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ORIGINAL ARTICLE

The accuracy of magnetic resonance imaging and ultrasound in evaluating the size of early-stage breast neoplasms

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Abstract

Objective Breast cancer is the most frequently diagnosed cancer in women. Accurate evaluation of the size and extent of the tumor is crucial in selecting a suitable surgical method for patients with breast cancer. Both overestimation and underestimation have important adverse effects on patient care. This study aimed to evaluate the accuracy of breast magnetic resonance imaging (MRI) and ultrasound (US) examination for measuring the size and extent of early-stage breast neoplasms.

Methods The longest diameter of breast tumors in patients with $T_{1–2}N_{0–1}M_0$ invasive breast cancer preparing for breast-conserving surgery (BCS) was measured preoperatively by using both MRI and US and their accuracy was compared with that of postoperative pathologic examination. If the diameter difference was within 2 mm, it was considered to be consistent with pathologic examination.

Results A total of 36 patients were imaged using both MRI and US. The mean longest diameter of the tumors on MRI, US, and postoperative pathologic examination was 20.86 mm ± 4.09 mm (range: 11–27 mm), 16.14 mm ± 4.91 mm (range: 6–26 mm), and 18.36 mm ± 3.88 mm (range: 9–24 mm). US examination underestimated the size of the tumor compared to that determined using pathologic examination (t = 3.49, P < 0.01), while MRI overestimated it (t = −6.35, P < 0.01). The linear correlation coefficients between the image measurements and pathologic tumor size were r = 0.826 (P < 0.01) for MRI and r = 0.645 (P < 0.01) for US. The rate of consistency of MRI and US compared to that with pathologic examination was 88.89% and 80.65%, respectively, and there was no statistically significant difference between them (χ^2 = 0.80, P > 0.05).

Conclusion MRI and US are both effective methods to assess the size of breast tumors, and they maintain good consistency with pathologic examination. MRI has a better correlation with pathology. However, we should be careful about the risk of inaccurate size estimation.

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Key words: breast neoplasm; magnetic resonance imaging (MRI); ultrasound; pathology

Breast cancer is the most frequently diagnosed cancer in women and also the leading cause of cancer-related death worldwide. It accounted for 23% of the total new cancer cases and 14% of the total cancer-related deaths in 2008 [1]. With increasing attention, improvements in diagnosis methods, and widespread adaption of screening programs, an increasing number of patients with early-stage breast cancer are being diagnosed.

Large-scale randomized trials have shown that breast-conserving surgery (BCS) is a safe surgical procedure for early-stage breast cancer patients and it results in locoregional control similar to that of radical mastectomy [2]. Usually, BCS requires the complete removal of the tumor with a negative margin. The tumor extent is limited to less than 3 cm in order to acquire a negative margin and achieve an acceptable cosmetic result. Therefore, an accurate evaluation of the size and extent of the tumor is crucial in selecting the most appropriate surgical method for patients with breast cancer.

Both overestimation and underestimation have important adverse effects on patient care. Overestimation can result in unnecessary over-resection of normal breast tissues and thus undermine the subsequent cosmetic results of BCS and might even result in the selection of a mastec-

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tomy when BCS might still have been possible. Underestimation may result in inadequate surgery and thus increase the risk of a positive margin and local failure even after postoperative radiation.

The preoperative assessment of tumor extent in clinical practice is generally performed by physical examination, mammography, ultrasound (US), or magnetic resonance imaging (MRI). Compared to traditional imaging methods such as mammography and US, breast MRI is more sophisticated and more expensive, but its proper indications are yet to be well understood. The primary goal of this study was to evaluate the accuracy and consistency rate of breast MRI and US in measuring the extent of early-stage infiltrating breast cancer with postoperative pathologic examination used as the gold standard.

Materials and methods

Patient selection and ethics statement

Patients admitted to the Second Affiliated Hospital, Xi'an Jiaotong University (China) from January 2010 to December 2011 with $T_{1-2}N_{0-1}M_0$ invasive breast cancer that had been proved histologically by core needle biopsy and who wished to receive BCS and were assessed by breast MRI and US concomitantly before surgery were included. All of the patients underwent BCS successfully. Their clinical and pathological characteristics are listed in Table 1. This study was approved by the Institutional Review Board of the Second Affiliated Hospital of Xi'an Jiaotong University. Written informed consent was obtained at the time of recruitment from all patients involved in the study.

Table 1 The clinicopathological features of the patients with breast cancer

Clinicopathological features	Patients	
	n	%
Age (years)		
≤ 35	9	25.00
> 35	27	75.00
T stage		
T1	25	69.44
T2	11	30.56
ALN status		
Negative	31	86.11
Positive	5	13.89
Histology type		
Infiltrating ductal cancer	27	75.00
Infiltrating lobular cancer	4	11.11
Others	5	13.89
Histology grade		
Grade 1	10	27.78
Grade 2	19	52.78
Grade 3	7	19.44
ER		
Negative	15	41.67
Positive	21	58.33
PR		
Negative	17	47.22
Positive	19	52.78
HER2		
Negative	6	16.67
Positive	30	83.33

Images and pathologic assessment

All of the assessments were performed by two physicians in our hospital who both have more than 10 years' experience in performing US and MRI. They had no access to the clinical data of the patients.

Breast US examinations were performed by using high-frequency transducers (12–15 MHz) and a breast-dedicated imaging preset that was routinely extended to the axillary nodes. The findings were depicted and classified using the Breast Imaging Reporting and Data System (BI-RADS) for US. The longest diameter of the tumors was measured and depicted.

Breast MRI examinations were performed with a 3.0 T high-field MRI device, using a breast-dedicated bilateral surface coil, with the patient in the prone position. The longest diameter of the tumor was calculated in the post-contrast images generated by dynamic evaluation according to the BI-RADS system for MRI.

Breast cancer diagnosis was made pathologically by preoperative core needle biopsy guided by US. The following parameters were evaluated on specimens from the core needle biopsy. The pathologic tumor diameter examinations from the resected tissue were assessed after surgery before paraffin fixation and the final pathologic tumor diameter was obtained from the pathology report provided by the Pathology Department.

Statistical analysis

The differences of means of the longest diameter measured by MRI, US, and the pathology of the tumor were calculated. Differences between the three techniques were tested by the paired-*T* test. If the diameter difference between the imaging method and the pathological method was less than 2 mm, the two methods were deemed consistent. The difference between the consistency rate of MRI and US and that of pathological examination was assessed by using the McNemar test. Correlations between the longest diameters as measured by MRI and pathology and between US and pathology were measured using a linear correlation coefficient. *P* values < 0.05 were considered statistically significant.

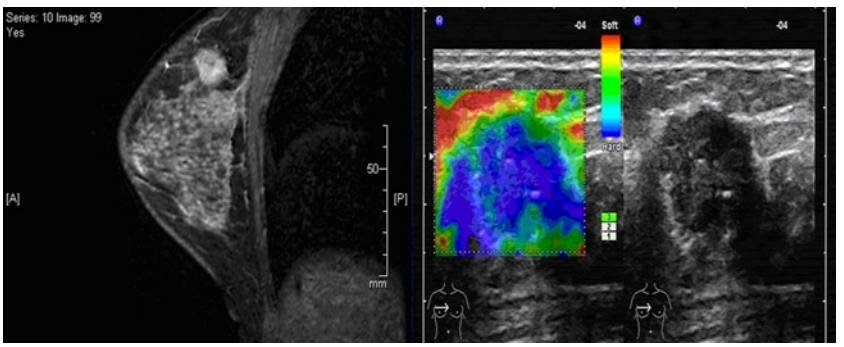

Fig. 1 T size measured by MRI and US was consistent

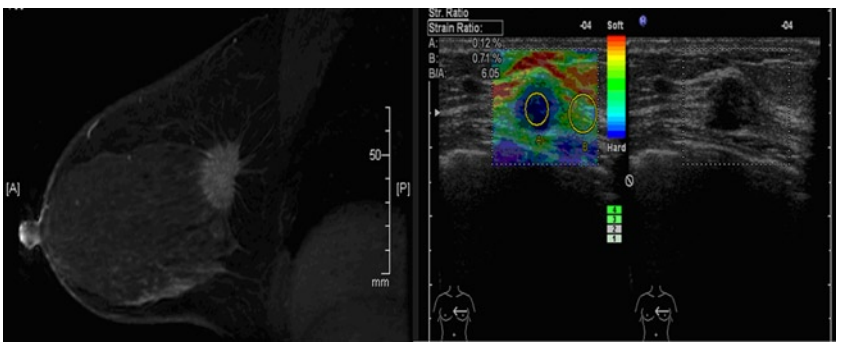

Fig. 2 T size measured by MRI and US was inconsistent

Table 2 The differences between MRI and US and pathology in measuring the breast neoplasms

Examination	Mean (mm)	Standard deviation (mm)	*t*	*P* value
Pair 1				
MRI	20.86	4.09	3.49	0.001
Pathology	18.36	3.88		
Pair 2				
US	16.14	4.91	−6.355	0.000
Pathology	18.36	3.88		

Table 3 The consistency rate of breast MRI and US with pathology in measuring the breast neoplasms

MRI	US		Total	χ^2	*P* value
	Consistent	Inconsistent			
Consistent	28	4	32		
Inconsistent	1	3	4	0.8	0.375
Total	29	7	36		

Results

Results of MRI, US, and pathology for measuring the breast neoplasms

The mean tumor diameters assessed by MRI, US, and pathologic examination were 20.86 mm ± 4.09 mm (range: 11–27 mm), 16.14 mm ± 4.91 mm (range: 6–26 mm), and 18.36 mm ± 3.88 mm (range: 9–24 mm), respectively. The US examination underestimated the size of the tumor compared with pathologic examination ($t = 3.49$, $P < 0.01$), while MRI overestimated it ($t = –6.35$, $P < 0.01$) (Table 2).

Comparison of the consistency rate of breast MRI and US with pathology in measuring the breast neoplasms

The size measured by pathology was considered to be the gold standard. If the difference of diameter between the imaging method and the pathologic method was within 2 mm, it was considered to be consistent with pathology. The size of tumors measured by MRI and US preoperatively was categorized as consistent or inconsistent (Fig. 1 and 2).

The consistency rate of MRI and US with pathology was 88.89% and 80.65%, respectively, and the difference of consistency between MRI and US had no statistical significance ($P > 0.05$) (Table 3).

The correlation between the imaging and pathologic methods of measuring the size of breast neoplasms

The correlation coefficient between MRI and pathology in measuring the size of breast tumors was 0.826 ($P < 0.01$) and for US and pathology it was 0.645 ($P < 0.01$). The correlation of MRI to pathology was better than that of US (Fig. 3 and 4).

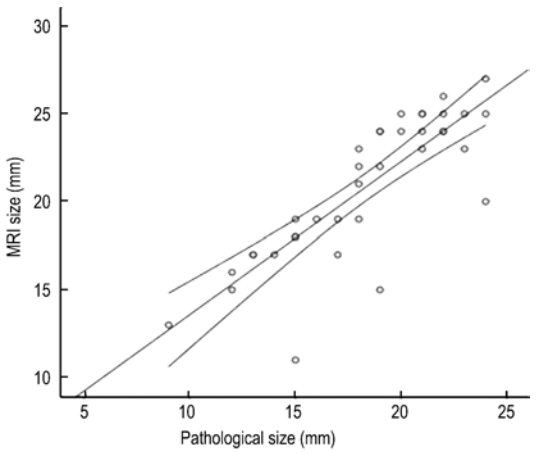

Fig. 3 The correlation between MRI and pathological size

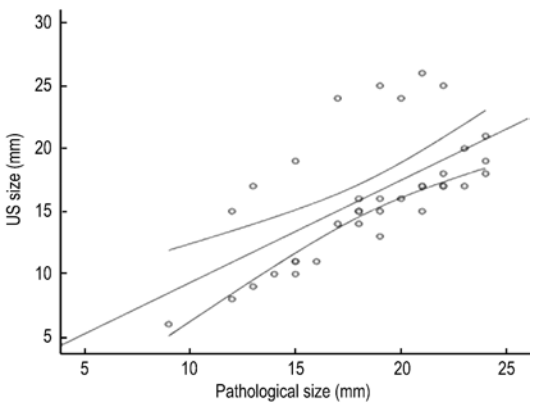

Fig. 4 The correlation between US and pathological size

Discussion

An accurate measurement of tumor size and extent is of key importance to evaluate the possibility of breast conservation and to optimize cosmetic results. In fact, a precise evaluation of a tumor allows correct preoperative planning, with appropriate selection of patient candidates for conservative surgery and a reduced chance of a positive margin, thereby improving local control and the cosmetic effect to the greatest extent.

Imaging techniques, such as mammography, US, and MRI, are widely used in the diagnosis and evaluation for treatment of breast cancer and have their own specific characteristics. In 2002, Kolb *et al* [3] showed breast US improved the sensitivity (97% versus 74%) when used adjunctively with mammography compared to physical examination and mammography. Breast MRI is frequently used as a complementary method to mammography for screening high-risk patients.

In addition to its superiority for the accurate evaluation of the extent of breast tumors, because it is widely available, noninvasive, and relatively inexpensive, US has been shown to produce relatively satisfactory results in clinical practice [4]. However, US is easily affected by breast density and subjective factors. Van *et al* [5] reported that 2-dimensional US usually underestimated the size of breast tumors because breast cancer often presents with an infiltrating growth pattern, and when the acoustic impedance between these two kinds of tissues is similar or the difference is not large enough to discriminate using US, 2-dimensional US may suggest a smaller size compared to the size measured by pathologic examination.

In the present study, the mean tumor diameter assessed by US and pathologic examination was 16.14 mm ± 4.91 mm (range: 6–26 mm) and 18.36 mm ± 3.88 mm (range: 9–24 mm), respectively, and the linear correlation between the US measurement and pathologic size was $r = 0.645$ ($P < 0.01$). If the difference between these two methods was less than 2 mm, it was regarded as consistent. The consistency rate of US compared to that of pathologic measurements was 80.65%, and US showed a tendency to underestimate the true size compared to that determined using pathologic measurements ($t = 3.49$, $P < 0.01$), suggesting that US is an effective method to evaluate the extent of a breast tumor, consistent with other reports [4–6]. Some authors have suggested that contrast-enhanced US may be more accurate in identifying the true size because breast cancer is neoangiogenesis-dependent and has more vessels than do benign tumors and normal breast tissue [5–6]. However, owing to limited evidence, this technique needs large-scale randomized experiments to confirm its superiority.

MRI has advantages of being multi-parameter, multi-sequenced, and multi-dimensional, and it has a higher sensitivity. It is not limited by the location, size, or the breast density. Therefore, MRI has advantages over mammography and US in determining the invasive tumor size, identifying multifocality, and evaluating intraductal components. Because of these advantages, this technique has been claimed to be the ideal tool to diagnose breast cancer and assess tumor extent in recent years, and it is believed that MRI may be able to more exactly identify margins to improve local control.

In this study, a cohort preparing for BCS was examined by MRI and US concomitantly and standardized by pathologic findings. The mean tumor diameters assessed by MRI, US, and pathologic examination were 20.86 mm ± 4.09 mm (range: 11–27 mm), 16.14 mm ± 4.91 mm (range: 6–26 mm), and 18.36 mm ± 3.88 mm (range: 9–24 mm), respectively, and the linear correlation between the image measurement and pathologic size was $r = 0.826$ ($P < 0.01$) for MRI and $r = 0.645$ ($P < 0.01$) for breast US. Although both MRI and US had a good accuracy and the difference in the consistency rate compared with pathology had no statistical significance (88.89% versus 80.65%,

$P > 0.05$), MRI seemed to be slightly superior ($r = 0.826$ versus $r = 0.645$). We also found that MRI displayed a tendency to overestimate the size of the tumor ($t = –6.35$, $P < 0.01$), while US showed a tendency to underestimate the true size compared with pathologic measurements ($t = 3.49$, $P < 0.01$).

However, because it is more sophisticated and expensive, the wide-spread use of MRI in the evaluation of breast masses before BCS remains controversial [7]. Turnbull *et al* [8] reported the addition of MRI to conventional assessment such as clinical palpation, mammography, and US was not associated with a significant reduction in the re-excision rate. Onesti *et al* [9] reported that the MRI-assessed size showed a good correlation coefficient ($r = 0.65$) compared with pathological size, while US measurements showed a worse correlation ($r = 0.47$) compared with pathologic size.

If we define a difference < 5 mm as concordance, MRI overestimates 35% of breast lesions, especially tumors with a diameter > 20 mm, regardless of the histological type of breast cancer. However, some studies have proposed that some patients (not all of them) may benefit from the addition of MRI before BCS [10], especially for those with invasive lobular carcinoma.

Multiplicity is the predisposing factor in local recurrence after BCS. MRI has been thought to be the most sensitive method of detecting multiplicity, but in the study by Choi *et al* [11], US was the most sensitive method in comparison with MRI and 18-fluorodeoxyglucose positron emission tomography/computed tomography in detecting primary lesions and evaluating multiplicity. Some authors have suggested that MRI can more clearly show the tumor boundary, especially the boundary of the tumor and the surrounding breast tissue after neoadjuvant chemotherapy, in invasive lobular carcinoma and ductal carcinoma in situ, and thus, MRI is superior to US.

In the present study, compared with the size on pathologic examination, although MRI showed a better correlation than that of US ($r = 0.826$ versus $r = 0.645$) the difference in the consistency rate between MRI and US compared with pathologic examination showed no statistical difference. Perhaps due to the few cases of invasive lobular carcinoma and ductal carcinoma in situ in this cohort, MRI did not display its superiority. Some authors have suggested MRI shows an extreme advantage over US in assessing the residual tumor extent after neoadjuvant chemotherapy. Perhaps in more sophisticated circumstances, MRI can display its advantages more thoroughly. However, in assessing normal palpable breast cancer, its advantages over US are limited.

Conclusion

In summary, these data suggest that MRI and US correlate well with pathology in assessing the extent of breast cancer, and no statistical difference was found in the consistency rate between MRI and US. Furthermore, US showed a tendency of underestimation while MRI showed a tendency of overestimation compared with pathologic examination.

Conflicts of interest

The authors indicated no potential conflicts of interest.

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