



## Contribution of Lumbar Vertebral Magnetic Resonance Imaging to Diagnosis in Women with Osteoporosis

Osteoporozlu Kadınlarda Lomber Spinal Manyetik Rezonans Görüntülemenin Tanıya Katkısının Değerlendirilmesi

İrfan Atik, Seda Atik\*, Enes Gül\*\*, Sema Bulut\*\*\*

Cizre State Hospital, Clinic of Radiology, Şırnak, Turkey

\*Cizre State Hospital, Clinic of Physical Medicine and Rehabilitation, Şırnak, Turkey

\*\*Niksar State Hospital, Clinic of Radiology, Tokat, Turkey

\*\*\*Sivas Cumhuriyet University Faculty of Medicine, Department of Radiology, Sivas, Turkey

### Abstract

**Objective:** The aims of this study are to compare bone mineral densitometry and magnetic resonance imaging (MRI) findings in postmenopausal women diagnosed with osteoporosis and the investigation of the effectiveness of MRI in the diagnosis of osteoporosis.

**Materials and Methods:** Forty female patients, 50 years of age or older who underwent lumbar MRI examination and were diagnosed with dual-energy X-ray absorptiometry (DEXA) osteoporosis were included in our study. Forty healthy women aged 20-29 years with lumbar MRI examinations were included in the control group. On sagittal T1-weighted (T1W) images of individuals in the patient and control groups signal-to-noise ratio (SNR) was measured from L1-L4 vertebrae. To facilitate the diagnosis of osteoporosis, a quantitative score called the M-score was obtained using SNR values. The relationship between DEXA and the obtained SNR and M-score values were investigated.

**Results:** In the patient group, median SNR values of L1, L2, L3, L4 vertebrae obtained from T1-weighted sequence was 57.49 (25.18-182.48), and they were 24.90 (7.40-41.70) in the control group. Receiver operating characteristics analysis was performed for L1, L2, L3, L4 vertebrae. The area under the curve for the mean value of L1-L4 vertebra was found to be 0.966 ( $p<0.001$ ), and the 95% confidence interval was found 0.933-1.000. The mean SNR predictive value of L1-L4 was calculated as 33.45, and sensitivity for this value was found to be 90%, and specificity was found to be 90%. There was a negative correlation between lumbar MRI SNR-DEXA ( $p>0.05$ ) and M score-DEXA ( $p>0.05$ ).

**Conclusion:** It has been concluded that L1-L4 vertebral SNR measurement in T1-weighted sequence in lumbar MRI can be used to distinguish osteoporosis patients from normal individuals. Thus, osteoporosis can be diagnosed without X-ray exposure.

**Keywords:** Magnetic resonance imaging, osteoporosis, M-score

### Öz

**Amaç:** Bu çalışmanın amacı osteoporoz tanılı postmenopozal kadınlarda kemik mineral dansitometri ve manyetik rezonans görüntüleme (MRG) bulgularının karşılaştırılması ve osteoporoz tanısında MRG'nin etkinliğinin araştırılmasıdır.

**Gereç ve Yöntem:** Çalışmamıza 6 ay içerisinde lomber MRG incelemesi yapılan ve dual-enerji X-ışını absorpsiyometri (DEXA) ile osteoporoz tanısı almış 50 yaş ve üstü 40 kadın hasta dahil edildi. Kontrol grubunda lomber MRG incelemesi bulunan 20-29 yaşlarında 40 sağlıklı kadın incelendi. Hasta ve kontrol grubundaki bireylerin sagittal T1 ağırlıklı görüntülerinde L1-L4 vertebralardan sinyal gürültü oranı (SNR) ölçümü yapıldı. Osteoporoz tanısında kolaylık sağlaması için SNR değerleri kullanılarak M-skoru adında kantitatif bir skor elde edildi. Elde edilen SNR ve M-skoru değerleri ile DEXA arasındaki ilişki araştırıldı.

**Bulgular:** L1, L2, L3, L4 vertebralalarının T1 ağırlıklı sekanstan elde edilen SNR ortanca değerleri hasta grubunda 57,49 (25,18-182,48), kontrol grubunda 24,90 (7,40-41,70) idi. L1, L2, L3, L4 vertebralalarının alıcı işletim karakteristiği analizi yapıldı. L1-L4 vertebra ortalama değeri için eğri altında kalan alan 0,966 ( $p<0,001$ ), %95 güven aralığı 0,933-1,000 bulundu. L1-L4 ortalama SNR kestirim değeri 33,45 olarak hesaplanmış olup bu değer için duyarlılık %90, özgünlük %90 olarak bulundu. Lomber MRG SNR-DEXA ( $p>0,05$ ) ile M-skoru-DEXA arasında negatif yönlü bir ilişki saptandı ( $p>0,05$ ).

**Sonuç:** Lomber MRG'de T1 ağırlıklı sekansta L1-L4 vertebra SNR ölçümünün osteoporozlu hastaları normal bireylerden ayırt etmede kullanılabileceği sonucuna varılmıştır. Böylece osteoporoz, röntgen ışınlarına maruz kalmadan teşhis edilebilir.

**Anahtar kelimeler:** Manyetik rezonans görüntüleme, osteoporoz, M-skoru

## Introduction

Osteoporosis (OP) is a chronic, degenerative, systemic skeletal disease that, as a result of a decrease in bone mass and deterioration in its microarchitecture, predisposes to fracture (1). Bone fractures caused by OP are an important cause of morbidity and mortality. The disease is characterized by low mineral density without fractures in the preclinical period (2).

Dual-energy X-ray absorptiometry (DEXA) and quantitative computed tomography are used routinely and widely in the diagnosis of OP and evaluation of fracture risk. Thanks to these methods, bone mass and density can be determined. However, with the studies conducted, it has been shown that bone mass and density alone are not important in determining bone strength, but also bone structural changes should be evaluated (2).

Since OP is an asymptomatic disease, although bone mineral density testing is required, many patients do not receive DEXA and cannot be diagnosed. However, many magnetic resonance imaging (MRIs) are performed due to the complications that are caused by low back pain and OP (3).

As the bone density decreases, the fat content in the vertebral bone marrow is observed to increase in osteoporotic patients (4). With studies, it has been shown that bone marrow adipose tissue is significantly higher in osteoporotic patients and there is an inverse relationship between bone mineral density and adipose tissue in the vertebral bone marrow (5,6). In addition, the risk of fracture was higher in patients with high bone marrow fat content (7).

With MR standard T1W images, the measurement of adipose tissue volume is quantitatively confirmed. In the determination of cellularity and adipose tissue in bone marrow, MR standard T1W images are the most sensitive sequence (8,9). There is an inverse relationship observed between bone marrow adipose tissue and bone mineral density in T1W images in healthy middle-aged men and women (10). T1W images cannot be used for scanning in OP patients due to the lack of quantitative score, even though there is a correlation between fat tissue that can be evaluated in T1W images in MRI and bone mineral density measured by the DEXA method (3). L1-L4 vertebra signal-to-noise ratio (SNR) measurement and M-score can be calculated from the MRI T1A sequence, and thus a new quantitative method can be applied to detect OP (11).

The objective of this study is to compare DEXA and no exposure to X-ray to perform quantitative MRI findings in postmenopausal women diagnosed with OP and to study the effectiveness of MRI in the OP diagnosis.

## Materials and Methods

### Study Group

The present study is retrospective and its permission was obtained from Sivas Cumhuriyet University Non-Invasive Clinical Research Ethics Committee on 11.09.2019 (decision no: 2019-09/03).

In our study, postmenopausal female patients over the age of 50 who underwent lumbar MRI between November 2013 and September 2019 in our hospital with a T-score of  $-2.5$  and below in DEXA were included. The patients who have oncologic pathologies, demyelinating diseases, metal prosthesis, traumas, inadequate quality sagittal T1W images and those with a duration of more than 6 months between DEXA and Lumbar spinal MRI examinations were excluded from the study. The study group consisted of 40 postmenopausal women who met the criteria.

In order to calculate the M-score similar to the T-score measured in DEXA, 40 healthy women aged 20-29 years, who underwent lumbar spinal MRI between August 2018 and February 2019 due to low back pain, were included in the study as a control group. The exclusion criteria are the same as those for the study group.

### Analysis of MR Images

All MR images were obtained with a 1.5T MRI device (Siemens, Magnetom Aera, Germany). All views include sagittal T1 fast spine echo (TR: 540, TE: 9.7, averages 2, slice thickness 4 mm, slice range 0.8 mm, FOV: 260x100, matrix: 320x72 mm).

Signal measurement was performed by placing it in the largest region of interest (ROI) from the sagittal T1W images from the L1-L4 vertebral corpuses, cortical bone, subchondral anomaly, to the area other than the posterior venous plexus (3,11). Each vertebral body was measured in 3 separate sections and with the same ROI width, and the mean value was used in our study. The noise value was measured from the outside of the image area with the same ROI size (Figure 1). SNR calculations were done by the averaged signal measured from 3 different sections for each vertebra and divided into noise.

### DEXA Analysis

Results were obtained by automatically using the DEXA device (QDR 4500 W) in the supine position. Lumbar bone mineral densities were measured from L1-L4 vertebrae. T-score was calculated by using bone mineral densitometry (BMD). According to the criteria of the World Health Organization, if the T-score is  $\geq -1$ , it means there is no OP. T-score between  $-1$  and  $-2.5$  was evaluated as osteopenia, and T-scores as  $\leq -2.5$  was evaluated as OP. Our study group consisted of only those with a T-score of  $-2.5$  and below (12).

### Statistical Analysis

In our study, SPSS 22.0 software was used for statistical analysis. Comparison of SNR values obtained from L1, L2, L3, L4 vertebral bodies in Lumbar MRI of individuals in patient and control groups was made and analysis was performed with graphics. To find a predictive value in distinguishing individuals with OP from normal individuals in the control group, receiver operating characteristics (ROC) analysis was performed. The best predictive values for L1, L2, L3, L4, L1-L4 mean SNR levels, and diagnostic performance indicators were calculated.

For the diagnosis of OP, there is a score obtained from MR images called the M-score. It is similar to the T-score in DEXA. T-score for a patient is found by the ratio of BMD to the average BMD in the reference population. Similarly, the M-score is calculated by the following formula using the SNR L1-L4 and SNR ref values of the patient and control group and the standard deviation (SD ref) value of the control group (3,11).

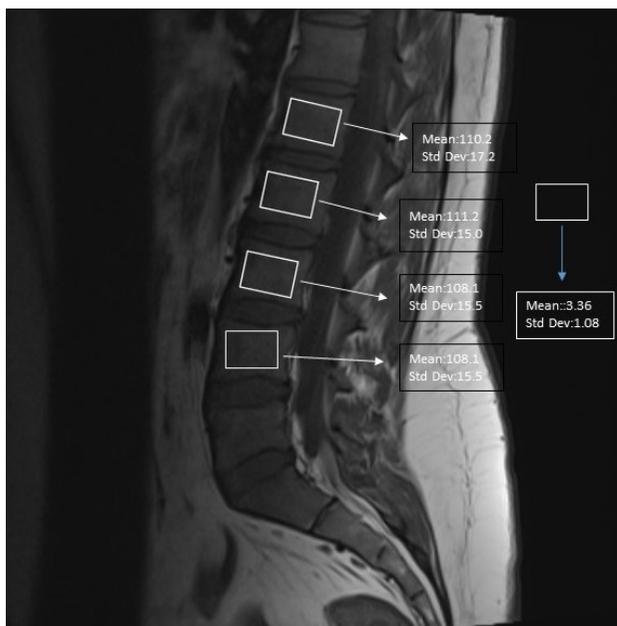
$$\bullet \text{ M-score} = \frac{\text{SNR}_{(L1-L4)} - \text{SNR}_{(Ref)}}{\text{SD}_{(Ref)}}$$

Spearman correlation test was performed to investigate the relationship between the SNR and the T-score and between the M-score and the T-score.

## Results

### Characteristics of the Patient and Control Groups

Forty postmenopausal women over 50 years of age who underwent lumbar MRI due to suspicious X-ray, laboratory and clinical findings and were also diagnosed with OP by DEXA (T-score <-2.5) were included in the study. The youngest in the patient group was 53 years old, and the oldest was 81 years old and the patient's mean age was 64.97±6.30. Forty women



**Figure 1.** In T1W sagittal measurements, signal measurement by placing the ROI on the L1-L4 vertebral corpuses, and noise measurement by placing it outside the image  
ROI: Region of interest, Std Dev: Standard deviation

aged 20-29 years who underwent lumbar spinal MRI for low back pain were included in the study as the control group. The youngest in the control group was 21 years old, and the oldest was 29 years old and their mean age was 25.32±2.28 (Table 1).

### SNR Analysis

The median SNR values for each vertebra are as follows respectively; in vertebra L1, 57.2 (26.31-187.50) in the patient group, 26.76 (8.88-45.9) in the control group; in vertebra L2, 57.74 (24.03-194.61) in the patient group, 24.36 (7.16-41.81) in the control group; in vertebra L3, 56.27 (23.26-193.70) in the patient group, 23.44 (6.54-41.81) in the control group; in vertebra L4, 56.48 (23.65-182.67) in the patient group, 23.06 (7.03-37.72) in the control group; and L1-L4 mean SNR was 57.49 (25.43-182.48) in the patient group and 24.90 (7.40-41.70) in the control group.

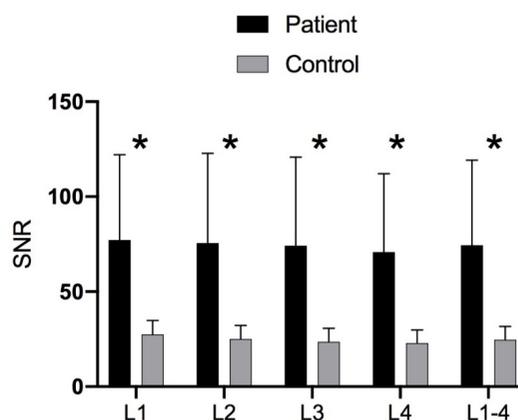
Individuals in the patient and control groups were compared in terms of L1, L2, L3, L4 and L1-L4 mean SNR values, and the difference between the groups was found to be significant (p<0.05) (Figure 2).

In order to find a predictive value in distinguishing individuals with OP from normal individuals in the control group, ROC analysis was performed (Figure 3).

The best predictive values, as a result of the ROC analysis, were found to be 36.35 for L1, 34.96 for L2, 32.20 for L3, 32.67 for L4, and 33.45 for L1-L4 mean. Table 2 shows the sensitivity and descriptive ratios of the predictive values.

### Analysis of SNR and M-score with DEXA

Between L1-L4 mean SNR value and M-score and DEXA value, Spearman correlation test was performed in the patient group



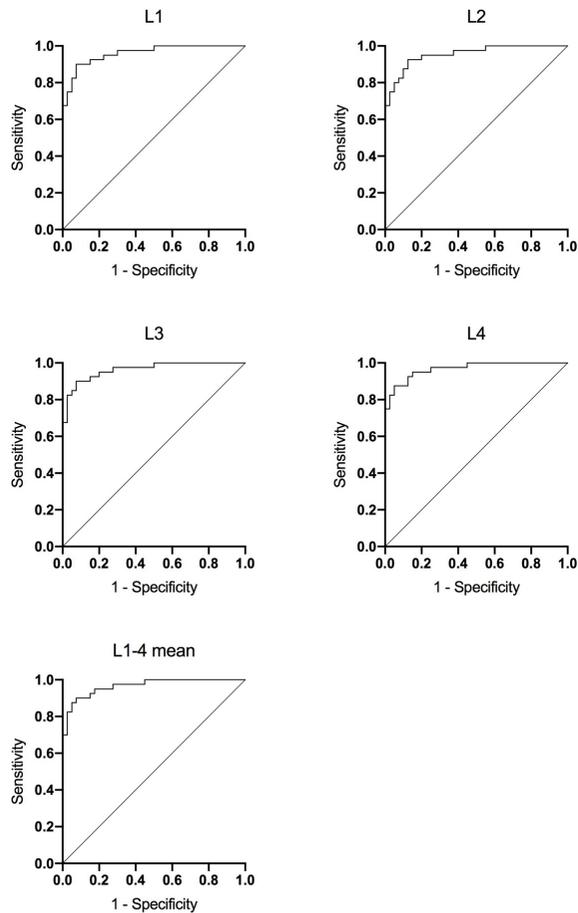
**Figure 2.** SNR values of L1, L2, L3, L4, and L1-4 means. Data were expressed as mean with standard deviation (\*p<0.05)  
SNR: Signal-to-noise ratio

	Groups	n	Mean
Age	Patient	40	64.97±6.30
	Control	40	25.32±2.28

and as a result, a negative correlation of -0.067 was found. This relationship is statistically insignificant (Figure 4).

## Discussion

DEXA is quantitative imaging with standardization in the diagnosis of OP (13), however many patients cannot be properly evaluated and diagnosed because it is not used frequently

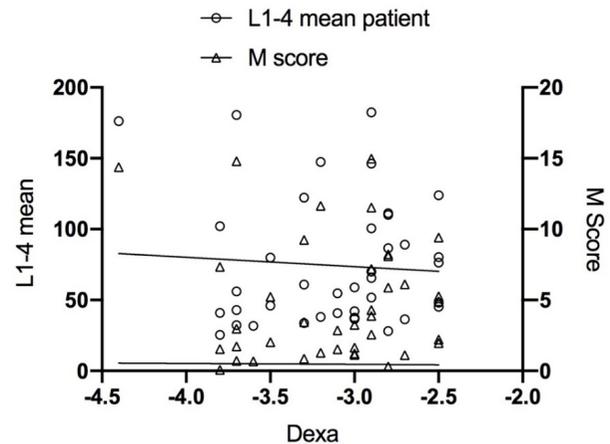


**Figure 3.** ROC curves for L1, L2, L3, L4, and L1-4 mean SNR measurements in distinguishing the patient group with OP from the control group

ROC: Receiver operating characteristics, SNR: Signal-to-noise ratio, OP: Osteoporosis

(1,14). Today, lumbar MR imaging is performed very frequently. In routine MRI images, a new quantitative measurement method based on SNR and M-score may help diagnose patients at risk of OP, and enable early diagnosis of many patients incidentally (11). MR T1A images are used to show bone marrow cell content due to their good detection of fat content. The hyperintensity in T1-weighted images indicates a decrease in cells in the bone marrow and an increase in fat content. This increase is associated with OP (8). One claim is that the increase in the amount of fat in the bone marrow is a mechanism to compensate for cellular content associated with OP in trabecular microarchitecture. Fat cells may fill areas with trabecular thinning and volume loss (15). All women in the patient group had postmenopausal OP. In the literature using T1W images, postmenopausal women were selected in 2 publications in which SNR and M-score were used as the patient group. In our study, women diagnosed with OP were included. However, unlike our study, in the other two studies mentioned, postmenopausal women were grouped as OP, osteopenia and normal, and all of them were included (3,11). The aim is to be able to distinguish between patients with definite OP.

SNR and M-score are device-dependent and there are not enough studies on this subject in the literature. In addition to these, L1, L2, L3, L4, and L1-4 mean SNR values were found



**Figure 4.** Relationship between patient group DEXA, L1-4 mean and M-score

DEXA: Dual-energy X-ray absorptiometry

**Table 2. Best predictive values and diagnostic performance indicators for L1, L2, L3, L4, L1-L4 mean SNR levels to distinguish osteoporotic individuals from normal individuals**

Indicators	L1 SNR	L2 SNR	L3 SNR	L4 SNR	L1-L4 mean SNR
Predictive value	36.35	34.96	32.20	32.67	33.45
Case (n)	80	80	80	80	80
Sensitivity	36/40 (90%)	35/40 (87.5%)	36/40 (90%)	35/40 (87.5%)	36/40 (90%)
Specificity	36/40 (90%)	36/40 (90%)	36/40 (90%)	36/40 (90%)	36/40 (90%)
p-value	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01

SNR: Signal-to-noise ratio

to investigate the situation in our country. In the light of these values, the M-score was calculated and the relationship between T and M scores was investigated.

In the measurement of SNR, there was a significant difference between the patient group and the control group ( $p < 0.001$ ). ROC analysis was performed on the SNR values and the predictive values were calculated in our study and it was investigated which values can be used in the diagnosis of OP in daily MRI use. The predictive values were found 36.35 for L1, 34.96 for L2, 32.20 for L3, 32.67 for L4, and 33.45 for L1-L4 mean. According to these values, the sensitivity of the predictive value was found 90%, and its specificity was found 90%. For the early diagnosis of patients with suspected OP, quantitative values can be determined in routine lumbar MRI examinations with predictive values. Shayganfar et al. (3) and Bandirali et al. (11) found a significant difference in SNR measurement between the patient group and the control group in their studies ( $p < 0.001$ ). Also, the sensitivity and specificity for the predictive values they found were found to be 90%, which are similar to our results.

L1, L2, L3, L4, L1-L4 mean SNR values obtained with lumbar vertebra T1W images were measured separately for the patient and control group and the M-score was calculated similarly to the T-score in the DEXA. In this direction, the aim is to obtain a quantitative score, facilitate the diagnosis of OP and reveal a general validity value.

There was a negative correlation found between the M-score and T-score obtained in our study, and the result is not statistically significant ( $r = -0.067$ ,  $p > 0.005$ ). In the study conducted by Shayganfar et al. (3) on this matter, similar to our study, a negative correlation ( $r = 0.564$ ) was found, and the result was statistically significant ( $p = 0.0001$ ). Similarly, a negative correlation ( $r = -0.682$ ) was found in the study performed by Bandirali et al. (11), and the result was statistically significant ( $p < 0.001$ ). The fact that we had a small number of patients and that only patients with OP were included in the case group and postmenopausal women with osteopenia and normal T-scores were not included in the case group may be the reason why the correlation between SNR and T-score and between M-score and T-score was not significant in our study. Also, although DEXA is the gold standard in the diagnosis of OP, we believe that its low sensitivity may also affect the results.

The reliability of our study increases due to the fact that all cases in our study consisted of postmenopausal female patients and all of them were proven by DEXA. To ensure the homogeneity of the case group, postmenopausal patients with normal bone mineral density and compatibility with osteopenia were not included in the study. Additionally, male patients with OP were not included in our study, and structural differences were avoided. Patients were not classified only according to DEXA results, lumbar MR images and files of 80 cases were examined and those with other diseases affecting the bone structure were not included in the study. In the study we conducted by excluding other factors, the aim is to increase reliability.

The reliability of our study increases due to the fact that all cases in our study consisted of postmenopausal female patients and all of them were proven by DEXA. To ensure the homogeneity of the case group, postmenopausal patients with normal bone mineral density and compatibility with osteopenia were not included in the study. Additionally, male patients with OP were not included in our study, and structural differences were avoided. Patients were not classified only according to DEXA results, lumbar MR images and files of 80 cases were examined and those with other diseases affecting the bone structure were not included in the study. In the study we conducted by excluding other factors, the aim is to increase reliability.

Despite the limitations stated in our study, it has been shown that T1W sequences in lumbar MR images taken for another reason can be used to predict OP. We believe that in the patient group who undergo lumbar MRI for low back pain every day, it may be possible to expand OP scanning without additional cost and radiation exposure. Studies conducted with large case groups prospectively are needed for the diagnostic value of MRI.

## Conclusion

In this study, it has been shown that lumbar MRI T1W sequences can be used to predict OP. It may be possible to expand the screening for OP without the additional cost and radiation exposure of multiple lumbar MRIs for low back pain. We think that prospective studies with larger groups are needed on this subject.

## Ethics

**Ethics Committee Approval:** The present study is retrospective and its permission was obtained from Sivas Cumhuriyet University Non-Invasive Clinical Research Ethics Committee on 11.09.2019 (decision no: 2019-09/03).

**Informed Consent:** Retrospective study.

**Peer-review:** Externally peer-reviewed.

## Authorship Contributions

Surgical and Medical Practices: İ.A., E.G., S.A., Concept: S.A., S.B., Design: S.B., S.A., Data Collection or Processing: İ.A., E.G., Analysis or Interpretation: İ.A., E.G., Literature Search: İ.A., S.A., E.G., Writing: İ.A.

**Conflict of Interest:** No conflict of interest was declared by the authors.

**Financial Disclosure:** The authors declared that this study received no financial support.

## References

1. Kanis JA. Diagnosis of osteoporosis and assessment of fracture risk. *Lancet* 2002;359:1929-36.
2. Laib A, Newitt DC, Lu Y, Majumdar S. New model-independent measures of trabecular bone structure applied to in vivo high-resolution MR images. *Osteoporos Int* 2002;13:130-6.
3. Shayganfar A, Khodayi M, Ebrahimian S, Tabrizi Z. Quantitative diagnosis of osteoporosis using lumbar spine signal intensity in magnetic resonance imaging. *Br J Radiol* 2019;92:20180774.

4. Tang GY, Lv ZW, Tang RB, Liu Y, Peng YF, Li W, et al. Evaluation of MR spectroscopy and diffusion-weighted MRI in detecting bone marrow changes in postmenopausal women with osteoporosis. *Clin Radiol* 2010;65:377-81.
5. Yeung DK, Griffith JF, Antonio GE, Lee FK, Woo J, Leung PC. Osteoporosis is associated with increased marrow fat content and decreased marrow fat unsaturation: a proton MR spectroscopy study. *J Magn Reson Imaging* 2005;22:279-85.
6. Griffith JF, Yeung DK, Antonio GE, Wong SY, Kwok TC, Woo J, et al. Vertebral marrow fat content and diffusion and perfusion indexes in women with varying bone density: MR evaluation. *Radiology* 2006;241:831-8.
7. Schellinger D, Lin CS, Hatipoglu HG, Fertikh D. Potential value of vertebral proton MR spectroscopy in determining bone weakness. *AJNR Am J Neuroradiol* 2001;22:1620-7.
8. Shah LM, Hanrahan CJ. MRI of spinal bone marrow: part I, techniques and normal age-related appearances. *AJR Am J Roentgenol* 2011;197:1298-308.
9. Abate N, Burns D, Peshock RM, Garg A, Grundy SM. Estimation of adipose tissue mass by magnetic resonance imaging: validation against dissection in human cadavers. *J Lipid Res* 1994;35:1490-6.
10. Shen W, Scherzer R, Gantz M, Chen J, Punyanitya M, Lewis CE, et al. Relationship between MRI-measured bone marrow adipose tissue and hip and spine bone mineral density in African-American and Caucasian participants: the CARDIA study. *J Clin Endocrinol Metab* 2012;97:1337-46.
11. Bandirali M, Di Leo G, Papini GD, Messina C, Sconfienza LM, Olivieri FM, et al. A new diagnostic score to detect osteoporosis in patients undergoing lumbar spine MRI. *Eur Radiol* 2015;25:2951-9.
12. WHO Scientific Group on Prevention, Management of Osteoporosis, and World Health Organization. Prevention and management of osteoporosis: report of a WHO scientific group. No. 921. World Health Organization, 2003.
13. NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy. Osteoporosis prevention, diagnosis, and therapy. *JAMA* 2001;285:785-95.
14. Elliot-Gibson V, Bogoch ER, Jamal SA, Beaton DE. Practice patterns in the diagnosis and treatment of osteoporosis after a fragility fracture: a systematic review. *Osteoporos Int* 2004;15:767-78.
15. Rosen CJ, Ackert-Bicknell C, Rodriguez JP, Pino AM. Marrow fat and the bone microenvironment: developmental, functional, and pathological implications. *Crit Rev Eukaryot Gene Expr* 2009;19:109-24.