Use of ultrasound combined with magnetic resonance imaging for diagnosis of breast masses and fibroids

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Abstract
Objective: To investigate the clinical value of ultrasound plus magnetic resonance imaging (MRI) for the diagnosis of breast masses and fibroids.
Methods: Clinical data for 357 patients with breast masses diagnosed at our hospital were analyzed retrospectively. The diagnostic performances were compared between 243 patients who underwent routine ultrasound examinations (control group) and 114 patients who underwent routine ultrasound plus MRI (test group).
Results: The overall accordance rates of routine ultrasound and routine ultrasound plus MRI for the diagnosis of breast masses, based on postoperative pathological diagnoses, were 70.78% (172/243) and 90.35% (103/114). The addition of MRI significantly improved the overall diagnostic performance of routine ultrasound for breast masses. The diagnostic accordance rate of routine ultrasound for the diagnosis of breast fibroids (fibroadenomas) was 74.12% (63/85 cases) compared with 93.94% (31/33 cases) for routine ultrasound plus MRI. The diagnostic performance of routine ultrasound plus MRI was therefore also significantly higher than routine ultrasound alone for diagnosing breast fibroids.
**Conclusions:** Routine ultrasound plus MRI can greatly improve the diagnostic accordance rates for breast masses and fibroadenomas.

**Keywords**
Routine ultrasound, magnetic resonance, breast fibroid, combined diagnosis, retrospective analysis, breast mass

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**Introduction**

Breast fibroids, also referred to as fibroadenomas, are benign breast lesions caused by the proliferation of fibrous tissue and glandular epithelial tissue, and are mainly found in young women.\(^1,2\) The occurrence of breast fibroadenomas is affected by the patient’s family history, fertility, breastfeeding status, and endocrine function.\(^3,4\) The incidence of breast fibroids has recently been increasing, with associated disruptions to patients’ lives. The most effective clinical treatment for breast fibroids is currently surgical resection.\(^5,6\) However, breast fibroids may progress to sarcomas with fibrous components with unpredictable consequences, and an accurate diagnosis is therefore essential.\(^7\)

Ultrasound is a conventional method for detecting breast diseases, and is often used for the clinical staging of breast cancer. Ultrasound has been widely used as a clinical diagnostic tool because of its low cost, noninvasive nature, high detection rate and high repeatability, and lack of radiation exposure. However, the interpretation of ultrasound images is affected by the subjective judgment of the imaging physicians.\(^8,9\) Magnetic resonance imaging (MRI) is an emerging imaging method for observing and identifying soft-tissue lesions.\(^10\) With the continuous development of medical technology, MRI has become a well-recognized technique for the diagnosis of breast diseases; however, its specificity remains unclear.\(^11,12\) Although routine MRI combined with diffusion-weighted imaging (DWI) and magnetic resonance spectroscopy (MRS) have effectively improved the specificity of MRI for the diagnosis of breast disease,\(^13,14\) the costs of these examinations are unaffordable for most patients. Furthermore, such specialized MRI techniques require more time and expertise, and they are therefore not normally used in routine clinical practice.

In the current study, we retrospectively analyzed data for 357 women with palpable breast masses to compare the diagnostic values of routine ultrasound with and without MRI for breast diseases, with the aim of improving the current clinical situation for these patients.

**Materials and methods**

**Clinical information**

Clinical data for 357 patients with breast masses detected at our hospital from February 2011 to May 2016 were analyzed retrospectively. The inclusion criteria were diagnosis confirmed by pathological examination, no dysfunction of the liver, kidney, or other organs before surgery, and no abnormal bleeding or coagulation dysfunction before surgery. The exclusion criteria
were excessively large or small masses, breast cysts, a history of breast tumors or other pulmonary or chest wall diseases, incomplete case data, and mental or learning dysfunctions (Figure 1). The study was approved by the ethics committee of the hospital, and all patients or their family members provided written informed consent. A total 243 patients who underwent routine ultrasound examinations were assigned to the control group and 114 patients who underwent routine ultrasound plus MRI were assigned to the test group. The diagnostic values of the two methods were analyzed and compared. All diagnoses were confirmed pathologically after surgical removal of the tumor, and breast masses were graded according to the American Radiological Society BI-RADS classification criteria.

**Routine ultrasound**

Routine ultrasound examination was carried out using an Hitachi HI VISION Avius color Doppler ultrasound system (Hitachi H-300, Verasonics, Kirkland, WA, USA) with linear probe 50 mm (13–5 Mhz) and linear volume array transducer (Verasonics). Ultrasound examination items included mass diameter, shape, marginal status, calcification, and thickness/length ratio. Routine ultrasound results were interpreted as benign, undetermined, and malignant tumors.

**MRI**

MRI was performed with an open permanent magnetic resonance imaging system (Ningbo Xingaoyi Magnetic Materials Co., Ltd., Zhejiang, China) using a 8-channel double-lumen breast surface coil, selective echo sequence and fast selective echo pulse sequence for T1- and T2-weighted and dynamic contrast-enhanced image scans at 1.5T. The matrix was reconstructed and the images were acquired in six phases (60 seconds per phase). Dynamic enhanced scanning was performed following intravenous administration of 0.2 mmol/kg

![Figure 1. Patient flow diagram](image_url)
Gd-DTPA at 3 mL/second. The parameter settings are presented in Table 1.

**Outcome measures**

The imaging performances, accuracies, sensitivities, and specificities of routine ultrasound with and without MRI were recorded and the diagnostic values were evaluated based on receiver operating characteristic (ROC) curves.

**Statistical analysis**

Test results were analyzed using SPSS 22.0 statistical software (AsiaAnalytics, formerly SPSS China, Shanghai, China). Continuous variables were presented as mean ± standard deviation and categorical variables were presented as percentages and analyzed using \( \chi^2 \) tests. \( P < 0.05 \) was considered statistically significant.

**Results**

**Patient information**

A total of 357 patients (aged 20–50 years, disease duration 90 days to 2 years) were included in this study. The pathological diagnoses were benign tumors in 201 patients and malignant tumors in 156 patients. Detailed pathological information for the control and test groups is provided in Table 2. There was no significant difference in general characteristics including age, mass diameter, or menopausal status between the two patient groups. However, significantly more patients in each group had masses with a diameter < 3 cm than \( \geq 3 \) cm (\( P < 0.05 \)). There were no significant differences in the incidences of benign and malignant masses between the two groups.

**Diagnostic results of routine ultrasound and MRI**

Among the 357 patients, the accordance rate between routine ultrasound and pathology for the diagnosis of a breast mass was 70.78% (172/357 cases), compared with 90.35% (103/357) for routine ultrasound plus MRI. The diagnostic performance was therefore significantly better for routine ultrasound plus MRI compared with routine ultrasound alone (\( P < 0.05 \)). In terms of breast fibroids, the diagnostic accordance rates for routine ultrasound alone and in combination with MRI were 74.12% (63/85) and 93.94% (31/33), respectively (\( P < 0.05 \)). The specific diagnostic accordance rates of routine ultrasound with or without MRI for the diagnosis of breast masses are shown in Tables 3 and 4. Notably, the ability of routine ultrasound to detect microcalcifications was poor.

### Table 1. MRI parameter settings

| Scan location          | T1WI-TSE                  | T2WI-inhibiting fat signal | Dynamic contrast-enhanced |
|------------------------|---------------------------|----------------------------|----------------------------|
| TR                     | 841 ms                    | 2500 ms                    | 4.53 ms                    |
| TE                     | 9.3 ms                    | 52.5 ms                    | 1.66 ms                    |
| Layer thickness        | 5 mm                      | 5 mm                       | 1.1 mm                     |
| Layer spacing          | 1.0 mm                    | 1.0 mm                     | None                       |
| Visual field           | 36 × 36 mm                | 36 × 36 mm                 | 36 × 21 mm                 |
| Matrix                 | 320 × 256                 | 320 × 192                  | 320 × 256                  |
| NEX                    | 2 times                   | 3 times                    |                            |
| Flip angle             | 15°                       | 150°                       | 8°                         |

TSE: turbo spin-echo, TR: repetition time, TE: echo time, NEX: number of excitations
The sensitivity and specificity of routine ultrasound for the qualitative diagnosis of breast masses were 62.16% and 78.03%, respectively, while the sensitivity and specificity of MRI were 85.09% and 89.47%, respectively, and the sensitivity and specificity of routine ultrasound plus MRI were 92.54% and 87.23%, respectively. ROC curve analysis showed that the areas under the curves (AUCs) for routine ultrasound, MRI, and routine ultrasound plus MRI for the diagnosis of breast masses were 0.674 (95% confidence interval [CI], 0.522–0.871), 0.834 (95% CI 0.692–0.898), and

Table 2. Clinical information

|                          | Control group (n = 243) | Test group (n = 114) | χ²/t | P   |
|--------------------------|-------------------------|----------------------|------|-----|
| Age (years)              | 32.7±8.6                | 31.6±8.3             | 1.232| 0.219|
| Benign mass (n (%))      | 145 (59.67)             | 56 (49.12)           | 3.509| 0.061|
| Fibroadenoma             | 85 (58.62)              | 33 (58.93)           | 0.002| 0.968|
| Scleroderma              | 26 (17.93)              | 10 (17.86)           | 0.000| 0.990|
| Intraductal papilloma    | 21 (14.48)              | 7 (12.50)            | 0.132| 0.716|
| Chronic mammary inflammation | 13 (8.97)    | 6 (10.71)            | 0.144| 0.704|
| with granulation tissue hyperplasia |            |                     |      |     |
| Malignant mass (n (%))   | 98 (40.33)              | 58 (59.65)           | 3.509| 0.061|
| Invasive ductal carcinoma| 64 (65.31)              | 38 (65.52)           | 0.001| 0.979|
| Intraductal carcinoma in situ | 26 (26.53)  | 15 (25.86)           | 0.008| 0.927|
| Invasive lobular carcinoma| 5 (5.10)               | 3 (5.71)             | 0.000| 0.985|
| Mucinous cancer          | 3 (3.06)                | 2 (3.45)             | 0.018| 0.894|
| Mass diameter (n (%))    |                         |                      |      | 0.526|
| <3 cm                    | 132 (54.32)             | 66 (57.89)           |      |      |
| ≥3 cm                    | 111 (30.04)             | 48 (42.11)           |      |      |
| Menopausal status (n (%))|                         |                      |      | 0.955|
| Non-menopausal           | 157 (64.61)             | 74 (64.91)           |      |      |
| Menopausal               | 86 (35.39)              | 40 (35.09)           |      |      |

Table 3. Diagnostic accordance rates of routine ultrasound and routine ultrasound plus MRI for diagnosis of breast masses

|                          | Control group (n = 243) | Test group (n = 114) | χ²/t | P   |
|--------------------------|-------------------------|----------------------|------|-----|
| Overall diagnostic accordance rate | 172/243 (70.78)      | 103/114 (90.35) | 16.795| <0.001|
| Breast fibroids           | 63/85 (74.12)           | 31/33 (93.94)       | 5.761| 0.061|
| Scleroderma               | 18/26 (69.23)           | 9/10 (90.00)        | 1.662| 0.197|
| Intraductal papilloma     | 14/21 (66.67)           | 6/7 (85.71)         | 0.933| 0.334|
| Chronic mammary inflammation with granulation tissue hyperplasia | 8/13 (61.54) | 5/6 (83.33) | 0.903| 0.342|
| Invasive ductal carcinoma | 46/64 (71.88)           | 35/38 (92.11)       | 5.968| 0.015|
| Intraductal carcinoma in situ | 18/26 (69.23) | 13/15 (86.67) | 1.568| 0.21 |
| Invasive lobular carcinoma| 3/5 (60.00)             | 2/3 (66.67)         | 0.036| 0.85 |
| Mucinous cancer           | 2/3 (66.67)             | 2/2 (100.00)        | 0.833| 0.361|

Values given as number (%)
The diagnostic value of routine ultrasound plus MRI was significantly higher than that of either routine ultrasound or MRI alone (P < 0.05; Table 5).

**Table 5.** Sensitivity and specificity of routine ultrasound, MRI, and routine ultrasound plus MRI for qualitative diagnosis of breast masses

|                  | Routine ultrasound | MRI         | Routine ultrasound plus MRI |
|------------------|--------------------|-------------|-----------------------------|
| Sensitivity      | 62.16%             | 85.09%      | 92.54%                      |
| Specificity      | 78.03%             | 89.47%      | 87.23%                      |
| AUC              | 0.674              | 0.834       | 0.913                       |
| 95% CI           | 0.522–0.871        | 0.692–0.898 | 0.835–0.991                 |

0.913 (95% CI, 0.835–0.991), respectively. The diagnostic value of routine ultrasound plus MRI was significantly higher than that of either routine ultrasound or MRI alone (P < 0.05; Table 5).

**Discussion**

Breast fibroadenomas are common benign lesions, accounting for about 60% of all benign breast lesions. However, the routine ultrasound findings of breast fibroadenomas are very similar to those of breast cancer, and the diagnostic value of routine ultrasound alone for the diagnosis of breast fibroadenoma is thus very limited. In this study, we retrospectively analyzed data for 357 patients with palpable breast masses to evaluate the diagnostic value of routine ultrasound plus MRI in patients with breast fibroadenomas.

The results of the current study showed that the diagnostic accordance rate for routine ultrasound plus MRI (90.35%) was significantly better than that for routine ultrasound alone (70.78%), on the basis of the ultimate pathological diagnosis (P < 0.05). Routine ultrasound is currently one of the most important methods used in tumor imaging diagnosis because of its economy and convenience. However, although ultrasound alone has good tissue-identification capacity and can be used to analyze hemodynamic differences in tumors, its ability to identify gland density or microcalcifications is poor. The density of breast fibroadenomas is related to the proliferation of fibrous and glandular epithelial tissues. The results of the current study showed a diagnostic accordance rate of only 74.12% for routine ultrasound compared with 92.59% for routine ultrasound plus MRI for the diagnosis of breast fibroadenoma (P < 0.05). MRI produces signal images by resonating with protons in tissues, and the signal intensity is
therefore closely related to the proton content. DWI is currently the only method that can detect the microscopic movement of water molecules in active tissues, and this method can therefore be used to quantify the movement of water molecules and can thus differentiate between benign and malignant tumors on the basis of cell density (i.e., higher density in malignant tumors causes slower movement of water molecules).\textsuperscript{16,21–23} The specific manifestation of breast fibroadenoma on MRI is a low T2WI signal, which is related to the formation of collagen fibers.\textsuperscript{24} In the current study, 16 (14.03\%) cases demonstrated low signals on T2WI MRI, and had a pathological diagnosis of breast fibroadenoma, similar to the results of Sawa et al.\textsuperscript{25} ROC curves showed that the sensitivity and specificity of routine ultrasound plus MRI were significantly higher than those of routine ultrasound alone: the AUC of routine ultrasound for the diagnosis of breast tumors was 0.674, compared with 0.913 for routine ultrasound plus MRI ($P < 0.05$). These results indicated that routine ultrasound plus MRI had good diagnostic value for breast tumor diagnosis; however, its specificity requires improvement. Although MRI plus DWI and MRS has been shown to effectively improve this specificity, these methods are not used routinely for the diagnosis of breast tumors because of their high cost and longer time to diagnosis.\textsuperscript{26}

The continuing popularization of medical knowledge means that people are paying more attention to their own health. The current data showed no significant difference in terms of body weight, age, diameter of the mass, menopause, and tumor grade between the control and test groups, suggesting that the two groups were comparable and the results were therefore reliable. However, the study had some limitations, including a small sample size and large standard deviation, which may have affected the results. Furthermore, the study did not assess the abilities of the two imaging techniques for differentiating between breast fibroadenomas and breast cancer, and further studies are required to investigate this aspect.

In summary, ultrasound alone shows good tissue-identification capacity and can thus be used to analyze hemodynamic differences in tumors, but routine ultrasound performs poorly in terms of identifying gland density and microcalcifications. Routine ultrasound plus MRI can improve the accuracy, specificity, and sensitivity of breast mass diagnosis, and can greatly improve the diagnostic accuracy of breast fibroadenomas. The results of this study thus provide an important basis for the early clinical treatment of breast tumors.

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**Declaration of conflicting interest**

The authors declare that there is no conflict of interest.

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