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ORIGINAL RESEARCH

Comparison of MRI and Ultrasound for Evaluation of Axillary Lymph Node Status in Early Breast Cancer

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Introduction: This study aimed to compare the diagnostic accuracy of ultrasound (US) and magnetic resonance imaging (MRI) in evaluating axillary lymph nodes (ALNs) status in breast cancer patients.

Methods: We retrospectively analyzed 590 female breast cancer patients who had undergone both ultrasound and MRI to assess ALNs prior to any invasive procedures. Using pathological results as the standard, we compared the diagnostic performance of the two imaging modalities.

Results: For differentiating between malignancy and benign ALNs, the diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of ultrasound were 68.98%, 38.14%, 86.67%, 62.12% and 70.96%, respectively. MRI demonstrated corresponding values of 72.03%, 38.60%, 91.20%, 71.55% and 72.15%. In assessing the burden status of ALNs (high vs low), ultrasound yielded values of 78.47%, 52.75%, 83.17%, 36.36% and 90.61%, while MRI showed corresponding values of 81.19%, 52.75%, 86.37%, 41.38% and 90.93%. There were no statistically significant differences between the two imaging modalities in their ability to evaluate ALN malignancy or burden status.

Conclusion: Both ultrasound and MRI offer comparable value in assessing ALN status. Whether evaluating for metastatic involvement or determining ALN burden, it may not be necessary for patients to undergo both imaging tests.

Plain Language Summary: 1. Both ultrasound and MRI have shown equally good value in assessing the ALNs status.

2. Whether evaluating for the metastatic ALNs or assessing the burden status of the ALNs, it is unnecessary for patients to undergo both tests.

Keywords: breast cancer, axillary lymph node, ultrasound, magnetic resonance imaging, assessment value

Introduction

Breast cancer is the most common malignancy among women worldwide.[1] At the time of diagnosis, approximately 20–30% of breast cancer patients have metastatic axillary lymph nodes (ALNs).[2,3] The presence of metastatic ALNs carries significant prognostic implications and influences treatment planning.[4] However, recent findings, such as Z0011 and AMAROS, have questioned the necessity of axillary lymph node dissection (ALND) in early-stage breast cancer patients with one or two metastatic ALNs.[5,6] This shift towards de-escalation has enabled 84% of patients to avoid the postoperative complications associated with ALND.[3] Consequently, in addition to determining the presence of metastatic ALNs, assessing the extent of high-burden ALNs is equally important.

Non-invasive alternatives such as physical examination, ultrasound (US), magnetic resonance imaging (MRI), computed tomography and positron emission tomography combined with CT (PET-CT) are commonly used to evaluate

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ALN status in breast patients. Among these, US and MRI are particularly popular due to their higher sensitivity and accuracy compared to physical examination, as well as their lower cost, non-radiative nature, and non-invasiveness.[7,8] To clarify the comparative diagnostic value of US and MRI in assessing ALN status—whether in determining malignancy or the extent of high/low burden ALNs—we conducted a retrospective analysis.

Materials and Methods

Patients

Our study included 590 women with early-stage breast cancer who underwent both ultrasound and MRI for the evaluation of ALNs prior to invasive procedures. These patients were treated at the Cancer Institute and Hospital of Tianjin Medical University between January 2015 and May 2019. The clinicopathological features of the patients included age, menopause status, family history of breast cancer, clinical tumor size, tumor location and quadrant, pathological type, tumor grade, subtypes, ALN status, and the expression levels of ER, PR, HER-2 and Ki67. In line with the ACOSOG Z0011 trial criteria, high-burden ALNs were defined as the presence of three or more metastatic ALNs. Additionally, following the 2022 guidelines from the Chinese Society of Clinical Oncology (CSCO), weakly positive ER expression was defined as 1–10% positive cells, while powerfully positive ER expression was defined as >10% positive cells. As this was a retrospective study, the requirement for informed consent was waived.

Ultrasound and MRI Examination

All patients underwent MRI (Discovery 750, GE Medical Systems), ultrasound (LOGIQ E9, LOGIQ 7 and SuperSonic Imaging Aixplorer Color Doppler Ultrasound System, GE, probe frequency: 6.0–15.0 MHz) prior to radical mastectomy in our hospital. The MRI and ultrasound images were reviewed by a breast imaging specialist. MRI data were obtained using sagittal and axial T1 and T2 weighted sequences using a GE 1.5 T magnet. A suspicious ALN on ultrasound was typically defined as having a shortest diameter ≥10 mm, an L/T (long/short axis of lymph nodes) <2, abnormal shape, heterogeneous hyperechoic cortex, rich blood flow, or a replaced hilum. MRI criteria for a suspicious ALN included a shortest diameter ≥10 mm, L/T <2 and a replaced hilum. Relevant parameters from both imaging modalities were collected and analyzed. Lymph nodes with two or more suspicious imaging characteristics were classified as radiologically malignant on either ultrasound or MRI.

Statistical Method

Data were analyzed using SPSS 22.0 (IBM Corp, NY, USA) and MedCalc 20.113 (MedCalc Software Ltd, Ostend, Belgium). The ages of all patients were in normal distribution (shown in Supplementary Figure 1). Mean ± SD was used to describe continuous variable. Descriptive statistics for categorical variables were reported as frequency. The comparison of categorical statistics was performed by x^2 test and fisher's exact test. The kappa value and area under curve (AUC) value of receiver operating characteristic (ROC) curves were used to evaluate consistency between MRI and ultrasound. Z test was applied in comparing of ROC curves. All statistical tests were two-sided with alpha level set to 0.05 for statistical significance.

Results

All patients were females. The mean age was 47.15 ± 9.84 years. The clinicopathologic features are listed in Table 1. The imaging parameters of ultrasound and MRI were shown in Tables 2 and 3 (The data of MRI and US for ALN from all patients is shown in Supplementary Table 1).

The Assessment Value of Ultrasound and MRI for Axillary Lymph Node Metastasis

When assessing the malignancy/benign of ALNs using ultrasound, 131 patients were diagnosed with metastatic ALNs of which 82 were pathologically confirmed as malignant. Among the 458 patients diagnosed with benign ALNs through ultrasound, 325 were pathologically confirmed as benign. Ultrasound demonstrated an accuracy of 68.98%, a sensitivity of 38.14%, a specificity of 86.67%, and a positive predictive value of 62.12%, a negative predictive value of 70.96%. The AUC was 0.624 (95% CI: 0.584–0.663), with a kappa value of 0.270, and a P-value <0.001.

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Table 1 Clinicopathological Feature in Early Breast Cancer Patients

Clinicopathological Feature		Patients n=590
Age	Mean±SD	47.15±9.84
	<35years	80(13.6%)
	≥35years	510(86.4%)
Menopausal status	Postmenopausal	227(38.5%)
	Premenopausal	363(61.5%)
Family history	Yes	64(10.8%)
	No	526(89.2%)
Quadrant	Inner upper	116(19.7%)
	Inner down	25(4.2%)
	Outer down	53(9.0%)
	Outer upper	253(42.9%)
	Central	143(24.2%)
Tumor size	≤20mm	323(54.7%)
	>20mm, and ≤50mm	241(40.8%)
	>50mm	26(4.4%)
Pathological type	Invasive ductal carcinoma	548(92.9%)
	Carcinoma in situ	38(6.4%)
	Special type of carcinoma	4(0.7%)
Tumor grade	I	13(2.2%)
	II	405(68.6%)
	III	172(29.2%)
ER	Negative	160(27.1%)
	Weak positive	28(4.7%)
	Power positive	402(68.1%)
PR	Negative	190(32.2%)
	Positive	400(67.8%)
HER2	Negative	467(79.2%)
	Positive	123(20.8%)
Ki67	<20%	168(28.5%)
	≥20%	422(71.5%)
Subtypes	Luminal A	32(5.4%)
	Luminal B	404(68.5%)
	HER2 enriched	59(10.0%)
	Basal-like	95(16.1%)
ALN status	pN0	375(63.6%)
	pN1	159(26.9%)
	pN2	46(7.8%)
	pN3	10(1.7%)

For MRI, 116 patients were diagnosed with metastatic ALNs, of which 83 cases were pathologically confirmed as malignant. Among the 474 patients diagnosed with benign ALNs through MRI, 342 were pathologically confirmed as benign. MRI demonstrated a higher accuracy rate of 72.03%, with a sensitivity of 38.60%, specificity of 91.20%, positive predictive value of 71.55%, and negative predictive value of 72.15%. The AUC was 0.649 (95% CI: 0.609–0.688), with a Kappa value of 0.331 and a P-value <0.001.

The Assessment Value of Ultrasound and MRI for the High/Low Burden State of ALNs

In the assessment of high/low burden ALNs using ultrasound, 132 patients were diagnosed with metastatic ALNs, of which 48 were pathologically confirmed to have high-burden metastatic ALNs. Among the 458 patients diagnosed with benign ALNs, 415 were pathologically confirmed to have low-burden ALNs. Ultrasound demonstrated an accuracy of

Table 2 The Ultrasound Parameters in Early Breast Cancer Patients

The Ultrasound Parameters		Patients n=590
The shortest diameter	<10mm	551(93.4%)
	≥10mm	39(6.6%)
Long/short axis of lymph nodes (L/T)	<2	138(23.4%)
	≥2	452(76.6%)
Cortex thickness	>3mm	201(34.1%)
	≤3mm	389(65.9%)
Hilum	Effacement	60(10.2%)
	Presence	530(89.8%)
Blood flow	Rich	44(7.5%)
	No/Poor	546(92.5%)
Shape	Regular	539(91.4%)
	Irregular	51(8.6%)

Table 3 The MRI Parameters in Early Breast Cancer Patients

MRI Parameters		Patients n=590
The shortest diameter	<10mm	388(65.8%)
	≥10mm	202(34.2%)
Long/short axis of lymph nodes(L/T)	<2	482(81.7%)
	≥2	108(18.3%)
Cortex thickness	>3mm	288(48.8%)
	≤3mm	302(51.2%)
Hilum	Effacement	143(24.2%)
	Presence	447(75.8%)

78.47%, sensitivity of 52.75%, specificity of 83.17%, positive predictive value of 36.36%, and negative predictive value of 90.61% in identifying the burden state of ALNs. The AUC was 0.680 (95% CI: 0.640–0.717), with a Kappa value of 0.303, and a P-value <0.001.

For MRI, 116 patients were diagnosed with metastatic ALNs, of which 48 were pathologically confirmed as high-burden. Among the 474 patients diagnosed with benign ALNs, 431 were pathologically confirmed as low-burden. MRI demonstrated an accuracy of 81.19%, sensitivity of 52.75%, specificity of 86.37%, positive predictive value of 41.38%, and negative predictive value of 90.93% in identifying the burden state of ALNs. The AUC was 0.696 (95% CI: 0.657–0.733), with a Kappa value of 0.352, and a P-value <0.001, shown in Table 4.

Comparing the Assessment Value of Ultrasound and MRI for Diagnosing ALNs Status

In comparing the diagnostic value of ultrasound and MRI for evaluating metastatic ALNs, no significant statistical difference was observed between the two imaging modalities (Z = 1.567 and P = 0.117). A similar result was found in the

Table 4 The Diagnostic Performance of Ultrasound and MRI for the ALNs

		Accuracy	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	AUC	Kappa	P value
High/low burden state of ALNs	US	78.47	52.75	83.17	36.36	90.61	0.680	0.303	<0.001
	MRI	81.19	52.75	86.37	41.38	90.93	0.696	0.352	<0.001
Metastatic ALNs	US	68.98	38.14	86.67	62.12	70.96	0.624	0.270	<0.001
	MRI	72.03	38.60	91.20	71.55	72.15	0.649	0.331	<0.001

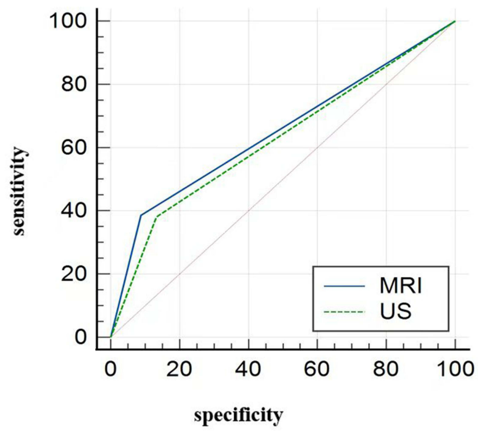

Figure 1 ROC curves of MRI and US for evaluation of metastatic axillary lymph nodes.

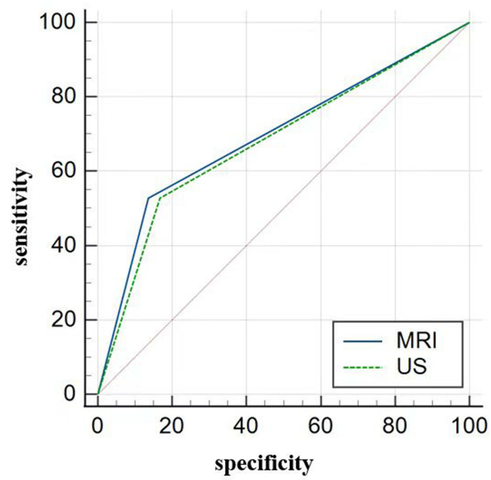

Figure 2 ROC curves of MRI and US for evaluation of high burden axillary lymph nodes.

assessment of the burden state of ALNs ($Z = 0.769$ and $P = 0.442$). The ROC curves for both diagnostic methods are shown in Figures 1 and 2.

Among patients whose ALNs were deemed benign by ultrasound but considered malignant by MRI, pathology confirmed 16 cases (3.49%) as metastatic ALNs and 6 cases (1.31%) as high-burden ALNs. Conversely, in patients diagnosed as benign by MRI but considered malignant by ultrasound, pathology confirmed 15 cases (3.16%) as metastatic ALNs and 6 cases (1.31%) as high-burden ALNs, in Table 4.

Discussion

In recent years, the early diagnosis rate of breast cancer has significantly increased, largely due to the widespread implementation of breast screening programs. However, only 20–30% of early breast cancer patients are found to have metastatic ALNs. This suggests that for the majority of patients, performing sentinel lymph node biopsy may be excessive.[2,3] A meta-analysis by KELL et al found that among early breast cancer patients who were clinically considered ALN-negative, only 27.6% were confirmed to have metastatic ALNs through sentinel lymph node biopsy.[9] Although it helps approximately three-fourths of patients avoid more invasive ALN dissection, it is still an invasive procedure, and postoperative complications such as pain, numbness, restricted range of motion, infection, and swelling may occur, though the severity of these symptoms usually decrease over time.[10] In the era of precision medicine, detailed

ALN assessment has become an essential component of patient care, playing a crucial role in staging, prognosis assessment, and treatment planning.[11–13] Multifactor models incorporating clinical and imaging features have been studied to accurately predict ALN metastasis. In our previous study, we developed a nomogram that combined imaging criteria with higher grade and tumor quadrant to calculate the probability of high-burden metastatic ALNs.[14] As emphasized in the CSCO guidelines, patients with metastatic ALNs should undergo neoadjuvant chemotherapy. Accurately identifying patients with metastatic ALNs before surgery remains a major challenge in breast cancer surgery, as it is key to optimize treatment strategies.

Most studies suggest that ultrasound and MRI have comparable efficacy in assessing metastatic ALNs in early-stage breast cancer patients,[15–17] which is consistent with my study. However, some researchers argue that MRI is superior to ultrasound in evaluating metastatic ALNs in breast cancer patients. In a study involving 271 newly diagnosed breast cancer patients who underwent both MRI and ultrasound, it was found that among the 25 patients initially assessed as having no metastatic ALNs by MRI, but later evaluated by ultrasound as having metastatic ALNs, only 1 case (4%) was pathologically confirmed as a true metastasis. Conversely, among the 27 patients initially assessed as having no metastatic ALNs by ultrasound, but later diagnosed with metastatic ALNs by MRI, 4 cases (15%) were pathologically confirmed as true metastasis.[18] Based on these results, some researchers believe that MRI should be considered the preferred initial imaging modality for ALN staging, as it may detect metastatic ALNs that ultrasound misses. Some experts even recommend that if a patient is initially found to have no metastatic ALNs on ultrasound but is later diagnosed with metastatic ALNs on MRI, a repeat ultrasound examination and possibly a biopsy should be performed to confirm the preoperative diagnosis.[19] However, in our study, only 3.49% of patients who were initially deemed to have no metastatic ALNs on ultrasound but were later diagnosed with malignant on MRI were pathologically confirmed as having metastatic ALNs. Similarly, only 3.16% of patients who were initially considered to have no metastatic ALNs on MRI but were subsequently diagnosed with malignant ALNs on ultrasound were confirmed as having metastatic ALNs. Therefore, we believe that for the assessment of metastatic ALNs, it is sufficient for patients to undergo either ultrasound or MRI, and repeat examinations are not necessary.

In the post-ACOSOG Z0011 and AMAROS trial era, accurately identifying patients with high-burden metastatic ALNs has become increasingly crucial. A study by Schipper et al found that when ALNs were clinically staged as cN0 based on ultrasound evaluation, only 4.4% of cases had pN2-pN3 disease, reflecting a negative predictive value (NPV) of 95.5% (ranging from 93.4% to 97.1%).[20] This highlights the effectiveness of preoperative axillary ultrasound in ruling out high-burden ALNs when the results are negative. Similar conclusions have been corroborated in other studies, emphasizing the importance of preoperative axillary ultrasound in excluding high-burden metastasis.[21–23] Our research further supports these findings. We observed that among patients diagnosed as N0 by ultrasound, the likelihood of being pathologically confirmed with high-burden ALNs was 9.4%. Similar results were seen with MRI diagnostics. Importantly, among patients who had negative ultrasound results but were subsequently identified as positive by MRI, only 1.31% were pathologically confirmed to have high-burden metastatic ALNs. Likewise, only 1.27% of patients who were initially negative on MRI and later identified as positive by ultrasound were confirmed to have high-burden metastatic ALNs. Thus, we conclude that for assessing high-burden ALNs, it is sufficient for patients to undergo either ultrasound or MRI, and it is unnecessary to use both modalities.

Conclusion

Both ultrasound and MRI have shown comparable effectiveness in assessing the status of ALNs. Whether evaluating for metastatic ALNs or determining the burden status, it is unnecessary for patients to undergo both imaging modalities, either ultrasound or MRI, is sufficient for accurate assessment.

Data Sharing Statement

The datasets used during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The research was approved by the Institutional Review Board of the Tianjin Medical University Cancer Institute and Hospital (protocol number EK20240042). Informed consent from the participants was waived by the institutional review board as the current study satisfied all of the requirements for the waiver of informed consent. The research was retrospective data analysis of previously collected medical records and involved no more than minimal risk to the participants.

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Disclosure

The authors have declared that no competing interests exist.

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