Learning objectives

To learn the basic principle of automated breast ultrasound (ABUS), its technical advantages and limitations. Through literature review give an overview on current state-of-the-art of ABUS as well as a glimpse on future developments.
Background

Mammography has been used as the standard imaging method for breast cancer screening, with reduction in breast cancer mortality however breast density significantly reduces the ability to visualize cancers on mammography.

At least one-half of cancers are missed by mammography in women with dense breasts. When missed, these cancers are usually small and are at a stage where treatment is usually less invasive and less costly. They are generally more deadly when discovered later[4]. Finding breast cancer in an early phase presents several challenges. Breast cancer is a heterogeneous disease, consequently, a single screening modality has limitations in imaging all the different subtypes at an equally early stage. A multimodality approach, which has been successfully used in the diagnostic work-up of mammographic and clinical findings, should be used in screening asymptomatic women as well [5].

Ultrasonography (US) has emerged as the most important adjunct to mammography for diagnosing breast disease. Most radiologists performing breast US now use handheld systems to image symptomatic lumps and predict the nature of indeterminate masses discovered through mammography. Several advantages of handheld US are widely recognized; for instance, it allows realtime imaging, is relatively inexpensive, and is well tolerated by patients [10], but at the same time is limited due to technical factors, such as breast size, considerable user variability and reproducibility, technical skill, and time constraints.

Handheld ultrasound is an operator-dependent examination for lesion detection and diagnosis therefore the knowledge and experience of the operator who controls the ultrasound transducer and characterizes a breast lesion will ultimately affect the accuracy of the diagnosis. Furthermore, it is difficult to localize a two dimensional (2D) image plane and reproduce the same image plane at the same location later down the track [6]. In contrast to mammography, the lack of standardization of sonographic documentation prevents the possibility of a second evaluation [10].

Therefore, automated three-dimensional (3D) ultrasound was developed.

The goals of automating breast ultrasound are:

- Decrease the radiologist's time per case
- Produce a standardized, high quality examination that improves the conspicuity of cancers
This will result in an increased positive predictive value, especially for 1 cm cancers. Studies suggested that these goals are possible because their data demonstrated a substantial reduction in radiologist time, with greater sensitivity and fewer false-positive [4].

Automated breast Ultrasound scanners were initially planned to effectively examine the breast in its entirety. Basically, ABUS scanners are either prone or supine types. The old generation prone-type scanner consists of a large water-filled tank with the transducers mounted at the base [15]. The patient is prone with the breast freely suspended in the warm water bath. An operator console allowed control of selective or automated movements of the motor-driven scanning assembly, and the selection of transducers or the setting of scan parameters (scan planes, grayscale dynamic ranges, and depth of view). Every scan provided a complete 2-dimensional image of the breast in a selected scan plane [1].

![Fig. 10: Diagram of the prone-type ABUS scanner. The transducers are mounted at the base of the main holding tank. The patient is in prone position with the breast freely suspended in the warm water bath.](image)

**References:** Chou, Y., Tiu C., Chen J., Chang R. (2007): "Automated Full-field Breast Ultrasonography: The Past and The Present"; Journal of Medical Ultrasound; v.15; n.1

Initially, the frequencies used by 3D ultrasonic transducer were in the range of 3.9-4.5 MHz and the detectability of lesions was unsatisfactory. More recently, automated breast ultrasound systems with higher frequency probe have been introduced with detectability and image quality of breast lesions scanner significantly improved. However, the main limitation of these systems was the coverage of the breast due to the small field of
view, leading to incomplete coverage of lesions [6]. Nowadays ABUS systems can automatically scan the entire breast in a standard manner with optimized settings (imaging presets) for volume acquisition based on the estimated size of the breast (A is smallest size; D+ is largest size), the system applies imaging parameters during acquisition based on the estimated size of the breast and automatically send all the images to an ABVS workstation.

Fig. 11: ABUS image of a fibroadenoma with uniform echogenicity, smooth border, and "wider than tall" appearances.

Fig. 13: The invasive ductal carcinoma is a stellate lesion with disruption of the surrounding breast tissue in ABUS. The transverse plane is upper, the sagittal plane is lower right and the coronal reconstruction is lower left. The yellow square mark: the position of the nipple.


Using scrolling slices, the radiologist can watch the "dynamic play" of all saved images on an ABVS workstation and provide a description and a diagnosis. This approach minimizes operational variability [1].
Fig. 14: (A) Series of images showing the transducer within the paddle casing, and (B) acquiring the information as it traverses the breast, perpendicular to the chest wall. (C) The reconstructed 2-mm coronal sections are stacked on top of each other. (D) The coronal sections begin at the level of the skin and are layered upon each other as they continue deeper toward the chest wall. The 2-mm thick coronal slices can be viewed together as images laid out in a consecutive order. The actual number of slices depends on the thickness of the individual’s compressed breast in the supine position.

Fig. 15: (A) Schematic presentation of a 10-mm invasive breast cancer, which is present in at least 4 of the 2-mm thick slices. (B) Large section, 2-mm thick subgross 3-D (10 8 cm) histology image shows the spiculated invasive carcinoma. (C) Comparative 3-D histologic 3-D coronal ultrasound section. (D) The series of 2 mm coronal 3-D ultrasound images demonstrates the entire radiating structure. The lesion is seen on several slices, making perception easier. The slices are akin to a stack of cards laid out on the screen side by side.

Fig. 11: ABUS image of a fibroadenoma with uniform echogenicity, smooth border, and "wider than tall" appearances.

Fig. 10: Diagram of the prone-type ABUS scanner. The transducers are mounted at the base of the main holding tank. The patient is in prone position with the breast freely suspended in the warm water bath.

**Fig. 13:** The invasive ductal carcinoma is a stellate lesion with disruption of the surrounding breast tissue in ABUS. The transverse plane is upper, the sagittal plane is lower right and the coronal reconstruction is lower left. The yellow square mark: the position of the nipple.


**Fig. 14:** (A) Series of images showing the transducer within the paddle casing, and (B) acquiring the information as it traverses the breast, perpendicular to the chest wall. (C) The reconstructed 2-mm coronal sections are stacked on top of each other. (D) The coronal sections begin at the level of the skin and are layered upon each other as they continue deeper toward the chest wall. The 2-mm thick coronal slices can be viewed together as images laid out in a consecutive order. The actual number of slices depends on the thickness of the individual's compressed breast in the supine position.

**Fig. 15:** (A) Schematic presentation of a 10-mm invasive breast cancer, which is present in at least 4 of the 2-mm thick slices. (B) Large section, 2-mm thick subgross 3-D (10 8 cm) histology image shows the spiculated invasive carcinoma. (C) Comparative 3-D histologic 3-D coronal ultrasound section. (D) The series of 2 mm coronal 3-D ultrasound images demonstrates the entire radiating structure. The lesion is seen on several slices, making perception easier. The slices are akin to a stack of cards laid out on the screen side by side.

Automated Breast Examination

ABUS is a high end ultrasound scanner that employs frequencies of 5 to 14 MHz and consists of a flexible arm with the transducer at the end, a touchscreen and a 3D workstation. Automatically acquires 15.4 cm × 16.8 cm × 6 cm volume data sets of breasts after one sweep with a wide-aperture linear array transducer (5-14 MHz bandwidth). The scan is performed with the patient in a supine position. Depending on the breast size, various preselected settings are available, and depth, frequency, focal zone placement and overall gain [10].
Fig. 1: Automated Breast Ultrasound

References: www.somoinsightstudy.org
Fig. 2

References: www.somoinsightstudy.org
A typical examination comprised three automated scans of each breast in the anteroposterior and both oblique positions. Occasional additional views were required for larger breasts, the scans being centered on a palpable abnormality or axillary lymph nodes.
Fig. 9: The regular ultrasound appearance of human breast tissue on automatic breast volume scanning: anterior-posterior view (AP), medial view (MED) and lateral view (LAT).


The usual acquisition time for automated ultrasound of the breast was 60 seconds per scan. The total acquisition time per patient, including setup time, was 15 minutes. The system captured the volume data at slice intervals of 0.5 mm [8].

After acquisition, the axial image series are automatically sent ABUS ultrasound to a dedicated breast ultrasound review workstation. The workstation presents images through multiplanar reconstruction (MPR) and reconstructs secondary images from the acquisition volume in any plane, including sagittal, coronal, radial and anti-radial views.
The radiologist then interpreted the images and reported the results. Interpretation can take between 5 and 15 min, depending on the experience of the radiologist and the complexity of the case [10].

ABUS software creates a cine loop of the images for interpretation, simulating the appearance of real-time imaging.

**Fig. 12**: Left: Retro areolar irregular mass seen in the coronal and transverse views. Right: Spiculated mass seen in the coronal and transverse views.

**References**: Dean, J. (2012): "Using Automated Breast Ultrasound to Reduce or Eliminate Interval Cancers" in www.diagnosticimaging.com
Images for this section:

Fig. 1: Automated Breast Ultrasound

© www.somoinsightstudy.org
Fig. 4

© www.somoinsightstudy.org
Fig. 9: The regular ultrasound appearance of human breast tissue on automatic breast volume scanning: anterior-posterior view (AP), medial view (MED) and lateral view (LAT).

**Fig. 12:** Left: Retro areolar irregular mass seen in the coronal and transverse views. Right: Spiculated mass seen in the coronal and transverse views.

Conclusion

ABUS is a computer-based system for performing and recording ultrasound of the entire breast. It has a workstation that allows physicians to review ultrasound images from different angles with reconstructions in the axial and coronal planes and three-dimensional. The transducer is attached to a computer-guided mechanical arm, and images acquired in longitudinal rows, acquiring transverse images.

**ABUS provides advantages of:**

- high diagnostic accuracy,
- better lesion size prediction,
- operator-independence
- visualization of the whole breast.

Recent studies concluded that the use of ABUS with mammography improved the accuracy of breast cancer detection, callback rates, and confidence in callbacks for women with dense breast tissue.

In conclusion ABUS reflects a promising modality in breast imaging however appears to be on a par with hand-held ultrasound in terms of diagnostic quality [9].
References

Personal Information

Ana Catarina Martins Pereira
Adjunct Professor of Radiology scientific area of the School of Health Dr Lopes Dias
Castelo Branco/ Portugal