

**Medical Review**  
**Evolution of Diagnostic Ultrasound Systems**  
**– Current Achievements in Breast Ultrasound**

**Dr. Ayumi Izumori, M. D.**

Department of Breast Surgery,  
Takamatsu Heiwa Hospital  
Tokushima Breast Care Clinic, Japan



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### Introduction

50 years of medical research, development, and manufacturing from Toshiba ultrasound has culminated in the introduction of the Toshiba Aplio™ i-series. The innovative, intelligent, and intuitive features of the Aplio i-series will be introduced in this White Paper.

### Features of Aplio i-series ergonomics

Aplio i-series has a high level of development focus on ergonomic features. The system is more compact and the system height range has been increased to provide an optimum working environment for all operators. Range of motion of the monitor and operating panel have also been expanded, improving ergonomics by increasing operator comfort when viewing the monitor or operating the control panel. Workflow has been enhanced as the control panel has been simplified with key multi-function buttons positioned around the trackball. The all new on-screen navigation on the monitor allows the operator to track and operate the trackball and associated function keys with their eyes remaining on the monitor, saving time and keeping the focus on the patient.

A second console is available through Wi-Fi connection with the main unit. This wireless tablet displays images on the Aplio i-series simultaneously and enables remote interactive operation between the tablet and the main unit.

### Newly developed high frequency transducers

Two new high-frequency i-series transducers were developed for Aplio i-series: ultra-wideband high frequency linear transducer i18LX5 and ultra-high frequency transducer i24LX8.

iBeam forming and Intelligent Dynamic Micro-Slice (iDMS) technology implemented in Aplio i-series ensures the formation of sharp, uniform and thin slice beams in both lateral and lens directions deliver clinical images with higher resolution, more homogeneity, and enhanced penetration.

The ultra-wideband high frequency linear transducer i18LX5 covers the frequency range normally covered by two transducers, combining the advantages of optimum resolution and penetration in one transducer. Compared with conventional linear transducers, the 2-in-1 transducer can delineate the breast structure with high spatial resolution from Cooper's ligaments

near the skin surface to the border of fascia and pectoralis major muscle in the deep region (Figure 1). The i24LX8 transducer is expected to be useful for visualizing clinical targets such as mucinous carcinomas located in deeper regions and where difficult to be distinguished from fatty tissue using a conventional transducer due to blurring.

The new i-series linear transducer i24LX8 offers an ultra-high frequency (UHF) up to 24MHz with outstanding spatial resolution while maintaining penetration as with conventional linear transducers. The elevated frequency range and unprecedented high resolution offer the capability to observe internal structure of a comedo-type ductal carcinoma in situ (DCIS) including the stroma structure, epithelial hyperplasia and echogenic foci (Figure 2).

### Doppler Imaging

The resolution and the sensitivity of color Doppler imaging have been further improved in Aplio i-series. The enhanced color Doppler image quality increases the detectability of minute vessels (Figure 3).

iBeam technology in the i-series further increases the sensitivity of Superb Microvascular Imaging (SMI). Advanveddvanced

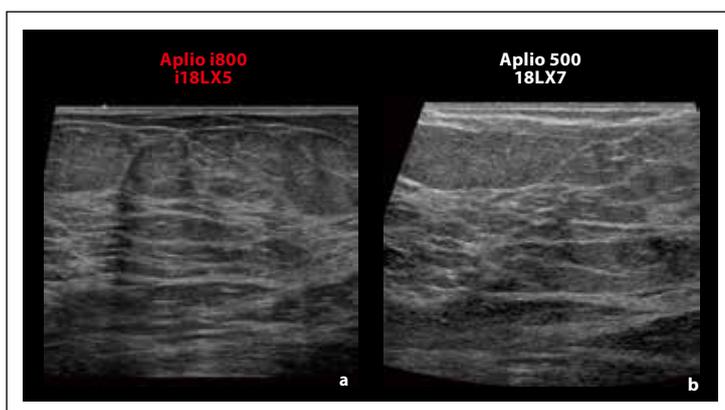


Figure 1. Comparison between ultra-wideband transducer i18LX5 in Aplio i-series (a) and conventional linear transducer 18LX7 (b).

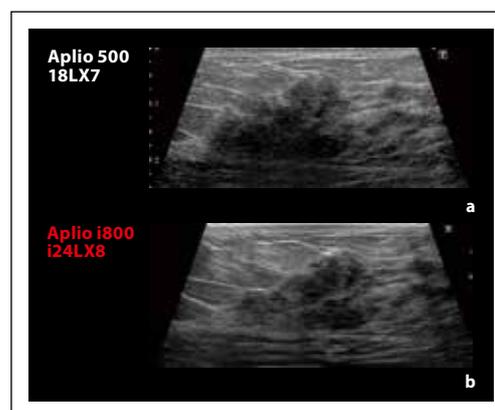


Figure 2. Comparison between 18LX7 (a) and ultra-high frequency transducer i24LX8 in Aplio i-series (b).

Doppler technology Superb Micro-vascular Imaging (Advanced SMI) provides clearer visualization of low-velocity flow in minute vessels with more details. Applying the “hold” function allows accumulation of SMI images and provides depth perception for overview of the vasculature in 3D. SMI can be activated with one button and delivers detailed vasculature information without the use of contrast medium, enabling fast and precise diagnosis of vascular structures which is important for lesion differentiation and treatment evaluation.

### Evolution of B-mode image quality

Interpretation of deviations from the normal structure using 3D breast ultrasound images is an innovative method for breast cancer evaluation. The evaluation of B-mode image quality provides ultrasound images with high resolution that encourages this new clinical approach. Image quality is the number one priority for breast ultrasound and it is essential to investigate the pattern of the internal structure to perform breast

examination precisely.

Although images with high contrast resolution are generally preferred for easy detection of breast lesions, hypoechoic areas in normal tissues might resemble malignant lesions and leads to false-positive results. With the enhanced spatial resolution from i-series transducers, normal breast tissue and pattern of the hypoechoic regions can be clearly depicted (Figure 4).

In order to guarantee accurate diagnosis for differentiation of malignancy on normal breast tissue, high resolution ultrasound images are essential to observe its internal structure. However, some operators feel that ultrasound images with increased resolution are associated with a decrease in contrast, so they prefer images with high contrast for easy visualization. Nevertheless, when compared with histological findings, ultrasound images with higher resolution provide morphological information that is closer to the actual histology. As a result, high resolution ultrasound images are important for differentiating abnormalities

in breast tissue.

Traditionally, it is necessary for the operator to decide image quality based on the trade-off between visibility and resolution. But with Aplio i-series and its newly developed transducers, internal structure of breast lesions is seen with high contrast resolution and spatial resolution. In the previous version of BI-RADS, the feature of halo sign is an indication for invasive cancer. In Figure 5, a halo sign is clearly delineated by using ultra-high frequency transducer, thus invasive cancer such as scirrhus carcinoma can be detected easily. In addition, the visibility of minute lesions and calcification have been improved. Detailed examination on echogenicity and evaluation of extent of infiltration can be performed more easily.

Because of the excellent spatial resolution of the new ultra-high frequency transducer, area under the skin surface and structure of nipple can be observed. It provides clinical value for evaluating extent of infiltration towards the nipple direction from invasive

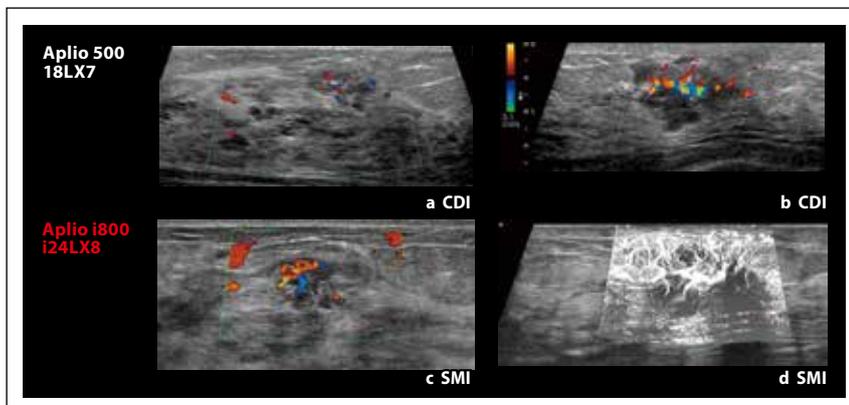


Figure 3. Comparison between 18LX7 (upper) and i24LX8 (lower) in color Doppler (a, b) and SMI mode (c, d).



Figure 4. Comparison of image quality on breast ultrasound between 18LX7 (a) and i24LX8 (b). Using ultra-high frequency transducer, internal structure of hypoechoic region can be visualized clearly (b).

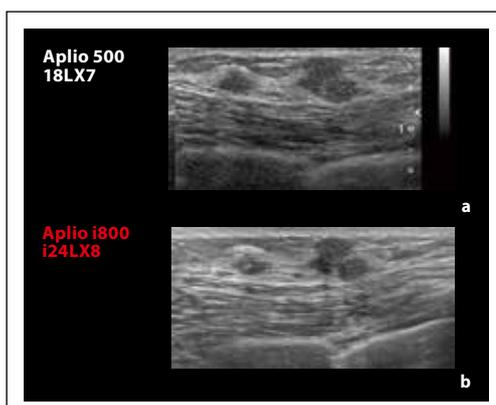


Figure 5. Comparison of invasive cancer between 18LX7 (a) and i24LX8 (b). Aplio i-series has high contrast resolution that can clearly detect the lesion and its halo sign.

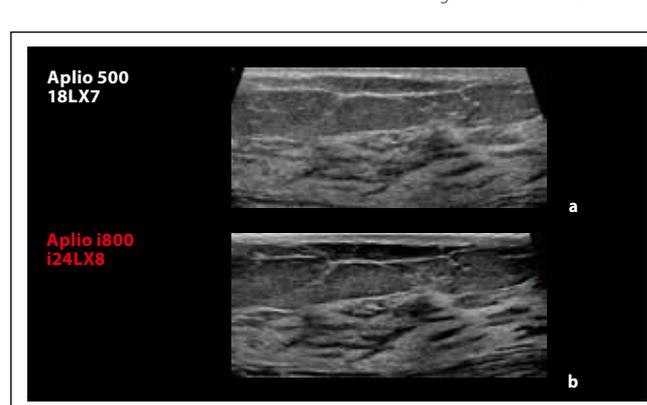


Figure 6. Comparison of normal breast tissue between 18LX7 (a) and i24LX8 (b). Aplio i-series has impressive spatial and contrast resolution in normal tissue (b). The approach of “deviations from the normal structure” can be performed easily.

tumors.

Aplio i-series has impressive spatial and contrast resolution for detecting deviations from the normal structure (Figure 6).

When investigating the isoechoic normal breast tissues with mottled pattern, the internal structure of slight hypoechoic stroma surrounding lobules can be depicted clearly. Compared to conventional transducers, isoechoic structures can be detected more easily, allowing fast detection of deviation from normal breast tissue. As discussed above, the new ultra-high frequency linear transducer is a unique transducer that ensures both excellent resolution and visibility.

### Importance of high resolution imaging in routine breast ultrasound

Normal breast tissue is heterogeneous and the internal structure of breast lesion can be highly variable. The author proposes a method to determine whether a lesion requires detailed examination or follow-up by interpreting the internal structures of the lesions. With the high resolution delivered by Aplio i-series, accurate diagnosis can be performed easily and the following approach can be incorporated into routine breast ultrasound.

For lesions where deviations from normal structure are found, if the deviations have a regular pattern, follow-up examination is suggested. In contrast, if the deviation pattern is irregular and there is disorderly proliferation, the lesion is suspicious for malignancy and detailed examination will be required.

Operators in our institute conduct ultra-

sound examinations based on the approach described above. In the prospective study of this approach, almost all clinical cases that are diagnosed based on collegial discussions to require follow-up examination are confirmed to be benign. Although a few patients with benign proliferative breast lesion were diagnosed to require detailed examination, no patients with malignant lesions were misdiagnosed as having benign lesions.

### Neoplasms

Figure 8 shows an example of a papillotubular carcinoma. Because of the expanded frequency range from the ultra-high frequency transducer, more detailed information of the internal structure can be obtained compared to conventional linear transducer, promising accurate diagnosis. Echogenicity and irregularity inside the lesion can be clearly depicted. In addition, microlobulated margin can be distinguished easily.

A benign fibroadenoma was also found. With Aplio i-series, a homogenous, hypoechoic, and well-encapsulated lesion was visualized, indicating that it was a cystic lesion. The lesion can be confirmed as fibroadenoma and only follow-up is required (Figure 9).

With improvement in grayscale image quality, diagnosis can be performed with more ease and accuracy.

### Diffuse breast pathology

Figure 9 shows a case of diffuse cystic mastopathy. In the fibrocystic region, a large amount of hypoechoic stroma and

multiple cysts can be observed. Benignancy can be confirmed as hyperechoic stroma with regular pattern pass through the lesion. Internal structure might be difficult to interpret with conventional transducers. However, with Aplio i-series, homogeneous echogenicity in the stroma can be observed and the hypoechoic area can be confirmed to be homogenous. The lesion can be easily evaluated as cystic.

Figure 10 shows an example of a comedo-type DCIS. Without the ultra-high frequency transducer, region of adhesion might be difficult to be distinguished in the internal structure. Aplio i-series can detect the distorted isoechoic pattern of the partially hyperplastic mammary ducts. The lesion is diagnosed as malignant and detailed examination is required. The internal structure can be observed in detail based on the extraordinary image quality, offering fast and accurate diagnosis, and facilities target to be identified easily during breast biopsy.

Infiltrating tumors such as scirrhous carcinoma, invasive lobular carcinoma and papillotubular carcinoma are difficult to be detect by mammography due to their diffuse growth pattern. In contrast, because of its high spatial resolution, ultrasound imaging is one of the state-of-art methods for detecting these infiltrating tumors.

The new ultra-high frequency transducer has excellent contrast and spatial resolution for the evaluation of internal structures of breast lesions. It provide significant clinical benefit as malignant lesions that require detailed examination can be identified earlier and extent of tumor

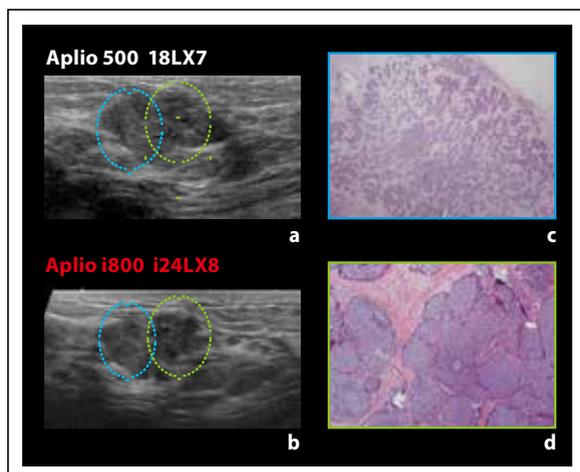


Figure 7. Papillotubular carcinoma (detailed examination). (a) 18LX7, (b) i24LX8 and (c,d) HE-stained specimens.

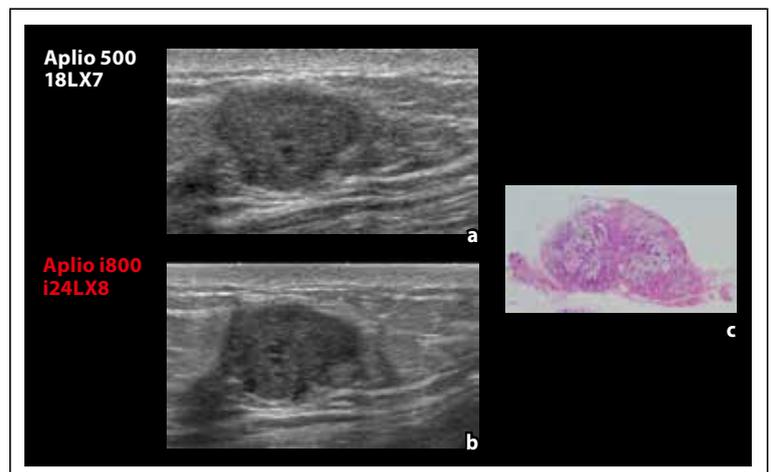


Figure 8. Fibroadenoma (Follow-up). (a) 18LX7, (b) i24LX8 and (c) HE-stained specimens.

infiltration can be diagnosed accurately. In addition, ultrasound-guided biopsy can be performed precisely with the help of ultrasound images with clear border and internal structure of the lesion. Increase of positive predictive value and further development of ultrasound examination can be strongly expected.

### New features in volume imaging

One of the new features of Aplio i-series is Smart Sensor 3D. Smart Sensor 3D technology creates reconstructed images from free-hand 2D acquisitions. Volume transducers can reconstruct 3D breast images, however, there can be limitations due to volume size. Using ultra-high frequency transducers with Smart Sensor 3D, breast images with extraordinary resolution can be obtained at arbitrary directions.

Shadow glass is an advanced 3D rendering software that utilizes the voxel data obtained by Smart Sensor 3D to

create semi-transparent glass rendering effect on breast tissue. By controlling the transparency of the skin and breast tissue, regions with high contrast and heterogeneity can be investigated. The ability to analyze the internal structures of breast lesions adds more clinical value to volume imaging (Figure 11).

The reconstructed images can be observed in different angles by either rotating the rendered image or adjusting position of the ambient light source. 3D overviews of internal structure and vasculature of tumors can facilitate the surgical planning and evaluation of treatment.

As voxel data can be acquired easily, automatic measurement of tumor volumes for evaluation of chemotherapy might be possible in the near future.

Furthermore, side-by-side display of a previously acquired image and real-time ultrasound might be useful for comparative imaging study as well as for the evaluation of chemotherapy.

### Conclusion

The newly developed high frequency transducers for Aplio i-series deliver unprecedented spatial and contrast resolution for obtaining crystal-clear clinical images. With the enhanced image quality, detection of deviations from the normal structure can be performed easily. Moreover, detailed examination can be performed with high accuracy by less-experienced operators. The internal structure of the breast can be observed by using detailed 3D images acquired from 2D ultra-high frequency transducer using Smart Sensor 3D which may be able to increase positive predictive value in breast examinations. Evaluation of treatment effect and inspection of breast lesions using grayscale imaging can be performed with high accuracy.

The Aplio i-series is expected to lead breast ultrasound to the next level.

### Reference

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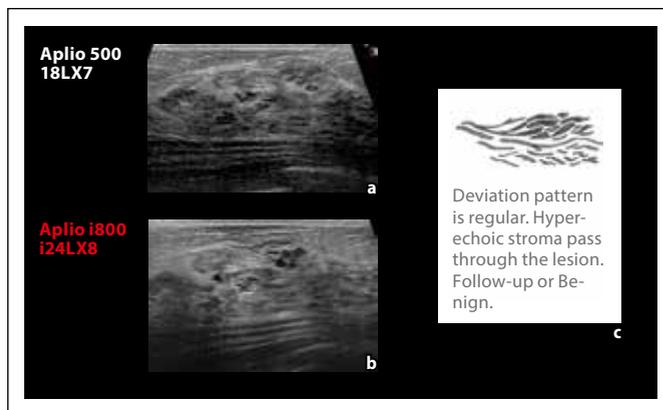


Figure 9. Diffuse cystic mastopathy with (a) 18LX7 and (b) i24LX8. (Follow-up). Thickened, hyperechoic stroma demonstrating benignancy (c).

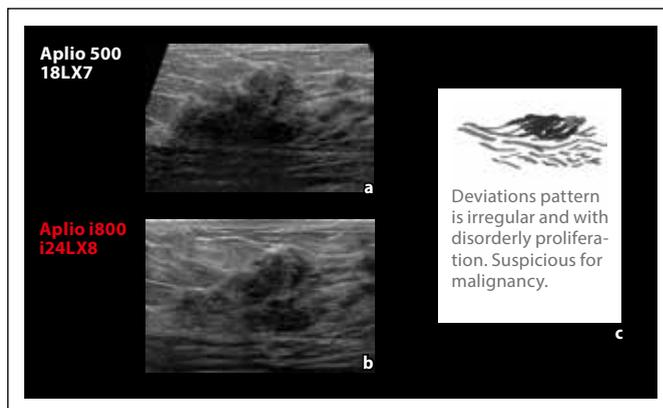


Figure 10. Comedo-type DCIS with (a) 18LX7 and (b) i24LX8. (Detail examination). Dense, hypoechoic structure demonstrating malignancy (c).

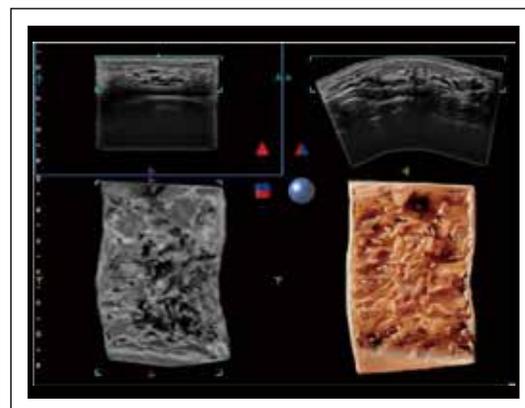


Figure 11. Shadow Glass Imaging. On the lower-right corner, internal structure of the lesion can be visualized in 3D.

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