Clinical experience with Aplio i-series: Improving interpretation for breast ultrasound

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Introduction

The newly developed 24 MHz linear transducer for Aplio i-series premium ultrasound platform delivers exceptional detail and definition for breast ultrasound. This transducer was designed to incorporate an extended frequency bandwidth along with more advanced technologies. In this white paper, the advantages of this ultra-high frequency linear transducer for breast ultrasound are described by means of clinical case studies.

The 24 MHz ultra-high frequency linear transducer (PLI-2004BX, 8.8 - 24.0 MHz) is a dedicated probe for superficial imaging. The new lens, piezoelectric oscillator, matching layer and backing materials combined together form the base for its capability of high frequency emission. The increased frequency range results in exceptional spatial resolution for evaluating fine anatomical details. This new transducer with a 1.5D array of elements supports iBeam forming and iBeam slicing technologies.

The innovative iBeam forming technology on Aplio i-series enables the formation of uniform high-density ultrasound beams that deliver extraordinary spatial and contrast resolution; while the iBeam slicing technology provides high-flexibility electronic focusing in the lens direction that generates sharp and homogeneous slice thickness creating images with outstanding contrast and elevation resolution. With this combination of innovative iBeam system architecture and transducer technologies, images with excellent axial, lateral and elevational plane resolution can be acquired. In my experience the ultra-thin slice thickness provides better image quality with fewer artifacts, improving sensitivity in deeper regions. As high-definition images with excellent penetration can be acquired with the 24 MHz transducer, the anatomical details from skin to chest wall can be clearly depicted. The new transducer was used in the following breast ultrasound case studies.

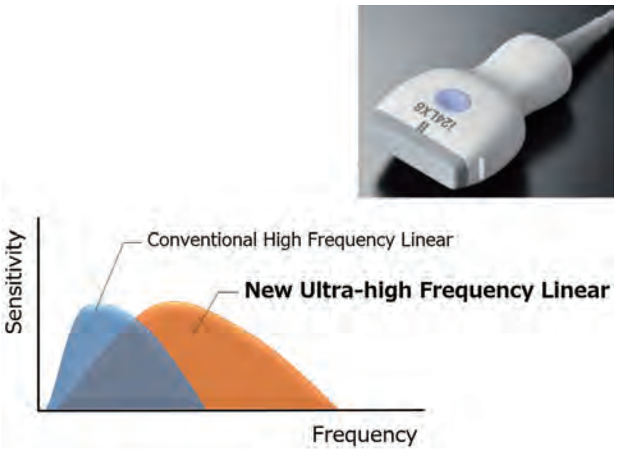


Figure 1. Ultra-high frequency linear transducer PLI-2004BX

Case Studies

Case 1.

A 29 year-old female underwent breast ultrasound after an abnormality was detected on mammogram. A spiculated mass was detected on the right MLO view (Figure 2a). The mass was classified as BI-RADS 5 and was strongly suspected to be malignant. On breast ultrasound, the mass presented with a fine lobulated contour, though not as hypoechoic as a scirrhous carcinoma (Figure 2b). The ultrasound signal posterior to the mass demonstrated both acoustic enhancement and acoustic shadowing, thus the mass was considered to have inhomogeneous echo texture resulting from the heterogeneous internal structure. The same observation was detailed in the longitudinal plane (Figure 2c), confirming that it was not a scirrhous carcinoma. In cine images, architectural distortion was visualized which could explain the spiculated margins observed on mammogram. These features rendered the mass more suspicious for sclerosing adenosis.

Results from strain elastography demonstrated that there was no significant distortion of the mass (Figure 2d). However, minute blood flow could be detected using Superb Micro-vascular Imaging (SMI), an innovative Doppler technology for detecting low-velocity blood flow (Figure 2e). The advanced volume rendering technology, Smart 3D, reconstructs volume images from 2D data obtained by a freehand ultrasound sweep with a 2D transducer. By combining Smart 3D and SMI, the entire microvasculature of the mass can be visualized in three dimensions (Figure 2f). The thin beam slice thickness made possible with iBeam slicing technology further increases the sensitivity of SMI, thus tumor vasculature can now be observed in more detail.

The mass was strongly enhancing in the contrast-enhanced MR mammography (Figure 2g), suggesting a diagnosis of ductal carcinoma in situ (DCIS) with sclerosing adenosis.

The patient underwent lumpectomy. Pathological images exhibited numerous features, including an intraductal lesion, colloids, and infected stromal tissue. The spiculated margin was inferred to be due to the process of sclerosis. In addition, intraductal papilloma was revealed and DCIS was also discovered (Figure 2h).

The 24 MHz transducer demonstrated a malignant tumor within the extensive benign lesion by picking up a 6 mm tubular carcinoma (an invasive ductal carcinoma, IDC), which was missed during preoperative ultrasonography. Comparing the breast ultrasound with the histopathological results, different levels of sclerosis in the intraductal lesion and dilated ducts were clearly visualized (Figure 2). In addition, the lesion was not as hypoechoic as a scirrhous carcinoma, which could be explained by the existence of hyperechoic intraductal papilloma's stroma and myxoid substances. The 24 MHz transducer is capable of depicting these complicated pathologies distinctly and with improved diagnostic confidence.

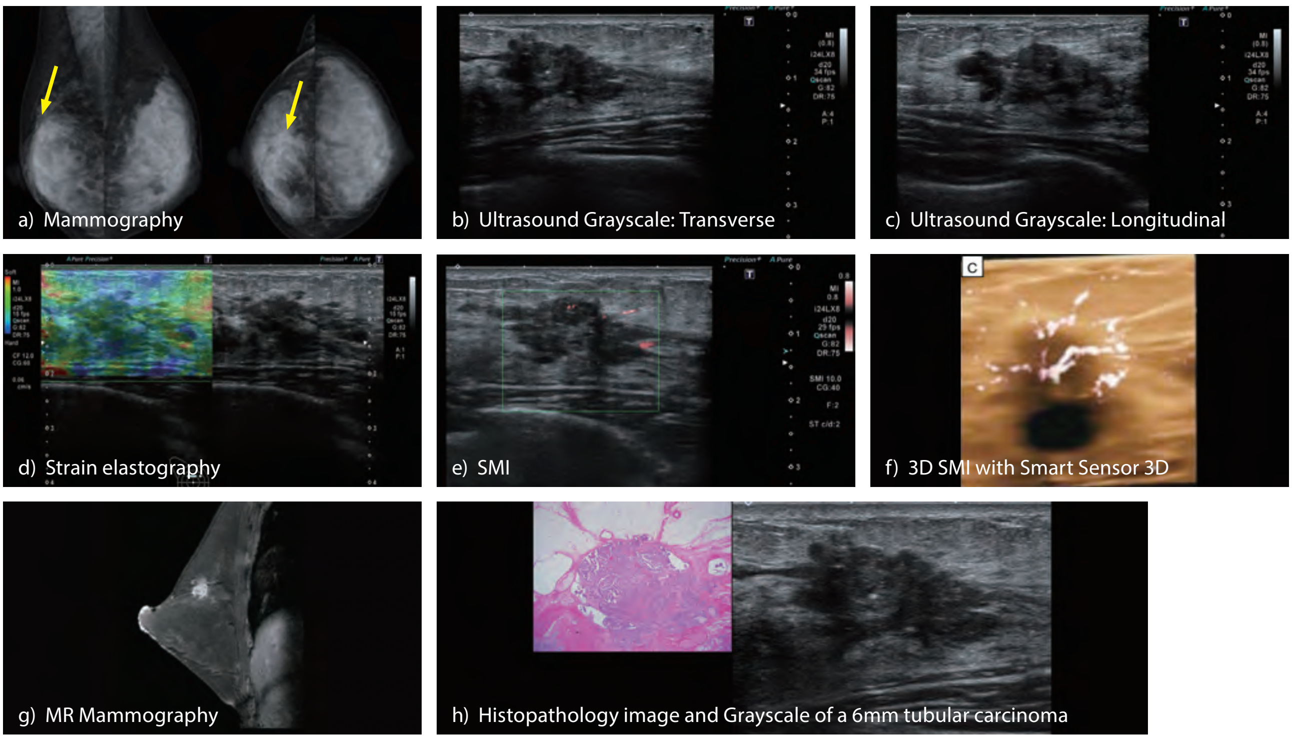


Figure 2. Case 1: A 29 year-old female underwent post mammogram breast ultrasound which detected additional abnormalities

Case 2: HER2-positive breast cancer in early stage

The interpretation of mammogram was difficult with this patient but a high density region associated with calcifications was visualized in the left breast (Figure 3a). Using tomosynthesis, a high density region was also detected at the center of the left breast but there was no abnormality detected in the right breast (Figure 3b).

This was a technically difficult patient with fatty breasts and it was challenging to differentiate a lesion from fatty tissue. However, the ultra-high frequency linear transducer was able to provide images with high spatial and contrast resolution to allow clear detection of the lesion (Figure 3c). In addition, SMI was able to depict minute microvascular flow within the lesion. The malignancy was confirmed with cytodiagnosis and a breast-conserving surgery (BCS) was performed.

On the pathological specimens at 3mm thickness, T1 to T7, invasive ductal carcinoma (IDC) were indicated with ○ and DCIS were indicated with ○ (Figure 3d). Histopathological images (Figure 3e) showed that the major lesion and its surrounding intraductal lesions are located at T4.

The patient was diagnosed with highly aggressive HER2-positive breast cancer. In planning the wide local excision of the left breast, it is critical to determine the extent of the lesion for accurate excision. Although HER2-positive breast cancer was suspected, the extent of the lesion was not evaluated accurately during pre-operative tumor marking. In order to increase the success of surgical outcomes, it is essential to examine both the lesion and its surrounding tissue.

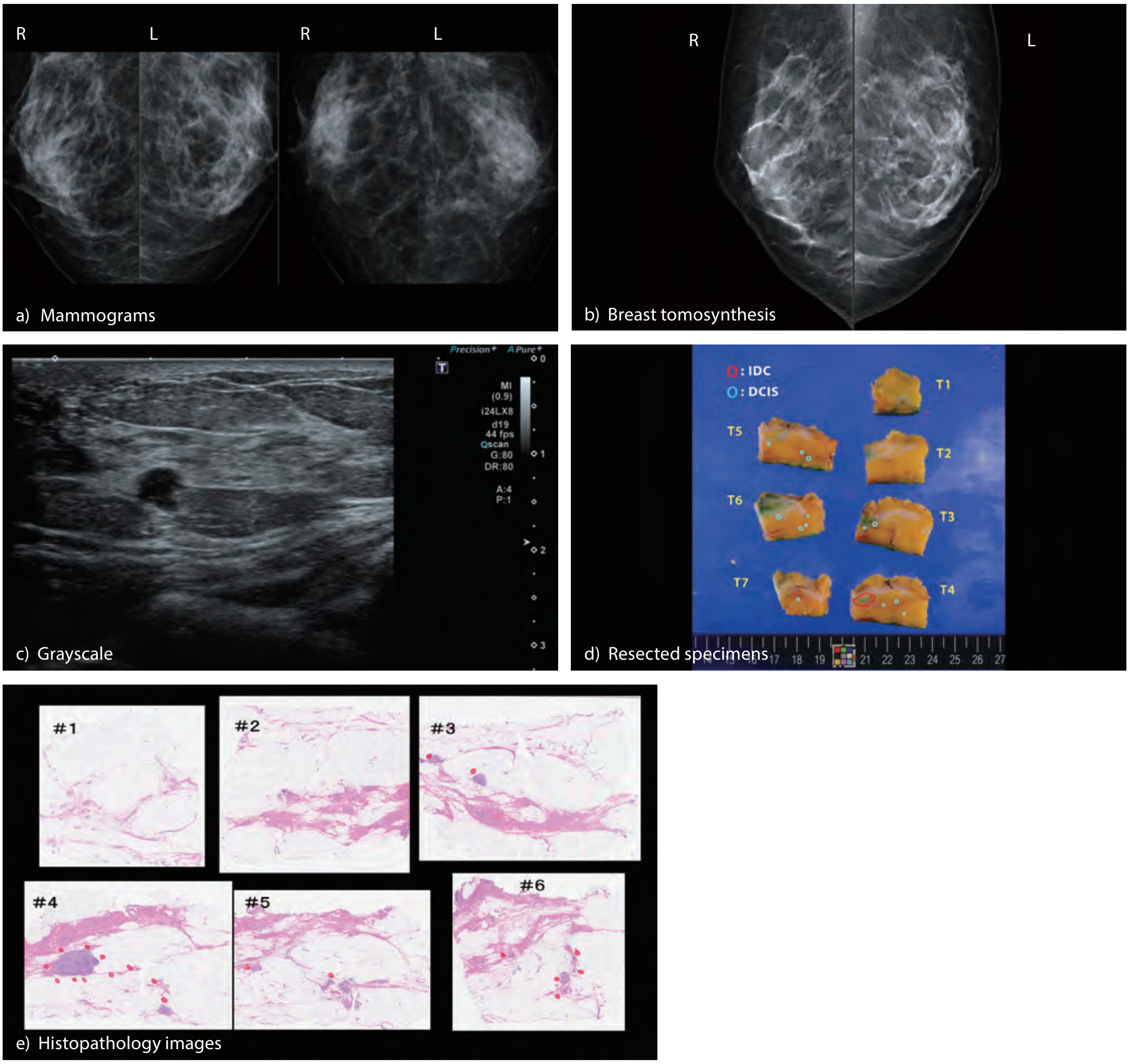


Figure 3. Case 2: HER2-positive breast cancer in early stage

Case 3: Fibrocystic breast change

This patient underwent mastectomy on the left breast. Mammography was performed on the right breast and a high density region was observed. Comparative evaluation could not be performed as only mammograms from the right breast were undertaken (Figure 4a). A conventional ultrasound system showed that the ultrasound signal posterior to the hypoechoic lesion attenuated severely (Figure 4b), thus the mass was suspected to be malignant. With the Aplio i800 – in spite of the dense mammary gland – high-definition images of the mammary gland, pectoralis major muscle and chest wall were acquired. It can be concluded that the hypoechogenicity resulted from fibrocystic breast change (Figure 4c). Scanning with the 24 MHz probe resulted in images with optimal resolution and sufficient penetration in the deeper regions of the breast.

Figure 4. Case 3: A 85 year-old patient with fibrocystic breast changes after mastectomy on the left breast

Case 4: Scirrhous carcinoma

From the mammogram (Figure 5a), a high density region associated with architectural distortion in the right breast was detected, classified as BI-RADS 4. With breast ultrasound, the mass was suspected to be a scirrhous carcinoma (Figure 5b). Lumpectomy was performed as the mass was located near the nipple. A diagnosis of Luminal A breast cancer was confirmed with histopathology and a second primary breast cancer was also revealed (Figure 5c). Using Aplio i800, the mammary gland structure, scirrhous carcinoma and second primary breast cancer were all depicted with detail (Figure 5d).

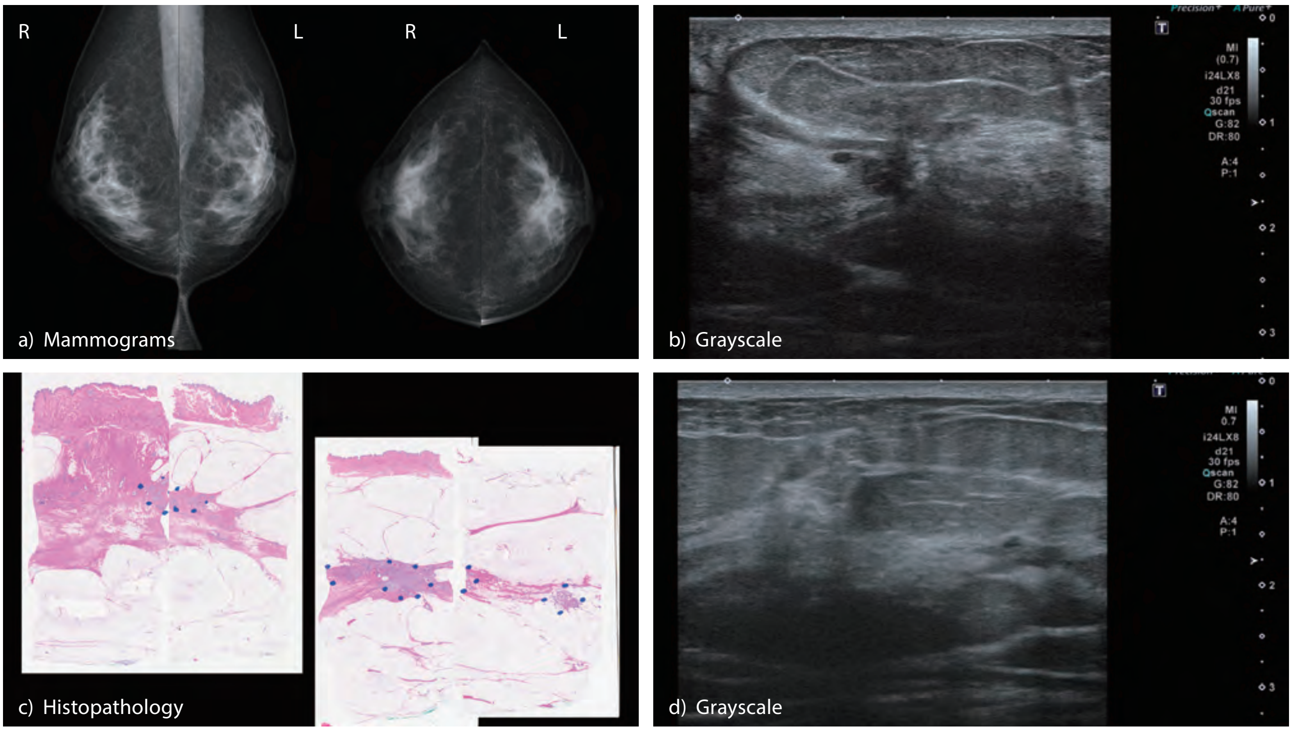


Figure 5. Case 4: Scirrhous carcinoma. Luminal A breast cancer confirmed by histopathology

Case 5: Lobular carcinoma in situ and DCIS with sclerosing adenosis

A patient in her fifties had been undergoing breast screening for 3 years (Figure 6a). From a screening in 2016, no abnormality was detected. Half a year later, however, the patient complained of a dent on her left breast and thus mammography was performed. Architectural distortion was seen at the lower portion of both breasts (Figure 6b). In general, it is challenging to detect architectural distortion during routine breast ultrasound, therefore a comprehensive assessment with ultrasound and mammography can improve diagnostic accuracy.

Ultrasound detected a slightly hypoechoic lesion in the left breast. During evaluation with strain elastography, the lesion did not exhibit significant distortion (Figure 6c). The pathological result after lumpectomy confirmed a diagnosis of lobular carcinoma in situ (LCIS) (Figure 6d). LCIS causes increase of abnormal cells in lobules without severe damage to the normal mammary gland structure. It is usually difficult to detect LCIS using ultrasound, however, Aplio i-series was clearly able to depict the lesion.

In the right breast, shadowing only existed partially posterior to the lesion, therefore there was a high possibility to miss this lesion. With Pathohistology, the patient was diagnosed with DCIS associated with sclerosing adenosis. As the DCIS was located within the sclerosing adenosis, a breast lesion excision was not performed. Figure 5e is the comparison of images acquired using a conventional ultrasound system and Aplio i800 at 12 o'clock and 6 o'clock of the right breast. Aplio i800 delivered the image quality needed to delineate anatomical structures in fine detail.

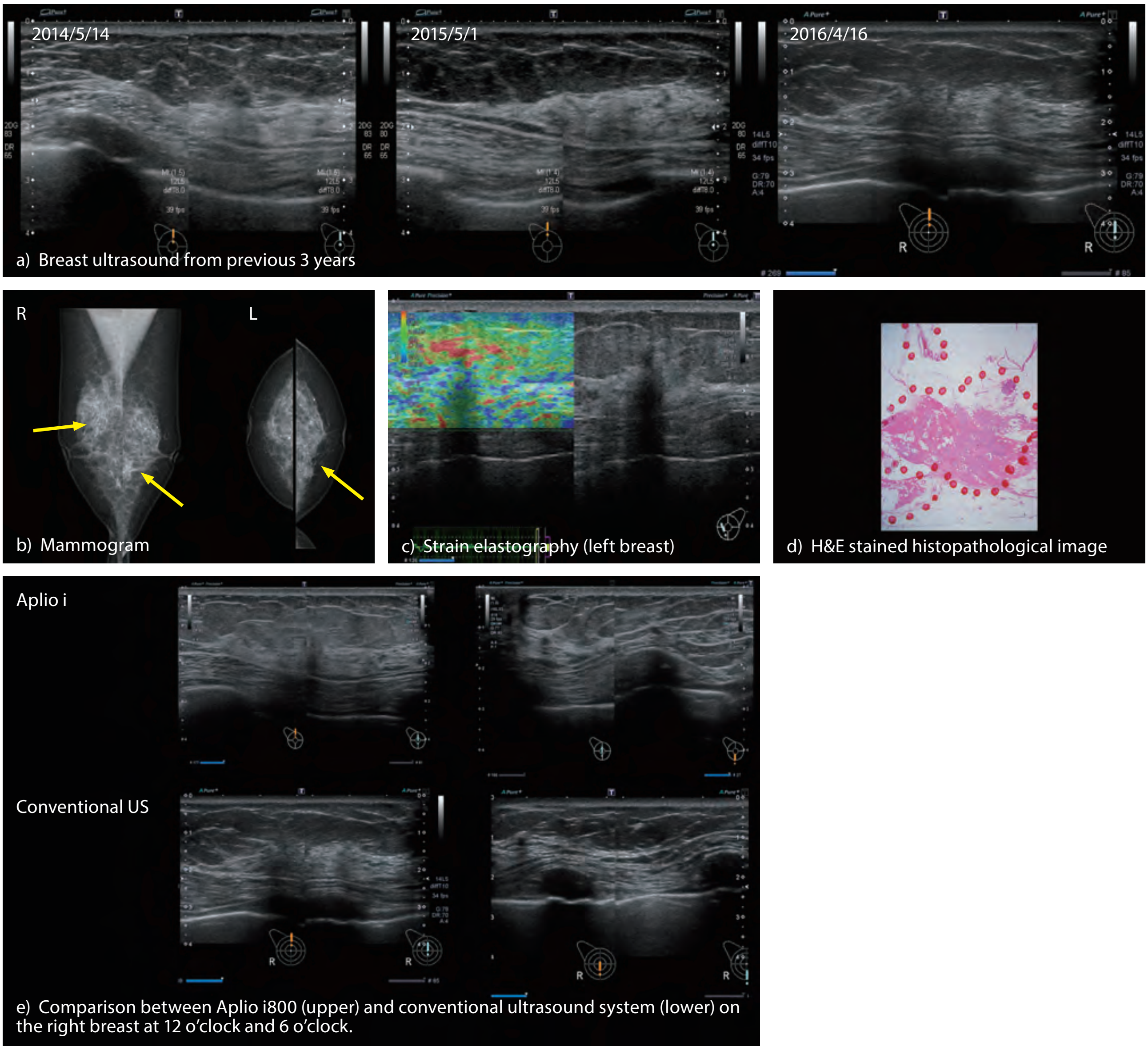
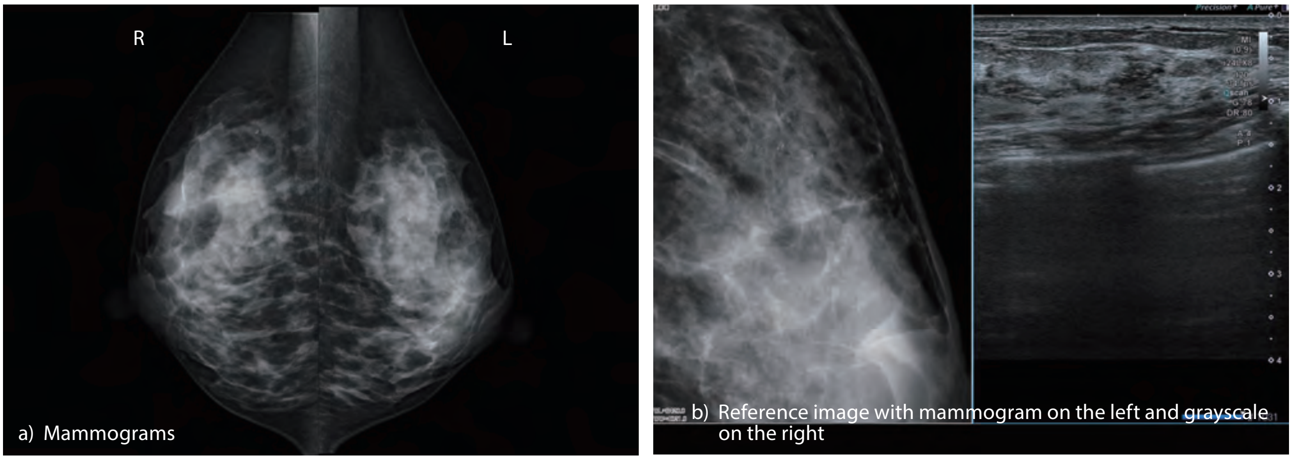


Figure 6. Case 5: LCIS (left breast) and DCIS associated with sclerosing adenosis (right breast)

Case 6: Calcification

About 40% of breast cancer develops calcification,* and it is often challenging to detect microcalcifications with ultrasound. On the mammogram, round-shaped microcalcifications could be observed in the left breast (Figure 7a). With the mammogram as a reference, we used ultrasound to search for a hypoechoic area at the location of the calcifications. With Aplio i-series' new reference display mode, the ultrasound image and mammogram can be displayed side-by-side, allowing quick and easy location of microcalcifications (Figure 7b).

Echogenic foci in the lumen of the duct were visualized with high-definition using Aplio i800. Combining mammography and breast ultrasound meant that diagnostic accuracy and confidence could be improved.



a) Mammograms
b) Reference image with mammogram on the left and grayscale on the right

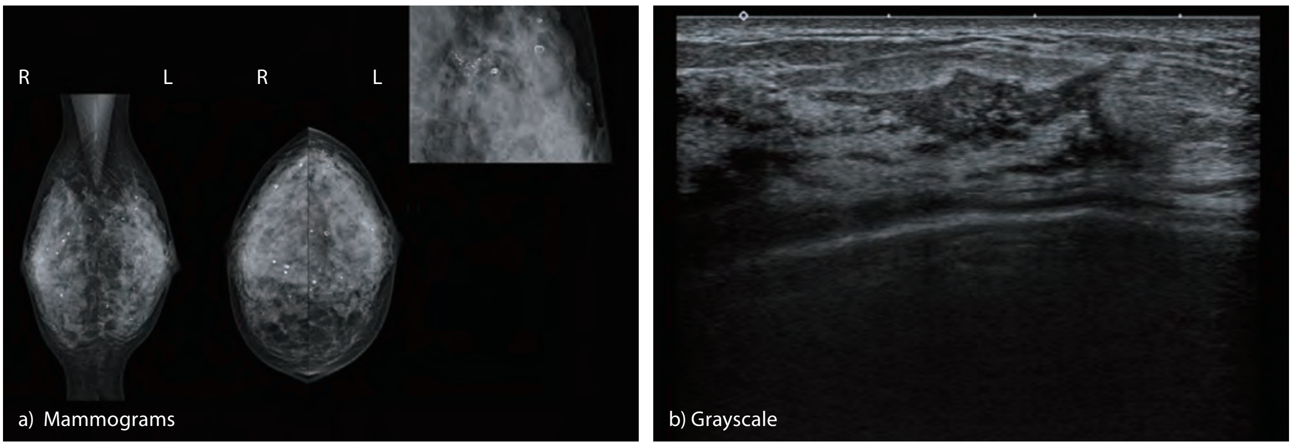
Figure 7. Case 6: Calcification

Case 7: Calcification

With the thin slice thickness generated by iBeam technology, images with higher resolution and more homogeneity can be acquired. During scanning, it is easy to perform fine adjustments to the thickness of the scan planes, improving detectability of microcalcifications. This allows detailed visualization of pathological structures to facilitate clinical diagnosis.

In this case, multiple benign microcalcifications were detected in the right breast with mammography. Nevertheless, the patient was assigned with a category BI-RADS 5 as typical malignant microcalcifications in linear and branching pattern were also observed (Figure 8a). In ultrasound images, in the hypoechoic mammary glands and lobules, hyperechoic echogenic foci were depicted with high definition, demonstrating the high resolution image quality of the Aplio i800 (Figure 8b).

This was a case of widespread DCIS and the dilated ducts enabled a better visualization of the microcalcification. Based on the results of the detailed examination a Mastectomy was proposed, though, it should be noted that normally for patients with a smaller lesion then a lumpectomy is suggested. A high level of accuracy is required in pre-operative evaluation to ensure precise surgical planning is possible.



a) Mammograms
b) Grayscale

Figure 8. Case 7: Calcification

* Paredes ES. Atlas of mammography. Lippincott Williams & Wilkins. (2007) ISBN:0781764335

Summary

SMI has significant advantages in low-flow imaging, including visualization of minute vessels, less motion artifact, increased sensitivity with the use of CEUS, and high frame rates.

SMI enables vascular imaging with outstanding detectability for low-velocity blood flows, even in studies performed without the use of a contrast medium. This technique may be of great value for treatment planning in patients with varying medical conditions as demonstrated in this paper.

Conclusion

The 24 MHz ultra-high frequency linear transducer for Aplio i-series delivers an exceptional level of image quality and provides optimum penetration. Despite dense mammary glands, breast structures can be visualized from skin to chest wall, in great detail, allowing a more accurate diagnosis. Benefiting from this high-resolution image quality, calcifications can be delineated clearly and associated masses can be identified more easily. The improvement in contrast resolution allows advanced detectability of tiny lesions, even in highly dense breasts.

Furthermore, the ultra-high frequency linear transducer enables clear differentiation between normal breast structure and architectural distortion. It is important to perform routine breast ultrasound with an ultrasound system that is capable of providing high resolution grayscale images, highly sensitive color Doppler applications and advanced tissue quantification tools such as strain elastography.

The clinical results described in this paper are the experience of the author. Results may vary due to clinical setting, patient presentation and other factors.

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