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Analysis of malignancy signs in breast magnetic resonance imaging

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► *Original article*

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ABSTRACT

Background: To analyse the signs of malignant tumours in breast magnetic resonance imaging (MRI) and further improve the imaging diagnosis level of malignant breast tumours. ***Materials and Methods:*** The plain and enhanced MRI data of 60 patients who visited our hospital between January 2011 and January 2021 were analysed retrospectively, with 118 lesions in total. Malignant breast tumour signs were assessed. ***Results:*** A total of 96 lesions were pathologically confirmed as breast cancer, with 76 cases of single breast and single lesion, 10 cases of double breast and single lesion, 6 cases of single breast and two lesions, and 4 cases of single breast and three lesions. Regarding morphology, 58 lesions were regular in appearance and 60 were irregular, of which 50 had a burr sign or sharp angle sign. Strengthening methods included 52 cases of homogeneous strengthening, 3 of annular strengthening and 2 of cluster strengthening. ***Conclusion:*** A burr margin, local skin thickening, depression, adhesion and axillary lymph node enlargement are reliable MRI signs of breast cancer. When combined with Breast Imaging Reporting and Data System grading, these signs can effectively differentiate between benign and malignant breast tumours and constitute a key reference value for the diagnosis of breast cancer.

INTRODUCTION

Breast cancer is now the most prevalent malignant tumour worldwide, posing a significant threat to women's health. The incidence and mortality rates have been increasing since the twentieth century, with approximately 180,000 new breast cancer cases reported annually in the United States alone [1,2]. Although China currently reports a relatively low incidence of breast malignancies, a disturbing trend is emerging, with younger populations increasingly being affected due to lifestyle changes [3,4].

The primary symptom of breast malignancy is a painless breast mass, and early detection, diagnosis and treatment remain the most effective approach to mitigation [5,6]. However, most patients display no apparent symptoms in the initial stages, and diagnoses often occur when the disease has advanced [7]. Traditional screening methods, such as mammography-targeted X-ray and B-ultrasound, play a crucial role in breast malignancy diagnosis. However, these methods have demonstrated a certain degree of misdiagnosis, especially in the early detection of in situ breast carcinoma [8,9].

Recently, advances in magnetic resonance imaging (MRI) hardware and software technology have provided a promising diagnostic tool for breast malignancies [10-12]. High field strength MRI equipment, breast coils and fat suppression techniques can effectively detect small and multiple lesions without causing radiation damage. This enhances the sensitivity of the diagnostic process, improving patient outcomes [13,14].

Although MRI has been extensively used in the detection of breast cancer, the uniqueness of this study lies in our retrospective analysis of 100 cases in our hospital, aiming to investigate the specific signs of malignant breast tumours. The novelty of this research resides in the identification and confirmation of reliable MRI signs, such as spiculation, local skin thickening, depression, adhesion and enlarged axillary lymph nodes, for diagnosing breast cancer. Furthermore, our study examines the efficacy of MRI coupled with Breast Imaging Reporting and Data System (BI-RADS) grading to distinguish benign and malignant breast masses, a combination that has not been thoroughly explored in prior studies. This study is expected to provide more effective information for future programme formulation and the evaluation of treatment efficacy in breast cancer treatment.

MATERIALS AND METHODS

General information

A total of 60 patients who visited the breast department of our hospital between january 2011 and january 2021 with complete breast MRI data were selected. A total of 118 lesions were identified.

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Patients were aged 39 – 81 years, with a mean age of 53 years. Basic patient information is provided in table 1. All cases were pathologically confirmed, and the patient signed an informed consent form. The study was approved by the Ethics Committee of Ma'anshan General Hospital of Ranger-Duree Healthcare, China (L2023713, 15 May 2021).

Table 1. Basic information of patients.

	Patient cohort
Age (years)	52.86 (39~81)
Genger	
Male	0
Female	60
Lesion Number	
One lesion	35
Two lesions	12
Three or more lesions	13

Note: The numbers following the age represent the mean and the age range of our patient cohort, while the other numbers indicate the number of patients.

Examination method

A 1.5T superconducting magnetic resonance instrument (Siemens Sonata, Germany) and bilateral breast coils (Invivo, USA) were used. The magnetic resonance contrast agent was Gadobenate Dimeglumine Injection (GD-BOPTA, MultiHance, Bracco, Italy), with a specification of 15 ml/bottle (7.04 g). Any metal items on the surface of the patient's body were removed before the scan. The patient assumed a horizontal posture, with both breasts hanging naturally in the special breast coil. The patient was instructed not to move the chest during the examination to avoid movement artifacts. The scanning sequence included horizontal axis T1-weighted imaging (T1WI) (repetition time (TR)/ echo time (TE): 480/7.7 ms), horizontal axis short tau inversion recovery (TR/TE: 8200/36.2 ms), sagittal T2-weighted imaging (T2WI) fat inhibition sequence (TR/TE: 3200/93 ms; layer thickness = 4.0 mm, layer distance = 1.0 mm) and dynamic contrast scanning. Passage was preestablished in the patient's dorsal hand vein before scanning and connected to a high-pressure injection pump. The contrast agent and normal saline were injected at 3 ml/s during the scan. One scan was performed before contrast infusion, and seven consecutive scans were conducted after the end of contrast infusion. Each reinforcement sequence was recorded simultaneously for subtraction and maximum density projection three-dimensional reorganisation.

Image analysis

The results were reviewed by two of the hospital's associate chief physicians, and a diagnosis was made when they reached agreement. When opinions differed, a higher level or senior imaging doctor reviewed the film together with a joint consultation, and a diagnosis was agreed on.

Pathology confirmation

In this study, pathological diagnoses were obtained post-surgery or through biopsy. The pathological samples were handled following standard procedures, fixed in formalin and embedded in paraffin. The samples were then sectioned and stained with haematoxylin and eosin for an evaluation under microscope performed by experienced pathologists in the hospital. The lesions were categorised according to the World Health Organization's Classification of Tumours of the Breast [15]. Malignant lesions consist of invasive ductal carcinoma, invasive lobular carcinoma and ductal carcinoma in situ; benign lesions comprise fibroadenomas, intraductal papillomas, breast cysts and other benign entities. The pathological findings served as the "gold standard" in our study for comparing and evaluating the diagnostic accuracy of the MRI findings.

RESULTS

Routine magnetic resonance imaging signal characteristics

Of the 60 patients in this study, 42 had malignant lesions, 36 had slightly lower T1WI signals, 6 had slightly high or high signals and all patients had high or slightly high T2WI signals. There were 18 benign lesions: 14 fibromas, 2 lesions with a slightly low T1WI signal and high T2WI signal, and 1 lesion with equal T1WI and T2WI signals; 1 lesion revealed a confounding signal, high T2WI signal separation and high T2WI fat inhibition sequence signal. The signals of the benign and malignant breast lesions were mostly equal and low T1WI signals, mostly slightly high T2WI signals and mostly high fat inhibition sequence signals. No obvious difference was identified between them, and they were therefore of little significance to the diagnosis.

Diagnosis results of breast magnetic resonance imaging

A total of 118 breast cancer lesions were detected in 60 patients, with 96 lesions confirmed as breast cancer by pathology. This included 76 cases of single breast and single lesion, 10 cases of double breast and single lesion, 6 cases of single breast and two lesions and 4 cases of single breast and three lesions. The analysis of the imaging features is presented in table 2. Morphology: In total, 58 lesions had a regular appearance (figure 1) and 60 were irregular (figure 2), of which 50 had burrs or sharp corners (figure 3). Strengthening methods included 52 cases of uniform strengthening (figure 4), 3 of circular strengthening (figure 5) and 2 of cluster strengthening (figure 6).

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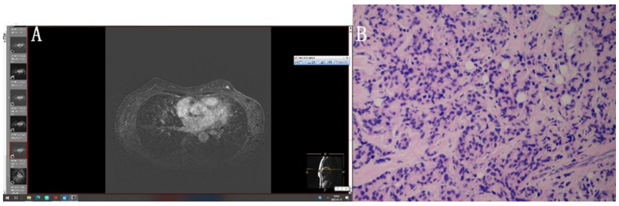

Figure 1. A) Morphologically regular. This figure displays an example of a lesion with regular morphology, observed through MRI imaging. The lesion exhibits uniform intensity and clear, smooth boundaries, which are common characteristics of benign breast lesions. **B)** Pathological images corresponding to this MRI image. This figure indicates benign breast lesion (stained with hematoxylin and eosin 200×).

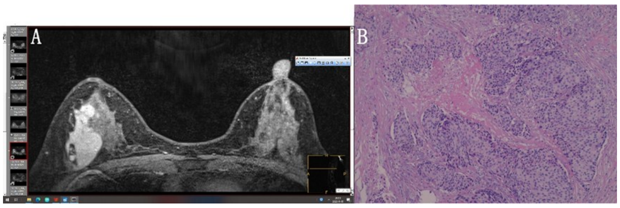

Figure 2. A) Morphologically irregular. This figure showcases an irregular lesion found in one of the patients in the study. Irregular shapes, blurred boundaries, and uneven internal signals, as can be seen here, are often indicative of malignant breast lesions. **B)** Pathological images corresponding to this MRI image. This figure indicates malignant breast lesion (stained with hematoxylin and eosin 200×).

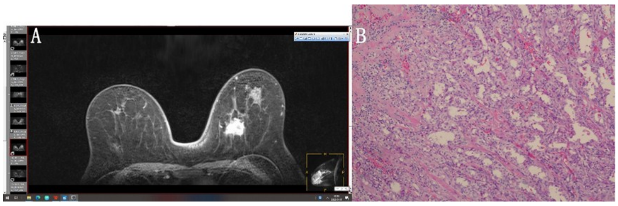

Figure 3. A) Spiculation sign. In this figure, the "spiculation sign" or radiating lines from the lesion, characteristic of malignant breast tumors, is clearly visible. The spiculation is due to the invasive growth pattern of the tumor into the surrounding tissue. **B)** Pathological images corresponding to this MRI image. This figure indicates malignant breast lesion, which is more aggressive (stained with hematoxylin and eosin 200×).

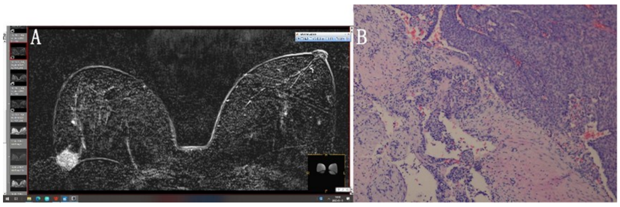

Figure 4. A) Homogeneous enhancement. This figure presents an example of a breast lesion showing homogeneous enhancement on MRI. This typically suggests benign nature of the lesion; as malignant lesions often show uneven enhancement due to irregular blood supply. **B)** Pathological images corresponding to this MRI image. This figure indicates benign breast lesion (stained with hematoxylin and eosin 200×).

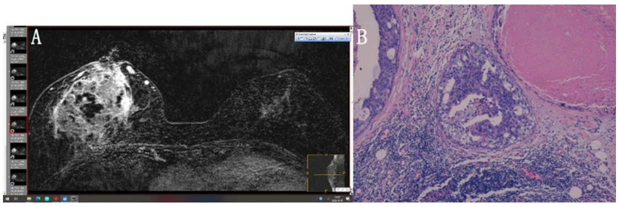

Figure 5. A) Annular enhancement. Illustrated here is a lesion showing annular or "ring-like" enhancement, a feature often seen in malignant breast lesions. This is due to the increased blood supply and permeability on the outer edges of the tumor, while the central area shows less enhancement due to necrosis or fibrosis. **B)** Pathological images corresponding to this MRI image. This figure indicates malignant breast lesion (stained with hematoxylin and eosin 200×).

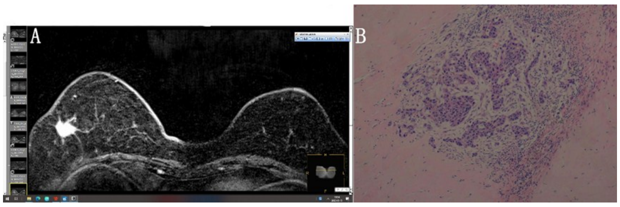

Figure 6. A) Cluster enhancement. This figure exhibits an instance of cluster enhancement, characterized by multiple pebble-like or small foci enhancements clustered together. This appearance can be seen in both benign and malignant lesions, and requires further clinical evaluation to ascertain the nature of the lesion. **B)** Pathological images corresponding to this MRI image. This figure indicates Atypical hyperplasia of the breast (stained with hematoxylin and eosin 200×).

Early enhancement rate of dynamic enhancement of benign and malignant breast lesions

Of the 42 malignant lesions, 26 had early enhancement rates < 50%, 10 had early enhancement rates of 50%–100% and 6 had early enhancement rates > 100%. Of the 18 benign lesions, 8 had early enhancement rates < 50%, 6 had early enhancement rates of 50% – 100% and 4 had early enhancement rates > 100%.

Table 2. Breast MRI signs.

Item	Number	Percentage (%)
The lesion morphology		
Regular	58	49.2
Irregular	60	50.8
Spiculation sign	50	42.4
Enhancement pattern		
Homogeneous enhancement	52	91.2
Annular enhancement	3	5.3
Cluster enhancement	2	3.5

Results of dynamic enhancement imaging for benign and malignant breast lesions

The diagnostic results of the dynamic enhancement imaging according to the BI-RADS classification criteria are summarised in table 3.

Table 3. Comprehensive diagnostic results of dynamic enhancement imaging.

Pathologic diagnosis	Dynamic enhancement imaging		
	Malignant	**Benign**	**In total**
Malignant(n=42)	38	4	42
Benign (n=18)	4	14	18
In total	42	18	60

Its sensitivity was 90.5% (38 / 42), specificity 77.8% (14 / 18), positive predictive value 90.5% (38 / 42), and negative predictive value 77.8% (14 / 18).

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DISCUSSION

Magnetic resonance imaging has a well-established role in evaluating soft tissues due to its high spatial resolution, offering distinct advantages in the medical field [16]. Traditional MRI imaging can clearly depict the morphology, boundaries and signal intensity of breast lesions, providing insights into internal structural changes [17].

Historically, benign breast lesions have been identified as circular or somewhat lobulated in nature, exhibiting clear boundaries and relatively homogenous internal signals [18,19]. By contrast, malignant lesions typically present as irregular, often displaying a 'spiculation sign', along with blurred boundaries and heterogeneous internal signals. Symptoms such as local skin or nipple retraction, skin thickening and axillary lymph node enlargement can accompany these malignant presentations [20, 21].

Our study revealed that the spiculation sign, observed in 4 out of 15 lesions with irregular margins, is a relatively specific indicator of malignancy. Prior studies have suggested that masses demonstrating this sign and having a crab-like appearance on MRI could indicate breast cancer [22, 23].

In addition, patients presenting with local skin thickening and depression alongside axillary lymph node enlargement were diagnosed with malignant lesions. However, some malignant lesions may exhibit regular morphology, which can lead to misdiagnosis and reduced sensitivity. Conversely, certain benign lesions can manifest irregular morphology or blurred boundaries, potentially decreasing diagnostic specificity.

The primary advantage of MRI is the lack of ionising radiation exposure, which can generate multi-directional imaging scans and a broad scanning range, providing exceptionally high soft tissue resolution. To standardise breast imaging reports, the American College of Radiology has developed the BI-RADS grading system, which includes ultrasound, X-ray imaging and MRI [24, 25]. In our study, 18 out of 48 patients with a BI-RADS grade greater than 2 had malignant lesions. These lesions mostly exhibited invasive growth and fibrous tissue hyperplasia, leading to a typical spiculation sign [26].

Annular enhancement is a key feature for differentiating benign from malignant breast lesions. Almost two-thirds of invasive cancers are known to present this feature, with a positive predictive value ranging from 79% to 92% [27]. Two out of the three lesions in our study exhibiting this enhancement were malignant. Reasons behind the annular enhancement in malignant tumours could include a higher microvessel density, the chemotactic effects of vascular growth factors and intra-tumoural pressure gradients [28, 29].

By contrast, benign tumours tend to present with more evenly distributed microvessels, and their growth rate often matches their blood supply, leading to more homogeneous enhancement. Lesions showing significant annular enhancement are typically associated with a higher expression of Ki-67, indicating a higher degree of malignancy and a more challenging prognosis [30].

However, certain limitations exist with MRI, such as long examination times, challenges in examining certain metal implants and low sensitivity to microcalcification, often a characteristic manifestation of intraductal carcinoma in situ. As a result, MRI might be prone to missed diagnoses of such lesions.

CONCLUSION

The combination of MRI indicators with the BI-RADS grading system can effectively discern benign from malignant breast masses, potentially reducing the need for further invasive examinations and their associated costs. Overall, breast MRI diagnostics has significant advantages in terms of non-invasiveness, specificity, sensitivity and accuracy, offering a comprehensive analysis of the lesion and providing valuable insights for treatment.

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Ethics approval and consent to participate: This study was conducted in accordance with the declaration of Helsinki.This study was conducted with approval from the Ethics Committee of Ma'anshan General Hospital of Ranger-Duree Healthcare. Written informed consent was obtained from all participants.

Consent for publication: Not applicable

Availability of data and materials: All data generated or analyzed during this study are included in this article.

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