Is quantitative magnetic resonance imaging valuable in the assessment of trabecular bone structure in osteoporosis?

Osteoporozda trabeküler kemik yapısının değerlendirilmesinde
niceliksel manyetik rezonans görüntüleme değerli midir?

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Objectives: This study aims to evaluate the value of quantitative magnetic resonance imaging in the assessment of bone trabeculae in osteoporosis by comparing the results with dual-energy X-ray (DXA) absorptiometry.

Patients and methods: The study consisted of 85 postmenopausal women (mean age 57.2 years; range 43 to 83 years) underwent both DXA absorptiometry and lumbar quantitative magnetic resonance imaging. T_2 and T_2^* values were calculated by magnetic resonance imaging and the results were compared with bone mineral density.

Results: According to bone mineral density t-scores; there were 32 normal, 30 osteopenic, and 23 osteoporotic patients. T_2 values of L1- L4 were different in normal with osteoporotic, and the osteopenic with osteoporotic groups. There were increased T_2 values with reducing t-scores. Comparing the normal and osteopenic groups, no statistical difference was found in T_2 measurements of lumbar vertebrae, except L4. T_2^* values of L1-L4 vertebrae were not statistically different between the study groups.

Conclusion: T_2 measurements of lumbar vertebra on quantitative magnetic resonance imaging may be useful in evaluation of bone trabeculae in osteoporosis, and may also be helpful in differentiation of osteoporotic from normal, and osteopenic from osteoporotic patients.

Key words: Lumbar vertebrae; magnetic resonance imaging; osteoporosis; photon absorptiometry.

Amaç: Çalışmada çift enerjili X-ışını (DXA) absorpsiyometri ile sonuçlar karşılaştırılarak osteoporozda kemik trabekül-lerinin değerlendirilmesinde niceliksel manyetik rezonans görüntülemenin değeri ortaya konuldu.

Hastalar ve yöntemler: Çalışmaya DXA absorpsiyometri ve niceliksel manyetik rezonans görüntüleme incelemeleri yapı-lan 85 menopoz sonrası kadın (ort. yaş 57.2 yıl; dağılım 43-83 yıl) dahil edildi. Manyetik rezonans görüntülemede T_2 ve T_2^* değerleri ölçüldü ve sonuçları kemik mineral yoğunluğu ile karşılaştırıldı.

Bulgular: Kemik mineral yoğunluğu t-skorlarına göre; 32 normal, 30 osteopenik ve 23 osteoporotik hasta bulunmak-taydı. L1-L4 vertebra T_2 ölçümleri normal ve osteoporotik ile osteopenik ve osteoporotik gruplar arasında farklı bulundu. T-skoru azaldıkça T_2 değerinde artış vardı. Normal ve oste-openik gruplar karşılaştırıldığında; L4 vertebra dışında, T_2 ölçümlerinde istatistiksel fark bulunmadı. L1-L4 vertebra T_2^* ölçümleri çalışma grupları arasında istatistiksel olarak farklı değildi.

Sonuç: Niceliksel manyetik rezonans görüntülemede lomber T_2 ölçümleri osteoporozda kemik trabeküllerinin değerlen-dirilmesinde yararlı olabilmekte ve normal hasta ile osteo-porotik ve osteopenik ile osteoporotik hastaları ayırt etmede yardımcı olacağı düşünülmektedir.

Anahtar sözcükler: Lumbar vertebra; manyetik rezonans görüntüle-me; osteoporoz; foton absorpsiyometri.

Osteoporosis is a metabolic bone disease characterized by both decreased bone mass and deterioration of bone microarchitecture, with an increased risk of fracture in weakened bone.[1,2] The evaluation of bone quality and quantity is very important in the assessment of fracture risk and effectiveness of treatment in osteoporotic patients.[3]

The World Health Organization (WHO) recommends the measurement of bone mineral density (BMD) with dual-energy X-ray absorptiometry (DXA) to quantify

osteoporosis.[4] Dual-energy X-ray absorptiometry is the most commonly used technique in the diagnosis and follow-up of the disease.[4] Although an inverse relationship was found between BMD and fracture risk, there are studies demonstrating that BMD is not a satisfactory predictor because deterioration in bone microarchitecture is also an important causative factor.[2,5,6]

In an effort to evaluate trabecular bone structure, magnetic resonance imaging (MRI) techniques developed. Quantitative MRI (QMRI) with different measurement parameters has been proposed as a useful method in the evaluation of trabecular bony network.[7,8]

The purpose of our study was to evaluate the value of T_2 and T_2^* measurements of lumbar vertebrae on QMRI in osteoporosis by comparing the results with DXA.

PATIENTS AND METHODS

Our institutional review board approved the study. Between April 2010 and August 2011, 118 postmenopausal women (at least one year since menopause) referred to us for lumbar MRI and who also had BMD data obtained on a DXA scanner in the last three months were included in the study. Informed consent was obtained from all patients following full explanation of the examination. Patients with MRI contraindications and history of disease or medications affecting bone metabolism such as malignancy, metabolic bone diseases, radiation therapy or chemotherapy were excluded from the study. The final study group therefore involved 85 postmenopausal women with a mean age of 57.2 years (age range, 43 to 83 years).

As body mass index (BMI) may affect the BMD data, heights and weights of the patients were measured, and BMI was calculated for each patient.

Bone mineral density measurements

Bone mineral density data were obtained on a DXA scanner (GE Medical Systems DPX Lunar). The L1-L4 vertebrae were scanned and measured in the anteroposterior direction. The patients were grouped as "normal," "osteopenic" and "osteoporotic" according to t-scores described by the WHO. The t-scores above -1 were considered normal, between -1 to -2.5 were considered osteopenic, and less than -2.5 were considered osteoporotic.

Magnetic resonance imaging technique

All MRI was performed by a 1.5 Tesla unit (Signa Excite 1.5T, GE Medical Systems, Milwaukee,

WI, USA). Following routine lumbar MRI, QMRI protocol for indirect assessment of bone trabeculae by measuring T_2 and T_2^* signal was obtained. In the QMRI protocol, sagittal fast spin echo and multiphase gradient echo sequences were obtained for T_2 and T_2^* measurements, respectively. The measurements were performed from the central portions of the L1-L4 vertebral body on mid-sagittal images by one radiologist blinded to DXA results. The mean signal intensity of the region of interest (ROI) was noted for each vertebra (Figures 1a, b).

Statistical analyses

Statistical analyses were performed using the SPSS (SPSS Inc., Chicago, Illinois, USA) for Windows version 15.0 software program. The variables were investigated using the Shapiro-Wilk test to determine whether they were normally distributed or not. Descriptive analyses for the variables in each group were presented by using means and standard deviations. One-way ANOVA and Kruskal-Wallis tests were used to compare the ages, BMI, and mean ROI values among the groups. When an overall significance was observed, pairwise post-hoc Tukey's test was used. *P* values of less than 0.05 were considered to have statistically significant difference. The correlations between variables were also analyzed with the Pearson test.

RESULTS

Of a total of 85 patients, the patients grouped according to t-score values were 32 normal, 30 osteopenic and 23 osteoporotic. According to t-score values, there was a statistical difference between the ages of the normal and osteoporotic groups (p<0.05). The BMI values showed no statistically significant differences between the groups (p>0.05). The demographic features of the patients are summarized in Table I.

T_2 measurements obtained from L1-L4 vertebrae showed statistically significant differences comparing normal with osteoporotic, and osteopenic with osteoporotic groups. In these groups, it was found that T_2 measurements increased with reducing t-score values. Comparing normal and osteopenic groups, there was no statistically significant difference in T_2 measurement of lumbar vertebrae, except L4. T_2 measurements of the study groups are shown in Table II.

T_2^* values of L1-L4 vertebrae did not show statistically significant differences between the study groups. T_2^* measurements of the study groups are demonstrated in Table III.
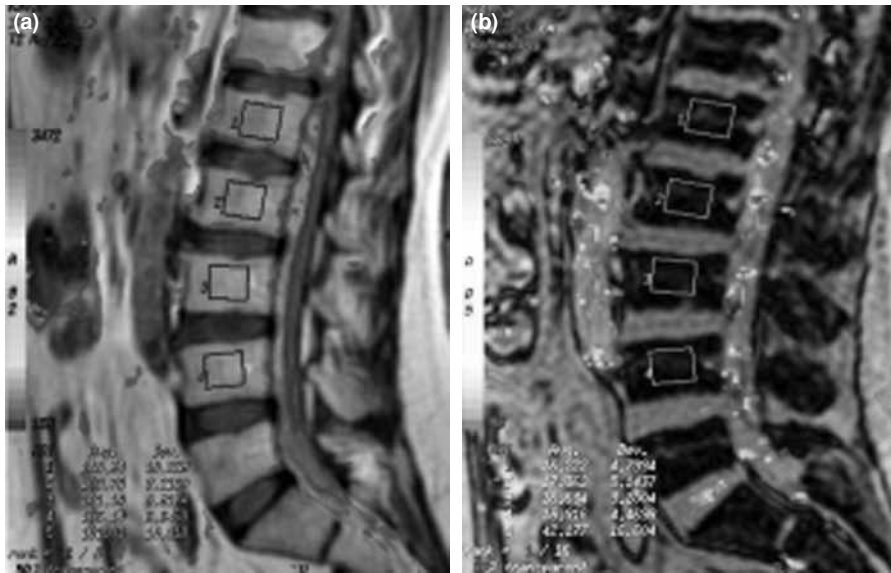
Figure 1. (a) On T_2 and **(b)** T_2* mappings of quantitative magnetic resonance imaging; region of interest is placed in the central portions of L1-L4 vertebral body on midsagittal images. The mean signal intensity of the region of interest is measured for each vertebra.

DISCUSSION

Osteoporosis is a clinical entity that not only has decreased bone mass, but also microarchitectural deterioration.[1,2,9] The diagnosis of osteoporosis is crucially important as it is associated with high risk of bone fracture.[10]

Although DXA is the only reference method in osteoporosis accepted by WHO, the fracture risk depends not only on BMD values, but also on qualitative and architectural changes in bone with aging.[2,5,11] Besides the advantage of being a non-ionizing radiation technique, in recent years, MRI was introduced as an effective imaging method for assessment of bone architecture.[3,7,8] Magnetic resonance imaging can be used to evaluate the trabecular network in two different ways. The first one is high resolution MRI (hrMRI) which enables direct visualization of the bone trabeculae.[12,13] The second one is MR relaxometry or QMRI which proves indirect measurement of structures of bone trabeculae.[14] As hrMRI necessitates advanced MR devices equipped with dedicated hardware and is also time consuming, its routine clinical usage is not practical. In contrast, QMRI can be performed on conventional MR devices and demands less evaluation time compared to hrMRI.

As the trabeculae alter the bone marrow signal features proportional to trabecular bone density,

TABLE I

The demographic features of the patients

Patient groups	n	Age	BMI
Normal	32	57.2±7.7*	30.6±4.1
Osteopenic	30	59.6±9.9	29.4±5.3
Osteoporotic	23	63.4±7.8*	30.6±5.2

BMI: Body mass index; * Statistical difference was found between the normal and osteoporotic groups (p<0.05).

TABLE II

T_2 measurements of the study groups

T_2 value	Normal	Osteopenic	Osteoporotic
	Mean±SD	Mean±SD	Mean±SD
L1	105.5±24.5*	109.2±31.9†	120.7±25.9*,†
L2	106.8±22.2*	109.6±23.4†	123.7±21.6*,†
L3	106.1±23.5*	110.9±32.8†	122.4±32.3*,†
L4	107.9±22.7*,‡	111.7±27.1†,‡	125.0±24.1*,†

SD: Standard deviation; * Statistical difference was found between the normal and osteoporotic groups (p<0.001); † Statistical difference was found between the osteopenic and osteoporotic groups (p<0.001); ‡ Statistical difference was found between the normal and osteopenic groups (p<0.001).

TABLE III

T_2* measurements of the study groups

T_2* value	Normal	Osteopenic	Osteoporotic
	Mean±SD	Mean±SD	Mean±SD
L1	19.0±13.5*	16.0±13.9*	17.3±10.9*
L2	18,9±11.7*	17.1±14.6*	18.3±11.6*
L3	19.0±12.2*	17.1±11.8*	19.0±12.3*
L4	18.7±14.9*	17.8±15.1*	21.1±14.1*

SD: Standard deviation; * No statistical differences were found between the study groups (p≥0.05).

QMRI measuring T_2 and T_2^* signal intensity of bone marrow has been reported to be directly proportional to trabecular bone density.[3,8,14-16] The difference in the magnetic properties of the trabecular network and bone marrow generates spatial inhomogeneity in the magnetic field and causes decreased T_2 and T_2^* MR signals.[8,15] In osteoporosis, there is a decrease in trabecular network, and QMRI studies demonstrated increased T_2 and T_2^* MR signals in this disease.[3,7,8,15-17]

We found similar findings with the literature that T_2 values of L1-L4 vertebrae were increased in osteoporotic patients comparing both normal and osteopenic patients. In our study, the ages of the patients in normal and osteoporotic groups were different. In a MRI study by Dooms et al.,[18] T_2 measurements of lumbar vertebra in women were not found to be statistically different comparing fourth and fifth decades. Therefore, we supposed that statistical differences between the ages of normal and osteoporotic groups would not have altered the results.

It is reported that over half of bone fractures in postmenopausal period arise in osteopenic women.[19] Consequently, the diagnosis of osteopenia in the postmenopausal period is very important. Although Wehrli et al.[20] found different lumbar T_2 values in normal, osteopenic, and osteoporotic patients, we could not find any statistical difference in T_2 values comparing normal and osteopenic groups while noting different T_2 values in normal and osteoporotic patients.

In contrast to reported studies, we did not find significantly different T_2^* values between the study groups.[7,8,15-17] The study by Brismar,[7] also supported our findings, and explained this result by several factors in spinal MRI. In the lumbar spine, individual differences in amounts of yellow and red bone marrow might affect the signal.[7] Respiration artifacts on lumbar MRI can also cause vertebral T_2^* signal intensity changes.[7] As a result, we did not find lumbar T_2^* measurements helpful in evaluation of osteoporosis.

Our study has a limitation in that we used DXA as a gold standard in BMD measurements. However, DXA is assumed to be a less sensitive method to measure BMD.[9] Our study has several advantages. Our study groups consisted of women. It is well known that fatty marrow content is different in women and men.[18] If we had studied both women and men, the signal intensity measurements of the groups would not have been compared reliably. The other advantage is that we standardized the study groups according to BMI as it might also change the signal intensity measurements on QMRI.

In conclusion, T_2 measurements of lumbar vertebra on QMRI may be useful in assessment of bone trabeculae in osteoporosis, and may also be helpful to differentiate osteoporotic from normal, and osteopenic from osteoporotic patients.

Acknowledgement

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

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