynchronous-calibration.

Methods
We compiled a retrospective cohort of CT scans including 168 vertebrae scans from 78 subjects and 73 proximal femur scans from 73 subjects. Subjects ranged in age from 3 to 97 years and the scans were collected from various scanner models produced by four major manufacturers. Bone Mineral Density (BMD) for each vertebra, femoral neck and the total hip femoral region was measured using QCT Pro™ v5.0 (Mindways Software Inc.) in both its conventional mode and a new mode for asynchronous calibration which uses independently acquired, scanner-specific Quality Assurance (QA) scans.

Results
Vertebral BMD ranged from 13.4 mg/cc to 262.2 mg/cc. The linear least-squares regression line between calibration conditions lay slightly off unity, showing a consistent bias wherein asynchronously calibrated BMD averaged 5.4% lower than conventional BMD. The SEE of this regression was 5.0 mg/cc. Results were similar in the proximal femur, with a correlation above 0.97, an average decrease of 5.8% versus conventional BMD, and a SEE of 0.021 g/cm² for data ranging from 0.335 to 1.254 g/cm². In addition, we assessed correlations of the BMD measurement bias to CT manufacturer, X-ray energy, and patient size. These revealed no statistically significant trends.

Conclusions
Asynchronously calibrated BMD is tightly correlated with conventional BMD, suggesting that the asynchronous approach has substantially equivalent accuracy in reproducing T-scores. A linear transformation is sufficient to correct the observed measurement bias (possibly caused by changes in beam hardening in the calibration phantom with and without the presence of the patient) without introducing significant distortion. Consequently, the asynchronous calibration approach may provide new clinical utility in dual-use and retrospective CT BMD screening with zero additional radiation dose.