Original Research Article

3T MRI evaluation of bone marrow changes of non traumatic adult spine

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Abstract

Background: This study was conducted to evaluate the prevalence and extent of involvement in various non traumatic bone marrow pathologies of spine using 3T Magnetic Resonance Imaging (MRI). **Aims:** To study the MRI signal changes, prevalence, extent and involvement of marrow various bone marrow pathologies in spine.**Settings and Design:** Cohort hospital based study.**Material and method:** A prospective study of 100 patients,with clinically suspected pathology involving the spine underwent imaging tests, MRI of spine on a 3.0 Tesla Siemen's Vida Magneton. **Results:** Various pathologies of spine were diagnosed in these patients based on clinical suspicion, correlation, radiological and hematological findings and treated accordingly.Maximum cases were degenerative. An almost equal male to female distribution was seen in our study group. Maximum patients were found in the age group of 41-60.**Conclusion:** Changes in normal pattern of bone marrow with advancing age should be understood and is important to correctly approach for various bone marrow pathologies. While standard imaging of bone marrow is based on a few standard sequences (in particular T1-weighted and STIR sequences) new techniques are being developed to better characterize certain pathologic conditions.Hence MRI serves as a screening method in bone marrow disorders and the diagnosis is established in context with the clinical findings or by biopsy.

Keywords: Bone marrow, spine, MRI, degenerative changes.

Introduction

Background

Bone marrow is the soft spongy tissue that lies within the hollow interior of bones.Two types of bone marrow-Red marrow responsible for red blood cells, white blood cells and platelets production, while yellow marrow consisting mainly of fat cells. Disorders that affect bone marrow can be divided into following categories: Reconversion due to hyperplasia, Marrow infiltration or replacement disorders, depletion of hematopoietic marrow, Depletion of myeloid elements with fibrosis and deposition of metabolic products.MRI offers exquisite spatial and contrast resolution for characterisation of various bone marrow changes. MRI may thus become the diagnostic gold standard for disease that involve or target the bone marrow. The current study aims to study the prevalence, extent, and involvement of MRI signal changes of bone marrow in various lesions such as anaemia, leukaemia, lymphomas and various bone marrow disorders.

Methods

Study participants

This is a prospective study of 100 patients who presented to the OPD or admitted between May 2018 to May 2020 with clinically suspected pathology involving the spine and underwent MRI spine imaging. Clinical details were obtained and baseline laboratory investigations were done. Additional imaging modes like plain radiography and computed tomography (CT) were done wherever required. Patients with clinical suspicion of spinal pathology, with nonspecific backache, radiating to upper or lower limbs, with laboratory changes suggestive of abnormal haematological profile, with backache with known primary malignancy and hyperpara-thyroidism were included in our study.

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MR image acquisition

MRI was performed with 3 Tesla Siemens Vida Magneton superconducting MRI scanner,with brain-spine 32 channel posterior coils only. Patients were scanned in the supine position with the arms positioned beside the body in a neutral position and the head entering the scanner first. Patients were asked to reduce swallow activity and body movement during the scanning.

MR sequences

Examination was performed on a 3.0 Tesla Siemens Vida Magneton which lasted for around 45 min to 1 hr. Scans were done as per the following MRI spine protocol. The routine spine evaluation on MRI typically includes T1-weighted,T2-weighted, and STIR sequences. Post contrast(intravenous gadolinium)fat-suppressed T1W,T1 FLAIR Imaging, Diffusion-weighted imaging (DWI), in- and out-of-phase MRI, MR spectroscopy (MRS), and dynamic contrast enhanced MRI (DCE-MRI) were used when needed.Examination was performed with patient in supine position. 0.1mmol/kg Gadolinium based contrast was injected at rate of 2.5 ml/sec followed by saline flush as and when required.

Results

100 patients with pathology involving spine were included in the study. MR spine of all patients was performed on elective basis with their due consent and findings were correlated and compared with hematological investigation.

The following observations and results were obtained.

1) **Prevalence of various bone marrow disorders**
   Maximum cases were degenerative. There were only 3 cases of depletion disorder and was no case with deposition disorder. Detail findings are shown in Table 1.

2) **Sex distribution:**48 patients were male and 52 were female. An almost equal male to female distribution was seen in our study group.

3)Age distribution: Maximum patients (n = 67) were found in the age group of 41-60. The mean age group was 45.37 years, with the range being 20 years to 72 years, as depicted in Table 2.

Individual pathologies, there prevalence and distribution

1)Degenerative disorder: In our study there were total of 60 cases of degenerative changes of spine on MRI -Disc degeneration , Disc bulge , Disc herniation , Modic changes type I and II ,Canal stenosis , Nerve root compression. Their frequency distribution are shown in Table 3. Most common site of involvement was lumbar followed by cervical region. 17 patients showed various Modic changes.

2)Infiltrative / replacement disorders: There were total of 16 cases of infiltrative / Replacement disorders of spine in our study of which most common was metastasis (68.7%). Marrow can be replaced by either neoplastic disorders or non-neoplastic disorders. Various neoplastic diseases include metastatic disease, lymphoma, leukaemia, and multiple myeloma, whose distribution is shown in Table 4.Posterior elements are most commonly involved in metastasis. Most of the metastatic lesions showed discrete margins and only 3 out of 11 patients (27.2%) showed aggressive margin. Only 4 out of 11(36.4%) patient with metastasis showed associated soft tissues.2 out of 11 patients (18.2%) with metastasis showed cord compression.

3)Reconversion Disorder: Classified in to the chronic anaemias, hyperparathyroidism and miscellaneous conditions (Heavy smoking , increase oxygen requirements) ,In our study, total of 11 cases of reconversion disorders of spine , of which most common was chronic anaemia due to thalassemia (45.5%) of all reconversion disorders as shown in Table 5.Most of the reconversion disorders show diffuse involvement of bone marrow

4)Depletion disorder: Only 3 cases of depletion disorders are found in our study. Classified into depletion disorders secondary to radio-chemotherapy, idiopathic and depletion disorders with fibrosis (myelofibrosis), aplastic anaemia as shown in Table 6.

5)Focal disorders of bone marrow: Various focal disorders of bone marrow in spine are focal edema, ischemia and trauma. Our study found 6 patients with focal edema. Causes of focal edema in spine are ischemia, tumour, infection and trauma. Excluding trauma, prevalence of causes of other focal bone marrow is as shown in Table 7.

Table 1: Showing distribution of various spinal pathologies (n=100)

Diagnosis	No of patient
Degenerative disorders	60 (60%)
Infiltration/replacement disorders	16 (16%)
Reconversion disorders	11 (11%)
Depletion disorders	3 (3%)
Deposition disorders	0 (0%)
Focal disorders of bone marrow	10 (10%)

Table 2: Showing age distribution in various pathologies in spine.

Sr NO	Age Group (years)	No of patient (%)
1	11-20	06 (6%)
2	21-30	07 (7%)
3	31-40	15 (15%)
4	41-50	33 (33%)
5	51-60	34 (34%)
6	61-70	03 (3%)
7	>71	00 (0%)

Table 3: Showing various degenerative findings in patients with degenerative disorders.

Sr no	Degenerative changes	Findings in patients with Degenerative disorders
1	Disc degeneration	41(68.3%)
2	Disc bulge	21(35%)
3	Disc Herniation	28(46.6%)
4	Modic changes	17(28.3%)
5	Canal stenosis/nerve root compression	40(66.7%)

Table 4: Showing prevalence of various infiltrative / replacement disorders in spine.

Sr. no	Infiltrative / Replacement disorders	No of patients
1	Metastasis	11(68.7%)
2	Lymphoma	1(12.5%)
3	Leukemia	0(0%)
4	Myeloma	0(0%)
5	Non-neoplastic disorders	3(18.8%)

Table 5: Showing distribution of reconversion disorders in spine

Sr no	Reconversion disorders	No of patients
1	Chronic anaemia :sickle cell anaemia	1(9.09%)
2	Chronic anaemia: Thalassemia	5(45.4%)
3	Hyperparathyroidism	2(18.1%)
4	Others (Heavy smoking, increase Oxygen requirements)	3(27.2%)

Table 6: Showing distribution of depletion disorders in spine.

Sr no	Depletion disorders	No of patients
1	Unknown cause	1(33.33%)
2	Myelofibrosis	1(33.33%)
3	Aplastic anaemia	1(33.33%)
4	Secondary to chemo or radiotherapy	0(0%)

Table 7: Showing prevalence of causes of focal bone marrow oedema in spine

Sr. no	Causes of focal edema (other than trauma)	No of patients
1	Ischemia	0
2	Tumour	0
3	Infection	6

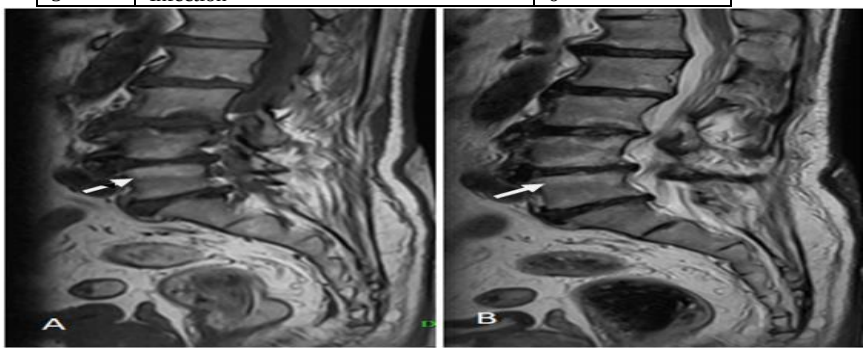

Fig 1: MRI spine showing degenerative changes (Type II Modic change); A) T1W sagittal image showing multiple anterior and posterior osteophytes with endplates(arrow) of L4, L5 vertebrae appearing hyperintense, B) On, T2W sagittal image of spine these endplates appearing hyperintense.

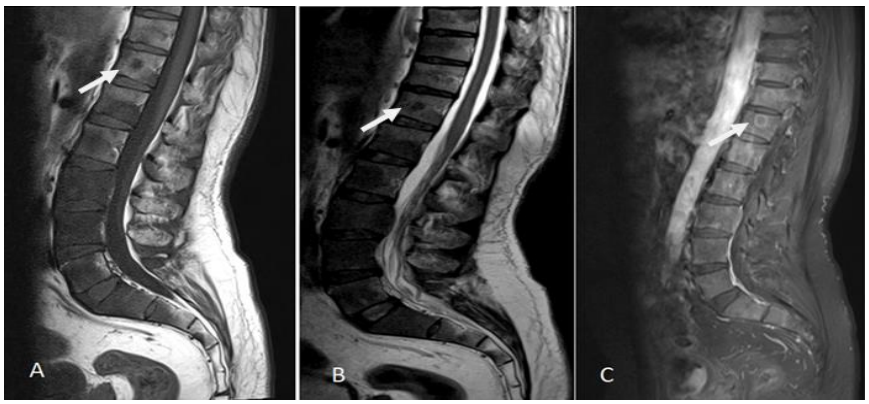

Fig 2: MRI spine showing sclerotic metastasis of lumbar spine A) T1W sagittal image showing hypointense lesion in T12 vertebra(arrow) and all lumbar vertebrae are showing diffuse hypointense signals; B) On T2W sagittal images these areas appearing hypointense suggestive of sclerosis; C) On post contrast enhancement the lesion in T12 vertebra showing peripheral enhancement.

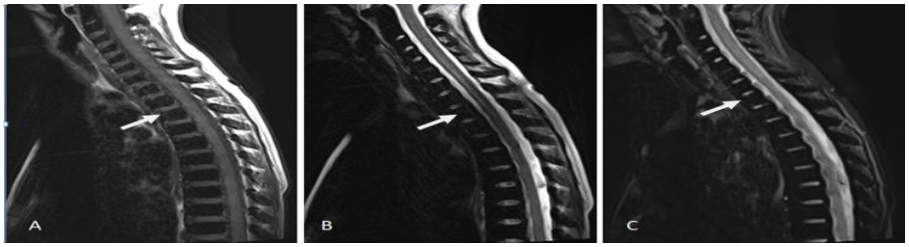

Fig 3: MRI spine in a case of Thalassemia; A) T1W sagittal image of cervical spine showing all vertebral bodies (arrow) and spinous processes are appearing hypointense to muscles. B) & C) are T2W and STIR sagittal images of cervical spine showing similar appearance.

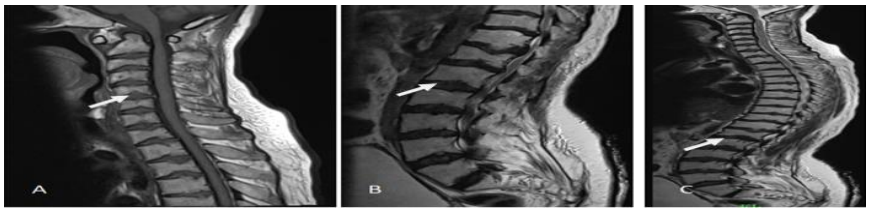

Fig 4: MRI spine in a case of Sickle cell anemia; A) T1W sagittal image of cervical spine B) T2W sagittal image of lumbar spine and C) T2W whole spine image showing central endplate depression (H-shaped configuration) (arrow) of all the vertebral bodies.

Discussion

MRI is used in our study to diagnose various bone marrow pathologies in spine as it has better tissue differentiation and detects bone marrow changes at an early stage as compared to other imaging techniques. Other advantages of MRI includes a) no known side effects or morbidity, b) noradiation exposure and is c) non-invasive[1,2]. It has high sensitivity and specificity.

1. **Incidence of bone marrow pathologies:**In our study of 100 patients of various spinal pathologies, majority (60%) were degenerative disorders followed by infiltration/replacement disorder (16%) of which most common was metastasis. Next common was reconversion disorder (11%) followed by focal disorders of bone marrow(10%). Vogleret. al., have nicely grouped the bone marrow disease conditions according to common pathophysiological patterns in to reconversion disorder , infiltration disorders , depletion disorders , bone marrow edema and bone marrow ischemia[3].
2. **Age distribution:**We found disease in all age groups with the mean age group being 45.3 years. Elder population are commonly involved as major cause of various marrow pathologies are degenerative and infiltrative / replacement disorder of which most common is metastasis,
3. **Gender distribution:**No significant difference was found amongst the male to female population in various spinal pathologies.

Degenerative disorder: Observed in majority of patients (60%) seen most commonly at lumbar levels in particular L4/L5 and L5/S1 levels[4-6]. Though partly a consequence of aging, the actual cause is not known but many factors(autoimmune, genetic, re-absorption and biochemical) have been implicated in accelerating the process. The mean age is 45±12.5 years and its prevalence increases progressively to over 90% by 50 to 55 years of age[7,8]. Disc degeneration was the most frequent finding observed in 41(68.3%) patients in our study followed by disc herniation, disc bulge and modic changes.Type II Modic change (Fig 1) was the most frequent in our study(70.6%) found in several studies(de Roos *et al*. 1987, Modic *et al*. 1988b, Braithwaite *et al*. 1998, Schmid *et al*. 2004, Karchevsky *et al*. 2005) [9-13],Also type II Modic changes are usually associated with a more stable degenerative process (Modic *et al*. 1988b)[10]. An association of Modic changes and intervertebral disc degeneration was confirmed in our study.

Infiltrative/ replacement disorders: We found metastasis as most common neoplastic process that involve the spine as infiltrative/replacement disorder, followed by lymphoma, and plasma cell dyscrasia, either solitary plasmacytoma or multiple myeloma[14].

Metastasis: In our study, out 11 patients with metastasis (Fig 2), posterior elements were involved in 10 patients (90.9%), vertebral body in 5 patients (45.45%) and endplates in 4 patients (36.36%). Hence, contradicting the results of previous study done by Algra et al that is the body is involved before the pedicles.In our study, 3 patients(27.27%) had both lumbar and thoracic spine involvement,5 patients (54.54%) had only lumbar involvement and in 3 patients (27.27%) had only thoracic involvement with no patient showing cervical spine involvement; these results were consistent with previous studies by Galasko et al[15]In our study, cord compression was present in 2 out 11 patients (18.18%), nearly similar to previous study done by Siegal T.Metastases often (but not consistently) have a rim of bright T2 signal around them (a halo sign)[16].The halo sign and diffuse signal hyperintensity were shown to be a strong indicator of metastatic disease. In our study, all patients with metastasis had hypo to isointense signal on T1 and heterogeneously hyperintense signal on T2 with 4 out of 11 were showing halo sign and 6 out 11 were showing the post contrast enhancement. Dual-FFE sequence was done in only 5 patients with metastasis; increased signal was noted in all the 5 patients on out phase.

Lymphoma: In our study, only 2 cases of lymphoma (i.e. 12.5%) were found out of 16 patients with infiltrative/ replacement disorders; both involving the vertebral body and both involving the dorsal and lumbar spine with no spinal cord compression. We found that, in patients with lymphoma, lesions were hypointense on T1 and hyperintense on T2WI[17].There was no significant post contrast enhancement in either of the patients.

Reconversion disorder:A total of 11 cases of reconversion disorders of spine in our study, most common was chronic anaemia due to thalassemia (45.5%), followed by hyperparathyroidism (18.18%) and sickle cell anaemia (9.09%).

HaemolyticAnaemia- Thalassemia (Fig 3): Marrow hypo intense to muscle in both T1- and T2-w images was identified as iron deposition within red marrow in transfusion-dependent patients with thalassemiaand sickle cell anaemia[18-21]

In our study , we found that 3 out of 5 patients (60%) with thalassemia had diffuse bone marrow hypointensity in all MR sequences.2 out of 5 patients (40%) had hypointensity on the T2*-w GRE sequence alone without any significant hypointensity on T1 and T2similar to study conducted by Drakonaki et al[22]

HaemolyticAnaemia- Sickle cell Anaemia:We had only one case of sickle cell anaemia (Fig 4) and findings were diffuse T1 hypointense signal involving entire spine consistent with findings of anaemia without any complications of osteomyelitis. There wasalso H–shaped configuration of vertebral body due to multilevel central end plate depression.Diffuse marrow replacement from anaemia, epidural abscess, epidural phlegmon, osteomyelitis/discitis, and bone infarct were other findings of sickle cell anaemia found in study conducted by Candocia et al.

Depletion disorders: Various depletion disorders are depletion disorders secondary to radiotherapy, chemotherapy, idiopathic and depletion disorders with fibrosis (myelofibrosis), aplastic anaemia. Only 3 cases of depletion disorders were found in our study showing diffuse T1 and T2 hypointensity involving the thoracic and lumbar region in all three patients. Findings were consistent with study conducted by Gupta et al[23]

Focal disorders of bone marrow Infection(Tuberculous spondylitis): In our study, we found 6 patients of Tuberculous Spondylitis out of which 5 had thoracolumbar spine involvement (i.e. 83.33%) which is the most common site of involvement[24] and 1 had multiple level diffuse involvement(16.67%).All 6 patients in our study, with tuberculous spondylitis had paraspinal

abnormal signal(100%), a thin and smooth abscess wall (100%) and presence of paraspinal or intraosseous abscess (100%) while sub ligamentous spread to three or more vertebral levels was seen in 1 patient (16.6%), and hyperintense signal on T2-weighted images in all 6 patients (100%).Similar to study conducted by Na-Young Jung et al[25]

Conclusion

- Changes in normal pattern of bone marrow with advancing age should be understood and is important to correctly approach for various bone marrow pathologies. Neoplastic disease of the bone marrow is a frequent pathology and may have different morphologic patterns. Storage diseases and hemoglobinopathies may have typical bone marrow patterns, which are well visualized with MRI. While standard imaging of bone marrow is based on a few standard sequences (in particular T1-weighted and STIR sequences) new techniques are being developed to better characterize certain pathologic conditions.
- Conventional radiology depicts changes of an altered bony matrix while MRI displays changes at a cellular level and is well suited for imaging the bone marrow. It is very sensitive, although the specificity of MRI findings is not always without fallacies. Hence MRI serves as a screening method in bone marrow disorders and the diagnosis is confirmed by clinical findings or by biopsy.

Abbreviations: DWIBS: Diffusion-weighted imaging with background subtraction; FOV: Field of view; MRI: Magnetic resonance imaging; NPV: Negative predictive value; PPV: Positive predictive value; STIR: Short tau inversion recovery;

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