Evaluation of Fusion Imaging Guidance in Radiofrequency Ablation for Early-Stage Breast Cancer

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Abstract

Radiofrequency ablation (RFA) is emerging as a minimally invasive treatment option for selected early-stage breast cancers in Japan, particularly for tumors ≤15 mm. However, accurate lesion localization can be difficult with conventional ultrasound (US), especially for small and/or non-mass lesions. In this study, fusion imaging combining contrast-enhanced MRI, US, and contrast-enhanced US (CEUS) markedly improved lesion detectability and enabled precise re-localization when additional ablation was required. Complete ablation was achieved in all cases, with no viable tumor cells identified on follow-up ultrasound-guided vacuum-assisted biopsy(US-VAB). These findings indicate that MRI–US/CEUS fusion imaging enhances the precision, safety, and reproducibility of RFA for early-stage breast cancer. Further clinical accumulation is required to refine protocols and establish standardized guidelines.

Introduction

RFA for early-stage breast cancer was approved for coverage under Japan's national health insurance in December 2023, following favorable results from several clinical trials. This study evaluated the clinical utility of fusion imaging to improve lesion targeting and procedural accuracy during RFA.

Materials and Methods

Fourteen patients underwent RFA guided by MRI–US/CEUS fusion imaging using V Nav®(LOGIQ E10x, GE Healthcare) system. Fusion imaging was performed by integrating contrast-enhanced MRI with real-time ultrasound using the V Nav®; volume navigation system. Anatomical landmarks such as the nipple were matched to ensure accurate spatial alignment. CEUS with Sonazoid® was used to assess intratumoral vascularity and to confirm post-ablation perfusion defects. After fusion-based targeting, a Cool-tip electrode was inserted with a planned 1-cm margin. Therapeutic efficacy was evaluated ≥4 weeks post-procedure using follow-up imaging and US-VAB of the ablation zone.



Fig. 1 Setup and synchronization process of fusion imaging (MRI–US fusion; V Nav ®)

Fusion imaging refers to the integration of information obtained from different imaging modalities. At our institution, US system(Fig. 1a(1)) is positioned on the right side of the patient, and the transmitter (Fig. 1a(2)) is placed on the left. First, contrast-enhanced breast MRI data are imported into the US system. A position sensor is attached to the US probe(Fig. 1a(3)) and connected to the magnetic field transmitter, enabling synchronization between real-time US and the pre-acquired MRI images. On the monitor, the US image appears on the left and the contrast-enhanced MRI image on the right. Registration is initially performed at the nipple position, followed by fine adjustment at the lesion site to achieve accurate image fusion.

Fig. 1a

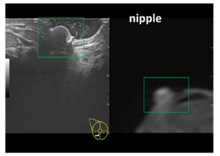


Fig. 1b

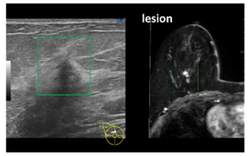


Fig. 1c

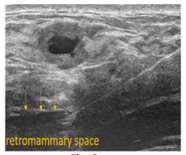


Fig. 2a

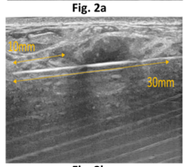


Fig. 2b

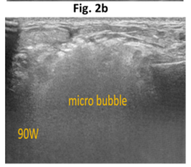


Fig. 2c

Fig. 2 Stepwise procedure of RFA under ultrasound guidance

The lesion was first identified on conventional US , and the puncture route was planned on the plane demonstrating the largest cross-sectional diameter. A 5% glucose solution was then injected into the retromammary space to create a protective space and to increase tissue impedance, reducing the risk of thermal injury to adjacent structures (Fig. 2a). Intratumoral impedance was assessed using a Cool-tip electrode with a 3-cm active tip (Fig. 2b), after which the electrode was positioned so that the active segment extended approximately 10 mm beyond the tumor margin. Radiofrequency ablation was initiated at 5 W, and the output was increased by 10 W at one-minute intervals. After roll-off occurred, the peak temperature achieved was confirmed.

Results

Patients were aged 34–82 years (mean 57 years), and tumor diameters ranged from 7 to 15 mm (mean 12.4 mm). Histopathologic diagnoses included ductal carcinoma in situ (DCIS; n = 8) and invasive ductal carcinoma (IDC; n = 6). Fusion imaging improved lesion visibility and delineation in cases that were difficult to detect on conventional US and enabled accurate re-localization for additional ablation. Complete ablation was achieved in all cases. Mean initial impedance was 169 Ω (116–245 Ω), maximum ablation temperature 93 ℃(83–100 ℃), and ablation time 20 minutes (14–32 minutes). One case of mild nipple retraction occurred, and no major complications were observed. No viable tumor cells were identified in any US-VAB specimens.

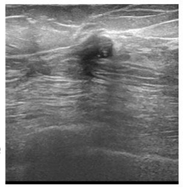


Fig. 3a

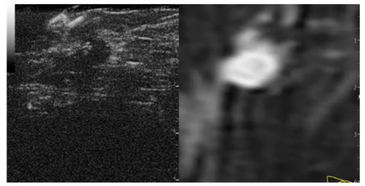


Fig. 3b

Fig. 3 On conventional US , the lesion appeared as a non-mass lesion and was difficult to localize. (Fig. 3a) Fusion with contrast-enhanced breast MRI enabled accurate and rapid localization. On breast contrast-enhanced MRI/CEUS fusion imaging, inflow signals from the feeding vessels were visualized within the lesion, and the heterogeneous enhancement with non-enhancing areas enabled recognition of the lesion as malignant.(Fig. 3b)

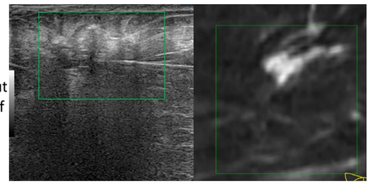


Fig. 4 Although the lesion often becomes difficult to identify when additional ablation is required, fusion imaging enabled accurate localization of the primary tumor.



Fig. 5. NADH-diaphorase staining enabled assessment of the presence or absence of viable cancer cells. Viable cells with preserved mitochondrial activity were stained blue, whereas necrotic cells remained unstained, allowing confirmation of complete coagulative necrosis induced by RFA.

Discussion

In RFA, regardless of whether the target is a mass or a non-mass lesion, combining fusion imaging with contrast-enhanced breast MRI enables rapid and accurate lesion localization and allows appropriate definition of the ablation field during additional ablation. Evaluation of the ablation zone after RFA is sometimes difficult on conventional US alone, as the margins can become indistinct. However, fusion imaging enables more accurate confirmation of the ablation area by referencing the pre-procedural MRI. Furthermore, CEUS, which enables assessment of microvascular perfusion, was useful for evaluating therapeutic efficacy. On CEUS, the ablation zone appears as a perfusion defect, making its boundaries easier to delineate and allowing reliable assessment of treatment effectiveness.
This study has several limitations. Because MRI was performed in the prone position and ultrasonography in the supine position, slight misregistration may have occurred during fusion due to differences in patient positioning. However, synchronization using the nipple followed by alignment with the lesion allowed relatively easy fusion. In addition, further refinement of techniques to correct positional discrepancies caused by changes in the scanning plane is required. The small sample size also represents a limitation of this study.

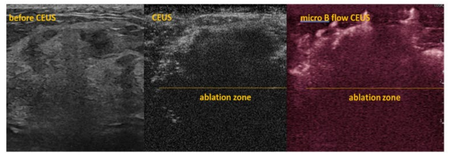


Fig. 6 While it is sometimes difficult to evaluate the ablation zone using conventional US alone, CEUS-which allows assessment of microvascular perfusion-enables a more accurate evaluation of the ablation zone

Conclusions

Fusion imaging with MRI and US/CEUS improved the accuracy and safety of RFA for early-stage breast cancer, particularly for lesions poorly visualized on conventional US. Further clinical accumulation is required to standardize protocols and optimize treatment outcomes.

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References

1. Toshikazu Ito, et al. Radiofrequency Ablation of Breast Cancer: A Retrospective Study. Clinical Breast Cancer. 2017
2. Toshikazu Ito, et.al. Understanding the basics and clinical applications of contrast-enhanced ultrasound for breast lesions, Journal of Medical Ultrasonics, 2024
3. Shogo Nakano, et al. Fusion of MRI and Sonography Image for Breast Cancer Evaluation Using Real-time Virtual Sonography with Magnetic Navigation: First Experience, Japan J Clin Oncol, 2009
4. Shogo Nakano, et al. Impact of real-time virtual sonography, a coordinated sonography and MRI system that uses an image fusion technique, on the sonographic evaluation of MRI-detected lesions of the breast in second-look sonography, Breast Cancer Res Treat, 2012
5. Kazuaki Nakashima, et al. MRI-detected breast lesions: clinical implications and evaluation based on MRI/ultrasonography fusion technology, Japanese Journal of Radiology, 2019
6. Junta Sakakibara, et al. A review of MRI(CT)/US fusion imaging in treatment of breast cancer, Journal of Medical Ultrasonics, 2023

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