ORIGINAL ARTICLE

To study the role of various magnetic resonance imaging sequences in assessment of vertebral marrow changes in postmenopausal Indian female population

Shagufta Wahab, Ibne Ahmad

Department of Radiodiagnosis, JNMCH, AMU, Aligarh, Uttar Pradesh, India

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Correspondence:
Dr. Shagufta Wahab, Kashan-e-Wahab, Street No. 4, Iqra Colony, Aligarh, Uttar Pradesh, India. Phone: +91-9410210350.
E-mail: drshaguftawahab@rediffmail.com

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Abstract

Background: Magnetic resonance imaging (MRI) appearance of vertebral bone marrow is highly variable varying with age and menopause in females. The differential appearance of marrow on various sequences can be used for assessing the marrow and studying the changes which are physiological with age and the changes which represent pathology.

Objective: The aim and purpose of this study is to evaluate the patterns of changes in the appearance of vertebral bone marrow occurring with age and menopause in Indian females on MRI.

Materials and Methods: MRI images of 60 female subjects −0.30 pre-menopausal females more than 25 years (25–35 and 35–45 years age group) and 30 post-menopausal females (45–55, 55–65, and more than 65 years age group) were evaluated. MRI was performed on 1.5 Tesla MRI Machine (Siemens Magnetom Avanto) and T1, T2 weighted and STIR images obtained in sagittal, axial, and coronal planes from D8 to L4 levels.

Results: There was variation in the appearance of bone marrow among individuals with increasing fat content with age and menopause. It usually followed large globular fat deposition pattern (Pattern 4 described by Ricci *et al.*) in 60% of post-menopausal group and all cases more than 65 years of age had almost homogenously increased signal intensity of vertebrae probably due to prevalent osteoporosis in post-menopausal Indian females. None of the cases in post-menopausal group had fine punctuated fatty replacement of bone marrow (Pattern 3 described by Ricci *et al.*).

Conclusions: MRI is a very helpful imaging modality in the evaluation of vertebral marrow changes with age and menopause but as the marrow is a tissue undergoing constant change its appearance on MRI is highly variable, and its accurate analysis requires radiological, acumen, expertise and a correct combination of various MRI pulse sequences.

Introduction

Bone marrow in vertebrae consists of red marrow, yellow marrow, and trabecular bone. Red marrow is hematopoietically active marrow while yellow marrow is considered inactive fat. In the adult red marrow is concentrated in the axial skeleton and yellow in the appendicular skeleton. Marrow content and its distribution in the body changes substantially with age and hormonal changes associated with menopause in female sex.[1,2] At birth, almost the entire bone marrow in body is active red marrow which on Magnetic resonance imaging (MRI) gives a signal intensity similar or even less than adjacent muscle.[3] Then, the marrow starts converting to the yellow marrow in a centripetal fashion. By 25–30 years of age the red marrow is restricted to axial skeleton mainly the vertebrae in an adult.[4] However, there is a variable mixture of red and yellow marrow in the vertebral column with a progressive increase in yellow marrow with age.[2] Normal bone marrow conversion that occurs with aging and the associated hormonal changes during perimenopause is not uniform. MR appearance of vertebral

bone marrow depends on the relative proportion of red and yellow marrow and other factors as water content, cellularity, and bone mineral density of the vertebra, thickness of bone trabeculae and the type of MRI sequence used.[5,6] At times it is very difficult to differentiate between pathology and a normal physiological change in the appearance of marrow associated with increasing age or menopause. The differential appearance of marrow on various sequences can be used for assessing the content and health state of marrow and studying the changes which are physiological with age and the changes which represent pathology.

The aim and purpose of this study is to evaluate the patterns of changes in appearance of vertebral bone marrow occurring with age and menopause in Indian females on MRI so that a clear understanding of physiological changes is made.

Materials and Methods

The study was conducted on 60 female subjects being referred for MRI Spine for various complaints to the Department of Radiodiagnosis, J NMCH. 30 pre-menopausal females more than 25 years (25–35 and 35–45 years age group) and 30 post-menopausal females (45–55, 55–65, and more than 65 years age group) were evaluated. After detailed clinical history taking, MRI was performed on 1.5 Tesla MRI Machine (Siemens Magnetom Avanto). T1, T2 weighted, and STIR imaging of spine was performed mainly in sagittal, axial, and coronal planes. Spine coil was used for imaging and spine was evaluated from D8 to L4 levels. Females <25 years of age till the adult pattern of marrow distribution and appearance is supposed to be established were excluded from the study as also cases with obvious features of infection, metastasis, primary tumor, or infiltrative bone disease in the spine on MRI.

Results

Of the 30 pre-menopausal females included in the study −22 were in the 25–35 age group and 8 were in the 35–45 age group while in post-menopausal group −10 were in the 45–55, 14 in 55–65, and 6 in more than 65 years age group. MR appearance of bone marrow depends on fat and water content. The spine evaluation on MRI in our study included routine T1-weighted, T2-weighted, and STIR sequences. We observed that there was a large variation in the MRI appearance of vertebral marrow between individuals; however, the appearance of marrow in different vertebral bodies in the same individual followed nearly the same pattern.

In pre-menopausal age group (25–45 years age group) red marrow appeared to be homogeneously distributed in the vertebrae and only small areas of fatty marrow was seen around the basivertebral plexus (Pattern 1 as described by Ricci *et al.*) [Figure 1]. In this group of patients on T1 weighted imaging, the vertebrae appeared homogenously intermediate in signal intensity less than that of subcutaneous fat but more

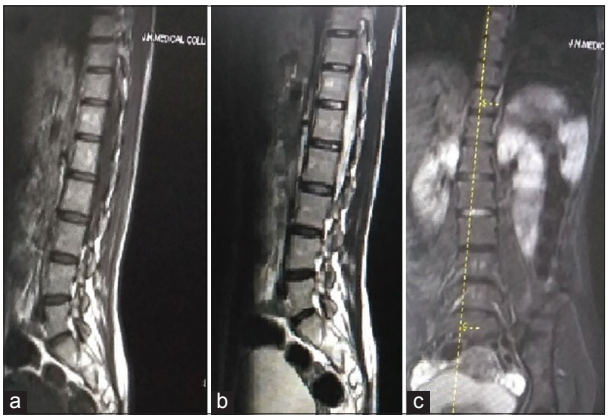

Figure 1: (a and b) T1 and T2 weighted sagittal magnetic resonance imaging of lumbar spine in pre-menopausal female showing hyperintensity only centrally along basivertebral plexus (pattern 1), (c) STIR image showing intermediate signal intensity

than adjacent disc or muscle. On T2 the signal intensity was intermediate, lower than yellow marrow and on STIR sequences it was more than yellow marrow which appeared hypointense due to suppression of signal from fat. Seven cases in pre-menopausal group also showed band-like and triangular foci of fat along the endplates and corners of vertebrae or tiny foci of interspersed yellow marrow either (Pattern 2 or 3 as described by Ricci *et al.*). In post-menopausal population and after 45 years of age there was variable distribution of fatty marrow replacing the red marrow. 18 cases (60%) of this group showed predominantly large globular areas of fatty replacement (Pattern 4 as described by Ricci *et al.*[7]) in 45-55 and 55–65 age groups. Differentiation from pathology was particularly difficult with this pattern due to the heterogeneous appearance of vertebrae, and it is in this group that STIR sequence had its high utility as it suppressed the fat signal. 6 (20%) cases in this group also showed band-like or triangular fatty replacement of marrow near corners and endplates (Pattern 2 as described by Ricci *et al.*) 12 cases had both Pattern 2 and 4 overlapping [Figure 2]. Pattern 2 was often confounded and may even be influenced by end plate Modic changes that required clinical correlation with symptoms. All the 6 (20%) cases beyond 65 years of age had a near homogenous replacement of vertebral marrow by fat probably due to predominantly osteoporotic post-menopausal female population in India. This replacement was seen as increased signal intensity on both T1 and T2 weighted sequences [Figure 3]. T2 weighted sequence appeared less reliable in assessing vertebral marrow unless pathologic replacement by water (metastasis, infection, etc.) leading to highly increased signal or sclerosis with the lower signal is present. STIR sequence which used an inversion pulse to cancel signal from fat offered better differentiation where all homogenously replaced fatty marrow appeared hypointense. However, we could not find any case of fine punctuate fatty replacement of bone marrow (Pattern 3) in post-menopausal group.

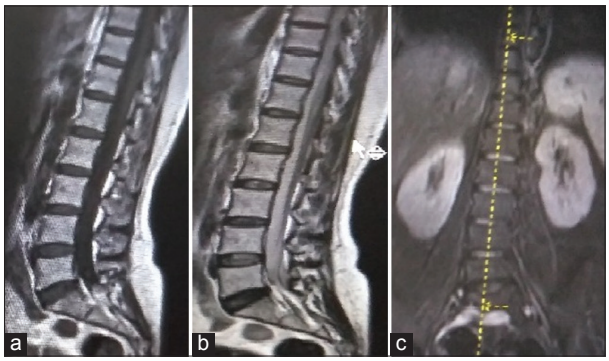

Figure 2: (a and b) T1 and T2 weighted sagittal magnetic resonance imaging of lumbar spine in post-menopausal 54-year-old female showing mixed Pattern 2 and Pattern 4 distribution of yellow marrow, (c) STIR sequence shows hypointensity in these areas of yellow marrow

Figure 3: (a and b) T1 and T2 weighted image showing homogenously hyperintense vertebra with near total fat replacement, (c) the vertebrae appear homogeneously hypointense on STIR sequence

Discussion

MRI of bone marrow has a variable appearance due to the age-related variation in the distribution of hematopoietic and fatty marrow. These patterns have large variations which vary with individuals, race, gender, and age.[5] MRI signal intensity of bone marrow on T1 weighted sequence lower than normal muscle invariably indicates pathology except at neonatal stage. Spinal bone marrow is characterized by the presence of red marrow, but the proportions of red and yellow marrow in the axial skeleton vary by age, gender (hormonal), and external factors. Women have a larger amount of red marrow in early adulthood, with an increase in the fat fraction after menopause compared with men.[6]

With advancing age, generally over age 40–45 years, the vertebral bone marrow is gradually replaced with fatty marrow. This may occur either as a band-like pattern of fatty replacement along the endplates, small foci of fatty marrow replacement, or large areas of fat replacement. Ricci *et al.* reported 4 patterns - Pattern 1 seen in younger patients where fat is visible centrally only along the basivertebral veins; Pattern 2 shows band-like and triangular foci of fat along the endplates and corners of vertebrae; Pattern 3 has tiny foci of interspersed yellow marrow and Pattern 4 shows larger, globular areas of yellow marrow replacement.[7] The importance of this subjective assessment of bone marrow and understanding the patterns to differentiate normal physiological changes from pathology cannot be overemphasized.

Some recent studies also suggest that elderly patients and post-menopausal females with severe osteoporosis may have almost complete replacement of vertebral marrow by fat as seen in our study where all 6 cases more than 65 years of age showed similar findings.[8] Due to hormonal, dietary and social factors, osteoporosis is more prevalent among females in India with the greatest bone loss occurring in women during perimenopause associated with estrogen insufficiency.[9-11]

At present, MRI is not considered as the preferred modality to investigate the status of trabecular bone, but with the use of differential imaging on various MRI sequences, we can know the changing status of bone marrow. Additional MRI sequences that can be used to obtain additional information about spinal bone marrow include diffusion-weighted imaging, in- and out-of-phase MRI and MR spectroscopy (MRS) to increase contrast and demonstrate the changes at the earliest. Furthermore, we can infer the status of underlying bone and its strength.[12] MRI may noninvasively provide an insight into the changes occurring in vertebral marrow with age and menopause defining marrow fat proportions. Recent studies with MRS and quantitative diffusion have shown that there is an increased amount of fat in the vertebral marrow in patients with osteoporosis, indirectly reflecting sparsity of bone trabeculae and decreased bone mineral density.[13]

The appearance of vertebral marrow in cases of premature menopause, in patients on hormone replacement, with sedentary and active lifestyle also requires further studies in a larger cohort.

Conclusion

MRI offers the advantage of using non-ionizing radiation besides being a one-stop investigation for a very detailed analysis of bone marrow, spine, spinal fluid, and spinal compression, and status of paraspinal muscles. MRI can diagnose and evaluate not only any neoplastic, infectious, infiltrative, or degenerative diseases of the spine but also the changes in bone marrow occurring with age and menopause. However, as the appearance of bone marrow changes with age and menopause in females its interpretation requires caution a clear understanding of these changes and a correct combination of different MRI sequences for differentiating pathology from physiological changes.

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