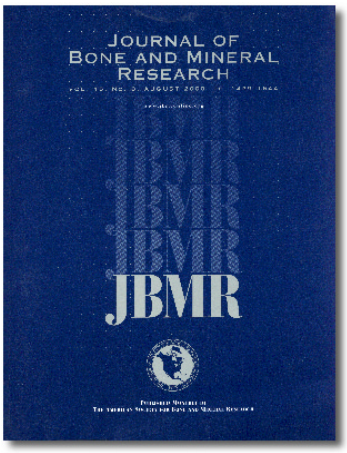
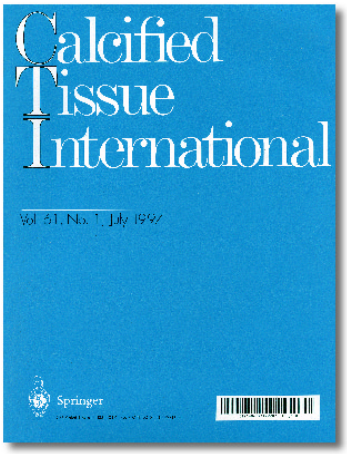
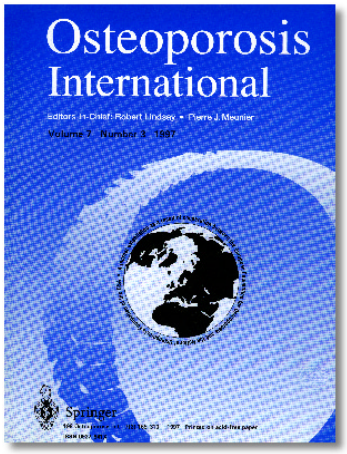
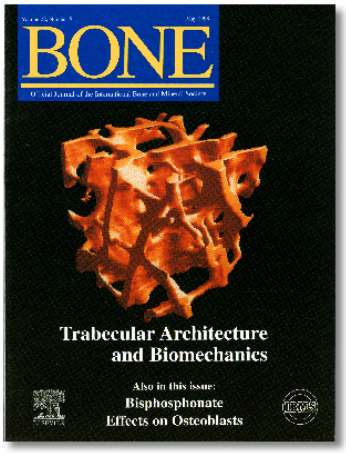
QCT versus DXA

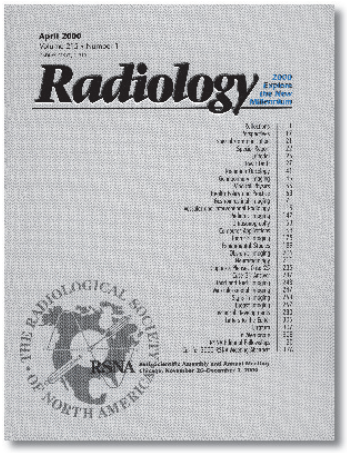
What the Experts Say

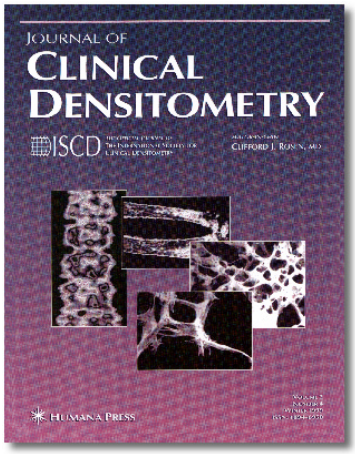












Excerpts from Leading Journals in the Field

"QCT-Pro has greater discrimination for vertebral fractures than DXA..."

Premenopausal Ovariectomy-Related Bone Loss: A Randomized, Double-Blind, One-Year Trial of Conjugated Estrogen or Medroxyprogesterone Acetate

J. C. Prior, Y. M. Vigna, J. D. Wark, D. R. Eyre, B. C. Lentle, D. K.B. Li, P. R. Ebeling, and L. Atley

Bone density measurements
Cancellous bone mineral density in vertebral centra from the 12th thoracic to the 4th lumbar spinal segments was measured by single-energy quantitative computed tomography (QCT) as previously reported. In our hands, QCT has a coefficient of variation (CV) of 0.8% from repeated examinations with repositioning in 78 premenopausal women. Measurements were obtained at 11.2 ± 0.7 (SD) month intervals (range 9–13 months). The rate of change was divided by the number of months between examinations, and this monthly change rate was multiplied by 12 to provide a common time frame for comparisons. A QCT-associated computer system change allowed only the first 33 enrolled (of 41) women to have QCT measurements.

Dual-energy X-ray absorptiometry (DXA, Lunar DPX, Lunar Corp., Madison, WI, U.S.A., software version 3.2) of the proximal femur region and whole body bone density were measured at baseline and 6 and 12 months following OVX. In our center, CVs in the proximal femur for eight normal-weight women age 40–60 years studied twice with repositioning were 2.9% for the femoral neck (FN), 2.3% for the Ward's area, and 2.1% for the trochanter bone density. The CVs for whole body determinations with repositioning in healthy adult women were 0.7%, for whole body bone density (WB) and 1.6% for the total (thoracic and lumbar) spinal region of the whole body DXA (WBS; n = 8). The total spine segment of the DXA whole body scan was studied for comparison with the spinal QCT measurement.

Changes in bone density and morphometrics over time
QCT cancellous spinal bone density decreased significantly across the year of therapy in both groups and averaged 12% in the entire cohort of 29 women for whom QCT data were available. CEE-treated women experienced a highly significant annual QCT loss of -11.5 mg/cm^3 (-8%) (t = -4.5, p = 0.0007), while MPA-treated women experienced a loss of -19.7 mg/cm^3 (-15%) (t = -7.4, p = 0.0001). The greater loss during MPA treatment just reached significance (p = 0.039).

Bone loss was less pronounced at all sites as measured by DXA compared with QCT; however, the total spine segment from the whole body also showed a significant loss of -4.0 ± 4.6% (t = -4.97, p = 0.0001). Again, the loss in the CEE group was less than in the MPA group (-1.5 ± 4.2% vs. -6.1 ± 3.7%/year, respectively, p = 0.002). By DXA, spinal bone loss in the CEE group was not significant (t = -1.36, p = 0.20). Figure 2 shows that the CEE group experienced mean DXA bone losses in the femoral neck and whole body density; however, no region showed statistically significant loss. At 12 months, the MPA group experienced significant loss in all hip sites, in the whole body, and in the spine region of the whole body bone density by DXA. These losses averaged -2.8% in whole body, -5.2% in the femoral neck, and -8.1% in Ward's area.

This trial was planned to be both larger (25 women per arm) and longer. However, as the results showing nearly universal QCT bone loss became apparent (Fig. 1), we felt it unethical to continue a randomized, blinded trial. We discontinued further enrollment and ended the study after 1 year of observation.

Journal of Bone and Mineral Research 12: 1851-1863, 1997

Non-Invasive Bone Mass Measurement: Techniques and Applications

J.E. Adams

Consequently, aortic calcification, degenerative change and osteophytes in the lumbar spine will cause inaccuracies. These factors have led to the development of lateral DXA scanning. This is more sensitive to detecting age related bone loss, but often the lateral measurement can be made only in one vertebral body (L3) because of overlying rib or iliac crest affecting measurements in the other lumbar vertebrae, and the technique has a poorer precision (3–5 per cent) than AP-DXA.

QCT is an established technique for measuring bone mineral density in the axial and appendicular skeleton. With its cross-sectional scanning plane, QCT is unique amongst methods of measurement in providing separate BMD estimations of trabecular and cortical bone, in both the axial and appendicular skeleton, as a true mineral density in mg/cc.

Examination time is 15 minutes. A low dose scanning technique can be used to minimize radiation dose (EDE) to 60μSv per examination, a dose similar to that for a PA chest x-ray and considerably less than background radiation (2400μSv per annum) and other radiographic procedures used in the investigation of osteoporosis.

If performed with meticulous care, the precision of the technique is 1–3 per cent. The accuracy of SEQCT is 1–2 per cent for K_2HPO_4 solutions and 5–15 per cent for human vertebral specimens spanning a wide age range.

There is also debate as to which technique should be applied. In studies assessing short term changes QCT may be the most sensitive since it measures trabecular bone which is some eight times more metabolically active than cortical bone.

Advanced Hospital Technology: Vol 1, 1992

Bone Mass Measurement in Osteoporosis and Other Bone Diseases

M.R. McClung

Only quantitative CT techniques of measuring bone density in the axial or peripheral skeleton, which measure actual volumetric density, can provide a true assessment of bone density when calibrated correctly. Other methods including SXA, DXA and radiographic absorptiometry (RA) only provide estimates of true bone density. Because they are projectional techniques, the true value of the depth of the skeletal region is not measured, and an expression of area density (in gm/cm^2) is generated. Parameters of ultrasound transmission velocity or attenuation may reflect both bone mass and bone architecture and cannot be truly calibrated against a bone mineral standard. Thus, besides QCT, none of these techniques provide truly accurate measurements of "bone density."

Abstract; Quality Assurance in Bone Mass Measurements, National Osteoporosis Foundation; 11/1995

Age and Bone Mass in Premenopausal Women

D. L. Rosenthal, W. Mayo-Smith, C. Hayes, J. S. Khurana, B. M.K. Biller, R. M. Neer, and A. Klibanski

Trabecular bone is approximately eight times more metabolically active than cortical bone. Quantitative computed tomography (QCT), which measures trabecular bone is therefore highly sensitive to changes in skeletal density.

Journal of Bone and Mineral Research 4: 533-538, 1989

Developments in QCT & Comparisons with DXA

J.E. Adams

QCT scans of the hip and/or spine were obtained in adults (age 61 ± 12, 26-84 (mean, SD & range) years)attending the Metabolic Bone Clinic using a Philips SR4000 CT Unit in conjunction with QCT-Pro (Mindways Software Inc., San Francisco). All patients had hip and spine DXA measurements using either a pencil beam (Lunar DPX-L) or a fan beam (Hologic 4500 Acclaim) system. A comparison was made between the precision (CV%) of the two techniques. The ability of QCT to identify patients with osteoporosis (DXA-lumbar spine T score <-2.5 (WHO)) was determined. Vertebral fracture discrimination by QCT vs DXA was also assessed.

The precision of 2D QCT (1.31%) in the lumbar spine is comparable to DXA (1.09% - fan beam; 1.57% - pencil beam). 3D QCT precision (0.5%, normal; 0.9%, osteoporotic) was superior to DXA.

A QCT T score of -3.8 identified the same number of individuals with spinal osteoporosis as defined by DXA. ROC curve analysis showed QCT was the better predictor of vertebral fracture.

CONCLUSIONS:
QCT-Pro has greater discrimination for vertebral fractures than DXA and can be applied to multiple anatomical sites (conventional and novel).

Abstract, RSNA 2000

Mild versus Definite Osteoporosis: Comparison of Bone Densitometry Techniques Using Different Statistical Models

A.F. Heuck, J. Block, C.-C. Gluer, P. Steiger and H.K. Genant

In conclusion, we found that direct measurement of spinal trabecular bone by QCT is the most powerful approach for discriminating postmenopausal women with mild vertebral deformities from those with definite fractures. These findings were consistent across all statistical tests undertaken with our BMD data.

Journal of Bone and Mineral Research 4: 891-900, 1989

Measurement of Axial and Peripheral Bone Mass by QCT

K. Faulkner

QCT provides a three-dimensional measurement of bone mineral density (BMD) as opposed to most other techniques, such as single and dual x-ray absorptiometry (SXA and DXA). Since DXA and SXA are projectional, they are limited to reporting area density (mass per unit of projected area). In contrast, the units of QCT are mass per unit volume as derived from the three-dimensional QCT image. The cross-sectional QCT images also allow the isolation of the trabecular bone, which is a more sensitive site for detecting bone mineral changes than cortical or integral sites.

Precision error is very small (1 to 2%) in experienced hands and with specialized analysis software.

When appropriately expressed in the correct units, the radiation dose due to a QCT examination is much less than a lateral x-ray of the spine routinely used to diagnose vertebral fractures. Thus the perception that QCT is a high radiation dose technique is not true.

While prospective data relating QCT to fracture risk are not available, cross-sectional data indicate the superior predictive capability for a vertebral QCT measurement compared to both anterior (AP) and lateral DXA of the spine (see table 2). This is likely due to the ability of QCT to measure purely trabecular bone of the vertebral body, which is thought to be the first to respond to menopausal changes.

QCT demonstrates both a stronger correlation with age than DXA and a greater degree of age-related loss than that seen with DXA. The diminished age-related decline in DXA of the spine can be attributed to the presence of osteophytes and other degenerative changes which mask the true BMD changes, particularly in the elderly. QCT is unaffected by these degenerative changes through the use of a central region of interest in the vertebral body. In addition, QCT is not affected by differences in height or weight which may confound the DXA measurements.

Table 2

Use of DXA and QCT bone mineral density to discriminate between 55 women with at least one spinal fracture and 168 non-fracture controls. Shown are the t-scores derived from a t-test between the two groups (with corresponding p-values), area under the receiver operating characteristic (ROC) curve, and age-adjusted odds ratio per standards deviation decrease in BMD.

Technique	t-score	ROC Area	Odds Ratio
AP spine DXA	3.36 (p<0.001)	0.650	1.47
Lateral spine DXA	5.22 (p<0.001)	0.714	1.88
QCT	8.45 (p<0.001)	0.797	3.17

National Osteoporosis Foundation; Bone Mass Measurement in Osteoporosis and Other Bone Diseases; November 1995

Assessing Osteoporosis: CT's Quantitative Advantage

H.K. Genant

Clinical results indicate that quantitative computed tomography can reliably evaluate and monitor the many forms of osteoporosis and its various treatments. The greatest advantages of spinal QCT for noninvasive bone mineral measurement lie in the high precision of the technique, the high sensitivity of the vertebral spongiosa measurement site, and the potential for widespread use.

Diagnostic Imaging, August 1985

"Solving the equations for the time to reach meaningful change revealed a mean time of 2.66 months for DXA and 1.54 months for QCT, DXA taking an average of 73% longer than QCT."

Effect of Osteoarthritis in the Lumbar Spine and Hip on Bone Mineral Density and Diagnosis of Osteoporosis in Elderly Men and Women

G. Liu, M. Peacock, O. Eilam, G. Dorulla, E. Braunstein, C.C. Johnston

ABSTRACT
To determine in the elderly the effect of osteoarthritis on bone mineral density (BMD) and on diagnosis of osteoporosis, lumbar spine and hip were radiographed and BMD measured by dual-energy X-ray absorptiometry (DXA) in 120 men and 314 women, aged 60–99 years. Prevalence and severity of osteoarthritis were scored on osteophytes, joint space narrowing and bone sclerosis. Ultrasound measurements were also made at the heel to examine whether osteoarthritis at hip or lumbar spine influence bone at this remote site. Osteophytes were the commonest feature, with men having a higher prevalence than women, and lumbar spine having more disease than hip. Lumbar spine osteophytes affected 75 % of men and 61.1 % of women, and hip osteophytes affected 31.7% of men and 27.4% of women. Stepwise multiple regression analysis using age, weight, height, osteophytes, sclerosis and joint space narrowing indicated that lumbar osteophytes explained 16.6% of variation in lumbar spine BMD in women, and 22.4% in men. Hip osteophytes had a minimal effect on hip BMD, accounting for only 2.2% of variation in women, and none in men. Sclerosis and joint narrowing had little effect on BMD at lumbar spine or hip. Indirect effects of osteoarthritis on BMD were small and inconsistent across genders. Lumbar spine osteophytes in men explained 3.1 % of hip BMD variation and 6% of variation in speed of sound at the heel, whereas hip osteophytes in women explained 2.2% of lumbar spine BMD variation. Osteoporosis at the hip, defined as BMD < 2.5 SD of the young normal mean, was present in 33.1% of women and 25.8% of men, whereas, at the lumbar spine it was present in only 24.2% of women and 4.2% of men. However, in women and men free of spinal osteoarthritis, 37.7% of women and 10% of men had osteoporosis. We conclude that lumbar spine osteophytes affect most subjects over the age of 60 years, and contribute substantially to lumbar spine BMD measured in the anteroposterior position by DXA. The effect is largely direct by virtue of osteophytes being included in the BMD measurement. However, a small indirect effect on remote skeletal sites is also present. Diagnosis of osteoporosis and assessment of osteoporotic fracture risk in the elderly should be based on hip BMD and not on anteroposterior lumbar spine, unless spinal osteoarthritis has been excluded.

Osteoporosis International 7:564-569, 1997

Noninvasive Assessment of the Skeleton: Current Status

H.K. Genant

In the standard posterior anterior (PA) measurement of the lumbar spine, the measured bone mineral density may be increased artificially due to osteophytes, aortic calcifications, degenerative facet hypertrophy and intervertebral disc space narrowing, especially in elderly patients.

A lateral examination of the lumbar spine makes possible an evaluation of the vertebral body with almost exclusive measurement of the trabecular bone, thereby reducing some of the errors in the PA examination of the lumbar spine. The reproducibility of the lateral DXA measurement, however, is poorer due to greater thickness and nonuniformity of the soft tissue in the lateral projection.

The capability of QCT to selectively assess the metabolically active and structurally important trabecular bone in the spine results in excellent ability to discriminate fracture and to monitor skeletal response to aging, disease, or therapy.

Osteoporosis Report (National Osteoporosis Foundation); Vol. 11, No. 2; Summer 1995

Effect of Spinal Degenerative Disease on Longitudinal Measurements of Bone Density

G. Jones, P.N. Sambrook, T. Nguyen, P.J. Kelly, J.A. Eisman

(DXA) Spinal BMD measurement and its sequential follow-up may be erroneous in the elderly due to concomitant degenerative disease.

Abstract; Perth International Bone Meeting; 2/1995

Anomalies in the Measurement of Changes in Total-Body Bone Mineral by Dual-Energy X-Ray Absorptiometry During Weight Change

P. Tothill, W.J. Hannan, S. Cowen, and C.P. Freeman

ABSTRACT
For an eating disorder study over a period of 1 year, we measured total-body bone mineral using a Hologic QDR 1000W in a total of 157 subjects and observed anomalies that questioned the accuracy of such measurements. Using the recommended Enhanced software, a change in total bone mineral content (ΔBMC) correlated positively with a change in weight (ΔW; r = 0.66), but a loss of weight was associated with an increase in bone mineral areal density (BMD; r = 0.58), arising from a reduction in bone area (AREA). Both regressions were highly significant. The dominant factor in this relationship was a strong correlation between ΔAREA and ΔBMC, for all parts of the skeleton, r > 0.9, with a slope close to 1. This is implausible because bone area would not be expected to change. When Standard software was used, the slope of the ΔBMC/ΔW correlation was steeper, but the ΔBMD/ΔW regression became positive. An artefact of dual-energy X-ray absorptiometry processing was suspected, and phantom measurements were made.

The phantom measurements offer an explanation of the anomaly in vivo and demonstrate that, under different circumstances, change in both BMC and BMD can be wrongly recorded. We believe that no valid conclusions can be drawn from measurements by the Hologic QDR 1000W of bone changes during weight change.

Journal of Bone and Mineral Research 12: 1908-1921, 1997

Inhomogeneity in Body Fat Distribution May Result in Inaccuracy in the Measurement of Vertebral Bone Mass

C. Formica, M.L. Loro, V. Gilsanz, and E. Seeman

When bone mineral content (BMC) is measured by dual x-ray absorptiometry (DXA), the x-ray beam is attenuated by bone and soft tissue. Since the component of the attenuation caused by the soft tissue overlying bone cannot be measured, the attenuation caused by the soft tissue adjacent to the bone is measured and is used in the calculation of BMC. The assumption underlying this approach is that the amount and composition of this adjacent soft tissue is the same as overlying bone. The aim of this study was to examine the validity of this assumption by determining whether fat distribution over and adjacent to bone differ and whether this introduces accuracy errors in the measurement of BMC by postero-anterior (PA) and lateral scanning.

In summary, the differing composition of soft tissue anterior and lateral to bone calls to question the validity of the assumption of soft tissue homogeneity needed for accurate measurement of BMC by DXA. In the elderly, BMC may be too high by PA scanning, resulting in a reduced cross-sectional diminution with age. Thus accuracy errors due to fat inhomogeneity compound those caused by osteophytes and suggests caution is needed in making inferences regarding the magnitude of age-related bone loss determined in vivo using bone densitometry.

Journal of Bone and Mineral Research 10: 1504-1511, 1995

Dual-energy x-ray absorptiometry (DXA) in obese patients: Are normal values really normal?

J.M. Weigert, C.E. Cann

Measurements of areal bone density using dual-energy x-ray absorptiometry (DXA) in clinically obese patients (body mass index [BMI] > 27 kg/m^2) have been reported to be increased in the spine and proximal femur relative to nonobese control patients.

The elevated BMD, as measured by DXA, in obese patients could be artifactual, which could cause the patient to be classified as normal or mildly osteoporotic when, in fact, their bone density is low and they may be at increased risk of fracture.

When the spine T score determined by DXA is plotted against the spine T-score determined by QCT in (control and obese) groups, there is a significant difference in the intercepts of the regression lines, with DXA values in the spine in obese women being 1.45 T-score units higher than those for QCT.

The results presented herein suggest that DXA scanning in obese patients can have substantial errors, overestimating the BMD by 1 or 2 T-score units and causing misdiagnosis of the patient if DXA is used as the primary diagnostic method. Although common practice dictates using an evaluation of femur BMD measured by DXA as the

primary measure if DXA of the spine is apparently too high, for example, from osteophytes, fractures, or aortic calcification, our results suggest that even the femur BMD is artificially elevated in the obese patient and may not be accurate for diagnosis of osteoporosis or osteopenia.

Our results suggest that, at least for the patient who is clinically obese, DXA may not be a suitable technique for this evaluation, and QCT may be a more accurate alternative.

We suggest that, in the evaluation of a patient who has a BMI in the range 25 kg/m^2 to 40 kg/m^2, either DXA not be used as the primary diagnostic method or the interpretation include the possibility that a high result may be in error.

Journal of Women's Imaging 1: 11-17, 1999

Cross Calibration of QDR-2000 and QDR-1000 Dual-Energy X-Ray Densitometers for Bone Mineral and Soft-Tissue Measurements

B. Abrahamsen, J. Gram, T.B. Hansen, H. Beck-Nielsen

In SB mode the QDR-2000 underestimated whole body and forearm BMD by 3% relative to the QDR-1000W, even after cross calibration using a spine phantom.

In FB with the QDR-2000, spine and whole-body BMD was underestimate by 3%, but femur total and neck BMD was overestimated by 2.2 and 2.8%, respectively, compared with SB on the same device.

Patients should be followed using the same scanning mode and analysis protocol whenever possible. Cross calibration by means of a single BMD anthropomorphic spine phantom is not sufficient to ensure identical results in all anatomic regions when a QDR-2000 replaces a QDR-1000W or is switched to FB mode.

Bone 16: 385-390, 1995

Scanner-Induced Variability and Quality Assurance in Longitudinal Dual-Energy X-Ray Absorptiometry Measurements

H. Sievänen, P. Oja, I. Vouri

Characteristics of typical malfunctions and scanner-induced variability observed in dual-energy x-ray absorptiometry (DXA), and their potential side effects on longitudinal reliability of DXA were evaluated. According to extensive, cumulative quality assurance (QA) data obtained from two successive x-ray sources during a a 3-yr period, the scanner-induced variability may derive from long-term drift (~0.5%/year), short-term drift (~0.2%-2.2%/day), inhomogeneity of the x-ray beam over the tabletop (~1%), and changes in internal filtration (~0.5%). The absolute magnitudes of these effects may be considerable with respect to expected small changes in bone characteristics observed in intervention studies. Furthermore, these effects may not be discriminated from each other. Therefore it may not be possible to correct their cumulative effect using long-term QA data only.

Medical Physics 21 (11): November 1994

Dual Energy X-Ray Absorptiometry: The Effects of Beam Hardening on Bone Density Measurements

G. M. Blake, D. B. McKeeney, S. C. Chhaya, Paul J. Ryan, and I. Fogleman

The effect of scale nonlinearity on the results of longitudinal studies was examined: For a spine scan at 20-cm body thickness, measured changes in BMD slightly overestimated the true change and implied an error of 0.15%/year for a measurement of a true rate of loss of 3%/year in a postmenopausal woman.

Medical Physics; 19 (2), 1992

Coding and Reimbursement Issues for Dual-Energy X-Ray Absorptiometry

D. J. Sartoris

I believe that the present level of reimbursement is too low to cover costs for DXA scanning, analysis, and interpretation. This concern is shared by the American College of Radiology, The National Osteoporosis Foundation, the American Society of Bone Mineral Research, the American College of Rheumatology, the Endocrine Society, the Society for Clinical Densitometry, and the Gynecologic Society of Florida.

The actual cost to obtain a scan, including calibration time, demographic information about the patient, data acquisition, analysis, interpretation, overhead, billing cost, and depreciation of equipment, is approximately $158.20.

TABLE 1: Breakdown of Typical Costs of Dual-Energy X-ray Absorptiometry

Description	Costs per Month ($)
Technician Salary (@ $10/hr)	1,733
Payroll tax + benefits	433
Rent (@ $3/sq. ft.)	2,400
Billing costs (includes personnel)	1,800
Physician's interpretation	6,000
Equipment costs[a]	4,000
Bad debt (assuming 90% collections)	2,250
Training and maintenance	417
Scheduling/secretarial	1,100
Malpractice/liability on premises	750

[a]Average dual-energy X-ray absorptiometric unit is $110,000.

American Journal of Roentgenology 163: 137-139, 1994

LATERAL DXA AVOIDS PA DXA'S PROBLEMS

The Superiority of Spinal Supine Lateral-QDR and QCT Over Spinal AP-QDR in Detecting Vertebral Compression Fractures

F.W. Lafferty and D.Y. Rowland

Both the supine Lat-QDR (r=-0.47) and tQCT of the spine (r-0.43) had highly significant correlations (p<0.001) in the presence of VCF-s whereas the AP-QDR of the spine failed to show a significant correlation (r=-0.16, p 0.13). Both the supine Lat-QDR (r-0.47) and the tQCT (r=0.49) of the spine also had highly significant correlations (p<0.001) with all types of fractures, but the correlation with the AP-QDR of the spine (r-0.28) was weaker (p<0.01). The correlation of the spinal Lat-QDR with the tQCT (r-0.71, p<0.001) exceeded that of the AP-QDR to the tQCT (r=0.56, p<0.001).

In conclusion, both the supine Lat-QDR and tQCT of the spine are markedly superior to the AP-QDR of the spine in detection of osteoporosis.

Journal of Bone and Mineral Research 9: S274, 1994

Precision of Lateral DXA and Correlation with QCT

G. Economou, S. Rushton, J.E. Adams and R.W. Whitehouse

DXA is a precise method for measuring bone mineral density (BMD) in the lumbar spine. Scanning in the conventional antero-posterior (AP) plane has the disadvantage in including spondylotic changes in the measurement. Lateral DXA has been developed to overcome this limitation. The study was undertaken to assess the application of lateral DXA in clinical practice.

Conclusion: The study confirms the greater sensitivity of lateral DXA to osteoporotic fracture than AP-DXA, but the reproducibility of lateral DXA at 5.9% may limit its use in longitudinal studies.

Abstract; Ninth International Bone Densitometry Workshop; Calcified Tissue International 52: 159, 1993

OR DOES IT?

Lateral DEXA of the Lumbar Spine is Not Superior to the AP Projection for the Diagnosis and Follow-Up on Bone Loss

K. Bjarnason, C. Hassager, C. Christiansen

We conclude that: 1) Five to ten years after menopause the lateral projection is not superior to the AP projection for the follow-up on bone loss. 2) At least one of the projections of the QDR-2000 seems to have an accuracy problem. 3) The exclusion of the posterior elements in the lateral projection does not increase the diagnostic value of spinal densitometry.

Journal of Bone and Mineral Research 9: 5274, 1994

Assessment of Spinal Bone Mass Loss by Lateral Versus Antero-Posterior View Revisited

A. Naïmi, D.O. Slosman, R. Rizzoli, A. Donath, F. Terrier, J.-Ph. Bonjour

Conclusions: In the context of a clinical setting, dorsal decubitus does not appear to be superior to lateral decubitus for the determination of lumbar spine BMD in LAT view. Because of the relatively small difference in postmenopausal BMD reduction between LAT and AP scanning, and of the relatively worse precision of LAT measurements, the lateral view does not appear yet to be more suitable for the diagnosis and follow-up of lumbar spine osteoporosis.

Bone 16:1495, 1995

"We believe that consideration should be given to the use of QCT as the 'gold standard' against which other measurements of spinal BMD are judged."

OSTEOPOROSIS: Diagnosis with Lateral and Posteroanterior Dual X-Ray Absorptiometry Compared with Quantitative CT

G. Guglielmi, S.I K. Grimston, K. C. Fischer, R. Pacifici

Quantitative CT has the ability to measure selectively the trabecular compartment of the vertebrae and has therefore been recognized as a sensitive method with which to assess BMD in patients with osteoporosis.

Quantitative CT has been shown to help discriminate between healthy women and those with osteoporosis better than PA-DXA.

The better diagnostic sensitivity of quantitative CT compared with PA-DXA may be a result of the fact that PA-DXA quantifies not only the trabecular compartment of the vertebral body but also the posterior compact bone elements of the vertebra. In addition, any hypertrophic and degenerative change and/or vascular calcification, which commonly occur in women over the age of 60 years, are also included in the final result from PA-DXA.

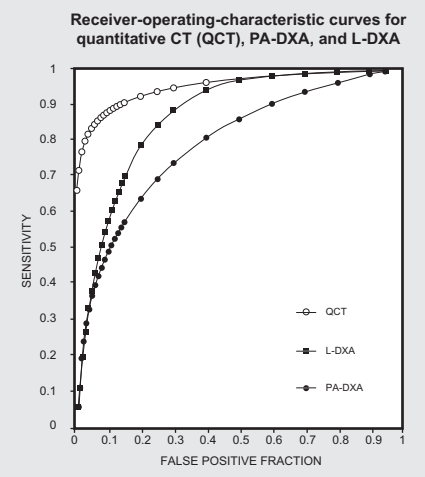
Moreover, findings at quantitative CT (r =-.76) and L-DXA (r = .69) correlated better with age than findings at PA-DXA (r = .56). The best-fitting curve was linear, and the correlation was independent of years since menopause. In the healthy women, a more significant linear decrease in BMD with age was found when measured with both quantitative CT and L-DXA than with PA-DXA.

Results of logistic regression analysis indicated both quantitative CT and L-DXA but not PA-DXA to be significant predictors of osteoporotic fracture ($P < .01$). In contrast, volumetric L-DXA, middle L-DXA, and L-3 L-DXA were not significant predictors of osteoporotic fracture. A similar finding was derived from analysis of receiver-operating-characteristic curves. The curves for fracture prediction (areas under curve: quantitative CT = 0.9518 ± 0.0228, L-DXA = 0.8741 ± .0332, PA-DXA = 0.7931 ± 0.0446) showed L-DXA to have a sensitivity and specificity higher than those of PA-DXA ($P < .05$) but lower than those of quantitative CT ($P < .05$).

In general, results indicated that scans obtained with PA-DXA do not help discriminate between healthy subjects and those with osteoporosis as well as quantitative CT does.

The choice of treatment modalities for osteoporosis often depends on the diagnostic sensitivity of screening procedures. In the present study, receiver-operating-characteristic curves were generated for each BMD measurement technique and were compared in terms of diagnostic sensitivity. With this procedure, L-DXA was shown to be superior to PA-DXA but inferior to quantitative CT in terms of accurate differentiation between fracture and nonfracture.

In conclusion, findings in this study demonstrate that the diagnostic sensitivity of L-DXA is between that of PA-DXA and quantitative CT. Moreover L-DXA is potentially more sensitive than quantitative CT to errors due to anatomic abnormalities or degenerative processes of the spine.



Radiology 192: 845-850, 1994

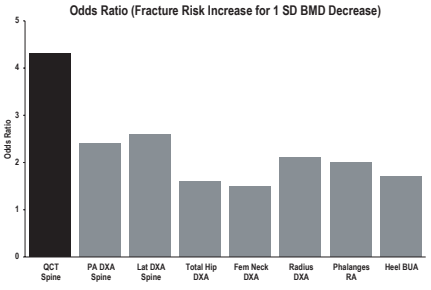
Comparison of Noninvasive Bone Mineral Measurements in Assessing Age-Related Loss, Fracture Discrimination, and Diagnostic Classification

S. Grampp, H. K. Genant, A. Mathur, P. Lang, M. Jergas, M. Takada, C-C Glüer, Y. Lu, M. Chavez

Detection of age- and menopause-related bone loss
In our study, we found that all the techniques except pQCT RAD TRAB BMD readily differentiated between healthy premenopausal and healthy postmenopausal subjects and reflected age- and menopause-related bone loss. In differentiating between healthy premenopausal and healthy postmenopausal women, the best abilities (based on percentage decrement and Student's t values) were shown by QCT, followed by DXA LAT BMD of the spine. Similar results were also obtained by Steiger et al. who found a decrement of 42% in the comparison of healthy premenopausal and healthy postmenopausal women for QCT TRAB BMD and 28% for QCT INTG BMD. DXA of the spine showed better abilities in the lateral (DXA LAT BMD) measurements compared with the PA (DXA PA BMD) measurements. This agrees with the results obtained by Guglielmi et al. who found the highest sensitivity and specificity for the detection of age- and osteoporosis-related changes for QCT TRAB BMD followed by DXA LAT BMD and by DXA PA BMD.

Discrimination of osteoporotic women
Of equal interest to the comparisons of the two healthy groups (reflecting age- and menopause-related changes) are the comparisons of the measurements in their ability to discriminate between healthy postmenopausal and osteoporotic postmenopausal women. We used the Student's t-test, odds ratios, and area under the ROC curve as statistical approaches to quantify the ability of the measurements to discriminate the osteoporotic postmenopausal group from the healthy postmenopausal group. Since most of the measurements are influenced by age, we adjusted for age in the logistic regression and ROC analysis. The results of odds ratios analysis reflected closely the trends shown by the Student's t-test. In our study, QCT TRAB BMD and QCT INTG BMD gave the best results based on age-adjusted odds ratios, followed by DXA LAT BMD and DXA PA BMD. The same trend, with QCT demonstrating the highest sensitivity for distinction between normal and osteoporotic women, was found in studies by Guglielmi et al. and by Jergas et al. who compared QCT with DXA LAT BMD and DXA PA BMD, by Pacifici et al. and by Van Berkum et al. who compared QCT with DXA PA BMD. Some appendicular measurements made in our study also gave a significant odds ratio but were generally lower compared with measurements at the spine.

The trend of spine measurements showing better discrimination for vertebral fractures has been reported in many cross-sectional studies comparing the abilities of measurements of the spine with those of peripheral sites. In contrast, it has been reported in both cross-sectional and longitudinal studies that peripheral measurements may be equal to spinal measurements when the latter are obtained by projectional techniques such as DXA. Cummings et al. and Davis et al. found that calcaneal DXA measurements were better than the DXA PA BMD for assessing hip fracture risk and age-related bone loss.



Journal of Bone and Mineral Research 12: 697-711, 1997

DXA versus QCT: Sensitivity to Vertebral Body Density Changes

B.D. Smith, E.E. Schulz, C.J. Flowers, D.J. Baylink

We set out to determine the capacity of DXA to detect changes in spinal density (DEN) over time, as compared with QCT. 179 osteoporotic patients who were receiving fluoride therapy had densitometry by both DXA and QCT a mean of 14.9 ± 4.7 months apart. Patients were included only if they were maintaining or gaining DEN.

Solving the equations for the time to reach meaningful change revealed a mean time of 2.66 months for DXA and 1.54 months for QCT, DXA taking an average of 73% longer than QCT.

In conclusion, these data show that QCT is better at discriminating changes in bone density in fluoride treated osteoporotics. Differences may be attributable to DXA measurements of not only the region of interest, but also overlying structures not responsive to therapy.

Calcified Tissue International 52:153-180, 1993

Diagnosis and Management of Osteoporosis: Guidelines for the Utilization of Bone Densitometry

D. T. Baran, K. G. Faulkner, H. K. Genant, P. D. Miller, R. Pacifici

Quantitative computed tomography (QCT) can determine in three dimensions the true volumetric density (mg/cm^3) of trabecular or cortical bone at any skeletal site. However, because of the high responsiveness of spinal trabecular bone, and its importance for vertebral strength, QCT has been principally employed to determine trabecular bone density in the vertebral centrum. QCT has been used for assessment of vertebral fracture risk, measurement of age-related bone loss, and follow-up of osteoporosis and other metabolic bone diseases. The validity of this technique for measuring vertebral cancellous bone is widely accepted and it is used at over 4000 centers worldwide. Generally, spinal QCT is performed on standard clinical CT scanners. It employs an external bone mineral reference phantom to calibrate the CT number measurements to bone equivalent values, as well as special software to place regions of interest (ROI) inside the vertebral bodies (typically of L1–L3). The QCT examination, when performed correctly, gives relatively low radiation exposure compared with conventional radiographs or standard CT studies, typically equivalent to a transcontinental airline trip.

The precision error of 2–4% and the accuracy errors of 5–15 % reported in vivo for spinal QCT are generally higher than those observed for posteroanterior DXA of the spine and comparable with those of lateral DXA. However, QCT's ability to selectively assess the metabolically active and structurally important trabecular bone in the vertebral centrum results in excellent ability to predict vertebral fracture and to serially measure bone loss, generally with better sensitivity than projectional methods such as DXA or DPA. The postmenopausal trabecular bone loss measured by QCT is 2–3 times greater than the integral bone loss measured by DXA.

Ross et al. employed prospective data to assess the predictive power of various BMD measurements for vertebral fracture and found that a spinal QCT measurement 2 SD below the normative value was 40% more predictive of future vertebral fracture than was the corresponding spinal DPA measurement.

Other studies have examined BMD decrements between normal subjects and those with vertebral fractures. These studies reported that the decrement as measured by spinal QCT is significantly higher than that observed by posteroanterior DXA and that vertebral fracture discrimination is generally superior with QCT. Because the metabolic rate in the vertebral trabecular bone is substantially greater than that of the surrounding cortical bone, QCT shows a comparatively good sensitivity for measurement of age-related bone loss following menopause. In a cross-sectional study of 108 postmenopausal women, Gulglielmi et al. measured overall bone loss rates of 1.96%/year with QCT compared with 0.97%/year and 0.45 %/year, respectively, for lateral DXA and posteroanterior DXA. Generally, it has been found that the crosssectional bone loss rate in females is typically 1-2%/year when measured with QCT and a little over one-half that value when measured with DXA or DPA.

Prediction of Fracture Risk

For Women Less Than 65 and/or Within 15 Years Since Menopause.

For this patient population, the following measurements for assessing fracture risk are recommended.

Preferred strategy: Obtain BMD measurements of the spine by DXA, lateral DXA, or QCT to detect effects of estrogen deficiency.

Obtain BMD measurements of the hip by DXA to acquire additional information on impact of peak bone density and genetic factors.

Acceptable strategy: Obtain BMD measurements of the spine only by DXA or QCT.

Alternative strategy: Peripheral measurements by SXA, RA, pDXA, or QUS.

For Women More Than 65 and/or More Than 15 Years Postmenopause.

For most women, bone loss at all skeletal sites begins to equalize after the age of 65, such that most skeletal sites provide important risk factor information. This has been confirmed by several prospective trials, which have shown that a BMD measurement at any skeletal site is an excellent predictor of fracture. Therefore, the potential utility of peripheral densitometry in this age group is greater than for those in early menopause. On the basis of this information, the following measurements for assessing fracture risk are recommended for this patient population.

Preferred strategy: Obtain BMD measurements of the hip by DXA and spine by either QCT, supine lateral DXA, or PA DXA (if degenerative or hyperthropic changes of the spine are excluded).

Acceptable strategy: Obtain BMD measurements of the hip by DXA.

Alternative strategy: Peripheral measurements by SXA, RA, pDXA or QUS.

Not recommended: Measurements of the spine only by PA DXA, because of the high incidence of degenerative and hyperthropic abnormalities of the spine.

Calcified Tissue International 61:433-440, 1997

Quantitative Computed Tomograpy (QCT): The Forgotten Gold Standard?

J.E. Adams, C. Alsop, E.J. Harrison, I. Lernbass, M. Davies, C. Cann, P.L. Selby

Although QCT was one of the earliest ways of measuring bone density its use has largely been superseded by the use of dual energy x-ray absorptiometry (DXA). QCT has several advantages over DXA, providing true volumetric density (so being size independent) separately in trabecular and cortical bone and being free of the inaccuracies caused by spinal DXA by extra-osseous calcification and hyperostosis. Development in QCT technology (spiral acquisition) and software has enabled rapid acquisition of 3D volume images and application to other relevant sites. We have therefore reassessed QCT in the assessment of patients with osteoporosis. One hundred and forty-nine patients being assessed for osteoporosis were studied. Thirty-six were male. Mean age was 60 (SD 12) years. BMD was measured in the lumbar spine by DXA and QCT, the latter using a Philips SR4000 scanner and specialized software (QCT-Pro, Mindways, San Francisco) using 2D (n=54) and 3D (n=95). Vertebral fractures were confirmed by spinal radiographs and/or QCT scoutview.

BMD measured by the two methods showed reasonable correlation ($r=0.64$, $p<0.0001$). However, if the WHO criterion for diagnosis of osteoporosis (T score <-2.5) is applied to both measurements there is poor diagnostic agreement ($k=0.3$). From the regression between the two methods a more appropriate threshold for QCT is T<-3.8. Even if this threshold is used for QCT diagnosis of osteoporosis the agreement is little better ($k=0.42$).

For individual vertebrae there was even less agreement between methods. QCT of vertebral bodies decreased from 96.8 (SE 5.2)g/cm^3 at T12 to 74.4 (3.7)g/cm^3 at L3 whereas DXA increased from 807 (16) mg/cm^2 at L1 to 938 (12) mg/cm^2 at L4 ($F=11.9$; $p<0.001$).

The ability of both techniques to discriminate between patients with and without fracture was determined using ROC curves. The fractional area under the ROC curve for QCT was 0.82 compared with 0.67 for DXA ($p=0.0005$).

Given the poor agreement between the two methods for the diagnosis of osteoporosis and the much better fracture discrimination with QCT we believe that consideration should be given to the use of QCT as the "gold standard" against which other measurements of spinal BMD are judged.

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