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ORIGINAL RESEARCH

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Molybdenum target X-ray examination and multimodality MRI in the diagnosis of breast cancer

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Abstract

Breast cancer is one of the most common malignant diseases, with a high mortality rate, affecting mostly females. This study aims to assess the diagnostic value of Molybdenum target X-ray examination and multimodality Magnetic Resonance Imaging (MRI) in breast cancer diagnosis. A total of 60 patients with suspected breast cancer were screened and included in the study. All patients underwent Molybdenum target X-ray and multimodality MRI, and the results were compared to pathological examination, which served as the reference standard for evaluating the diagnostic efficacy of the different screening methods. Molybdenum target X-ray examination identified 19 positive cases and 41 negative cases. Comparatively, multimodality MRI detected 43 positive cases and 17 negative cases. Compared to Molybdenum target X-ray, multimodality MRI demonstrated higher diagnostic accuracy, specificity, and sensitivity. Further analysis revealed that among the 45 positive patients, 13 were classified as stage 1, 20 as stage 2, 9 as stage 3, and 3 as stage 4. The pathological types were categorized as invasive ductal carcinoma, intraductal carcinoma, and ductal carcinoma *in situ*, with 25, 6 and 14 cases, respectively. Intraductal carcinoma exhibited higher levels of enhancement rate and signal enhancement ratio, as well as shorter peak time, compared to the other two types. No significant difference was observed between invasive ductal carcinoma and ductal carcinoma *in situ*. In the clinical diagnosis of breast cancer, multimodality MRI examination proves to be more comprehensive and accurate in determining the tumor's nature and the type of disease, with significant clinical value in the field.

Keywords

Molybdenum target X-ray; Multimodality MRI; Breast cancer; Diagnostic efficacy

1. Introduction

The incidence of malignant neoplastic diseases in women has significantly increased, with breast cancer accounting for a considerable proportion and posing a significant risk to women's health, safety, and family stability [1, 2]. In general, breast cancer often lacks noticeable clinical manifestations or typical symptoms in its early stages, making it easily overlooked [3, 4]. Without regular physical examinations, early detection becomes challenging, and without timely and effective intervention, the disease can progress, increasing the risk of adverse outcomes [5]. Numerous clinical studies have shown that prompt treatment of breast cancer in its early stages can significantly improve the five-year survival rate [6, 7]. Thus, improving the diagnosis and early detection of breast cancer are crucial factors in improving prognosis.

Currently, breast ultrasound, molybdenum target X-ray, Computed Tomography (CT) and MRI are the commonly used diagnostic methods in clinical practice for breast cancer [8], with each method having their own advantages and disadvantages. Comparatively, ultrasound is easy to perform, widely accepted by the public, cost-effective, and repeatable [9]. However, it may not accurately detect malignant calcifications, especially small ones [10]. Alternatively, the application of molybdenum target examination provides an understanding of the lesion's condition but lacks accurate guidance for surgery and has limited clinical application. With the rapid development of imaging technology, MRI has gained widespread use and high evaluation in breast cancer diagnosis. The diagnostic efficacy can be greatly improved with conventional MRI, dynamic enhanced scanning and magnetic resonance diffusion-weighted imaging, as well as significantly increasing the detection rate of breast cancer [11, 12].

To address the limitations of conventional MRI technology, our study aimed to evaluate the effectiveness of multimodality MRI in patients admitted to our hospital with suspected breast cancer. We compared its performance with that of molybdenum target X-ray.

2. Materials and methods

2.1 General data

For this study, 60 patients with suspected breast cancer admitted to our hospital from January 2020 to December 2022 were screened. All patients were female, aged 35 to 62 years, with a mean age of (51.65 $\pm$ 6.43) years. The disease duration ranged from 7 months to 9 years, with a mean of (3.58 $\pm$ 0.50) years. The inclusion criteria were as follows: (1) aged 35–62 years; (2) presence of nodules, masses, breast skin abnormalities, nipple depression, discharge, or other related conditions detected during health examinations or breast palpation; (3) initially diagnosed with suspected breast cancer through Molybdenum target X-ray or multimodality MRI examination, with a mass diameter $<$10 mm; (4) patients capable of normal communication, consciousness, and cooperation; (5) willingly participated and provided informed consent after receiving study information and relevant precautions from a healthcare professional. The exclusion criteria were: (1) presence of comorbid immune system disorders; (2) contraindications to examination; (3) history of previous thoracic chemoradiotherapy; (4) clear history of mental illness; (5) mental retardation, cognitive abnormalities, or inability to cooperate effectively; (6) refusal to undergo pathological examination.

2.2 Diagnostic protocol

Both examinations were completed by senior physicians in the same group, and health education was provided by the professional staff to introduce the examination precautions to improve patient compliance and ensure the successful completion of the examinations.

The Molybdenum target X-ray examination utilizes a full-field digital mammographic device (Crystal Nova AI, GE, Fairfield, CT, USA). The specific procedure involves the following steps: First, in the inspection process, the fully automatic exposure mode is selected, and the pressure is set within the range of 3–7 daN. Next, the patient is positioned in a standing posture, with their breasts exposed. Axial and lateral oblique views of both breasts are taken by placing them between the radiography table and the compression film, followed by an automatic exposure. The breast tissue on both sides of the patient is then compared. It is important to note that the symmetry of the breasts is crucial in clinical identification, as any lesions present can affect this symmetry. The reading and analysis of the mammogram are performed by a professional doctor, who closely observes various aspects such as the shape, size, margin, and density of the lesion, as well as the presence of calcifications, skin thickening, vascular thickening, nipple retraction, and axillary lymphadenopathy.

During the multimodality MRI examination, all metal products were removed beforehand, and the patient's breasts were naturally draped and scanned while in a supine position. The scanning instrument used was a digital magnetic resonance scanner (Ingenia 1.5 T, Philips, Amsterdam, Netherlands). The sequence selection for the MRI examination were: T2WI-SPAIR (T2 weighted imaging-spectral attenuated inversion recovery) (TR (repetition time) 5000 ms, TE (echo time) 65 ms, FOV (time of flight) 220 $\times$ 340 mm, slice thickness 4 mm, number of excitations 1), T1WI-TSE (T1-weighted imaging-turbo spin echo) (TR677 ms, TE8 ms, number of excitations 1), T2WI-TSE (TR3600 ms, TE120 ms, number of excitations 2), and T2WI-TRA (transverse). Diffusion-weighted imaging was also performed using a diffusion sensitivity factor of 1000 s/mm^2. For the dynamic enhanced scan (dyn-eTHRIVE TRA), the parameters used were TR4.5 ms, FOV340 $\times$ 340 mm, TE2.2 ms, slice thickness 2 mm, slice spacing $-$1 mm, and 1 excitation. Gadopentetate dimeglumine was selected as the contrast medium and injected through the cubital vein at a dose of 0.2 mmol/kg. After completion, the tube was flushed with 20 mL of NS (Normal saline) solution (0.9% concentration). The dynamic enhanced scan involved collecting data for 8 consecutive acquisitions, with a first collection interval of 43 seconds and a total collection time of 57 seconds. The diffusion-weighted magnetic resonance imaging data were processed using a workstation, and ADC maps were generated by software to measure ADC (apparent diffusion coefficient) values in specific regions of interest.

2.3 Outcome measures

1. Diagnostic criteria for multimodality MRI.

Criteria for malignancy included: (1) an irregular breast mass with a spiculated margin and abnormal signal intensity on the scan; (2) the plain scan results confirmed a T2WI high signal intensity without a clear boundary; (3) enhancement of the mass on contrast-enhanced scans as either homogeneous or heterogeneous, and (4) the time-signal curve exhibited an outflow pattern.

The time-signal intensity curve of contrast-enhanced MRI was divided into three types, whereby type 1 exhibits a slow ascending curve, which is often associated with benign lesions; type 2 shows a plateau curve, which might indicate benign and malignant overlapping areas in the breast; and type 3 exhibiting an outflow pattern, mostly indicating malignancy.

2. Disease detection was based on pathological outcomes and compared the diagnostic efficacy (sensitivity, specificity, accuracy) among different groups using both examination methods.

3. Positive cases of multimodality MRI were evaluated using various criteria. The judgment was based on the following factors: (1) pathological classification: sampling was conducted according to the location indicated by the multimodality MRI and the breast cancer pathological criteria by the World Health Organization (WHO) for accurate classification; and (2) clinical stage. Stage 1 refers to tumor confinement to the breast tissue, with a diameter of less than 2 cm, and no evidence of metastasis or fusion with other tissues was observed. Stage 2 refers to a tumor size ranging from 2 to 5 cm, characterized by skin adhesions, lymphadenopathy and limited tumor spread without fusion to adjacent tissues. Stage 3 refers to a tumor size equal to or larger than 5 cm and exhibited adhesion to the pectoralis major muscle or skin tissue, involving the fusion of lymph nodes. Stage 4 refers to a tumor that has extensively invaded the breast skin and the clear presence of satellite nodules.

4. The collection of multimodality MRI indicators included enhancement rate, signal enhancement ratio and peak time.

5. The collection of morphological findings of breast cancer lesions encompassed several aspects, including lesion type,

shape, margin, internal enhancement characteristics, and dynamic enhancement curve type.

2.4 Statistical analysis

The data were imported into SPSS 21.0 (IBM, Armonk, NY, USA) for analysis. Enumeration data are expressed as n (%), and the chi-square (χ^2) test was used. Measurement data are presented as mean $\pm$ standard deviation ($\bar{x} \pm s$), and *t*-test was also conducted. A *p*-value less than 0.05 was considered statistically significant.

3. Results

3.1 Pathological diagnosis results

Of the 60 patients who underwent pathological examination, a diagnosis of breast cancer was made in 45 patients, accounting for 75% of the total cases.

3.2 Comparison of findings and pathology from molybdenum target X-ray and multimodality MRI

The detailed results are presented in Table 1. The molybdenum target X-ray examination confirmed 19 cases (31.67%) as positive for breast cancer, while 41 cases (68.33%) tested negative. In contrast, the multimodality MRI findings indicated that 43 cases (71.67%) were positive for breast cancer, while 17 cases (28.33%) tested negative.

TABLE 1. Comparison of findings and pathology from molybdenum target X-ray and multimodality MRI.

Diagnostic methods	Pathologic findings		Total
	Positive	Negative	
Molybdenum target X-ray			
Positive	35	6	41
Negative	10	9	19
Multimodality MRI			
Positive	42	1	43
Negative	3	14	17
Total	45	15	60

MRI: Magnetic Resonance Imaging.

3.3 Comparison of diagnostic efficacy of different imaging techniques

Based on the results from Table 2, we observed that multimodality MRI exhibited relatively higher diagnostic accuracy, specificity, and sensitivity compared to molybdenum target X-ray examination, with excellent diagnostic efficacy ($p < 0.05$).

3.4 Results of multimodality MRI

The clinical stage and pathological type results for the 42 patients accurately detected as positive for breast cancer are shown in Table 3.

TABLE 2. Comparison of diagnostic efficacy of different imaging techniques (n (%)).

Group	Specificity	Sensitivity	Accuracy
Molybdenum target X-ray	60.00	77.78	73.33
Multimodality MRI	93.33	93.33	93.33
χ^2 value	4.658	4.406	8.640
p value	0.031	0.036	0.003

MRI: Magnetic Resonance Imaging.

TABLE 3. Analysis of results of multimodality MRI.

Item	Category	Case	Proportion (%)
Clinical stage			
	Stage 1	12	28.57
	Stage 2	19	45.24
	Stage 3	8	19.05
	Stage 4	3	7.14
Pathological type			
	Invasive ductal carcinoma	24	57.14
	Intraductal carcinoma	5	11.90
	Ductal carcinoma *in situ*	13	30.95

3.5 Comparison of multimodality MRI indicators in different pathological types

Based on the data shown in Table 4, of the 42 patients who were accurately detected as positive for breast cancer, a comparison of the different types revealed the following: (1) intraductal carcinoma exhibited a higher enhancement rate and signal enhancement ratio compared to the other two types, with lower peak time level, and the differences between groups were statistically significant ($p < 0.05$), and (2) invasive ductal carcinoma and ductal carcinoma *in situ* showed no significant differences in terms of enhancement rate, signal enhancement ratio, and peak time level ($p > 0.05$).

3.6 Analysis of morphology and enhancement characteristics in multimodality MRI

The detailed results in terms of lesion performance, lesion morphology, enhancement on enhanced scan, and dynamic curve enhancement type are shown in Table 5.

4. Discussion

Breast cancer has emerged as a growing concern and now poses the greatest threat to women's health. Various studies have revealed that early detection is critically important to improve the prognosis and reduce the risk of mortality associated with the disease. Therefore, early screening measures are essential for enhancing the detection rate of breast cancer. In clinical practice, imaging studies are a key component in diagnosing breast cancer [13, 14]. Various imaging techniques, including

TABLE 4. Comparison of multimodality MRI indicators in different pathological types (n, %).

Group	Case	Enhancement rate (%)	Peak time (s)	Signal enhancement ratio (%)
Invasive ductal carcinoma	24	1.20 ± 0.29	242.08 ± 22.01	1.10 ± 0.39
Intraductal carcinoma	5	1.91 ± 0.42	172.17 ± 21.20	1.60 ± 0.41
Ductal carcinoma *in situ*	13	1.36 ± 0.40	238.00 ± 23.79	1.10 ± 0.40
Invasive ductal/intraductal carcinoma				
	t value	4.6189	6.4960	2.5878
	p value	0.0001	0.0000	0.0154
Invasive ductal carcinoma/ductal carcinoma *in situ*				
	t value	1.4001	0.5234	0.0000
	p value	0.1703	0.6040	1.0000
Intraductal carcinoma/ductal carcinoma *in situ*				
	t value	2.5801	5.3991	2.3605
	p value	0.0201	0.0001	0.0313

TABLE 5. Analysis of morphology and enhancement characteristics in multimodality MRI (n, %).

Item	Category	Case	Proportion (%)
Lesion presentation			
	Mass type	28	66.67
	Non-mass type	14	33.33
Lesion morphology			
	Round shape	12	28.57
	Lobulated	11	26.19
	Irregular shape	19	45.24
Enhanced scan enhancement			
	Homogeneous enhancement	18	42.86
	Heterogeneous enhancement	20	47.62
	Ring enhancement	4	9.52
Dynamic Curve Enhancement Type			
	Plateau pattern	19	45.24
	Outflow pattern	23	54.76

color Doppler ultrasound, molybdenum target X-ray, CT scans and MRI, are employed to determine the presence of the disease. Among these, molybdenum target X-ray and color Doppler ultrasound are commonly utilized as initial screening tools [15, 16]. However, a comprehensive examination is often necessary to accurately assess the nature and characteristics of the tumor [17, 18].

X-ray examinations have been widely utilized in clinical practice for disease identification, including the evaluation of breast tumors. By carefully analyzing the anatomical structure of the breast, healthcare professionals can gather information about the lesion's specific characteristics [19, 20]. Notably, calcifications in breast lesions are often considered a significant radiological finding and serve as a typical sign in the clinical screening for breast cancer [21, 22]. However, X-ray examinations have certain limitations. The detection rate of microcalcifications in breast tissue is generally low, and the dense breast tissue commonly found in Chinese women can potentially obscure the location of the lesion, leading to false negatives. Moreover, small lesions in particular individuals or locations can be challenging to identify accurately [23, 24]. Therefore, while X-ray examinations have diagnostic value, their overall accuracy is relatively poor.

MRI offers advantages in terms of multi-parametric and omnidirectional scanning, which improves tissue resolution compared to other diagnostic methods. However, only performing an MRI examination may be slightly less effective than other techniques [25, 26]. Although the use of multimodality MRI in clinical practice has shown satisfactory results, gaining a comprehensive understanding of the histomorphological characteristics can enhance the efficacy of breast cancer diagnosis, facilitate accurate determination of the clinical stage, and provide a detailed basis for clinical decision-making [27, 28]. The findings of this study confirm that multimodality MRI exhibits higher diagnostic accuracy, specificity, and sensitivity compared to molybdenum target X-ray, demonstrating its superior diagnostic efficacy. This can be attributed to the presence of abundant adipose tissue

in the breast, which produces high signal intensity and needs to be effectively suppressed to accurately detect early lesions [29, 30]. One of the challenges in MRI imaging of the breast is that bilateral breasts may not obtain a uniform degree of magnetic field, which can impact the imaging quality and consistency. However, multimodality MRI addresses this issue by enabling multi-sequence and omnidirectional scanning, allowing for comprehensive breast lesion evaluation and meticulous observation and precise determination [31]. Among the 42 positive patients, intraductal carcinoma displayed a higher enhancement rate, signal enhancement ratio, and lower peak time than the other two types ($p < 0.05$). However, no significant difference was observed between invasive ductal carcinoma and ductal carcinoma *in situ* ($p > 0.05$), suggesting that multimodality MRI can accurately identify different pathological types of breast cancer tissues based on morphology and possesses robust soft tissue resolution capabilities. Regarding lesion characteristics, 28 cases were classified as the mass type while 14 as the non-mass type. In terms of lesion shape, 12 cases were round, 11 were lobulated and 19 were irregular. Contrast-enhanced scans revealed homogeneous enhancement in 18 cases, heterogeneous enhancement in 20 cases, and circumferential enhancement in 4 cases. Dynamic enhancement curve types included 19 cases with a plateau pattern and 23 with an outflow pattern. Collectively, these results indicated that multimodality MRI, through the identification of typical signs, could accurately diagnose breast cancer.

Despite the important findings reported in this study, there were some limitations that should be acknowledged, such as the small sample size and single-center data source. Future research could focus on evaluating the diagnostic effectiveness of different examination methods in larger and more diverse patient populations, which might lead to more scientifically robust and comprehensive conclusions, providing valuable references and rationale for clinical practice for improving the diagnosis of breast cancer.

5. Conclusions

In summary, multimodality MRI demonstrated higher accuracy, specificity and sensitivity in the clinical diagnosis of breast cancer compared to molybdenum target X-ray examination in this investigated cohort and offered comparative advantages in terms of diagnostic efficacy. However, it is important to consider factors such as radiation exposure and cost when selecting the appropriate imaging modality for each patient based on their individual circumstances and needs. Molybdenum target X-ray examination remains valuable in early screening for breast cancer.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper, and the raw data may be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

ZZH and YLC—designed the study and carried them out. ZZH, JX and BTH—supervised the data collection, analyzed the data, interpreted the data, prepared the manuscript for publication and reviewed the draft of this manuscript. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Ningbo Yinzhou No. 2 Hospital (Approval no. 2020041). Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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