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Assessment and comparison of normal age related changes in spinal bone marrow on magnetic resonance imaging in relation to T1, T2 and STIR sequences

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Abstract
Background: Interpretation of bone marrow on magnetic resonance imaging (MRI) requires an understanding of normal pattern of maturation or conversion, as well as an understanding of hematopoietic and fatty constituents of marrow which contribute to the normal MRI appearance. The in depth knowledge of normal appearance of marrow intensity allows for recognition of pathologic marrow process.
Aim: The aim of this study was to see normal distribution of age related changes in bone marrow.
Material and method: A prospective and comparative study was carried out from August 2018 to April 2019 in the Department of Radio-imaging and Diagnosis at SGT University Hospital, Gurugram. A total of 56 asymptomatic subjects were taken as a sample. Sagittal images were acquired on MRI, and signal intensity were measured on the level of D12, L1, L2 vertebras on T1, T2, STIR weighted images. A comparative study of signal intensity and age was done for the assessment of normal age related changes.
Result: In this study 56 asymptomatic subjects were taken as a sample comprising 33 male and 23 female. The average signal intensity (SI) calculated on T1 weighted images (T1WI) were lowest as 682.25 and highest being 862.28. On T2 weighted images (T2WI) THE lowest was 598.57 and the highest being 946.25. Short tau inversion recovery (STIR) images had shown the lowest signal intensity being 52.56 and the highest as 733.59. T1WI showed linear relation with $p<.05$. T2WI also showed linear relation with age with $p<.05$. STIR did not show any particular relation with age. There was more rapid change in bone marrow from red to yellow in male population than female counterpart.
Conclusion: The signal intensity in T1WI and T2WI had shown significant relation with age. MRI with its variety of sequences is proven to show different patterns of marrow in normal spine which is a key factor in assessment of pathologic conditions. The conversion of red marrow to fatty marrow and its reconversion to red marrow under stimuli like physiologic stress seems to be common.

Keywords: signal Intensity, magnetic resonance imaging, red marrow, yellow marrow

Introduction

The spinal bone marrow is the mixture of cellular elements present within the vertebrae. These cellular mixture are present within the trabeculae of bone tissue providing regular supply of red cells, platelets and white blood cells. There are mainly two variety of spinal bone marrow depending upon the cellular composition namely red marrow and the yellow marrow. Both the marrow is chemically composed of three major elements in different fractions namely fat, water and proteins. The red marrow is highly vascular type of marrow with richness in haemoglobin content whereas yellow marrow are less vascular having fat tissue as main cellular constituent [1]. The marrow present in the infants is red marrow which is gradually converted into the fatty marrow as the age advances. This conversion starts in a centripetal fashion and is concluded within the adulthood [2]. The fatty marrow is converted back to red marrow due to external stimuli such as obesity, pathology, heavy training athletes to effectuate the increased demand of haemoglobin and oxygen. The conversion pattern is not orderly but occurs randomly appearing like the patches of red marrow within the yellow marrow [1, 2, 3]. The appearance of marrow in MRI depends on its contents. The basic sequences for assessing the spinal bone marrow includes the T1WI, T2WI and STIR. The cellular contents in T1WI are best demonstrated because of the fat content. The red marrow as compared to yellow marrow gives slightly low signal due to high water content. The conventional T2WI with fats suppression gives the brighter signal from the red marrow in comparison to yellow marrow. STIR sequence produces more homogenous fat suppression than T2 fast spin echo which is performed with the frequency selective fat saturation. The main drawback of the STIR sequence is that it

cancels every signal close to fat which enhance the bone marrow lesions within suppressed background.

Materials and Method

A prospective and comparative study was carried out from August 2018 to April 2019 in the Department of Radio-diagnosis and Imaging of Faculty of Allied Health Sciences and Faculty of Health Sciences of SGT University, Gurugram. This study was based on the age related changes in spinal bone marrow. The observation and findings were compared at different level of vertebrae at T12, L1 and L2. The signal intensity on different sequences of T1, T2 and STIR were taken for the comparison. The present study was performed on 56 patients.

Inclusion Criteria

The patients of age between 10 to 60 years of all gender with no bone marrow related abnormality were included in the study.

Exclusion criteria

The patients with chronic illness related to spine or any known bone marrow disease, history of trauma, malignancy, focal lesions including neoplasm, infection and prolonged immobilization or with a history of corticosteroid treatment, radiation therapy or chemotherapy were excluded from the study.

The study was carried out on 1.5 Tesla Multiva Philips using spinal array surface coil. Sagittal TlWI, T2WI and STIR images of the lumbar spine were acquired. T1WI images were acquired by using a fast spin-echo (FSE) sequence with parameter of TR 575 ms and TE 8 ms with section thickness of 4 mm for 15 slices. Similarly for T2WI were obtained by using FSE with TR 3275 ms and TE as 88 ms with section thickness of 4 mm for 15 slices. STIR sequence were procured with parameters of TR as 2800 ms and TE as 80 ms with slice thickness of 4mm for 15 slices. Values were measured from operator defined regions of interest on each T1, T2, and STIR sequences. Regions of interest (ROI) as circle of size 1 cm^2 were placed in the centre of T12, L1 & L2 vertebrae with 0.5 cm away from the periphery of vertebra to avoid the cortex. For each vertebral body the ROI was drawn manually on the images for quantitative measurement of the T1, T2 and STIR value of the T12 L1 and L2 vertebrae. The data collected was compiled, tabulated, analysed and subjected to statistical tests. Analysis was done using SPSS 20.0.

Results

There were 56 patients included in the study, 33 male and 23 female fitting under the inclusion criteria (Figure 1). Another chart shows the demographic data of patients under different age groups (Figure 2).

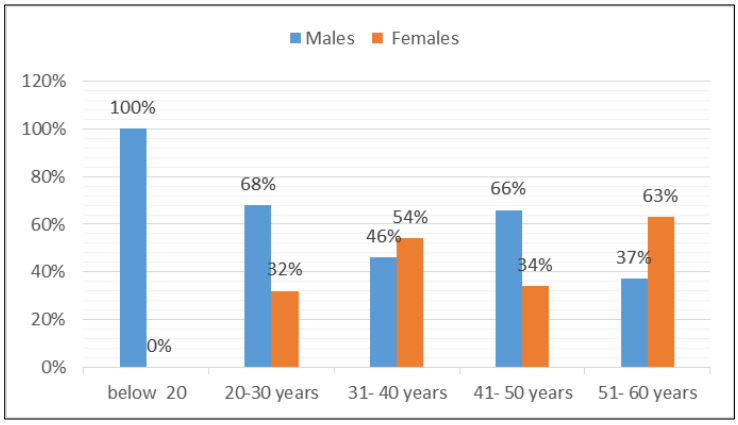

Fig 1: Distribution of the sample as per the gender and age group.

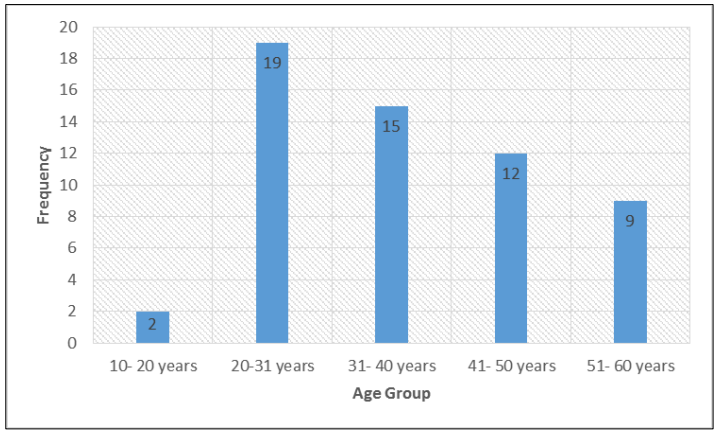

Fig 2: Distribution of patients in different age groups. The chart shows different five age groups and their distribution. The frequency of patients from the age group 20-30 years was maximum.

Various intensities have been shown in the chart which can be comapared to each other (Figure 3)

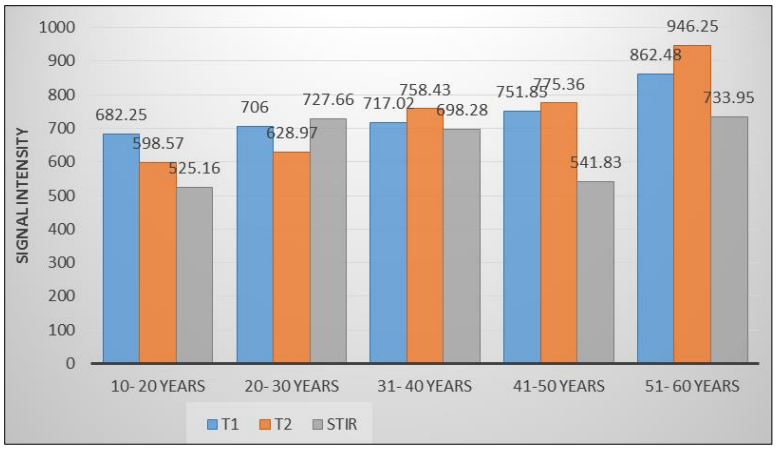

Fig 3: Shows the Distribution of signal intensity (T1, T2 and STIR) according to age group.

The relation between T1 Signal intensity and age group. In this study it was found that there was a linear relationship between T1 signal intensity and age (Figure4)

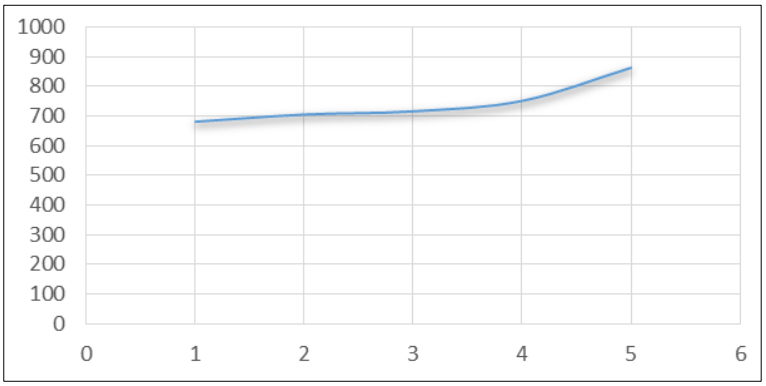

Fig 4: Shows Relation between T1 Signal intensity and age group. In this study it was found that there was a linear relationship between T1 signal intensity and age. T1 signal intensity tended to increase with increase in age.

The relation between T2 Signal intensity and age groups shows linear relation between T2 signal intensity and age. T2 signal intensity tended to increase exponentially with increase in age, with a statistical significance $F = 11.944$ $p < 0.05$ (Figure5)

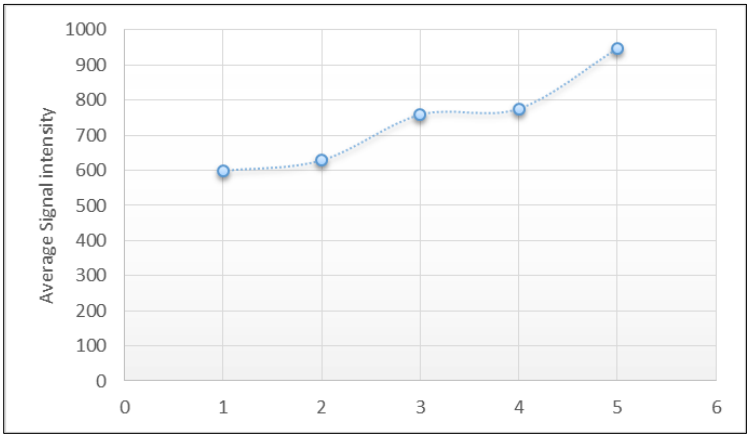

Fig 5: Shows relation between T2 Signal intensity and age groups. The graphical representation shows linear relation between T2 signal intensity and age.

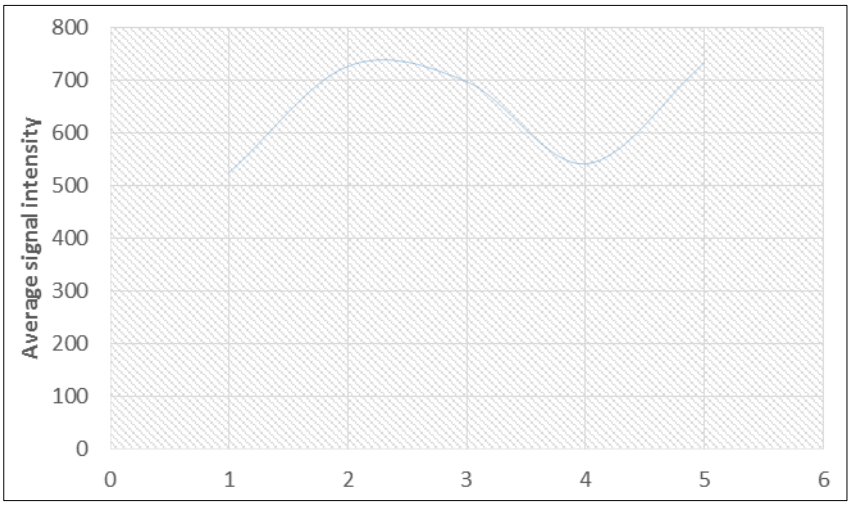

Fig 6: Relationship between STIR signal intensity and age groups. As per graph above graph there is no any peculiar relationship between STIR SI and age, it is clearly seen that signal intensity first increases and then decrease in 3rd and 4th group and then again increases in 5th age group.

There was no particular relation of STIR sequences in relation to the age (Figure 6)

Discussion

Bone marrow is evaluated in MRI especially during lumbosacral spine pathologies. T1WI and T2WI are the two basic sequences for evaluating the bone marrow. STIR sequence further adds to the more description in evaluation. In case of pathologies the sequence intensity is better understood if the pathologies can be categorised as per the underlying aetiology as compared to normal intensity variation as per aging. (Table 1)

Table 1: Bone marrow pathologies can be divided into three categories for the easy explanation of bone marrow changes.

Category I	Category II	Category III
Traumatic	Neoplastic	Metabolic
Insufficiency /Stress fractures	Infections	Hematopoietic Disorders
Complex regional pain syndrome		Neuropathic disorders
Inflammatory Arthropathy		Chemotherapy and radiotherapy related bone marrow changes
Degenerative osteoarthropathy		Paget's disease
Acute bone infarct /Ischemia		Antiretroviral therapy
HIV infections		Serous bone marrow lesions

The constituents of marrow plays a great role in the intensity of marrow. It is important to know the predominance of the particular component as had been mentioned in Table 2.

The signal intensity in T1WI and T2WI differs in various dominant component. The normal intensity of the marrow will not exclude the infiltration. Baur and collegues had advocated further for evaluation by diffusion weighted imaging (DWI). Benign compression fractures are hypo- or iso intense as compared to malignant which are hyperintense [4].

Table 2: Both red and yellow marrow are shown with different percentage component of water,fat and hemopoietic contents.

Contents	Red Marrow	Yellow marrow
Water content	40%	15%
Fat content	40%	80%
Hemopoietic cells	20%	5%

It is important to have knowledge of normal changes in MRI appearance of vertebral red and yellow marrow with age is essential for the recognition for of abnormal conversion and reconversion patterns as well as for identifying infiltration of marrow by tumour and other pathologic processes. Since fat exhibits shorter relaxation than water, T1, T2 and STIR sequences can serve as guide to marrow distribution [5, 6, 7]. In our study it was found that there was a linear relationship between T1 signal intensity and age. The linearity might be due to conversion of red bone marrow into the yellow marrow. T1 signal intensity tended to increase with increase in age, with a statistical significance F= 12.88036, $p< 0.05$. In the our study, there was linear relation between T2 signal intensity and age. T2 signal intensity tended to increase exponentially with increase in age, with a statistical significance F = 11.944 $p<$. o5. In this study there was no any particular relation between STIR SI and age, it is clearly seen that signal intensity first increases and then decrease in 3rd and 4th group and then again increases in 5th age group. The decline of the signal intensity may be because of the region, as all patients were from same region or the kind of food the population takes. The T1 signal intensity of both male and female population increased linearly with age. TIWI signal intensity was higher in male as compared to females because of fat deposition till 50 years of age. This was contrary to 5th group

where T1WI signal intensity increased as compared to male population. The main reason behind was the fat contents [8].

Conclusion

MRI is very essential choice of modality for assessment of changes in spinal bone marrow with accordance of age. There is significant difference in signal intensity in accordance to the age. MRI with its variety of sequences is proven to show different patterns of marrow in normal spine which is a key factor in assessment of pathologic conditions. This also highlights the conversion of red marrow to fatty marrow and its reconversion to red marrow under stimuli like physiologic stress seems to be common.

Acknowledgement

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Conflict of interest

Nil

Financial support

Nil

Consent of the patients

The written consent of the patients were taken.

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