Retrospective Study

Combined molybdenum target X-ray and magnetic resonance imaging examinations improve breast cancer diagnostic efficacy

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Abstract

BACKGROUND
Early-stage breast cancer patients often lack specific clinical manifestations, making diagnosis difficult. Molybdenum target X-ray and magnetic resonance imaging (MRI) examinations both have their own advantages. Thus, a combined examination methodology may improve early breast cancer diagnoses.

AIM
To explore the combined diagnostic efficacy of molybdenum target X-ray and MRI examinations in breast cancer.

METHODS
Patients diagnosed with breast cancer at our hospital from March 2019 to April 2021 were recruited, as were the same number of patients during the same period with benign breast tumors. Both groups underwent molybdenum target X-ray and MRI examinations, and diagnoses were given based on each exam. The single (i.e., X-ray or MRI) and combined (i.e., using both methods) diagnoses were counted, and the MRI-related examination parameters (e.g., T-wave peak, peak and early enhancement rates, and apparent diffusion coefficient) were compared between the groups.

RESULTS
In total, 63 breast cancer patients and 63 benign breast tumor patients were recruited. MRI detected 53 breast cancer cases and 61 benign breast tumor cases. Molybdenum target X-ray detected 50 breast cancer cases and 60 benign breast tumor cases. The combined methodology detected 61 breast cancer cases and 61 benign breast tumor cases. The sensitivity (96.83%) and accuracy (96.83%) of the combined methodology were higher than single-method MRI (84.13% and 90.48%, respectively) and molybdenum target X-ray (79.37% and 87.30%, respectively) (P < 0.05). The combined methodology specificity (96.83%) did not differ from single-method MRI (96.83%) or molybdenum target X-ray (95.24%) (P > 0.05). The T-wave peak (169.43 ± 32.05) and apparent diffusion coefficient (1.01 ± 0.23) were...
INTRODUCTION

Breast cancer can present as multiple malignancies, and recently, the incidence and morbidity are increasing in younger populations[1]. Early-stage breast cancer patients often lack specific clinical manifestations, and without timely diagnosis and intervention, the disease may progress, potentially invading the skin and the thoracic muscles and fascia. For some, undetected malignancies result in lymphatic and distant metastases, which are life-threatening and affect a patient’s quality of life[2-4]. Therefore, early breast cancer diagnosis is critical.

Molybdenum target X-ray examinations are often used to diagnose breast cancer as they have high repeatability and resolution and are noninvasive. However, they have poor penetrability, making satisfactory diagnostic results for deep and high breast cancers difficult[5,6]. Radiological technology is constantly developing, and magnetic resonance imaging (MRI) is also valuable for diagnosing breast cancer; it has high soft-tissue resolution and plainly presents abnormal enhancements in breast images, providing an objective reference for diagnosing and evaluating breast cancer[7].

Therefore, we explored the combined diagnostic efficacy of molybdenum target X-ray and MRI examinations to improve the early detection of breast cancer.

MATERIALS AND METHODS

Patient selection

This study was approved by the Ethics Committee of our hospital. All participating patients and their families provided informed consent. Patients diagnosed with breast cancer at our hospital from March 2019 to April 2021 were recruited, as were the same number of patients diagnosed with benign breast tumors during the same period.
The inclusion criteria were: (1) Pathologically confirmed cancerous or benign tumors; (2) < 80 years of age; (3) The patient had good compliance and communication skills and could cooperate to complete the investigation; (4) An estimated survival time of the breast cancer patients of > 6 mo; and (5) A disease stage of II-IV.

The exclusion criteria were patients with: (1) Other benign or malignant tumors; (2) Cardiovascular or cerebrovascular diseases; (3) Speech communication or hearing disorders; (4) Mental disorders; (5) Allergies; and (6) Contraindications to molybdenum target X-ray or MRI examinations.

All patients in both groups received molybdenum target X-ray and MRI examinations.

**Molybdenum target X-ray examination**
A GE Senographe 2000D Digital Mammography System (GE Healthcare, Chicago, IL, USA) with a molybdenum target X-ray camera and automatic exposure was used. Patients were instructed to stand with their arms up to optimally expose the breast to the X-ray camera. Next, horizontal and axial position breast radiography were performed for a closer examination of specific parameters, such as the breast lesion border, shape, number, and size, to determine if the axillary lymph nodes were enlarged, if there were abnormal blood vessels or microcalcification, and if the tumor lesions had invaded the skin, areola, or nipple.

**MRI examination**
A Magnetom Avanto 3.0T superconducting MRI scanner (Siemens, Munich, Germany) equipped with a special phased-array surface coil for the breast was used. First, the examination procedure was explained to the patient in detail. Then, patients were instructed to take the prone position, placing both breasts into the coil hole on the surface of the special phased array, then resume regular light breathing to minimize image artifacts and decreased image quality caused by chest breathing movements. The axillary position of the breast was placed into the coil as far as possible, and an auxiliary fixation device was used to pressurize the breast. A plain MRI was performed first. The sagittal and horizontal axial positions of the left and right mammary glands were obtained using the T1-weighted image (T1WI) spin-echo sequence, an echo time (TE) of 15 ms, and a repetition time (TR) of 580 ms. A short-time reversal recovery sequence was added to the T2WI turbo spin-echo sequence. The interval was 0.6 mm with a 3-mm-thick layer, and the inversion time (i.e., Ti) was 230 ms, TE was 56 ms, and TR was 4820 ms. Next, dynamic enhanced MRI scanning was performed using T1WI axial scanning with fat suppression and rapid small-angle excitation of the three-dimensional dynamic imaging sequence, repeated six times. The parameters were: 55 s single scan, a 296 × 384 matrix, 104 Layers, 0.9-mm layer thickness, 1.7 ms TE, and 4.6 ms TR. A special double-tube high-pressure syringe was used to inject 0.15 mmol/kg gadolinium-dextran solution at a rate of 2 mL/s through the cubital vein.

The images were transferred to MRI workstation software for reconstruction. The maximum signal projections of the images were analyzed before and after enhancement. The area of interest in the lesions was manually selected to ensure that the MRI on the same plane was within the range of the lesions. To prevent errors, a minimum area of 2 mm² was used to avoid necrosis or cystic components in the lesions. Two physicians with considerable diagnostic experience examined the radiographs together, and the MRI and molybdenum target X-ray examinations were analyzed with emphasis on the number, location, shape, and size of the lesions.

**Observation indexes**
The examination conditions, diagnostic efficacy parameters (e.g., the sensitivity, specificity, and accuracy), and examination parameters (e.g., T-wave peak, peak and early enhancement rates, and apparent diffusion coefficient) were compared between the breast cancer and benign tumor groups based on the diagnosis methodology [single-method (X-ray or MRI) or combined-method (both X-ray and MRI)].

**Statistical analyses**
Data were analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Measurement data were analyzed by t-test and represented by means ± SD. Enumerated data were analyzed by the χ² test and represented as n (%). Statistical significance was set at P < 0.05.
RESULTS

Patient demographics
In our hospital, 63 patients were diagnosed with breast cancer from March 2019 to April 2021 and were included in the study, along with 63 patients diagnosed with benign breast tumors during the same period. The mean age of the breast cancer group was 58.32 ± 10.77 years (range, 44-73 years). There was 1 mucinous carcinoma case, 2 intraductal carcinoma cases, and 60 invasive ductal carcinoma cases. Regarding the disease stage, 24 cases were stage II, 21 were stage III, and 18 were stage IV. There were 39 cases with lymph node metastasis and 24 with no metastasis. A total of 31 cases were highly differentiated, 15 were moderately differentiated, and 17 were poorly differentiated.

The mean age of the benign tumor group was 60.03 ± 11.38 years (range, 42-76 years). There were 43 fibroadenoma cases, 13 intraductal papilloma cases, and 7 Lobular tumor cases.

The baseline data, such as age, did not differ between the two groups ($P > 0.05$).

Molybdenum target X-ray and MRI examination conditions
MRI detected 53 breast cancer cases and 61 benign breast tumor cases. Molybdenum target X-ray detected 50 breast cancer cases and 60 benign breast tumor cases. The combined methodology detected 61 breast cancer cases and 61 benign breast tumor cases (Table 1).

Diagnostic efficacy
The sensitivity (96.83%) and accuracy (96.83%) of the combined methodology were higher than the single-method molybdenum target X-ray (79.37% and 87.30%, respectively) and MRI (84.13% and 90.48%, respectively) ($P < 0.05$). However, the combined methodology specificity (96.83%) did not differ from single-method molybdenum target X-ray (95.24%) or MRI (96.83%) ($P > 0.05$) (Table 2).

MRI-related examination parameters
The T-wave peak and apparent diffusion coefficient were lower in the breast cancer group (169.43 ± 32.05 and 1.01 ± 0.23, respectively) than in the benign tumor group (228.86 ± 46.51 and 1.41 ± 0.35, respectively). However, the peak early enhancement rates (1.08 ± 0.24 and 1.07 ± 0.26, respectively) were significantly higher in the breast cancer group than in the benign tumor group (0.83 ± 0.19 and 0.75 ± 0.19, respectively; $P < 0.05$) (Table 3).

DISCUSSION

Breast cancer has a relatively high morbidity rate among females due to lacking specific clinical manifestations in the early stages, resulting in very high missed- and misdiagnosis rates. There is also adhesion between the lesion and surrounding tissue, and a lack of good activity, easily leading to negative palpation[8]. Therefore, identifying more exact breast cancer diagnosis methods remains a key topic.

Molybdenum target X-ray is a common low-cost, simple to operate diagnostic measure that can effectively identify the breast lesion’s edge morphology and clarify the breast tissue density. However, the breast volume of Asian females is smaller with higher density than other populations, making a cancer diagnosis easy to miss due to the lack of good wrapping in the molybdenum target X-ray photography process. Moreover, X-ray examination emits a certain amount of radiation, leading to clinical application limitations[9,10]. It is also difficult to distinguish tumor infiltration and the margin of fibrous tissue proliferation by molybdenum target X-ray, thus disturbing the testing and evaluation conditions of breast lesions. Further, molybdenum target X-ray examination usually adopts an axial or head-to-tail projection, but the maximum diameter of breast lesions may be in an oblique position, which can affect the detection of the tumor’s maximum diameter, consequently underestimating the size[11].

There are also many heterogeneous and tanglesome new blood vessels in breast cancer tissue, consisting of an incomplete fissure vascular network without relaxation and contraction, making it easy to unusually enhance the microvascular permeability, tissue gap volume, microcirculation flow, and velocity on a molybdenum target X-ray image. The incidence and progression of breast cancer are closely related to an incomplete vascular network[12]. Through intravenous injections of contrast dye with
Table 1 Molybdenum target X-ray and magnetic resonance imaging combined methodology examination conditions

| X-ray   | Pathological result | MRI | Pathological result | Both | Pathological result |
|---------|---------------------|-----|---------------------|------|---------------------|
| +       | 50                  | +   | 53                  | +    | 61                  |
| -       | 13                  | -   | 10                  | -    | 2                   |
| Total   | 63                  | Total| 63                  | Total| 63                  |

MRI: Magnetic resonance imaging.

Table 2 Molybdenum target X-ray and magnetic resonance imaging diagnostic efficacies

| Diagnostic method               | Sensitivity | Specificity | Accuracy |
|---------------------------------|-------------|-------------|----------|
| Molybdenum target X-ray         | 79.37% (50/63) | 95.24% (60/63) | 87.30% (110/126) |
| MRI                             | 84.13% (53/63) | 96.83% (61/63) | 90.48% (114/126) |
| Combined methodology            | 96.83% (61/63) | 96.83% (61/63) | 96.83% (122/126) |

$\chi^2 / P$ value (Combined vs molybdenum target X-ray)

| Diagnostic method               | Sensitivity | Specificity | Accuracy |
|---------------------------------|-------------|-------------|----------|
| Molybdenum target X-ray         | 7.568/0.006 | 0.000/1.000 | 6.572/0.010 |
| MRI                             | 4.513/0.034 | 0.262/0.609 | 4.271/0.039 |

MRI: Magnetic resonance imaging.

Table 3 Magnetic resonance imaging-related examination parameters (mean ± SD)

| Group                          | T-wave peak | Apparent diffusion coefficient | Peak enhancement rate | Early enhancement rate |
|--------------------------------|-------------|--------------------------------|-----------------------|------------------------|
| Breast cancer ($n = 63$)       | 169.43 ± 32.05 | 1.01 ± 0.23                  | 1.08 ± 0.24           | 1.07 ± 0.26            |
| Benign tumor ($n = 63$)        | 228.86 ± 46.51 | 1.41 ± 0.35                  | 0.83 ± 0.19           | 0.75 ± 0.19            |

$t$ value and $P$ value

| Group                          | $t$ value | $P$ value |
|--------------------------------|-----------|-----------|
| Breast cancer ($n = 63$)       | 8.351     | 0.000     |
| Benign tumor ($n = 63$)        | 7.581     | 0.000     |

MRI: Magnetic resonance imaging.

A high-pressure syringe, MRI examination can effectively identify breast cancer lesions. Thus, it is possible to analyze and evaluate the hemodynamic characteristics of breast lesions to provide an objective reference for diagnosing and evaluating breast cancer based on the blood vessels distribution in the lesions[13]. However, there are still some limitations to diagnosing only by MRI; it has low sensitivity to common micro-needle calcifications in the early stages of breast cancer and the image quality is easily affected by several factors, such as respiratory artifacts and heartbeats[14].

Our study diagnosed breast cancer using molybdenum target X-ray and MRI examinations together and found that both T-wave peak and apparent diffusion coefficient were lower in the breast cancer group than in the benign tumor group, yet the peak and early enhancement rates were significantly higher in the breast cancer group than in the benign tumor group. The combined methodology sensitivity and accuracy were also significantly higher than either single method. These results suggest that each method has particular strengths but using both methods together enhance the diagnostic sensitivity and accuracy and reduce the risk of missed diagnosis and misdiagnosis. Several reasons may explain our results. First, molybdenum target mammography of the breast includes full-screen digital mammography and digital tomography synthetic mammography, which has been further developed in recent years and is highly sensitive to calcification, which is important for the screening and early diagnosis of breast cancer. However, in patients with dense breast cancer, the lesions are easy to cover, and the penetrating power of the molybdenum target X-ray is limited. Therefore, tiny lesions in deep glands are easily overlooked, resulting in missed diagnoses. However, an advantage to
molybdenum target X-ray examination is the ability to accurately examine microcalci-
fications[15].

Second, MRI accurately identifies soft tissue and then presents the tumor lesions in a
multi-image and multi-directional manner. Further, it does not induce radiation
damage to the body, guaranteeing patient safety. MRI can also improve the accuracy
detecting breast cancer lesions, judge dense breast tumors, perform differential
diagnosis between fibrous scar and local recurrence after surgery, examine multicenter
and concealing venereal lesions, and dynamically examine the blood supply around
the lesion. Kuhl[16] reported that MRI examinations helped detect bilateral breast
lesions by achieving three-dimensional localization of the breast and tumor, accurately
measuring the distance between the breast tumor and the areola, and identifying the
invasion of breast lesions to tissue. However, some reports found a significantly higher
multifocal and axillary lymph node metastasis and peripheral invasion detection rate
by MRI, compared to molybdenum target X-ray, but the detection rate of extensive
microcalcification lesions was lower by MRI than by molybdenum target X-ray. Therefore,
the advantages and disadvantages of the combined methodology are
complementary and improve the overall sensitivity and accuracy[17]. However, the
results of this study are limited by the nature of this being a single center study, and
must be further clarified by a multi-center alliance.

CONCLUSION

Combined molybdenum target X-ray and MRI examinations improved the sensitivity
and accuracy of breast cancer diagnoses, minimizing the missed- and misdiagnoses
risks and promoting timely treatment intervention.

ARTICLE HIGHLIGHTS

Research background
The incidence of breast cancer among young people has been on the rise in recent
years.

Research motivation
Early breast cancer diagnosis is critical.

Research objectives
Explore more sensitive and accurate breast cancer screening methods.

Research methods
Patients diagnosed with breast cancer at our hospital were recruited, as were the same
number of patients diagnosed with benign breast tumors during the same period.

Research results
The combined methodology detected 61 breast cancer cases and 61 benign breast
tumor cases. The sensitivity (96.83%) and accuracy (96.83%) of the combined
methodology were higher than single-method magnetic resonance imaging (MRI)
(84.13% and 90.48%, respectively) and molybdenum target X-ray (79.37% and 87.30%,
respectively).

Research conclusions
Combined molybdenum target X-ray and MRI examinations for diagnosing breast
cancer improved the diagnostic sensitivity and accuracy.

Research perspectives
Early diagnosis of cancer is very important, we need to find more early cancer
diagnosis methods in the future.
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