THE DIAGNOSIS OF OSTEOPOROSIS BY MEASURING LUMBAR VERTEBRAE DENSITY WITH MDCT: A COMPARATIVE STUDY WITH QUANTITATIVE COMPUTERIZED TOMOGRAPHY (QCT)

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ABSTRACT

Objective: To compare the densities in Hounsfield Unit (HU) measured from corpus lumbar vertebrae using Multi-Detector Computerized Tomography (MDCT) with the T and Z scores measured using a bone densitometry software (Quantitative CT) from lumbar vertebrae; to evaluate the feasibility of diagnosing osteoporosis and osteopenia by only measuring the lumbar density and to determine the threshold values in density.

Materials and methods: 208 subjects were included in the study (126 men, 82 women). Bone densitometry measurements from lumbar vertebrae were made using Philips BMD option software. The density values, which were taken from the vertebrae of the same level, were recorded. The T and Z scores taken from the corpus vertebrae and the density measurements taken from the same level were statistically compared.

Results: A significant relationship was determined between the T score and the HU values measured from the L5 level of vertebrae (p=0.014) in the female. For the male patients, the density values were most statistically correlated with the T score at the L4 vertebral level compare with others (p=0.016).

Conclusion: One hundred and thirty-five (135) HU at L4 vertebral level for males and 130 HU at L5 vertebral level for females can be used as the threshold values to predict osteoporosis.

Key words:Bone mineral Density; Osteoporosis; Quantitative CT.

Introduction

Osteoporosis is defined as a systemic skeletal disease, which is characterized by loss of bone mineralization and bone tissue, followed by an increase in bone fragility and fracture sensitivity[1]. The risk of developing a fracture in connection with osteoporosis is estimated to be up to 50% in women and 20% in men throughout their life.

According to official institutions such as the International Society for Clinical Densitometry (ISCD)[2] and the National Osteoporosis Foundation (NOF)[2-3]. Dual-energy X-ray Absorptiometry (DXA) of the lumbar vertebrae and proximal femur is the preferred measurement method for Bone Mineral Density (BMD).

Using this method, men and post-menopausal women over 50 years of age with a T-score below -1 are diagnosed as having osteopenia, and if the T-score is equal to or below -2.5, they are diagnosed as suffering from osteoporosis[3].

Quantitative CT (QCT), is one of the standard techniques for BMD assessment of the lumbar vertebrae and proximal femur.(4) During the non-contrast abdominal CT examination when the lumbar vertebrae are in view, the real-time BMD measurement of the lumbar vertebrae by QCT analysis without being subjected to radiation exposure and additional radiological examination is defined in medical literature as potentially beneficial and superior to DXA[5, 6, 7].

The purpose of this study was to compare the densities in Hounsfield Unit (HU) measured from corpus lumbar vertebrae using Multi-Detector Computerized Tomography (MDCT) with the T and Z scores measured using a bone densitometry software (QCT) from lumbar vertebrae, to evaluate the feasibility of diagnosing osteoporosis and osteopenia by only measuring the lumbar density and to determine the threshold values in density.

Materials and methods

A total of 230 patients who were admitted to our clinic for several reasons between July 2010 and July 2011 underwent a non-contrast abdominal CT examination using 64-MDCT (Philips Brilliance) device and the images were retrospectively reviewed. The Local Ethics Committee granted approval for the study.

Patients with a compression fracture in the lumbar vertebrae, metallic transpedicular fixation, primary malignancy and metastasis, widespread skin edema and severe fatty muscle atrophy were excluded from the study, since those conditions might affect the results of the density measured from the corpus vertebrae. Overall, 208 subjects were included in the study (126 men, 82 women).

Bone densitometry measurements were made using Extended Brilliance Workspace post-processing system (version 3.5 or 4.0) Philips BMD option software on a Multi-Detector Computed Tomography (MDCT) device. In this process, the density of trabecular bone, muscle and fat planes were separately measured in HU, which was required for the software. For each patient, at the axial cross-sections of the middle part of L1, L2, L3, L4 and L5 vertebrae and corpus anterior parts, a set of 100 mm2 ROI area of trabecular bone were used to measure the density in HU. In addition, ROI measurements were made from paraspinal muscles and adjacent subcutaneous fat planes.

On the workstation, T and Z scores were determined to European standards using the above-mentioned software. In addition, the density values, which were taken from the vertebrae of the same level, were recorded. Especially non-fatty paraspinal muscles were preferred. If the patients had fatty atrophic paraspinal muscles, the psoas and gluteal muscles were used as an alternative localization. Especially for the fat density measurement in young patients, when the subcutaneous fatty planes were inadequate, perirenal areas and mesenteric fatty planes were used (Figure 1,2,3 and 4).
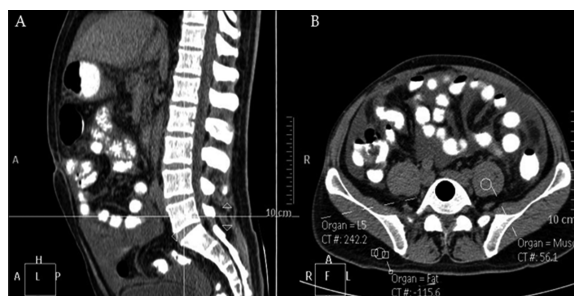

Figure 1: (A) Sagittal CT image shows how to determine the central portion of the corpus vertebrae. (B) Axial images shows the density measurement technique from trabecular bone (dark ROI), subcutaneous fat planes and the psoas muscle.
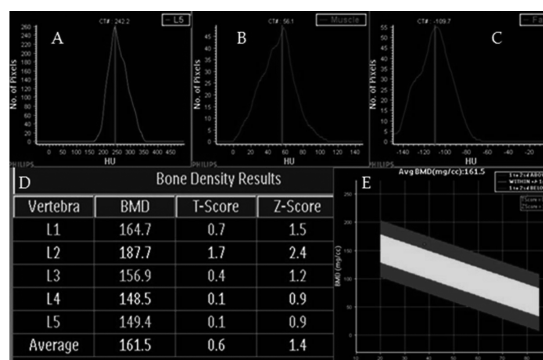

Vertebra	BMD	T-Score	Z-Score
L1	164.7	0.7	1.5
L2	187.7	1.7	2.4
L3	156.9	0.4	1.2
L4	148.5	0.1	0.9
L5	149.4	0.1	0.9
Average	161.5	0.6	1.4

Figure 2: Results of analysis in quantitative CT (QCT). Graphical representation of the measured density values corpus vertebrae (A), muscle (B) and subcutaneous fat plans (C).Eventually, BMD, T and Z-scores are monitored in the table (D). This patient was interpreted as normal (T score=0,6). (E) Mean BMD results are shown as a graphically.
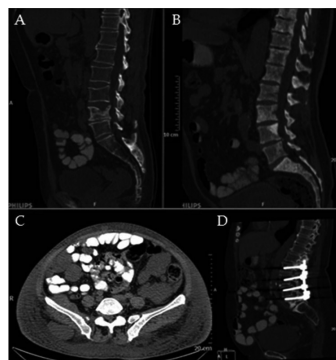

Figure 3: Patients who were excluded from the study. Patients with a compression fracture in the lumbar vertebrae (A), primary malignancy and metastasis (B), metallic transpedicular fixation (C), and widespread skin edema were excluded from the study.

The T and Z scores taken from the corpus vertebrae and the density measurements taken from the same level were statistically compared using the chi-square test. Statistical evaluation was made sep-

arately for males and females. Using ROC analysis, the threshold values of the density measured from corpus vertebrae for osteopenia and osteoporosis were determined. Statistical significance level was taken as p<0.05. All the statistical analyses were made using SPSS (Statistical Package for Social Sciences) version 15.0 software for Windows.

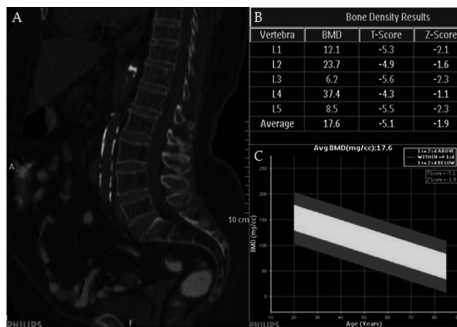**Figure 4:** Sagittal CT image (A) and results of quantitative CT (B, C) in the osteoporotic patient (T score= -5,1).

Results

The study comprised 82 female and 126 male patients. The mean age was 53.8±31.6 (mean±2SD; range, 21-79 years) for females and 45.6±19.6 (mean±2SD; range, 20-79 years) for males.

In all the females, the T and Z scores taken via bone densitometer software were statistically compared with the HU values of each corpus vertebrae. In the chi-square test, no statistically significant relationship was determined between the HU values measured from L1, L2, and L3, L4 level of vertebrae and the T and Z scores (p>0.05). A significant relationship was only determined between the T score and the HU values measured from the L5 level of vertebrae (p=0.014). At this level, no significant relationship was determined between the HU and Z scores (p>0.05).

In order to differentiate between the osteopenia, osteoporosis and normal cases among the female patients, the threshold values of the density values were determined using ROC analysis at the L5 corpus vertebrae level. Accordingly, the values below 130 HU were identified as osteoporosis, between 130-184 HU as osteopenia, 185 HU and above as normal. The limit of 130 HU had 100% sensitivity (36/36) in detecting the patients with osteoporosis. The values 130-184 HU had 82% (19/23) sensitivity in detecting the osteopenia cases and 185 and above HU had 69% (16/23) sensitivity in detecting the normal cases (Table 1).

Threshold values of the density (HU)	Diagnosis	Sensitivity
<130	Osteoporosis	100% (36/36)
130-184	Osteopenia	82% (19/23)
≥185	Normal	69% (16/23)

Table 1: Results of the analysis at the L5 corpus vertebrae level among the female patients.
HU: Haunsfield unit

For the male patients, the HU values of the each vertebra were also statistically compared with the T and Z scores taken from the same vertebral level. The results of the chi-square test identified a statistically significant correlation between the HU values and T scores measured from L1, L3, L4 and L5 vertebral levels. (p= 0.048, p=0.049, p= 0.016, p= 0.021 respectively) However, no statistically significant correlation was identified between the HU values and T scores measured from L2 corpus vertebrae (p= 0.085). From these results, the density values were most statistically correlated with the T score at the L4 vertebral level. No statistically significant correlation was identified between the density values and Z scores measured from corpus vertebrae (p>0.05).

Using ROC analysis at the L4 corpus vertebrae level, the threshold values were determined in order to differentiate between osteopenia, osteoporosis and normal cases among the male patients. Accordingly, the values below 135 HU were identified as osteoporosis, between 135-190 HU as osteopenia and above 190 HU as normal. The osteoporosis limit of 135 HU had 100% sensitivity (45/45). Similarly, the values 135-190 HU had 95% (44/46) sensitivity for the osteopenia cases and above190 HU had 80% (28/35) sensitivity in detecting the normal cases (Table 2).

Threshold values of the density (HU)	Diagnosis	Sensitivity
<130	Osteoporosis	100% (45/45)
135-190	Osteopenia	95% (44/46)
>190	Normal	80% (28/35)

Table 2: Results of the analysis at the L4 corpus vertebrae level among the male patients.
HU: Haunsfield unit

When the age groups of the male and female patients were classified as 20-39, 40-49, 50-59, 60-69 and 70-79, no statistically significant correlation was found between the age groups in respect of the HU values of the corpus vertebrae and T and Z scores of the same level when compared with the chi-square test. (p>0.05)

Discussion

Diagnosis of osteoporosis has an important role in determining the risk of fracture in a trabecular bone. Appropriate treatment can be applied by diagnosing osteopenia or osteoporosis with DXA and QCT[4]. This study was intended to determine whether the density values measured from the corpus vertebrae during non-contrast abdominal CT scans, taken in accordance with the indications, can provide enough information to the radiologist to diagnose osteopenia or osteoporosis without using QCT. According to the statistical results, it was determined that the density measurements made from the L4 level for male patients and L5 for female patients can help to diagnose osteopenia or osteoporosis.

In a study conducted on 252 patients by Pickhardt et al[6], comparing corpus vertebrae densities with DXA and QCT, it was determined that when the threshold values were taken as 160 HU at L1 vertebra, 130 HU at L3 vertebra and average 145 HU between T12-L5, they are 100% sensitive in the diagnosis of osteoporosis.

In the current study, some differences were found between males and females. In female patients, there was only a significant correlation between the HU values at L5 corpus vertebrae and T scores of the same level. The threshold value of 130 HU was 100% sensitive in the diagnosis of osteoporosis in females. In female patients, other than at L2 vertebral level, there was a significant correlation between all the lumbar corpus vertebrae HU values and T scores. However, there was a stronger statistical correlation between the L4 corpus vertebra HU values and T scores. Therefore, when the value of 135 HU is taken as the base value at L4 level, it was found to be 100% sensitive in the diagnosis of osteoporosis. Nevertheless, they were found to be less sensitive in the diagnosis of normal cases and osteopenia. (Based on the threshold value of 190 HU in males, the sensitivity was 95% in the diagnosis of osteopenia and 80% in the diagnosis of normal cases. Based on the threshold

value of 185 HU in female patients, the sensitivity was 80% in the diagnosis of osteopenia and 85% in the diagnosis of normal cases). It has been reported in literature that bone densitometry measurements may vary depending on race, gender, age, nutrition, physical activity, measured area, equipment and method used[8,9]. The different results in the study by Pickhardt et al may have arisen from differences in the population (e.g. race, number, age and gender) or the use of DXA as a reference test.

In some studies, it has been reported that QCT gives more accurate results than DXA in the evaluation of bone mineral density[10,11,12]. Although Pickhardt et al could not detect any significant difference between these two methods, they emphasized that the ROI measurements from lumbar corpus vertebrae and quantitative CT and DXA results are similar, and ROI measurements could be used for rapid diagnosis of osteoporosis[6].

In a study by Banks et al[7], it was reported that the calcifications adjacent to lumbar vertebrae (e.g., aortic calcification) or significant degenerative changes in the vertebrae may change the bone mineral density measured by DXA and may cause false results. However, bone mineral density can be measured more accurately by avoiding calcified and sclerotic areas in QCT. Nevertheless, it should be taken into consideration that increased BMD could be measured with DXA in patients with a compression fracture. However, the vertebrae with a compression fracture can be seen more clearly with QCT and BMD measurement may be avoided. Other benefits of QCT are that it provides volumetric 3D BMD information and allows the separate examination of trabecular and cortical compartments[13].

In the current study, age groups were classified to observe the differences between the T and Z scores, but no statistically significant results were acquired. The Z score is more important than the T score in premenopausal females, but in the current study no statistically significant correlation was determined between the Z scores and density in all patients and patient groups[14].

This study had some limitations. Firstly, the study could have been made comparatively with DXA. However, as this was a retrospective study that was not a possibility. In addition, not all the patients had a DXA examination available. Secondly, the density measurements could be repeated and the consistency between the radiologists could be examined. Thirdly, density values could be compared with BMD and T scores.

As a conclusion, QCT is one of the modalities that can be used in the diagnosis of osteoporosis. Since not all the radiology departments have QCT software, density measurements from lumbar vertebrae could be utilized in order to speed up the diagnosis of osteoporosis during routine non-contrast CT scans. Finally, it was determined from the results of this study that 135 HU at L4 vertebral level for males and 130 HU at L5 vertebral level for females can be used as the threshold values to predict osteoporosis.

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