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Research Article

Can lumbar magnetic resonance imaging be used to predict osteoporosis in men?

Lomber manyetik rezonans görüntüleme erkeklerde osteoporozu tahmin etmek için kullanılabilir mi?

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Abstract

Aim: This study aims to compare the findings of Dual Energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI) in male patients and investigate MRI's effectiveness in diagnosing osteoporosis

Material and Methods: This prospective, controlled study included 26 men diagnosed with osteoporosis by DXA and 26 men without osteoporosis, all of whom underwent lumbar MRI, with sagittal T1-weighted images (T1WI). A novel quantitative approach utilizing T1WI images for signal-to-noise ratio (SNR) measurements of lumbar vertebrae 1–4 (L1–L4) and M-scores derived from these SNR values has been calculated and the relationship with DXA T scores was investigated.

Results: In men with osteoporosis, the average vertebra SNR values were found as follows: L1 vertebra 78.30 (18.16-185.98), L2 vertebra 77.47 (16.64-152.12), L3 vertebra 65.15 (16.34-151.72), L4 vertebra 63.53 (15.02-151.52), and the average of L1-L4 vertebrae was 72.54 (16.49-161.24). Compared to the control group, all values were statistically significant. The M value was measured as 1.66 (0.98-5.86) in men with osteoporosis, while it was 0.77 (0.88-1.06) in the control group ($p = 0.018$). In male patients with osteoporosis, the M score was found to be negatively correlated with the DXA values of the L1-L4 lumbar vertebrae ($r = -0.408$, $p = 0.029$). The optimal cutoff value for the M score was 0.38, which yielded a sensitivity of 69.2% and a specificity of 73.1%.

Conclusion: The M score can be used as a screening method for osteoporosis in male patients for early diagnosis and treatment of high-risk patients before serious complications develop without additional radiation.

Keywords: magnetic resonance imaging, dual energy X-ray absorptiometry, osteoporosis, men

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Öz

Amaç: Bu çalışmanın amacı, erkek hastalarda Dual Energy X-ray absorpsiyometrisi (DXA) ve manyetik rezonans görüntüleme (MRI) bulgularını karşılaştırmak ve osteoporozu teşhis etmede MRI'nin etkinliğini araştırmaktır

Gereç ve Yöntemler: Bu prospektif, kontrollü çalışmaya DXA ile osteoporoz tanısı konmuş 26 erkek ve osteoporozu olmayan 26 erkek dahil edildi; hepsinin lomber MRI ile sagital T1 ağırlıklı görüntüleri (T1WI) incelendi. Lomber vertebra 1–4'ün (L1–L4) sinyal-gürültü oranı (SNR) ölçümleri ve bu SNR değerlerinden türetilen M-skorları için T1WI görüntülerini kullanan yeni bir kantitatif yaklaşım hesaplandı ve DXA T skorlarıyla ilişkisi araştırıldı.

Bulgular: Osteoporozlu erkeklerde ortalama vertebra SNR değerleri şu şekilde bulundu: L1 vertebra 78.30 (18.16-185.98), L2 vertebra 77.47 (16.64-152.12), L3 vertebra 65.15 (16.34-151.72), L4 vertebra 63.53 (15.02-151.52), L1-L4 vertebra ortalaması ise 72.54 (16.49-161.24). Kontrol grubuyla karşılaştırıldığında tüm değerler istatistiksel olarak anlamlıydı. Osteoporozlu erkeklerde M değeri 1.66 (0.98-5.86) olarak ölçülürken, kontrol grubunda 0.77 (0.88-1.06) olarak bulundu ($p = 0.018$). Osteoporozlu erkek hastalarda M skorunun L1-L4 lomber vertebraların DXA değerleriyle negatif korelasyon gösterdiği bulundu ($r = -0,408$, $p = 0,029$). M skoru için optimal kesim değeri 0,38 iken bu değer ile duyarlılık %69,2 ve özgüllük %73,1 olarak saptandı.

Sonuç: M skoru, ek radyasyona gerek kalmadan ciddi komplikasyonlar gelişmeden önce yüksek riskli hastaların erken tanısı ve tedavisi için erkek hastalarda osteoporoz için bir tarama yöntemi olarak kullanılabilir.

Anahtar kelimeler: manyetik rezonans görüntüleme, dual energy X-ray absorpsiyometri, osteoporoz, erkekler

Introduction

Osteoporosis is a chronic and progressive disease that impacts the skeletal system as a whole. It is characterized by a decline in bone density and deterioration of bone microarchitecture, leading to an increased risk of fractures [1]. The International Osteoporosis Foundation reports that nearly one-third of women and one-fifth of men aged 50 and above are expected to experience an osteoporotic fracture at some point in their lives [2]. Dual Energy X-ray absorptiometry (DXA) is routinely and widely used for diagnosing osteoporosis and assessing fracture risk by measuring bone mass and density [3]. Nonetheless, it is widely recognized that DXA has significant limitations that may hinder accurate osteoporosis detection, and relying solely on the DXA-based T-score the diagnostic criterion for osteoporosis is insufficient for identifying patients at high risk of fractures. Therefore, other techniques, such as quantitative computed tomography (QCT) and magnetic resonance imaging (MRI), have gained growing attention in recent years for imaging-based studies of etiology, treatment strategies, and fracture risk assessment [4,5].

Unlike DXA, MRI enables the assessment of the different components of bone marrow. The primary factors influencing the magnetic resonance (MR) imaging characteristics of bone marrow are its fat and water composition. MRI T1-weighted images (T1WI) are ideal for assessing the cellular content of bone marrow, as they effectively differentiate between fat, water, and the cellular matrix [6]. In osteoporotic patients, a decline in bone density is accompanied by an increase in fat content within the vertebral bone marrow [7]. Studies indicate that osteoporotic individuals exhibit notably higher levels of bone marrow fat, with an inverse correlation between bone mineral density and fat accumulation in the vertebrae [8,9]. Those with elevated bone marrow fat percentages are at a greater risk of fractures [10]. T1-weighted imaging (T1WI) allows for the quantitative assessment of fat tissue volume and is the most sensitive sequence for evaluating cellularity and fat content in bone marrow [11,12]. Research has demonstrated an inverse relationship between bone mineral density (BMD) and bone marrow adiposity in healthy middle-aged individuals, as observed through T1WI [13]. While a correlation exists between fat tissue detected on T1WI and BMD obtained via DXA, T1WI lacks standardized quantitative scoring, limiting its utility for osteoporosis screening [14]. However, emerging quantitative methods employing T1WI-based signal-to-noise ratio (SNR) measurements and M-scores show promise in enhancing osteoporosis detection [14].

To the best of our knowledge, there is no study in our country investigating MRI and DXA values in male patients with osteoporosis. Osteoporosis is often asymptomatic and usually only presents with fractures, DXA is not ordered in patients which is why it is frequently missed in many male patients. This way, a lumbar MRI performed for back pain can diagnose

osteoporosis, allowing for earlier treatment and preventing complications. We propose that lumbar MRI can detect osteoporosis in men, leading to early diagnosis.

This study aims to compare the findings of DXA and MRI in male patients and investigate MRI's effectiveness in diagnosing osteoporosis.

Material and Methods

This is a cross-sectional, controlled study that included 26 men diagnosed with osteoporosis and 26 men without osteoporosis, between January 2024 and January 2025, all of whom underwent lumbar MRI within the last six months, with sagittal T1-weighted images of adequate quality. Exclusion criteria included lumbar spinal MRIs older than six months; evidence of trauma, fractures, cysts, masses, or metastases on lumbar MRIs; metal prostheses interfering with DXA imaging; known or suspected demyelinating diseases, rheumatic disorders, or oncologic conditions; and the use of drugs that contribute to bone mineral density loss, such as corticosteroids, chemotherapeutics, or antiepileptics. Participants' demographic and clinical data were recorded. Their fracture history and medication use were recorded, and fracture risk was assessed using the Fracture Risk Assessment Tool (FRAX) [15]. All participants were informed about the study in advance, and their written consent was obtained. The research was carried out in accordance with the principles of the Declaration of Helsinki and received approval from the university's ethics committee (2023-171).

Bone mineral density assessment

BMD measurements were performed using a DXA device. DXA is the gold standard for diagnosing osteoporosis and is routinely used. The patients were scanned in a supine position using the Horizon bone densitometry system (MAN-04871). L1-L4 vertebrae (lumber total), right femoral neck, and femoral total were scanned. T-scores were recorded. According to WHO diagnostic criteria for osteoporosis, patients were divided into two groups based on their DXA results: the control group (T-score > -1), and the osteoporosis group (T-score ≤ -2.5) [16].

MRI protocols

All images were reviewed by the same radiologist with five years of expertise in spine imaging. Lumbar MRI images (TR = 600 ms; TE = 11 ms; 1.5 Tesla) taken within the last six months will measure sagittal T1WI of L1-L4 vertebral bodies (Signa; 16 channel, Excite, GE Healthcare, Milwaukee). The signal values will be calculated by placing the Region of Interest (ROI) outside the cortical bone, subchondral anomaly, and posterior venous plexus. SNR will be calculated by dividing the signal value by the noise value measured from the same ROI width outside the imaging area (Figure 1). Using the SNR values from patient and control groups, the M-score will be calculated [14] as follows: M-score = [SNR (L1–L4) –SNR (Ref)] /SD (Ref)

This method allows for the standardization of SNR values across subjects by comparing patient data to the reference distribution obtained from controls. The reference values (SNR (Ref) and SD (Ref)) were derived from the healthy control group included in this study. The SNR values of L1, L2, L3, L4, and their averages were compared between the two groups. Additionally, T-scores and M-scores were compared.

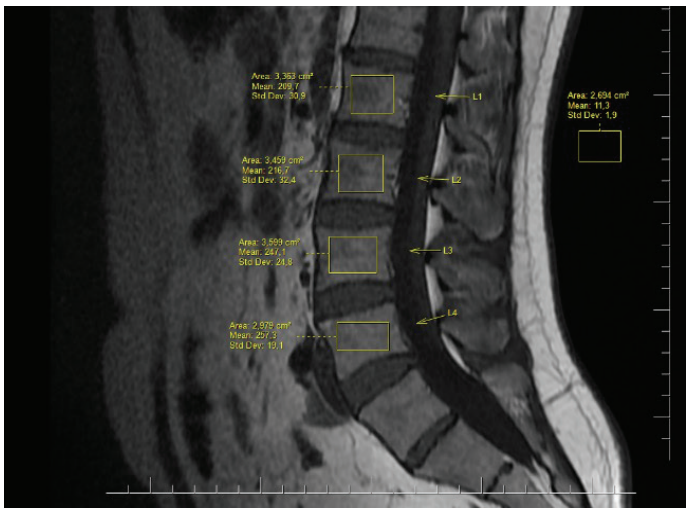

Figure 1. The figure displays a sagittal T1-weighted MRI of the lumbar spine. Signal intensity was obtained from manually drawn ROIs over L1 to L4, and noise was measured using an ROI positioned outside the patient's body.

Statistical Analyses

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), version 15.0. The normality of variables was evaluated through visual methods (histograms and probability plots) and analytical methods (Kolmogorov-Smirnov test). Continuous variables are presented as mean ± standard deviation (SD) and median (25th–75th percentiles), while categorical variables are expressed as frequencies and percentages. The independent sample t-test was used to compare normally distributed numerical variables between groups, while the Mann-Whitney U test was employed for non-normally distributed data. Nominal variables were analyzed using the Chi-Square test. Spearman's correlation coefficient was utilized to examine the linear relationships among predictive variables. Receiver

operating characteristic (ROC) analysis was performed to assess the diagnostic capability of signal-to-noise ratio (SNR) at L1–L4, with lumbar vertebral DXA serving as the reference standard. The relationship between the M-score, T-score, and bone mineral density (BMD) was also analyzed using Spearman's correlation. The L1–L4 T-score was used as the reference for determining the diagnostic accuracy of the M-score through ROC analysis. A p-value below 0.05 was considered indicative of statistical significance.

Results

There were no differences between the groups in terms of age, height, weight, and BMI (Table 1). Among the patients with osteoporosis, 50% smoked and 26.9% consumed alcohol, whereas in the control group, 23.1% smoked and 19.2% consumed alcohol; the difference was not statistically significant.

Table 1. Characteristics of the groups.

	Patient group n=26	Control group n=26	P value
Age (years)	67 (53-73.25)	62.5 (51-76)	0.942
Height (cm)	165.12±6.41	166.85±7.46	0.374
Weight (kg)	70.58±9.36	75.15±8.1	0.066
Body Mass Index (cm2/kg)	25.89±3.12	27.02±2.7	0.171
Smoking	13(50%)	6 (23.1%)	0.083
Alcohol Use	7 (26.9%)	5 (19.2%)	0.743
Lomber L1-L4 T Score	-3 (-3.42—2.7)	0.1 (-0.95-0.82)	<0.001
Femoral Neck T Score	-2.55 (-2.62—2.5)	0.3 (-0.72-0.7)	<0.001
FRAX Major	7 (4.95-9.3)	2.85 (2.2-3.4)	<0.001
FRAX Hip	2.8 (1.7-6)	0.5 (0.2-0.8)	<0.001

Fracture Risk Assessment Tool (FRAX), L1-L4 (Lomber vertebrae), p-value of less than 0.05 was considered statistically significant.

In men with osteoporosis, the average vertebra SNR values were found as follows: L1 vertebra 78.30 (18.16-185.98), L2 vertebra 77.47 (16.64-152.12), L3 vertebra 65.15 (16.34-151.72), L4 vertebra 63.53 (15.02-151.52), and the average of L1-L4 vertebrae was 72.54 (16.49-161.24). Compared to the control group, all values were found to be statistically significant (Table 2). In the control group, the average SNR values were as follows: L1 vertebra 22.39 (15.94-58.79), L2 vertebra 21.73 (15.65-57.58), L3 vertebra 20.27 (14.40-55.64), L4 vertebra 20.06 (11.94-51.88), and the average of L1-L4 vertebrae was 21.11 (14.87-56.05). The M value was measured as 1.66 (0.98-5.86) in men with osteoporosis, while it was 0.77 (0.88-1.06) in the control group (p = 0.018). In male patients with osteoporosis, the M score was found to be negatively correlated with the DXA values of the L1-L4 lumbar vertebrae (r = -0.408, p = 0,029).

Table 2. MRI findings of the groups.

	Patient group n=26	Control group n=26	P value
SNR1	78.30 (18.16-185.98)	22.39 (15.94-58.79)	0.025
SNR2	77.47 (16.64-152.12)	21.73 (15.65 -57.58)	0.021
SNR3	65.15 (16.34-151.72)	20.27 (14.40-55.64)	0.023
SNR4	63.53 (15.02-151.52)	20.06 (11.94-51.88)	0.006
SNR1-4	72.54 (16.49-161.24)	21.11 (14.87-56.05)	0.018
M score	1.66 (0.98-5.86)	0.77 (0.88-1.06)	0.018

SNR: signal to noise ratio), p-value of less than 0.05 was considered statistically significant.

To determine the predictive value for distinguishing individuals with osteoporosis (OP) from those in the control group, a ROC analysis was conducted (Figure 2). The analysis revealed the optimal predictive values as follows: 29.20 for the SNR L1-L4 average and 0,38 for the M score average. The sensitivity and descriptive ratios for these predictive values of the M score were presented in Table 3.

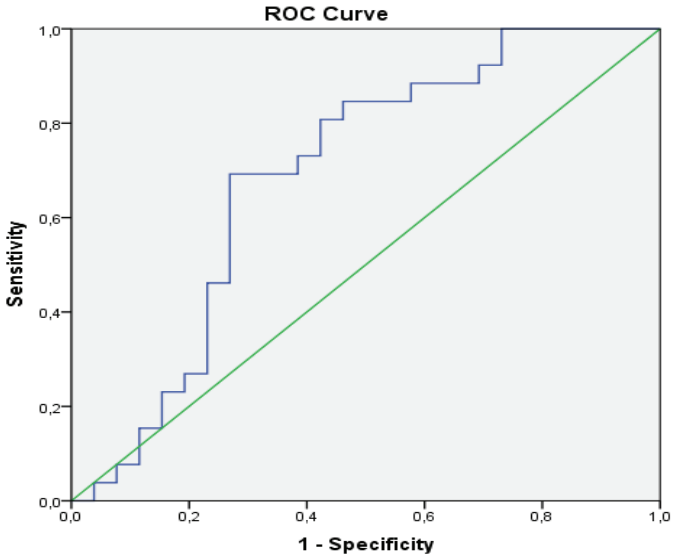

Figure 2. Receiver operator characteristic curve of M-score.

Table 3. Diagnostic performance of M-score in the groups.

	M score
AUC with 95%CI	0.691 (0.54-0.84)
Cuttoff point	0.38
Sensitivity	%69.2
Specificity	%73.1
p value	0.018

AUC=area under the curve; p-value of less than 0.05 was considered statistically significant.

Discussion

In the study, SNR and M scores were effective in detecting osteoporosis and were negatively correlated with lumbar vertebra T-scores obtained from DXA. We found that the

optimal predictive values were 29.20 for the SNR L1-L4 average and 0.38 for the M score average respectively. In the study, the M score had a sensitivity of 69.2% and a specificity of 73.1%.

Although postmenopausal women are routinely screened for osteoporosis, the prevalence of osteopenia in men is 38%, and the prevalence of osteoporosis is 4%, yet male osteoporosis is often underestimated and underdiagnosed in outpatient settings [17,18]. Upon reviewing the literature, the majority of studies focus on female osteoporosis. While DXA remains the most commonly used method for diagnosing osteoporosis, factors such as degenerative changes in the spine, osteophyte formation, and aortic calcification can affect measurement accuracy [19]. On the other hand, lumbar MRI is frequently requested in cases of low back pain or before surgery. If these MRI scans were also evaluated for osteoporosis, many asymptomatic male patients could be diagnosed, allowing for early intervention before serious osteoporotic complications, such as fractures, occur. Despite men having a lower lifetime risk of osteoporotic fractures compared to women, the mortality risk is higher when fractures do occur [20]. To this end, a practical measurement method that can be easily performed by a radiologist using MRI is needed. Bandirali et al proposed a new diagnostic score called the M score for use in MRI [14], and their study found a negative correlation between the SNR and M score with lumbar DXA. They also demonstrated that in patients with degenerative changes and obesity, the sensitivity of MRI was greater than that of DXA. On the other hand, although Atik et al. found an inverse relationship between the M score and the T score, the result was not statistically significant [21]. In the study conducted by Cho et al patients were divided into three groups: healthy, osteopenic, and osteoporotic, and the SNR values were found to differ among the three groups [22]. Düzkalır et al. found a weak negative correlation between the M and T scores [23]. In our study, we found a statistically significant negative correlation between the SNR and M score with lumbar DXA but we have two groups and we did not assess osteopenic patients. The discrepancies in these studies may be due to the use of different types of MRI and the inability to employ certain statistical analysis methods because of the small sample sizes.

Another study conducted on 56 healthy women demonstrated a strong inverse relationship between DXA measurements and bone marrow adipose tissue [8], and in our study, a similar correlation was observed. Kadri et al [24] measured vertebral bone quality and SNR in patients scheduled for lumbar surgery, and their results showed that SNR was effective, consistent with our findings. In a previous study, the sensitivity of the M score was 54%, while another study conducted on postmenopausal women with osteoporosis found the sensitivity and specificity of SNR to be 90% [14]. In another study by Saad et al. [25], conducted on 50 postmenopausal patients, the sensitivity was reported as 83%. In our study, the sensitivity of the M score was found to be 69.2%. This discrepancy could be attributed to differences in the sample group, sample size, patient age, and gender. We selected a control group similar in terms of age and BMI, whereas previous studies compared women over 50 with a control group aged 20–29. Understanding the normal maturation process of bone marrow with age is crucial for detecting abnormalities through imaging [11]. While women have more hematopoietic marrow in early adulthood, there is a decline in the water-fat fraction after age 60, which is more pronounced in men; this decline occurs within the first 25 years in men [26]. This may explain why results can vary between male and female patients, even when the same methods are used. While women are routinely screened for osteoporosis in the postmenopausal period, screening in men may be neglected as osteoporosis progresses silently unless there is a fracture. Therefore, male patients may present with direct fractures. We think that lumbar MR imaging is valuable for the early detection of osteoporosis and prevention of fractures in men. This study is extremely important in terms of emphasizing the importance of MR imaging in the prevention of male osteoporosis and contributing to future studies and clinical follow-up of clinicians. The routine use of M score in MR imaging will play an important role in the early detection and treatment of male osteoporosis.

Limitations of the study

Since we only included male patients over the age of 50, our findings cannot be generalized. We did not separately assess the osteopenia group, and we did not acquire MRI and DXA images simultaneously.

In conclusion, based on the results of this study, we believe that lumbar MRI can be used as a screening method for osteoporosis in male patients without exposing them to additional radiation, incurring extra diagnostic costs, or requiring additional time. This would enable early diagnosis and treatment of high-risk patients before serious complications develop.

Institutional Review Board Statement

This study was reviewed and approved by The Human Institutional Ethics Committee of the Hitit University (14.12.2023 number 2023-171).

Conflicts of Interest

The authors declare no conflicts of interest.

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Author Contributions

Conceptualization, P.Ö.B.; data curation, P.Ö.B., M.B.; formal analysis, M.B.; investigation, P.Ö.B.; methodology, P.Ö.B; project administration, P.Ö.B; resources, P.Ö.B.; software, P.Ö.B.; supervision, P.Ö.B; validation, P.Ö.B.; writing—original draft, P.Ö.B.; writing—review and editing, M.B. All authors have read and agreed to the published version of the manuscript.

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