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Research Article

Comparison between Quantitative Computed Tomography and Dual-Energy X-Ray Absorptiometry in the Detection of Osteoporosis in Postmenopausal Women

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ABSTRACT

Background: Osteoporosis is denoted by low bone mass and microarchitectural breakdown of bone tissue, directing to increased fracture risk and bone fragility. Fractures may lead to a decreased quality of life and increased medical costs. Thus, osteoporosis is widely considered a significant health concern.

Objective. This study aimed to compare quantitative computed tomography (QCT) and dual-energy X-Ray absorptiometry (DXA) to detect osteoporosis in postmenopausal women.

Subjects and Methods. We measured spinal volumetric bone mineral density (BMD) with QCT and areal spinal and hip BMD with DXA in 164 postmenopausal women. We calculated the osteopenia and osteoporosis detection rate for the two methods. The difference between these rates for DXA versus QCT was analyzed using the chi-square test.

Results. The detection rate of osteoporosis was 57.9% for QCT and 50.6% for DXA (significant difference, p=0.002). At the same time, the detection rate of osteopenia was 36.6% for QCT and 31.7% for DXA (significant difference, p=0.002).

Conclusions. Quantitative CT bone densitometry is an excellent tool for the evaluation of BMD. It is more sensitive than DXA for detecting osteoporosis in postmenopausal women.

Introduction

Postmenopausal osteoporosis is a subtype of primary osteoporosis that occurs due to estrogen deficiency after menopause and results in accelerated loss of trabecular bone, with an increase in the risk of fractures, especially in the spine and wrist and to a lesser extent, in the hips (1,2). By definition, osteoporosis is a decreased bone mineral density less than -2.5 SD (more than 2.5 standard deviations under the young-adult mean (T-score)), which is measured by dual-energy x-ray absorptiometry (DXA) while osteopenia is defined as a bone mineral density score between -1 and -2.5 standard deviations compared to a young adult reference mean (3).

Imaging in osteoporosis aims to achieve an early diagnosis so that appropriate treatment can be initiated early. DXA is a well-standardized and easy-to-use technique with high precision (3,4). DXA has some pertinent disadvantages that need to be considered. Firstly, it is a two-dimensional (2D) measurement, which only measures density/area (in grams per square centimeter) and not the volumetric density (in milligrams per cubic centimeter). Secondly, areal BMD is susceptible to bone size and will thus overestimate fracture risk in individuals with a small body frame, who will have lower areal BMD than normal-sized individuals. Thirdly, spine and hip DXA are also sensitive to degenerative changes, and individuals

with substantial degenerative disease will have increased areal density, which will suggest a lower fracture risk than is present. Fourthly, all structures overlying the spine, such as aortic calcifications, or morphologic abnormalities, such as after laminectomy at the spine, will affect BMD measurements. Finally, checking DXA images for artifacts is critical, which may alter BMD values (5-8).

Quantitative computed tomography (QCT) is a new medical technique that measures BMD using a traditional X-ray computed tomography in which the CT scanner is calibrated using solid phantoms (made of calcium hydroxyapatite, representing various bone mineral densities) placed under the patient in a pad. With this calibration, the Hounsfield units of the CT images are converted to BMD values. The technique can be used for both peripheral and central BMD measurements, with lumbar spine and hip being preferred locations (9,10).

QCT has some advantages; it can be used in cases of scoliosis, can be helpful in obesity, its results doesn't not significantly affected by the spinal degenerative process unlike DXA.. However, QCT use more radiation dose compared to DXA and this could be regarded as a disadvantage (11).

Although the ionizing radiation dose of spinal QCT is higher than for DXA, the dose compares favorably with those of other radiographic procedures (spinal radiographs) performed in patients suspected of having osteoporosis. The radiation dose from peripheral QCT scanners is negligible (12).

This study aimed to compare QCT and DXA in detecting osteoporosis in postmenopausal women.

Subjects and Methods

This comparative prospective cross-sectional study was conducted in our radiology department from October 2016 to December 2020. Our study was conducted under the Declaration of Helsinki and was approved by the hospital's ethics and scientific research committee (registration code: 22/2016). We gained informed consent from all the patients involved in the study, and their personal health information was safeguarded.

Data collection and patient criteria

One hundred sixty-four patients in the age range (45-78years) (mean=61.5years) were enrolled in this study. An abdominal CT scan examined all cases to exclude internal pathology. Inclusion criteria include all asymptomatic postmenopausal women referred for an abdominal CT scan. Exclusion criteria include patients with a secondary cause of osteoporosis, history of osteoporotic fracture, multiple myeloma, or bone tumor, and history of drugs that affect bone metabolism (e.g., anti-coagulant, anti-epileptic, and thiazide diuretics). All patients who meet these inclusion and exclusion criteria were selected for DXA after undergoing QCT in our department.

Examination technique

Quantitative computed tomography measurement was done on Philips, Brilliance 64 slices CT machine. The patients were lying supine on the CT bed, and we did an abdominal CT scan for them. Data were analyzed using the patient-specific phantomless calibration, which means utilizing the patient's own internal tissues as the calibrating reference materials. At first, we select the vertebra from the sagittal CT sections (as shown in Figure 1. A), and then we determine the area required from the cancellous bone (avoiding the cortical bone) on cross CT sections. Then we also choose the same place for muscles and fat (as shown in Figure 1. B)

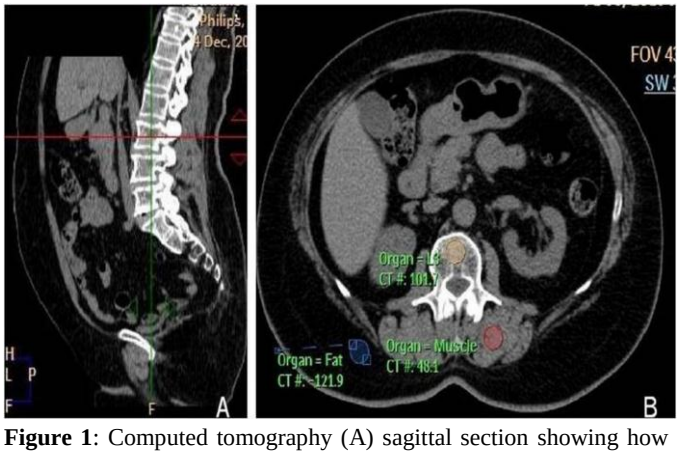

Figure 1: Computed tomography (A) sagittal section showing how to choose the vertebra required for Bone Mineral Density measurement, (B) cross-section showing the areas required for cancellous bone, muscles, and fat.

Vertebrae from lumbar 1 to lumbar 4 (mainly lumbar 3) were used. Average BMD is calculated and then compared to age and sex-matched controls. Since the phantom- versus phantomless-calibrated measurements were equivalent (slope not different than unity, $R2 \geq 0.98$) according to Lee D et al. study (13), the volumetric BMD measurement made at spine were compared to standard thresholds from the American College of Radiology (ACR) (14) as follow: a BMD < 80 mg/cm3 means osteoporosis; a BMD < 120 mg/cm3 and > 80 mg/cm3 means osteopenia, and a BMD >120 mg/cm3 is regarded normal. After completion of the CT scan, the patient was appointed for a DXA scan. DXA measurements were obtained by our department device (DMS/STRATOS), and data were analyzed using the manufacturer's software. The values were measured by T-score, which is a comparison by the standard deviation (SD) of youthful adult people, corresponding to sex and ethnicity. The T-score values were considered according to the following reference database (4,6): normal > -1 osteopenia -2.5 to -1, osteoporosis < -2.5, severe osteoporosis < -2.5 + fragility fracture. Then we compared the results (for QCT and DXA).

Statistical analysis

Collected data were introduced into an excel sheet (Microsoft excel sheet 16) and loaded into Statistical Package for Social Sciences (SPSS), SPSS® for Windows, Version 24.0 (IBM Corp, Armonk, NY). Descriptive statistics were presented through frequency distribution tables. A Chi-square test was used to analyze the categorical variables and determine the significance of the reading differences between QCT and DXA. A P-value of 0.05 was considered as a cut-off point for discrimination of significance of differences.

Results

A total of 164 patients were included in this study with the age range [45-78years] (mean=61.5years). The patients were divided into three groups according to age.

When the BMD is measured by QCT bone densitometry, only (9/164) patients were normal, and (155/164) were either osteopenic (60/164) or osteoporotic (95/164) Figure 2.

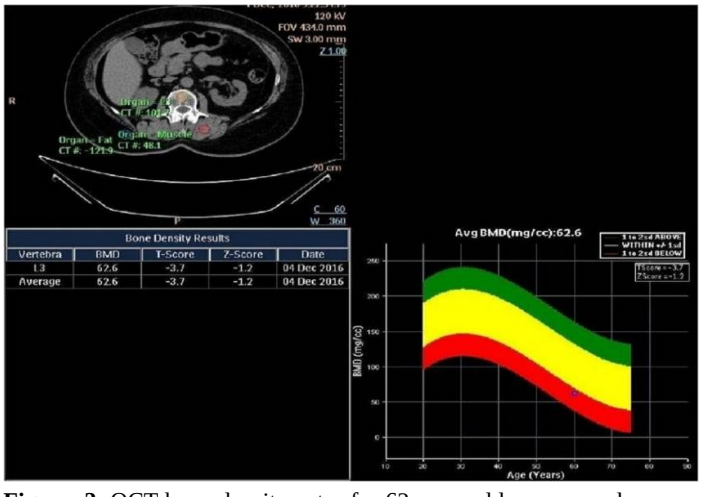

Figure. 2: QCT bone densitometry for 62 years older women shows that the BMD value is 62.6, which means osteoporotic changes

Table 1 shows the distribution of BMD by QCT among postmenopausal women. This table shows a highly significant association between increasing age and decreasing BMD when measured by QCT (p=0.0001).

Table 1: Distribution of BMD (by QCT) among post-menopausal women

Age group (years)	Number	Normal BMD	osteopenia	osteoporosis	p-value
45-54	72	7 (9.7%)	36 (50.0%)	29 (40.3%)	0.0001
55-64	44	2 (4.5%)	16 (36.4%)	26 (59.1%)	
65 and above	48	0 (0.0%)	8 (16.7%)	40 (83.3%)	
Total	164	9 (5.5%)	60 (36.6%)	95 (57.9%)	

BMD; bone mineral density

Table 2 shows the distribution of BMD by DXA among postmenopausal women. This table shows a significant association between increasing age and decreasing BMD when measured by DXA (p=0.004). When the T-score is measured by DXA, (29/164) patients were normal, (52/164) were osteopenic, and (83/164) were osteoporotic.

Table 3 compares the prevalence of osteopenia and osteoporosis when measured by QCT and DXA. The p-value was 0.002, which indicates the significant variation of BMD when measured by QCT and DXA.

Table 2: Distribution of BMD (by DXA) among post-menopausal women

Age group (years)	Number	Normal BMD	osteopenia	osteoporosis	p-value
45-54	72	15(20.8%)	30 (41.7%)	27 (73.5%)	0.004
55-64	44	9 (20.5%)	14 (31.8%)	21 (47.7%)	
65 and above	48	5 (10.4%)	8 (16.7%)	35 (72.9%)	
Total	164	29(17.7%)	52(31.7%)	83(50.6%)	

BMD; bone mineral density

Table 3: Comparison between the prevalence of osteopenia and osteoporosis when measured by QCT and DXA

	QCT	DXA	p-value
Normal	9 (5.5%)	29(17.7%)	0.002
Osteopenia	60(36.6%)	52(31.7%)	
Osteoporosis	95(57.9%)	83(50.6%)	
Total	164	164	

QCT; Quantitative computed tomography, DXA; Dual X-Ray absorptiometry

Discussion

Complications related to osteoporosis, such as vertebral or hip fractures, can create social and economic burdens, making early diagnosis essential for timely treatment and identifying patients at risk for fractures (2,15). Several imaging modalities have been developed to facilitate early diagnosis. In addition to conventional radiography, which allows qualitative and semiquantitative evaluation of osteoporosis, other imaging techniques such as DXA and QCT have been developed to quantify bone mineral content and assess bone loss (1,10,13).

Quantitative CT scans are mainly used to evaluate BMD at the lumbar spine and hip (9). QCT enables spine BMD measurements on patients with scoliosis, which cannot usually be measured using DXA. In addition, QCT can avoid the artificially high BMD measurements that can confuse the results from DXA in arthritic patients, patients who are obese, who suffer from disc space narrowing or degenerative spinal diseases, aortic calcification or osteophytes (10).

Developing a differential diagnosis is fundamental because it allows the differentiation of osteoporosis from other metabolic bone diseases and other disease entities with similar imaging findings (15,16). In this study, we use QCT bone densitometry to measure the BMD; QCT is also used to diagnose any structural abnormality in the bone that DXA can't detect.

Various approaches have been proposed to calibrate without an external calibration phantom (13, 17, 18). In QCT, the most widely used method for calibration utilizes an external calibration phantom (7, 16). However, the need for a phantom, which must be placed under the patient during scanning, adds expense and increases the logistical burden of clinical imaging. Our study applied a patient-specific phantomless calibration by utilizing the patient's internal tissues as the calibrating reference materials.

The difference in findings between QCT and DXA was significant, indicating that the QCT is better in detecting osteoporosis in postmenopausal women. By QCT bone densitometry, only 5.5% of the sample size was with normal BMD, 36.6% showed osteopenia and 57.9% showed osteoporotic changes. By DXA, 17.7% of the women show normal BMD, 31.7% show osteopenia, and 50.6% show osteoporotic changes. This was in agreement with Na Li et al. (5). They showed that QCT is better in detecting osteoporotic changes (by DXA, 37.1% showed normal BMD, 50% showed osteopenic changes, and 12.9% were osteoporotic. By QCT, 13.6% were normal, 40% were osteopenic and 46.4% show osteoporotic changes). However, compared to the latter study, the high difference in the prevalence of osteoporosis by DXA reported in our study may be attributed to the different characteristics of our study population and may be related to the DXA machine itself.

This high prevalence of decreased BMD in our study agreed with other studies like Marwaha et al. (19), which show 44.9% prevalence of osteopenia and 42.5% prevalence of osteoporosis.

In the present study, BMD is significantly decreased with increasing age; these results are in harmony with those reported by other studies (20-22).

Conclusion

Quantitative CT bone densitometry is an excellent tool for evaluating postmenopausal osteoporosis if patients have already done an abdominal CT for other causes. It is better than DXA in the detection of BMD changes. We advised using QCT as an adjuvant investigation for diagnosing and monitoring the bone density in osteoporotic patients.

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Conflict of Interest

No conflict of interest

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