Am J Transl Res 2021;13(6):7335-7341
www.ajtr.org /ISSN:1943-8141/AJTR0128817

Original Article

An analysis of clinical values of MRI, CT and X-ray in differentiating benign and malignant bone metastases

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Received December 22, 2020; Accepted March 19, 2021; Epub June 15, 2021; Published June 30, 2021

Abstract: Objective: To investigate the clinical values of magnetic resonance imaging (MRI), computed tomography (CT) and X-ray in differential diagnosis of benign and malignant bone metastases. Methods: A total of 80 patients with bone metastases admitted to our hospital were selected as the study subjects. X-ray, CT and MRI examinations were performed, respectively. The pathological examination results were taken as the gold standard to analyze the lesion sites of metastatic tumors in 80 subjects. The diagnostic sensitivity, specificity and accuracy of X-ray, CT and MRI examinations were calculated and compared. Results: Among the 80 patients, 71 cases were diagnosed as malignant bone metastases and 9 cases as benign lesions according to pathological examination. The diagnostic sensitivity, specificity and accuracy of X-ray, CT and MRI examinations were 63.38%, 33.33% and 60.00%, 84.51%, 66.67% and 82.50%, and 90.14%, 77.78% and 88.75%, respectively. MRI was superior to X-ray in the sensitivity, specificity and accuracy of differential diagnosis of benign and malignant bone metastases ($P < 0.05$). MRI was superior to CT, but there was no significant difference between the two groups ($P < 0.05$). The diagnostic sensitivity, specificity and accuracy of CT + MRI were significantly higher than those of any single detection method ($P < 0.05$). Conclusion: MRI, CT and X-ray exhibit a good value in differential diagnosis of benign and malignant bone metastases. Overall, MRI is superior to CT and X-ray in the screening effects, and the combined detection methods are more satisfactory. It is recommended that CT should be used for primary screening, and CT + MRI should be implemented for a enhanced diagnosis.

Keywords: MRI, CT, X-ray, bone metastases, differentiation between benign and malignant tumors, clinical values, analysis

Introduction

Malignant tumors are one of the leading causes of death in China and play a pivotal role in the global mortality rate [1]. According to statistics, there is an increase of 30% in the mortality rate of malignant tumors in China compared with that at the beginning of the 20th century. The diagnosis and treatment of malignant tumors have been widely explored by medical workers all over the world [2, 3]. Malignant tumors constitute great burden to the lives of patients and their families. Bone metastases refer to malignant tumors originating from extraskeletal organs or tissues, metastasize to skeletons through lymphatic and blood systems and continuing to progress [4, 5]. The epidemiological studies suggest that the incidence rate of bone metastasis in patients with advanced malignant tumors is about 30%-75%. Approximately 15%-30% of patients with advanced lung cancer, colon cancer, gastric cancer and rectal cancer develop bone metastases [6, 7]. Patients with malignant tumor and bone metastasis usually have a significantly reduced survival rate and can hardly be cured [8]. Forty percent of patients with malignant tumor die of bone metastasis. In particular, patients with spinal metastasis often experience pathological fractures and spinal cord compression due to osseous destruction, resulting in poor quality of life [9].

The differentiation of benign and malignant bone metastases is the key to determine clinical intervention protocol. Currently, imaging,

blood biochemical treatment, and medical history and symptoms and signs are used for a comprehensive diagnosis. Imaging is an effective method to differentiate benign and malignant bone metastases [10, 11]. To date, X-ray, computed tomography (CT), magnetic resonance imaging (MRI), and radionuclide whole-body bone imaging have been used as the imaging options for differential diagnosis of benign and malignant bone metastases. Among them, X-ray is cost-effective, simple and suitable for primary screening. X-ray exhibits a satisfactory value in the diagnosis of spinal bone metastases [12], While CT examination, featuring a high specificity, can more clearly show the bone destruction and is conducive to the identification of the nature of lesion [13]. MRI is sensitive to the edema of tumor tissues and their surroundings in myeloid tissues containing fat. However, the high price and long duration of examination of MRI restrict its clinical application [14]. Radionuclide bone imaging is conducive to identifying early lesions. However, abnormal density shadows often occur in patients with trauma or infections, leading to a reduction in diagnostic accuracy [15].

This study aimed to evaluate the effects and clinical values of MRI, CT and X-ray as well as the combined detection methods in differentiating benign and malignant bone metastases, so as to provide a reference for improvement of the prognosis of such patients.

Materials and methods

General data

A total of 80 patients with bone metastases admitted to our hospital from January 2018 to October 2020 were selected as the study subjects. There were 46 males and 34 females aged 30-81 years, with an average age of (55.19 ± 4.20) years. Among the subjects, there were 32 cases with lung cancer, 20 cases with breast cancer, 10 cases with prostate cancer, 8 cases with liver cancer, 6 cases with rectal cancer, 3 cases with esophageal cancer and 1 case with nasopharyngeal cancer. Regarding clinical manifestations, there were 39 cases with ostealgia and 41 cases without severe ostealgia.

Inclusion criteria: patients (1) diagnosed as bone metastases by clinical examination; (2) with clear consciousness and ability to cooperate with the investigation; (3) with complete medical records. This investigation has been reported to the Hospital Ethics Committee for approval and implementation. Patients or their families voluntarily signed the informed consent form.

Exclusion criteria: patients (1) with mental illness; (2) with poor study compliance; (3) pregnancy or lactation; (4) alcohol or drug addicts; (5) with systemic immune diseases.

Intervention methods

The enrolled subjects were examined by X-ray, CT and MRI, respectively. The plain films were obtained using Philips digital radiography (DR) system in X-ray examination, and the corresponding photography methods were selected based on different test sites in the patients, and the test sites were imaged after the positioning of patients. The VCT machine (GE Company, United States) was selected for CT examination, and the soft tissue window and bone window were used for observation and imaging after the parameters was set. The Philips Intera Nova 1.5T MRI Scanner was selected for MRI examination. The scanner was set as a spin-echo sequence, and T1 weighted imaging (T1WI) and T2 weighted imaging (T2WI) were performed on transverse, coronal and sagittal planes.

Observational indices and assessment criteria

The results of X-ray, CT and MRI examinations were evaluated by two attending physicians in the Department of Pathology, and the different opinions were discussed and unified by the two physicians. Finally, the sensitivity, specificity and accuracy of X-ray, CT, MRI examinations and the combined detection methods were evaluated, with the histopathological examination results of bone marrow puncture as the gold standard.

Statistical method

The collected data were input into an EXCEL table, and SPSS 22.0 was adopted for statistical analysis. The collected data were detected using normal distribution. The data conforming to normal distribution were expressed using [n (%)]. The differences between groups were

Table 1. Analysis of metastasis sites in 80 patients with bone metastases

Primary tumors	n	Metastasized sites and frequency					
		Spine	Ribs	Chest	Pelvis	Skull	Limbs
Lung cancer	32	11	11	3	4	2	1
Breast cancer	20	6	4	5	3	1	1
Prostate cancer	10	3	2	1	2	1	1
Liver cancer	8	3	2	1	1	0	1
Rectal cancer	6	3	2	1	0	0	0
Esophageal cancer	3	2	1	0	0	0	0
Nasopharyngeal cancer	1	1	0	0	0	0	0
Total	80	29	22	11	10	4	4
Composition ratio (%)	100	36.25	27.50	13.75	12.50	5.00	5.00

Table 2. Distribution of spinal metastases in 29 cases

Primary tumors	n	Cervical vertebra	Thoracic vertebrae	Lumbar vertebrae	Sacral vertebrae
Lung cancer	11	1	6	3	1
Breast cancer	6	0	2	3	1
Prostate cancer	3	1	0	2	0
Liver cancer	3	0	2	1	0
Rectal cancer	3	0	1	1	1
Esophageal cancer	2	0	0	2	0
Nasopharyngeal cancer	1	0	1	0	0
Total	29	2	12	12	3
Composition ratio (%)	100	6.90	41.28	41.38	10.34

detected using Chi-square test. The measurement data were expressed using mean ± standard deviation. The differences between groups were analyzed using t test. $P < 0.05$ indicated a statistically significant difference. The graphs were plotted using GraphPad Prism 8 [16].

Results

Distribution sites of bone metastases in subjects

The analysis of the lesion sites of bone metastases in the subjects showed that the spine and ribs (36.25% and 27.50%) were the primary sites of bone metastases in 80 subjects, followed by the chest and pelvis (13.75% and 12.50%) and skull and limbs (5.00% and 5.00%) (**Table 1**). The analysis of the spinal site with the highest metastasis rate revealed that there was the highest metastasis rate (41.38%) at the lumbar vertebra site in 29 patients with spinal metastasis, followed by at the thoracic vertebra site (41.38%), sacral vertebrae site (10.34%) and cervical vertebra (6.90%) (**Table 2**).

Analysis of values of X-ray, CT and MRI in differentiating benign and malignant bone metastases

The diagnostic values of X-ray, CT and MRI in differentiating benign and malignant bone metastases were explored, with the pathological examination results as the gold standard. The results showed that the sensitivity, specificity and accuracy of X-ray, CT and MRI examinations were 63.38%, 33.33% and 60.00%, 84.51%, 66.67% and 82.50%, and 90.14%, 77.78% and 88.75%, respectively (**Tables 3**-**5**).

Analysis of values of combined detection methods in differentiating benign and malignant bone metastases

The diagnostic values of X-ray, CT and MRI in differentiating benign and malignant bone metastases were investigated. The results exhibited that the sensitivity, specificity and accuracy of X-ray + CT, X-ray + MRI and CT + MRI were 90.14%, 66.67% and 86.25%, 92.96%, 66.67% and 90.00%, and 98.59%, 88.89% and 97.50%, respectively (**Tables 6**-**8**).

Comparison of diagnostic values between single and combined detection methods

The comparison of the diagnostic values in differentiating benign and malignant bone metastases between single and combined detection methods suggested that the sensitivity of any two combined detection methods for differentiating benign and malignant bone metastases was higher than that of single detection method ($P < 0.05$). Among the three combined detection methods, CT + MRI exhibited the highest sensitivity, specificity and accuracy, and its clinically diagnostic value was the most prominent (**Table 9**).

Table 3. Analysis of the value of X-ray examination in the diagnosis of benign and malignant bone metastases

X-ray	Pathologically malignant (n=71)	Pathologically benign (n=9)
Malignant (n=51)	45	6
Benign (n=29)	26	3

Table 4. Analysis of the value of CT examination in the diagnosis of benign and malignant bone metastases

CT	Pathologically malignant (n=71)	Pathologically benign (n=9)
Malignant (n=63)	60	3
Benign (n=17)	11	6

Table 5. Analysis of the value of MRI examination in the diagnosis of benign and malignant bone metastases

MRI	Pathologically malignant (n=71)	Pathologically benign (n=9)
Malignant (n=66)	64	2
Benign (n=14)	7	7

Table 6. Analysis of the value of X-ray combined with CT in the diagnosis of benign and malignant bone metastases

X-ray + CT	Pathologically malignant (n=71)	Pathologically benign (n=9)
Malignant (n=68)	64	4
Benign (n=12)	7	5

Table 7. Analysis of the value of X-ray combined with MRI in the diagnosis of benign and malignant bone metastases

X-ray + MRI	Pathologically malignant (n=71)	Pathologically benign (n=9)
Malignant (n=69)	66	3
Benign (n=11)	5	6

Table 8. Analysis of the value of CT combined with MRI in the diagnosis of benign and malignant bone metastases

CT + MRI	Pathologically malignant (n=71)	Pathologically benign (n=9)
Malignant (n=71)	70	1
Benign (n=9)	1	8

Discussion

In recent years, with the aging of population and the changes of life and dietary structure, tumors have become one of the common clinical diseases [17]. Bone metastasis is common in patients with advanced malignant tumors. A study [18] suggests that the incidence rate of bone metastasis is about 35-40 times that of primary malignant tumors, and bone metastasis usually causes significant cancer pain, induces spinal cord compression, pathological fractures, hypercalcemia, bone marrow failure and other complications, which seriously affect the quality of life of cancer patients. A previous study analyzed the bone metastasis rate in patients with several common malignant tumors, and the results revealed that the metastasis rates of breast cancer, prostate cancer, thyroid cancer, bladder cancer, and lung cancer were 65%-75%, 65%-75%, 60%, 40%, and 30%-40%, respectively [19]. The survival rate of patients with metastatic bone cancer has been improved significantly these years, however, early diagnosis and treatment remain an important approach to improve the quality of life and to prolong the overall survival (OS).

Bone metastases in patients with early malignant tumors are mostly asymptomatic. The occurrence of pain symptoms often indicates that the optimal treatment opportunity has been missed. The early identification of bone metastasis and implementation of differential treatment are conducive to improving the prognosis of patients [20]. Currently, imaging analysis has been extensively applied in the diagnosis of bone metastases in patients with malignant tumors and differentiation of benign and malignant bone metastases. X-ray, CT and MRI are the commonly used imaging methods. In this study, a total of 80 patients with bone metastases were examined with X-ray, CT and MRI to differentiate benign and malignant bone metastasis, and the advantages and disadvantages of X-ray, CT and MRI were compared. The results demonstrated that MRI was superior to

Table 9. Comparison of values of the three detection methods in differentiating benign and malignant bone metastases (%)

Detection methods	Sensitivity	Specificity	Accuracy
X-ray	63.38	33.33	60.00
CT	84.51	66.67	82.50
MRI	90.14	77.78	88.75
X-ray + CT	90.14*	66.67	86.25
X-ray + MRI	92.96*	66.67	90.00
CT + MRI	98.59*	88.89*	97.50*

Note: *Compared with any single examination methods, the differences were statistically significant.

X-ray and CT in terms of the sensitivity, specificity and accuracy of diagnosis of benigh or malignant tumors with bone metastases. A study of enhanced CT and MR imaging in 110 patients with malignant tumors showed that, with the pathological results as the gold standard, the diagnostic sensitivity and specificity of CT for bone metastases were 71.7% and 66.75, while those of MRI were 86.9% and 66.7% respectively. The diagnostic sensitivity of MRI was markedly higher than that of CT. It is believed that MRI was superior to CT and X-ray in the early identification of lesions [21]. Bone metastases can be categorized into osteolytic metastases, osteoblastic metastases, and a mixed phenotype of both on X-ray. The X-ray images of early lesions are not obvious, and there are many overlapping structures on X-ray images, which can easily lead to missed diagnosis and mis-diagnosis of bone metastases. This contributes to the diagnostic accuracy of only 60% of X-ray examination in this study. A study suggests that X-ray films are not sensitive to minor lesions, and negative can only be determined when bone metastases lead to a serious osseous destruction and the diameter of lesions is greater than 15 mm. Therefore, it is recommended that X-ray should only be used as a primary screening method for bones of limbs, and should not to be used to differentiate in such parts as spine [22].

In this study, the sensitivity, specificity and accuracy of CT examination for differentiation of benign and malignant bone metastases were 84.51%, 66.67% and 82.50%, respectively, indicating that CT was significantly superior to X-ray. A controlled study on 68 patients with bone metastases suggested that the positive rate (57%) of X-ray in differentiating malignant bone metastases was markedly lower than that of CT. The low diagnostic sensitivity of X-ray might be related to the operations of physicians and the lesions mostly covered by high-density cortex due to the reason that osteoclasia induced by bone metastases did not involve cortex [23]. CT examination is sensitive to the lesions with osseous changes. It can not only show the lesion sites from multiple angles and the fine destruction of cortical bone and bone trabeculae, but also enable the observation of the soft tissues around the lesions, and thus facilitate determination of the lesion nature. Therefore, CT examination has higher diagnostic sensitivity and specificity. However, CT is inferior to MRI in differentiating the nature of osteosclerosis. Therefore, it is not recommended that CT should be used as a separate method for differentiation [24]. The results of MRI for differentiation showed that MRI was superior to X-ray and CT in the sensitivity, specificity and accuracy. This may be related to the reason that edema in and around the pathological tissues can be diagnosed using MRI, and MRI is superior to CT in the value for differentiating lesions caused by soft tissue involvement [25]. In addition, in case of malignant bone metastases, the water content in the metastases is higher because of bone marrow invasion, and the blood supply in malignant tissues is significantly greater than that in the surrounding tissues, providing a theoretical basis for MRI examination. A whole-body MRI examination on 39 children with malignant tumors showed that the number of detected lesions (80.77%) by MRI in 51 cases was slightly lower than that (90%) by radionuclide bone imaging, with the pathological results as the gold standard. MRI is believed to exhibit a high sensitivity in early identification of lesions, facilitating the determination of the invasive sites and scope of bone metastases and the involvement of the surrounding soft tissues [26].

In summary, MRI, CT and X-ray exhibit a good value in differentiating benign and malignant bone metastases. Overall, MRI is superior to CT and X-ray in the screening effects, and combined detection methods are more satisfactory. It is recommended that CT should be used for primary screening, and CT + MRI should be implemented for a defined diagnosis. The innovation of this study lies in the analysis of the values of X-ray, CT and MRI for differentiation of

benign and malignant bone metastasis, and the comparison of the advantages and disadvantages of the three detection methods, providing a theoretical reference for the clinical treatment. The deficiency of this study is that there was no comparative analysis on the differentiation of multiple benign and malignant lesions, and the influences of underlying health conditions on the diagnosis results needs to be improved in the future studies.

Disclosure of conflict of interest

None.

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