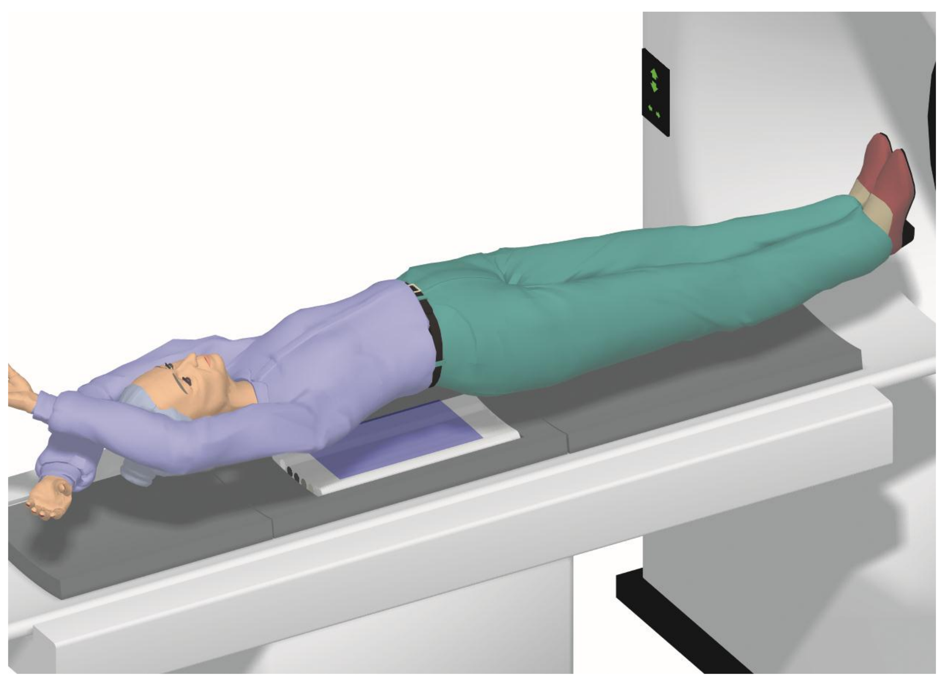
A New Clinical Approach to Quantitative CT (QCT) Bone Densitometry with Asynchronous Calibration

Gabriel Bodeen, J. Keenan Brown, and Alan Brett
Mindways Software, Inc., Austin, Texas, United States

Objectives

Quantitative Computed Tomography (QCT) bone densitometry, commonly used as a diagnostic aid for osteoporosis, has conventionally relied for its accuracy and precision on scanning a calibration phantom simultaneously and coextensively with the patient anatomy. Asynchronous calibration methods for QCT may permit more convenient patient scanning workflow and dual-use or retrospective extraction of QCT measurements from other abdominal and pelvic CT procedures. We report here assessments of systematic and random measurement differences between a prototype commercial QCT device using asynchronous calibration and a commercially available conventional simultaneous calibration QCT device.

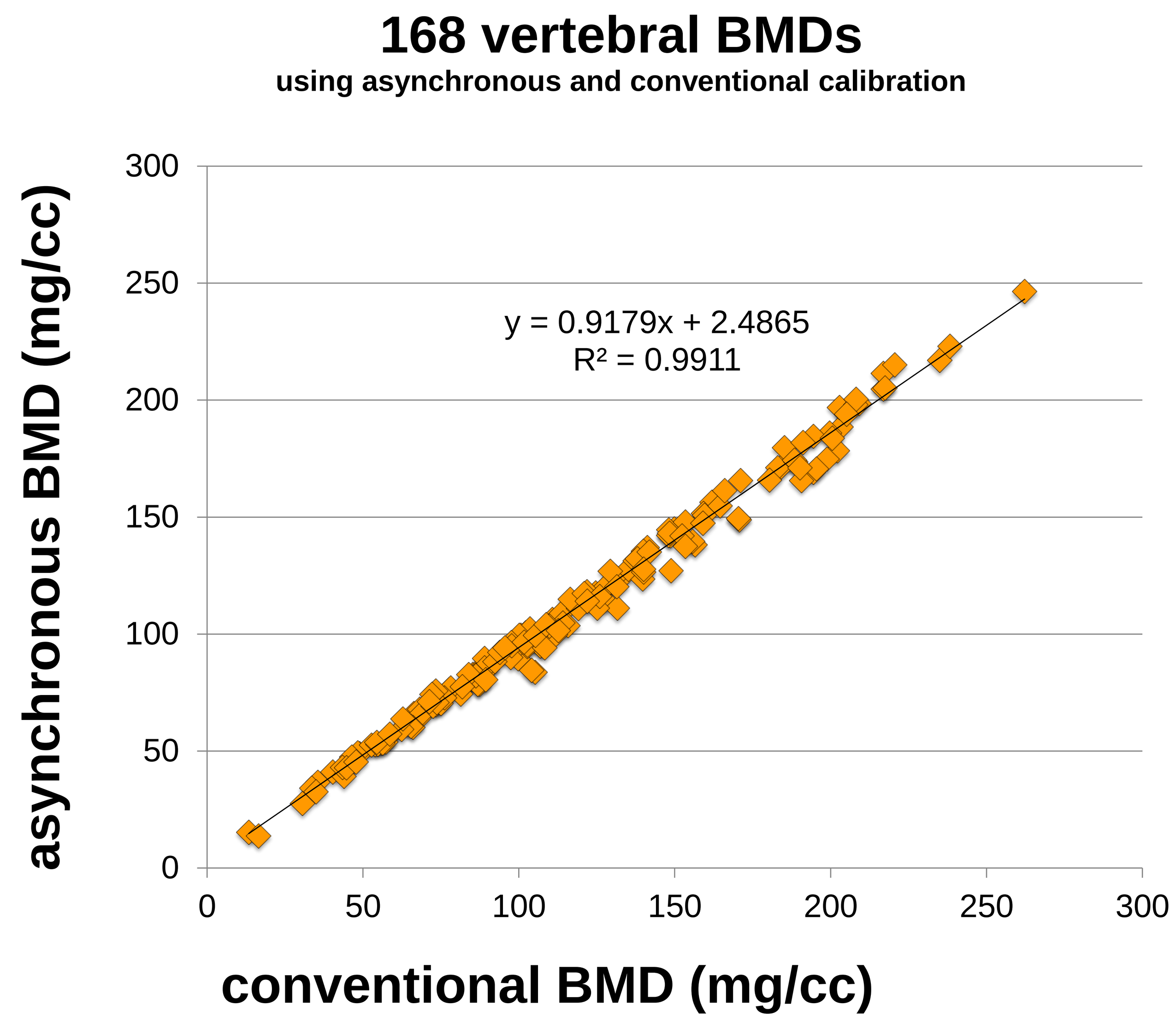


Above: Example patient placement over a conventional CT calibration phantom
Left: The conventional QA and CT calibration phantoms

Results

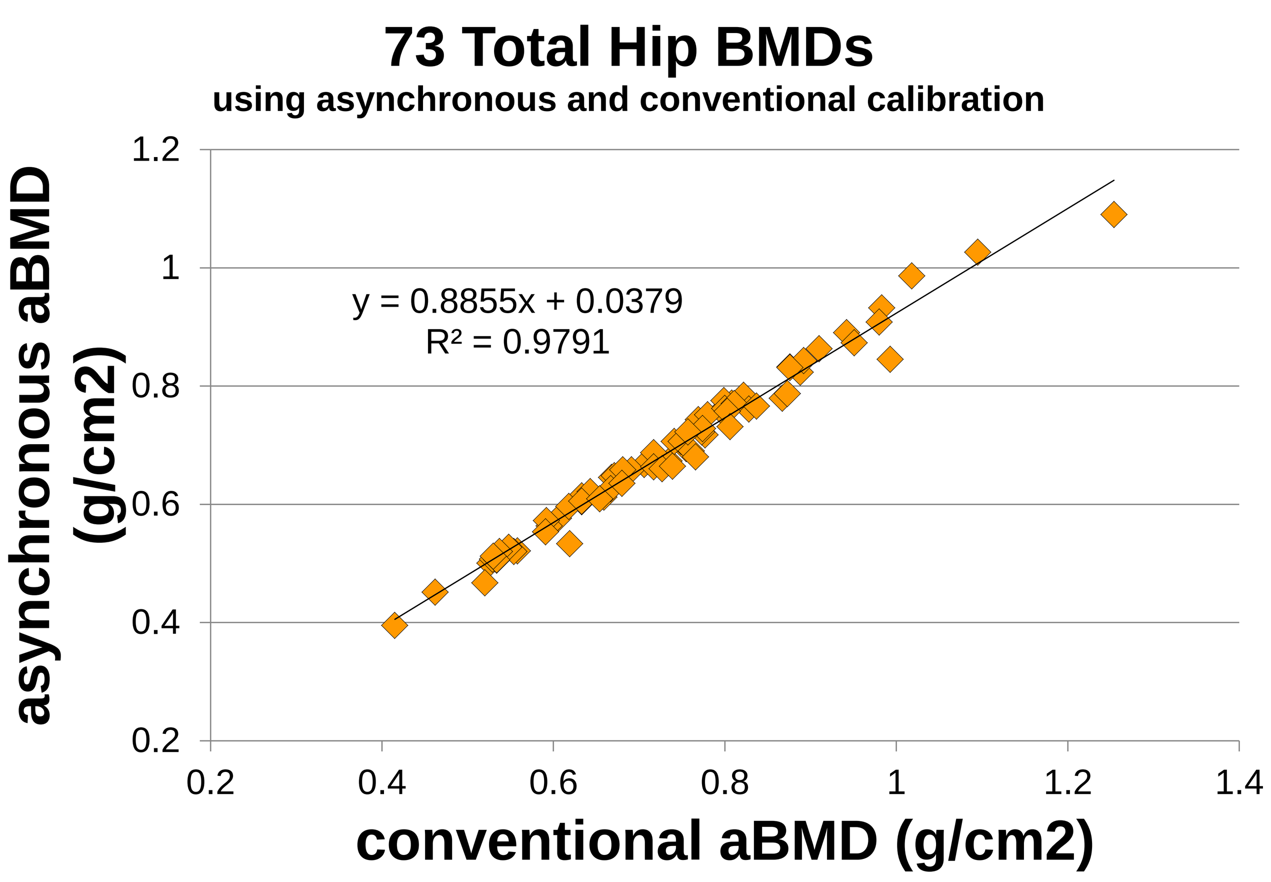
Vertebral BMD ranged from 13.4 mg/cm^3 to 262.2 mg/cm^3. The linear least-squares regression line between calibration conditions lay slightly off unity, showing a consistent bias wherein asynchronously calibrated BMD averaged 5.4% lower than conventional BMD. The SEE of this regression was 5.0 mg/cc.

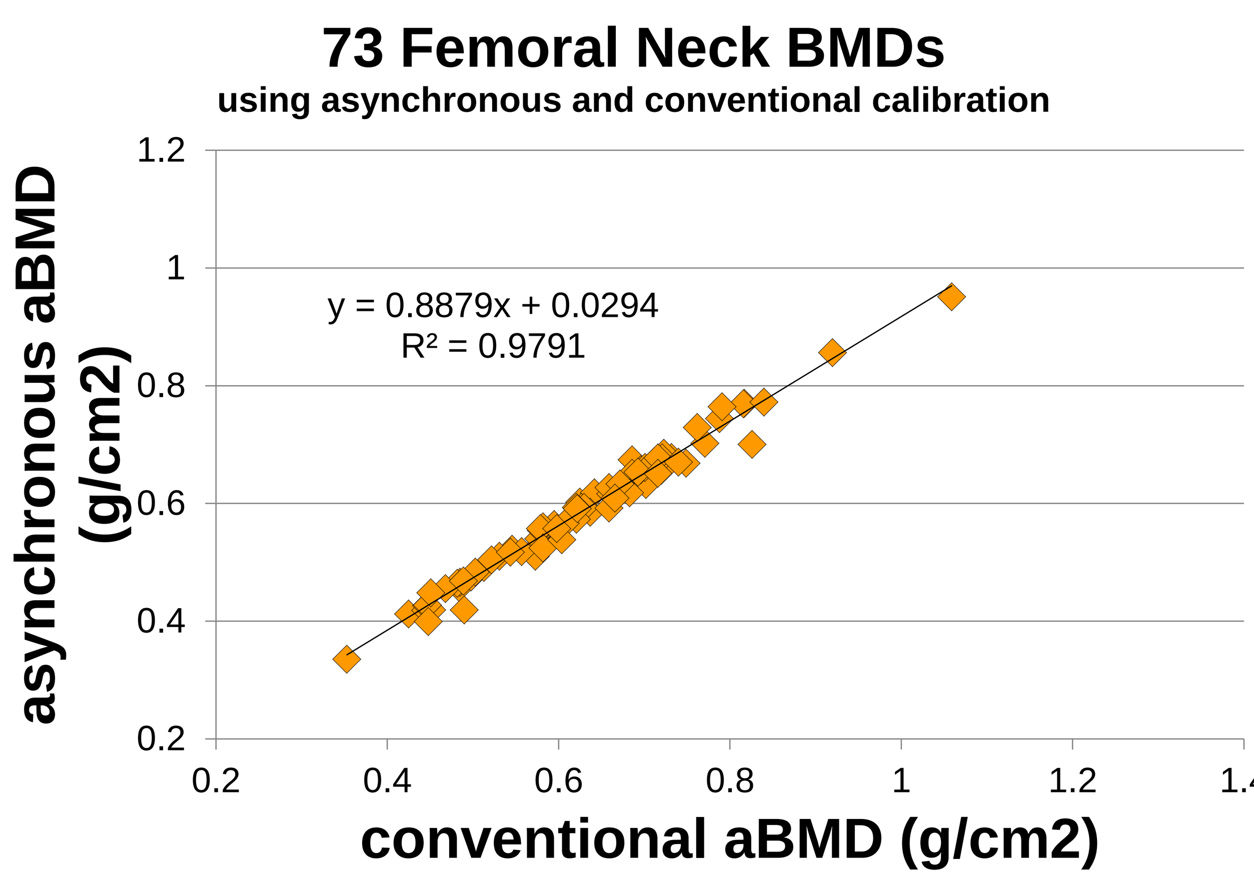
Results were similar in the proximal femur, with a correlation above 0.97, an average decrease of 5.8% versus conventional BMD, and a SEE of 0.021 g/cm^2 for data ranging from 0.335 to 1.254 g/cm^2. In addition, we assessed correlations of the BMD measurement bias to CT manufacturer, X-ray energy, and patient size. These revealed no statistically significant trends.



Above: The plot shows the low variance around the best-fit line over the whole physiologically interesting range of trabecular vertebral bone.

Below Left & Right: Similar results obtain for both standard regions of interest in the proximal femur.

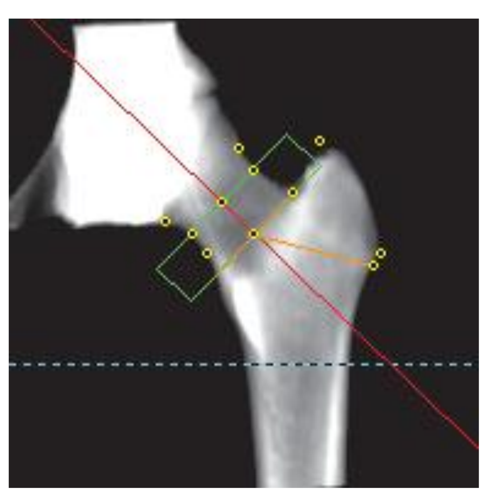




Methods

We compiled a retrospective data cohort comprising CT scans of 168 vertebrae from 78 subjects and of 73 proximal femur scans from 73 subjects. Subjects ranged in age from 3 to 97 years; the scans were collected from multiple scanner models produced by each of four major manufacturers. Bone mineral density (BMD) for each vertebra and for each femoral neck and the total hip femoral region was measured using QCT Pro™ Version 5.0 (Mindways Software, Austin, Texas, USA) in its conventional mode and in a new mode for asynchronous calibration using independently acquired, scanner-specific Quality Assurance scans.

Top: The red ellipse shows the placement of an elliptic cylinder region of interest for measurement of volumetric BMD in the lumbar spine.



Bottom: The green rectangle shows the placement of a region of interest for measurement of areal BMD in the femoral neck. The "total hip" region of interest is between the green rectangle and the blue line.

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 variance. Consequently, the asynchronous calibration approach may provide new clinical utility in dual-use and retrospective CT BMD screening with zero additional radiation dose.

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