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Differentiating Multiple Myeloma and Vertebral Metastases Using T1-Weighted MRI Signal Intensity Ratio

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Abstract: ***Magnetic resonance imaging (MRI) plays a critical role in identifying vertebral lesions, yet differentiating multiple myeloma from metastases remains challenging. This retrospective study evaluated 100 patients with pathologically confirmed lesions, measuring the signal intensity ratio between spinal lesions and the spinal cord on T1 - weighted MRI. Results revealed a significantly higher signal intensity ratio in multiple myeloma (1.39 ± 0.24) compared to metastases (0.85 ± 0.31), with hepatocellular carcinoma metastases exhibiting a uniquely elevated ratio. The study introduces a practical visual threshold (≥1) that may be used during image interpretation to differentiate these conditions more effectively. The findings highlight a potentially simple, visual diagnostic aid in distinguishing between these spinal pathologies.***

Keywords: multiple myeloma, vertebral metastases, T1 - weighted MRI, spinal cord, signal - intensity ratio

1. Introduction

Multiple myeloma is a disease characterized by clonal expansion of malignant plasma cells that accumulate in the bone marrow [1]. The spine is one of the main sites of involvement in patients with multiple myeloma due to its rich content of bone marrow [2]. The spine is also one of the frequently involved sites of metastasis in patients with primary malignant neoplasm [3]. In view of the different lines of treatment of multiple myeloma and metastasis [1, 4], differentiation between the two is important. Though magnetic resonance (MR) imaging is one of the best imaging modalities for the diagnosis of focal lesions of the spine [3], differentiation of multiple myeloma and vertebral metastasis may be difficult [5], particularly in patients with occult primary neoplasm at the time of the initial presentation.

The primary aim of this study is to assess whether the signal intensity ratio between vertebral lesions and spinal cord on T1 - weighted MRI can serve as a distinguishing feature between multiple myeloma and metastases

2. Material and Methods

One hundred patients were included in the present retrospective observational study. The study has been approved by the ethical committee of the institution. The inclusion criterion was the presence of a focal lesion of the vertebral bodies or appendages on MR imaging of the spine. The exclusion criteria were poor image quality, lack of histopathological proof of the diagnosis, focal lesions associated with vertebral body collapse and diffuse involvement of the spine in cases of multiple myeloma. The study included 41 patients with pathologically proven focal multiple myeloma of the spine and 59 patients with pathologically proven vertebral metastases (table 1). Patients with vertebral metastases included 26 patients with breast carcinoma, 11 patients with bronchogenic carcinoma, 7 patients with prostatic carcinoma, 5 patients with hepatocellular carcinoma, 3 patients with renal cell carcinoma, 2 patients with gastric carcinoma, one patient with thyroid carcinoma, one patient with neuroendocrine carcinoma, one patient with nasopharyngeal carcinoma, one patient with colon carcinoma, and one patient with tongue carcinoma.

The signal intensity of focal lesions and that of the spinal cord were measured by operator - determined region of interest (ROI). The signal intensity of the vertebral focal lesions to that of the spinal cord was calculated for each patient.

Statistical analysis was done by the Student's t - test and by the Receiver - Operating - Characteristic (ROC) curve analysis.

3. Results

The signal - intensity ratio of the lesion to the spinal cord was significantly higher in multiple myeloma (1.39 ± 0.24) than that of metastases (0.85 ± 0.31) ($p< 0.0001$) (table 2) (fig 1). The lesion - to - cord signal - intensity ratio showed a maximum diagnostic accuracy of 76% when the lesion - to - cord signal - intensity ratio was equal to or greater than 1 for the diagnosis of multiple myeloma and an area under the ROC curve of 0.78 (fig 2). One type of metastases, those of hepatocellular carcinoma, showed a statistically significant higher signal intensity ratio to the spinal cord (1.33 ± 0.4) than that of the rest of metastases (0.80 ± 0.27) ($p< 0.0002$) (table 3) (fig 1). There was no statistically significant difference between signal intensity ratios of multiple myeloma and hepatocellular carcinoma metastases ($p< 0.6268$). On re - analysis of the ROC curve after exclusion of hepatocellular carcinoma metastases, diagnostic accuracy for multiple myeloma at the threshold ≥1 increased to 80% and the area under the curve increased to 0.82.

4. Discussion

Differentiation between multiple myeloma and metastases of the spine is important when spinal focal lesions are encountered due to the different lines of treatment of the two diseases. Differences between the two diseases have been described on imaging studies. However, the overlap of diagnostic parameters may still exist [6 - 10].

The present study describes a new sign that may differentiate focal lesions of the spine caused by multiple myeloma from those due to metastases based on the relatively higher signal intensity of multiple myeloma lesions compared to those from metastases.

There are two presumable reasons for the relatively high signal intensity of multiple myeloma: its high cellularity and its high protein content. The monocellular nature of multiple myeloma with little or no connective tissue between the cells probably results in a larger number of cells per MRI voxel compared to metastasis which has a larger connective tissue matrix binding the cells together. The plasma cells of multiple myeloma are known for their protein synthesis and excretion by their intracellular Golgi apparatus [11].

Hepatocellular carcinoma metastasis to the spine demonstrated on MR imaging have been mentioned in several case reports and they may occur as the initial presentation before the diagnosis of the primary hepatic neoplasm [4, 12, 13, 14]. However, its relatively high signal intensity compared to other vertebral metastases has not been previously reported.

Multiple myeloma of the spine may be focal or diffuse. In the present study, diffuse multiple myeloma has not been included as they are readily distinguished from metastases while focal multiple myeloma may be difficult to differentiate from metastases.

One of the limitations of the present study is that it does not include cases of melanoma metastases which are rare in the regional population of the present study. Melanoma metastases may show high signal intensity on T1 - weighted images due to their melanin content.

Different threshold value of the lesion - to - spinal cord SNR have been evaluated in the present study. The highest accuracy occurs when this ratio is equal to or greater than 1. This means that the new sign is not only valid as a quantitative sign but can also be appreciated simply by visual comparison of the lesion to the nearby spinal cord, making it an easy - to - use sign during the routine visual review of images.

The practical impact of the present study is that the relatively high signal intensity of the lesion in relation to the spinal cord on T1 - weighted images should prompt an assessment of the possibility of hepatocellular carcinoma metastasis and the possibility of multiple myeloma.

The proposed imaging marker could support radiologists and oncologists in making quicker, more accurate treatment decisions, particularly in cases where the primary neoplasm is unknown.

5. Conclusion

T1 - weighted MRI offers a valuable diagnostic clue in differentiating multiple myeloma from vertebral metastases through the signal intensity ratio relative to the spinal cord. A threshold value of ≥1 serves as a practical and intuitive marker during routine radiologic evaluations. While hepatocellular carcinoma metastases may mimic multiple myeloma in signal appearance, this exception further highlights the need for contextual clinical correlation. Future prospective studies are warranted to validate these observations across broader populations.

Tables:

Table 1: Demographics of the patients included in the study

Diagnosis	Number	Percentage
Multiple myeloma	41	41%
Breast carcinoma metastases	26	26%
Bronchogenic carcinoma metastases	11	11%
Prostatic carcinoma metastases	7	7%
Hepatocellular carcinoma metastases	5	5%
Renal cell carcinoma metastases	3	3%
Gastric carcinoma metastases	2	2%
Thyroid carcinoma metastases	1	1%
Neuroendocrine carcinoma metastases	1	1%
Nasopharyngeal carcinoma metastases	1	1%
Colon carcinoma metastases	1	1%
Tongue carcinoma metastases	1	1%
	100	100%

Table 2: Lesion - to - cord signal intensity ratio of multiple myeloma and metastases. Statistical analysis was done by the unpaired Student's t - test.

Diagnosis	Lesion - to - cord signal intensity ratio	P value	T value
Multiple myeloma	1.39 ± 0.24	p< 0.0001	t=9.3675
All metastases	0.85 ± 0.31		
Hepatocellular carcinoma metastases	1.33 ± 0.4	p< 0.0002	t=4.0335
Other metastases	0.80 ± 0.27		

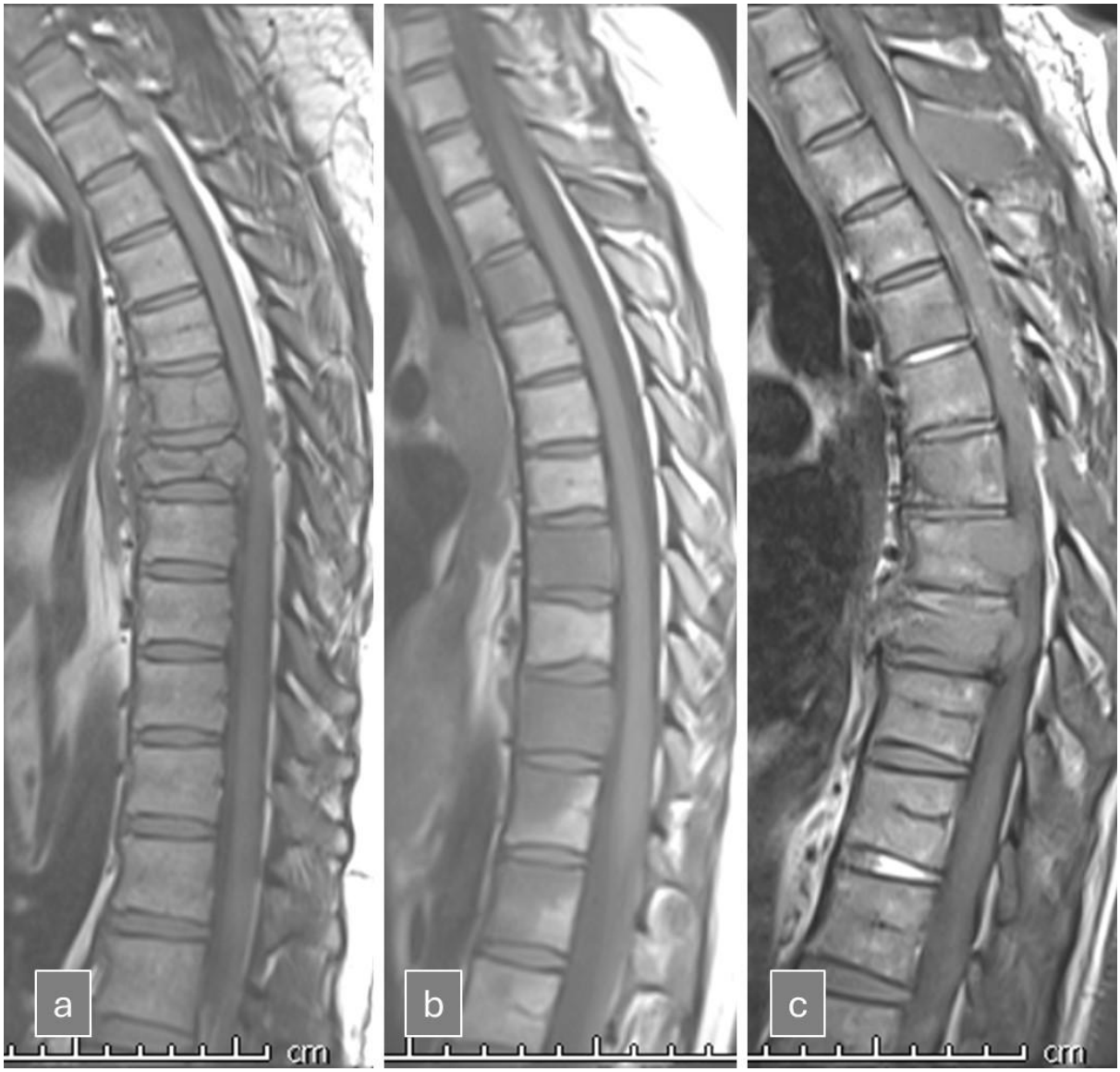

Figure 1: Sagittal T1 - weighted MR images of the thoracic spine in three different patients with multiple myeloma (a), breast carcinoma metastasis (b) and hepatocellular carcinoma metastasis (c). The signal - intensity ratio of the lesion to the spinal cord was 1.25 in a, 0.79 in b, and 1.47 in c. Visual assessment shows also that multiple myeloma and hepatocellular carcinoma metastasis have higher signal intensity and breast carcinoma metastasis has lower signal intensity compared to the spinal cord.

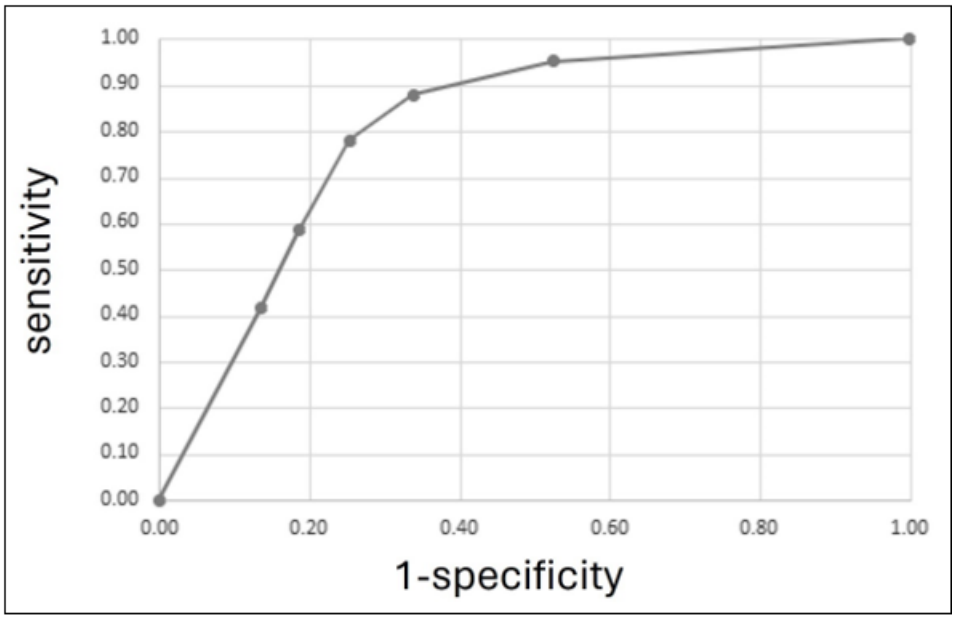

Figure 2

Receiver - Operating Characteristic (ROC) Curve at a lesion - to - spinal cord signal intensity ratio threshold value of 1 for the differentiation of vertebral metastases and multiple myeloma.

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