Assessment of Trabecular Bone Structure with Magnetic Resonance T2 Relaxation Time in Osteoporosis

Osteoporozda Manyetik Rezonans Görüntüleme T2 Relaksasyon Zamanı Tekniği ile Trabeküler Kemik Yapının Değerlendirilmesi

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Summary

Objective: This study was planned to investigate the utility of Magnetic Resonance Imaging MRI in assessing osteoporosis in a quantitative manner by evaluating bone micro architecture and to assess the correlation between MRI measurements and dual energy X-ray absorptiometry (DXA).

Materials and Methods: The study group consisted of 31 postmenopausal osteoporotic women and control group consisted of 31 healthy postmenopausal women with normal bone mineral density (BMD). BMD measurements were performed with DXA at spine and at femur. The MRI T2 relaxation time (T2 RT) measurements were performed at lumbar 3 (L3) vertebra and calcaneus. The results of L3 vertebra DXA measurements of the postmenopausal subjects were compared with L3 vertebra MRI T2 RT and calcaneus T2 RT.

Results: There was a significant difference between postmenopausal women with normal BMD and those with low BMD regarding the T2 RT of L3 vertebra and calcaneus ($p<0.001$). We found a negative correlation between L3 vertebra BMD and L3 vertebra T2 RT and calcaneal T2 RT. There was a positive correlation between L3 vertebra T2 RT and calcaneal T2 RT.

Conclusion: The MRI results obtained by this technique were found to be correlated with the DXA results. It seems to be possible to discriminate postmenopausal osteoporotic and healthy women with MR T2 RT which assess trabecular bone structure. *Turk J Phys Med Rehab 2008;54:50-3*

Key Words: Osteoporosis, MRI T2 relaxation time, dual energy x-ray absorptiometry

Özet

Amaç: Bu çalışmada, osteoporozda kemik mikromimarisinin kantitatif olarak değerlendirilmesinde Manyetik Rezonans Görüntüleme (MRG) yönteminin kullanılabilirliğini ve MRG yöntemi ile dual enerji x-ray absorpsiyometri (DXA) yöntemi arasındaki korelasyonu araştırmayı amaçladık.

Gereç ve Yöntem: Çalışmamıza 31 postmenopozal osteoporotik kadın ve 31 postmenopozal normal kemik mineral yoğunluğuna (KMY) sahip sağlıklı birey alındı. Ölçümler DXA ile omurga ve femurdan yapıldı. MRG T2 relaksasyon zamanı (T2 RZ) ölçümleri lomber 3 (L3) vertebra ve kalkaneusdan yapıldı. Postmenopozal bireylerdeki L3 vertebra DXA sonuçları L3 vertebra T2 RZ ve kalkaneus T2 RZ ölçüm sonuçları ile karşılaştırıldı.

Bulgular: L3 vertebra ve kalkaneus T2 RZ ölçümlerinde osteoporotik ve normal KMY'ye sahip postmenopozal kadınlar arasında anlamlı fark saptandı ($p<0,001$). L3 vertebra KMY'si ile L3 vertebra T2 RZ ve kalkaneus T2 RZ arasında negatif korelasyon vardı. L3 vertebra T2 RZ ve kalkaneus T2 RZ arasında ise pozitif korelasyon saptanmıştır.

Sonuç: DXA sonuçları ile T2 RZ yöntemiyle yapılan MRG sonuçlarının korele olduğu tespit edilmiştir. Trabeküler kemik yapısının değerlendirilebildiği MR T2 RZ ölçümleri ile postmenopozal osteoporotik ve sağlıklı bireylerin ayırımının mümkün olabileceği sonucuna varılmıştır. *Türk Fiz Tıp Rehab Derg 2008;54:50-3*

Anahtar Kelimeler: Osteoporoz, MRI T2 relaksasyon zamanı, dual enerji x-ray absorbsiyometre

Introduction

Osteoporosis is a skeletal disorder characterized by compromised bone strength that results in an increased risk of fracture (1). Bone strength is the reflection of bone quality and quantity and is also one of the most important factors in the assessment of fracture risk and effectiveness of the treatment in osteoporosis (2).

Currently, methods based on magnetic resonance imaging (MRI) and micro computerized tomography (CT) are more often

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used to evaluate the constituents of the bone quality. In recent years, with the advances in the MRI technology, characteristics and structure of the trabecular bone are being successfully evaluated. In addition to description of the structure of trabecular bone we can also quantify its biomechanical properties with MRI. MRI can be used to assess the properties of trabecular bone in two different ways. The first one is termed as relaxometry or quantitative magnetic resonance (QMR) and is an indirect measure of characteristics of trabecular bone. This method takes advantage of the fact that trabecular bone alters the adjoining marrow relaxation properties in proportion to its density and structure and thereby provides information, regarding trabecular bone network. The second method is the direct visualization of the trabecular bone itself. Because of its low water content and short relaxation time in MRI, trabecular bone appears dark, in a stark contrast to the bright bone marrow fat and water in high-resolution MR images (3-6). Currently, measuring the T2 relaxation time (T2 RT) seems to be the most promising approach to quantitative evaluation by MRI. We used the relaxometry method in our study.

Depending on these, this study was planned; (1) to investigate the utility of MRI in assessing osteoporosis in a quantitative manner by evaluating bone micro architecture, (2) to assess the correlation between MRI results (L3 vertebra and calcaneus) and dual energy X-Ray absorptiometry (DXA).

Materials and Methods

Postmenopausal patients (at least one year since menopause) were enrolled in the study. Patient evaluation included a complete history and physical examination. Laboratory investigations were performed for the patients and controls to exclude secondary osteoporosis. Anteroposterior (AP) X-Rays of pelvis, AP and lateral X-Rays of thoracic and lumbosacral vertebrae were also taken. Subjects with history of diseases or medications affecting bone metabolism, patients with anatomic deformities of the spine which can influence bone mineral density (BMD) measurements and patients with fractures in the lumbar vertebrae, patients in which MRI studies are contraindicated (pacemaker, metallic implants, vascular clips, claustrophobia, morbid obesity) were excluded. A total of 62 subjects were enrolled in this study, and consisted of postmenopausal women with osteoporosis (T score<-2.5, n=31, mean age 56.68±6.6 years) (Group I), and postmenopausal women with normal BMD (T score >-1, n=31, mean age 54.48±6.1 years) (Group II). All the subjects were informed of the purpose of the study and gave their consent.

Dual-energy X-Ray absorptiometry (Norland EXCELL, USA) was used to assess BMD. Left hip and posterior-anterior lumbar spine (L2-L3-L4) scans were performed with the patient lying supine on the imaging table using the protocols recommended by the manufacturer. The measurement results were expressed in absolute values, as T score (the difference in standard deviation (SD) with respect to the peak bone mass in a young adult of the same race and sex) and Z score (the difference in SD with respect to that found for healthy age matched controls of the same race and sex). Osteoporosis was defined according to the conventional World Health Organization (WHO) definition. The BMD results of lumbar 3 (L3) vertebra of all participants were also recorded.

Quantitative Magnetic Resonance (QMR) measurement

In our study, we used MR relaxometry technique, in which trabecular bone structure was evaluated indirectly via measuring MR relaxation time of the neighboring bone marrow. MR studies were done using 1.5 Tesla device with active magnet, 30 mT/m gradient (Magnetom Symphony Maestro, Siemens, Erlangen, Germany). Before the MRI examinations each patient was informed about the procedure, interrogated about the contraindications of MRI (pacemaker, aneurysm clips, pheromagnetic prosthesis) and screened with a metal detector. Vertebrae examinations were done using an original Phased Array (PA) spinal coil and calcaneus examinations were done using a special circular polarized extremity coil. Measurements of both regions were done in the same session separately. The parameters are shown in Table 1.

The total duration of the examination was approximately 20 minutes for each patient. After the examination, images were transferred to the computer in the work station and evaluated by using post-examination processes. T1 weighted images of the vertebral column and calcaneus were taken to evaluate the anatomical structures for additional pathological findings (compression fracture, neoplastic lesions, etc). Images in the work station were processed by a special software programme (Leonard, Siemens AG, Erlangen-Germany) to measure T2 RT. In the work station; T2 map series, which were obtained from the images after analyzing the T2 RT measurements were recorded and measurements were performed. For this purpose in each case a transverse section from the central portion of the vertebral corpus of L3 and a sagittal section from central portion of calcaneal corpus were taken. A circular region of interest (ROI) was used, excluding the cortical bone and using the pixels in this region T2 RT was obtained (Figures 1 and 2).

Table 1. MRI parameters.

Sequence	Plane	TR (mSec)	TE (mSec)	FA degree	Crosscut thickness (mm)	Crosscut range (mm)	FOV (mm)	ACQ	Time
Vertebrae									
Scout	multi	24	6	30	10	3	480	1	26 sec
HR T1.TSE	right sagittal	1200	15	150	2	0.2	200	4	5.34 min
T2-T2. GRE	right sagittal	2500	15/73	150	5.1	0.5	250	4	3.38 min
Calcaneus									
Scout	multi	24	6	30	5	5	200	1	26 sec
HR GRE T1	right sagittal	220	8.5	60	3	0.6	180	2	3.54 min
T2-T2 GRE	right sagittal	2500	15/73	150	5.1	0.5	250	2	3.53 min

HR: High resolution, FOV: Field of view, TE: Time-to-echo, T1 TSE: T1 turbo spin echo, ACQ: Acqusition, TR: Time-to-repetition, T2-T2 GRE: T2 gradient recalled echo, FA: Flip Angle

Statistical Analyses

Results were expressed as mean value±SD. All data were evaluated for normal distribution with Kolmogorov Smirnov test. Comparisons of patient and control group values were made by Student-t test and Mann-Whitney-U test where appropriate. Relationship among variables was assessed by Spearman's test. P values less than 0.05 were considered statistically significant.

Results

Demographic characteristics of the study group are described in Table 2. Mean lumbar T and Z scores of the osteoporotic group were significantly lower than the control group (p<0.001). L3 vertebra T2 RT of the osteoporotic women and healthy controls were 315.31±98.27, 152.72±44.84, whereas calcaneal T2 RT of the osteoporotic women and healthy controls were 312.35±91.90, 107.72±24.50, respectively. T2 RT values of L3 vertebra and calcaneus were found to be significantly higher in the osteoporotic group (p<0.001). The DXA and MR T2 RT measurements for postmenopausal women with osteoporotic and healthy controls are given in Table 3.

There was a positive correlation between L3 vertebra T2 RT and calcaneal T2 RT (r=0.87, p=0.001). We found a negative correlation between L3 vertebra BMD and L3 vertebra T2 RT (r=-0.70, p=0.001). There was also a negative correlation between L3 vertebra BMD and calcaneal T2 RT (r=-0.78, p=0.001) (Table 4).

Discussion

Because of its complex physiopathology, osteoporosis is a clinical entity that still needs an acceptable, objective method for its definition, therapy and follow-up. Currently diagnostic assess-

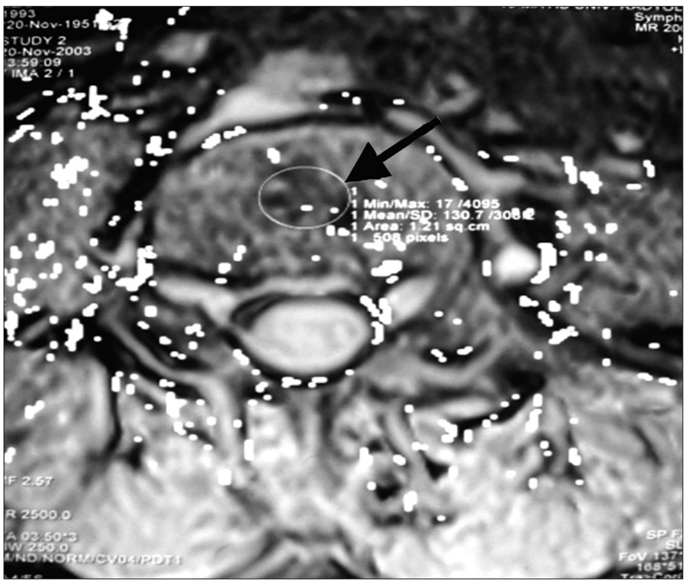

Figure 1. T2 RT map image: Lumbar vertebra T2 RT measurement area.

Figure 2. T2 RT map image: Calcaneus T2 RT measurement area.

Table 2. Demographic characteristics of the study group.

	Group I (n=31)	Group II (n=31)	P
Age (age range) (years)	56.68±6.60 (45-72)	54.48±6.10 (48-70)	>0.05
Height (cm)	156±5.39	156.84±16.11	>0.05
Weight (kg)	66.35±8.65	80.84±19.22	<0.001
BMI (kg/m^2)	27.03±3.10	30.81±5.00	<0.001
Age of menarche (years)	13.68±1.51	13.48±1.31	>0.05
Age of menopause (years)	42.81±4.56	46.00±4.14	<0.01
Years since menopause	13.93±8.26	8.43±7.85	<0.01

Table 3. BMD and T2 RT values of study group.

	Group I (n=31)	Group II (n=31)	P
Lumbar T score	-3.40±0.50	0.26±0.08	<0.001
Femur T score	-1.63±0.61	-0.52±0.69	<0.001
L3 vertebra BMD (g/cm^2)	0.71±0.05	1.13±0.12	<0.001
L3 vertebra T2 RT (msec)	315.31±98.27	152.72±44.84	<0.001
Calcaneus T2 RT (msec)	312.35±91.90	107.72±24.50	<0.001

BMD: Bone mineral density, T2 RT: T2 relaxation time ment includes patient's history, laboratory testings and BMD measurements. Hereby, DXA is regarded as the gold standard. Currently with the new bone quality concept in full bloom techniques to quantify trabecular bone architecture as new surrogates of bone strength are of increasing significance. Spatial high-resolution techniques such as MRI and new CT techniques have shown their potential in assessing trabecular bone structure (7).

The shortening of MR T2 RT of bone marrow and loss of signal intensity due to this shortening is directly proportional to the trabecular bone density and structure (6,8-10). Link et al. (3) have differentiated osteoporotic patients (patients with osteoporotic hip fracture) from healthy premenopausal and postmenopausal controls by using T2 RT measurements of proximal femur. Similarly, Guglielmi et al. (11), Wherli et al. (12) and Funke et al. (13) have found prolonged T2 RT values in lumbar vertebrae examinations in osteoporotic patients. We found also prolonged T2 RT values in lumbar vertebra and calcaneus when we compared osteoporotic women with healthy controls. The results of the present study indicate that T2 RT measurements of L3 vertebra and calcaneus may be used to differentiate osteoporotic and healthy postmenopausal women. The relationship between BMD and QMRI has been reported previously (9,10,14,15). We also found significant correlations between BMD and T2 RT of the L3 vertebra. Calcaneus was chosen as a second measurement site to ensure the measurement procedure and to confirm the results. A significant correlation was also determined between lumbar and calcaneal T2 RT values.

Due to the high cost of MRI and the limited number of the qualified MRI technicians, T2 RT measurements could be performed for only one lumbar vertebra. This is the limitation of our study. There are also some limitations of MRI technique. In the definition of osteoporosis, BMD values and presence of fractures are the main issues. Mean BMD values of young healthy individuals obtained from large population studies are used to define the terms, osteopenia and osteoporosis. There are no such established cut-off values to define osteopenia and osteoporosis by MRI. For this reason currently MRI can not be used for diagnosis and follow-up of osteoporosis. Large population studies are required to establish the use of MRI in this field. Furthermore the contraindications of MRI (presence of metal implants, pacemakers, claustrophobia and morbid obesity) are the other disadvantages of this technique.

Further clinical studies are required to investigate the usage of MRI in osteoporosis and to assess the reproducibility, inter and intraobserver correspondence of the measurement procedure. For assessment of the efficacy of the treatment modalities in osteoporosis a close follow-up is required. The measurement method should be reliable, safe and its reproducibility should be high. With its 3D, non-invasive, non-ionizing properties MRI has the potential to take an important part in assessment of osteoporosis in the near future, but currently MRI can be used to assess the osteoporosis in only selected patients and to endorse the DXA results.

Table 4. Correlation between DXA and QMR measurements.

Spearman	L3 vertebra	L3 vertebra	Calcaneus
n= 62 r p	BMD	T2 RT	T2 RT
L3 vertebra BMD	1.000		
L3 vertebra T2 RT	-0.700 0.001	1.000 -	
Calcaneus T2 RT	-0.786 0.001	0.873 0.001	1.000

p<0.05 significant
BMD: Bone mineral density, T2 RT: T2 relaxation time

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