Beyond BI-RADS®US... Our experience with Automated Breast Volume Scanner (ABVS).

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Learning objectives

To demonstrate the semeiotics of benign and malignant lesions in ABVS applying BI-RADS®US criteria and to compare ABVS findings with hand-held ultrasound (HHUS) images.

To emphasize sonographic features better demonstrated by ABVS than by HHUS (posterior shadowing, background enhancement and lesion margins).

To show similarity between ABVS images and full-field digital mammography (FFDM), digital breast tomosynthesis (DBT) or magnetic resonance (MRI) images.
Background

Automated breast ultrasound (ABUS) is an ultrasonographic tool that recently enhanced breast imaging techniques with some advantages over HHUS like better reproducibility with possibility to review whole exam in any moment, less operator-dependency and possibility of multiplanar reconstructions (MPRs) [1] that are visualized on a dedicated working station (Figure 1). Reconstructions may be helpful in precise localization (depth and distribution) of the lesions, especially when multiple (Figure 2). The real breakthrough of ABUS is that it separates the moment of acquisition from the moment of the interpretation: acquisition and interpretation can be done in different moments; in addition, ABUS is performed by the technician and interpreted by the radiologist. However, this technique presents some limitations, for example lack of Doppler mode, elastosonography, exclusion of axillary regions from acquisition, false positive findings. Anyway, additional manual ultrasound can be performed at the end of ABUS examination, if suspicious finding is found. Learning curve showed reduction of false positive cases (i.e. cases requiring additional manual ultrasound) while operators’ experience increases [2]. ABUS applications in various clinical settings are still under research. Kelly et al. [3] demonstrated in a multicentre study that ABUS added to mammography improved cancer detection rate and sensitivity in dense breast screening. In the clinical setting the detection of breast lesions was reported to be similar between ABUS and HHUS for many authors [1]. As for lesion characterisation, Shin et al. [4] and Kim et al. [5] found substantial agreement for final BI-RADS assessment. Detection of calcifications was better in ABUS than in HHUS [6]. The retraction phenomenon is a recently-introduced semiotic feature with high diagnostic accuracy for breast malignancy [7]. It is exclusive for ABUS and can be observed in the coronal reconstruction. Several studies have analysed the diagnostic accuracy in differentiation between malignant and benign lesions demonstrating high values for sensitivity (92.0%) and specificity (84.9%), as reported in a recent meta-analysis [8]. In preoperative setting ABUS demonstrated promising results as a second look tool [9] and when assessing the breast cancer size ABUS performs better than HHUS and approaches MRI [10].

Acquisition details

We performed ABUS examination using Acuson S2000 ABVS ultrasound system (Siemens Medical Solutions, Inc., Pleasonton, CA, USA), supplied with a flexible mechanical arm enriched by 5-14MHz linear transducer (Siemens 14L5BV) covering a surface of 15.4x16.8 cm and dedicated touch screen monitor that allowed to check the patient and to evaluate the image quality during the acquisition in order to achieve good quality images. Special attention was given to the nipple area where the presence of artifacts is frequent (Figure 3). The software offered five pre-set cup sizes with different frequencies (Table 1). The patient was in the supine position with the arm over the head. The probe was applied to the breast with tender and uniform compression. If the
transducer was not correctly positioned and not compressed the obtained images may result non-diagnostic (Figure 4). Sufficient contact with the skin surface was guaranteed by the replaceable disposable membrane covering the transducer. Whole breast was covered by necessary quantity of ultrasound gel. Each breast was studied apart through three main scan views: anterior-posterior (central), lateral and medial. When larger breasts or specific region of interest (lesion centred) were under examination additive views were performed: for example superior, inferior, single quadrant view (Figure 5). Scan depth was up to 6 cm. The nipple, as a reference point, had to be contained in all acquisitions, in order to enable correct orientation and further post-processing reconstructions. The mean acquisition time per scan was 1 min, for an overall duration of approximately 3 min per breast (three scans). The average time of the complete bilateral examination, including the preparation of the patient and the probe positioning was about 15 min. The interpretation time ranged from five to 10 minutes according to complexity of individual case.
**Fig. 1:** Working station appearance. A-acquisition axial plane, B-coronal reconstruction, C-sagittal reconstruction. IDC grade 2.

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**Fig. 2:** Multiple cysts. *-same cyst visible in all three images, ^-posterior enhancement that expresses the depth of the cyst.

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**Fig. 3:** ABVS nipple area artifacts. A-lack of gel and/or presence of air, B-fibrous nipple.

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Table 1: Frequencies of pre-set cup sizes.

<table>
<thead>
<tr>
<th>Cup</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>D+</th>
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<tbody>
<tr>
<td>Frequency</td>
<td>11 MHz</td>
<td>10 MHz</td>
<td>9 MHz</td>
<td>9 MHz</td>
<td>9 MHz</td>
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</table>

Fig. 4: Incorrect ABVS acquisition. A-wrong compression and probe positioning causing non-diagnostic images, B-lack of compression causing shadowing artifacts of fibroglandular tissue.
Fig. 5: Dedicated acquisition performed in order to evaluate specific region of interest - axillary tail lymph nodes.

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Fig. 28: Antero-posterior ABVS acquisition.

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Findings and procedure details

Our purpose is to show ABVS features of benign (Table 2), high-risk (Table 3) and malignant lesions (Table 4) based on our experience of 1400 acquisitions performed during 18-months period.

Tissue composition - background echotexture

Following BI-RADS lexicon [11] (Table 5) we identified three basic background echotextures (Figure 6) in axial plane and also in coronal and sagittal reconstructions:

A) Homogeneous - fat

B) Homogeneous - fibroglandular

C) Heterogeneous

Benign findings

1. Simple cyst (Figure 7). Oval anechoic lesion with well circumscribed margins with posterior enhancement that is more evident in ABVS (A) than in HHUS (C). When moving cursor right under the cyst in axial plane (D), (B, E) hyperechoic posterior enhancing artifact with the same shape of the cyst is demonstrated in coronal image.

2. Liponecrosis (Figure 8). Hyperechoic calcification with posterior shadowing. ABVS axial plane (A) shows the same image of HHUS (D) but ABVS better demonstrates the posterior artifact in axial and sagittal planes (C). Coronal reconstruction (B) demonstrates hyperechoic rim, image corresponds to a radiolucent opacity in FFDM, cranio-caudal projection (E).

3. Ductal ectasia (Figure 9). Correct acquisition without posterior shadowing in retroareolar area offers excellent evaluation of the ducts. ABVS axial images (A, C) mirror HHUS image (B), while ABVS coronal reconstruction (D) offers panoramic view of parareolar area.

4. Angioma (Figure 10). Hyperechoic lobulated well circumscribed lesion. ABVS (A, C, D) and HHUS images (B) demonstrate the same finding.
5. Intramammary lymph node (Figure 11). Oval well circumscribed hypoechoic lesion with hyperechoic hilum (A) and typical hilar vascularity (B) corresponding to round well circumscribed opacity on FFDM (C) is well recognised in all planes of ABVS (D-F).

6. Fibroadenoma (Figure 12). Oval isoechoic well circumscribed mass with parallel orientation and posterior enhancement visible in ABVS axial and sagittal plane (A, C) and HHUS (B) found during an examination performed for presurgical evaluation in a patient with contralateral breast cancer. Ultrasound morphology of the fibroadenoma reflects the benign features demonstrated by tomosynthesis (E) and MRI examination (D).

7. Hamartoma (Figure 13). Hamartoma is a benign tumour-like nodule composed of circumscribed normal breast tissue, with different presentation depending on predominance of adipose, glandular or fibrous breast tissue. Both in ABVS (all planes; A, D, F) and HHUS (B) heterogeneous hyper-hypoechoic (composed predominantly of fibroglandular tissue) oval, well circumscribed nodule is shown, that corresponds to heterogeneous opacity in tomosynthesis (E) (same image as ABVS coronal reconstruction; D) and hypointense oval finding in T1 weighted MRI (C) (same image as ABVS axial image; A).

8. Fibrocystic mastopathy (Figure 14). ABVS (A) and HHUS (C) show heterogeneous iso-hypoechoic area with hyperechoic dots (detail in coronal image, B) corresponding to a cluster of irregular microcalcifications visualized on DBT (E). HHUS (C), sagittal ABVS (D) and DBT (E) show malignant lesion (^) next to the benign finding presenting as a hypoechoic lobulated nodule with vertical orientation and spiculated opacity, respectively.

**High-risk lesions**

1. Intraductal papilloma (Figure 15). It presents as focally dilatated anechoic duct in para-areolar region with an isoechoic vascularized intraluminal lesion. ABVS does not allow the Doppler mode evaluation. However, when the lesion is observed during ABVS acquisition (A-D), a manual exam with HHUS (E, F) and Doppler mode (G) can be added when automated ultrasound acquisition is completed.

2. Intraductal papilloma (Figure 16). Rounded hypoechoic lesion presenting posterior enhancement with partially circumscribed and lobulated margins and initial vertical orientation (A, B) corresponding to hypointense lesion in MRI T1 weighted image (C). Doppler on HHUS is able to show rich vascularisation (B) that is confirmed at MRI after contrast agent (CA) injection (F). Tomosynthesis (E) demonstrates oval opacity with partially indistinct margins.
3. Abriskossoff tumour (Figure 17). Abriskossoff granular cell tumour is a rare high-risk lesion originating from perineural or putative Schwann cells of the peripheral nerves or their precursors that grows in the lobular breast tissue [12]. On ultrasound, it appears as inhomogeneous hypoechoic lesion (A, B). Hypointense in T1 weighted MRI (C) and hyperintense in T2 weighted sequences (F) with diffusion restriction. ABVS in axial (A) and sagittal (D) planes demonstrates posterior enhancement and its typical deep position (close to pectoralis muscle), confirmed in MRI. ABVS coronal plane (E) helps to evaluate lesion distance from the nipple.

4. Sclero-elastotic lesion (Figure 18). Small hypoechoic lesion with posterior shadowing (B, D) and distortion in coronal ABVS (E) and DBT (C), corresponding to irregular enhancing lesion in MRI (F).

5. Lobular carcinoma in situ and atypical lobular hyperplasia (Figure 19). Both ultrasound techniques (A-D) show two hypoechoic irregular nodules, with posterior acoustic shadowing in HHUS (B) and in ABVS axial (A) and sagittal (D) images and with architectural distortion in ABVS coronal plane (C). Ultrasound morphology strictly reflects MRI appearance (E).

**Malignant lesions**

1. Low-grade ductal carcinoma in situ (DCIS) with hematoma (Figure 20) after vacuum assisted biopsy (VAB) with the presence of residual microcalcifications corresponding to neoplasia. Oval inhomogeneous hypoechoic lesion (hematoma) with a presence of intralesional and extralesional microcalcifications (A-C, E). Tomosynthesis demonstrates irregular opacity associated with few fine microcalcifications with linear distribution (D). The hematoma presents the same morphology in MRI (F) and ABVS coronal reconstruction (C).

2. Invasive ductal carcinoma (IDC) grade one (Figure 21). Axial ABVS (A) and HHUS (B) demonstrate small hypoechoic lesion. Coronal ABVS well shows retraction phenomenon (C), corresponding to distortion in DBT (D) and MRI (E).

3. Bifocal IDC grade two (Figure 22). Axial ABVS image (A) shows suspicious spiculated hypoechoic lesion, better visualized than in HHUS (E), with posterior shadowing (sagittal ABVS, D). Coronal ABVS (C) demonstrates two close hypoechoic distortions. Applying a specific tool, we rotate the image and obtain para-axial plane (B) that overcomes the limits of fixed plane acquisition with evidence of both lesions in one plane.

4. IDC grade two with DCIS (Figure 23). Axial ABVS (A) and HHUS (B) demonstrate inhomogeneous hypoechoic lobulated mass with hyperechoic dots inside the mass
corresponding to microcalcifications. Spiculations of the lesion are identified in coronal MPR (D) as well as in DBT image (E). Sagittal plane (C) confirms the deep position of the lesion.

5. Papillary invasive carcinoma (Figure 24). MRI (E, F) and DBT (D) are very well demonstrate the extent of disease showing mass like lesion associated with regional contrast enhancement and superficial lobulated opacity with multiple deep irregular clusters of microcalcifications, respectively. ABVS (A-C) demonstrates suspicious multiple oval hypo- and an-echoic superficial lesions in para-areolar area with hypechoic dots in the depth that may be expression of microcalcifications (*).

6. Invasive lobular carcinoma (ILC) grade two (Figure 25). The main lesion is visualized in axial ABVS plane (A) presenting with hypoechogenicity, spiculations, distortion, posterior shadowing and vertical orientation. However, coronal reconstruction of antero-posterior (D) acquisition displays the additional lesion (multifocality) confirmed by para-axial reconstruction (B). Following acquisition of lateral view (E) demonstrates a third suspicious lesion (multicentricity) as confirmed by MRI (C, F).

7. IDC with mucinous aspects grade two (Figure 26). ABVS (A, D, E) and HHUS (B) demonstrate a deeply-located inhomogeneous iso-hypoechoic lesion with irregular and lobulated margins and distortion of the surrounding tissue visible in coronal plane (E). Sonographic morphology is similar to that demonstrated by MRI after CA (F). Mucinous component is represented by hyperintensity in T2 weighted images (C).

8. Invasive mucinous carcinoma (Figure 27). Palpable nodule. Inhomogeneous hypoechoic area with partially indistinct and lobulated margins (A, B) and rich vascularization on Doppler exam (E), localized in axillary tail. The lesion is difficult to detect in FFDM (C) and presents just mild contrast enhancement after injection of contrast agent in MRI (D). Cranio-caudal extension is well demonstrated in sagittal ABVS image (F).
Table 2: Benign findings.

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Table 3: High-risk lesions.

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<table>
<thead>
<tr>
<th>Malignant lesions</th>
<th>ABVS axial image</th>
<th>Malignant lesions</th>
<th>ABVS axial image</th>
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</thead>
<tbody>
<tr>
<td>Low grade DCIS with hematoma post biopsy</td>
<td></td>
<td>Papillary invasive carcinoma</td>
<td></td>
</tr>
<tr>
<td>Invasive ductal carcinoma grade 1</td>
<td></td>
<td>Multicentric invasive lobular carcinoma grade 2 (main lesion)</td>
<td></td>
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<tr>
<td>Bifocal invasive ductal carcinoma (main lesion)</td>
<td></td>
<td>Invasive ductal carcinoma with mucinous aspects</td>
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<td>Invasive ductal carcinoma with ductal carcinoma in situ</td>
<td></td>
<td>Invasive mucinous carcinoma</td>
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**Table 4:** Malignant lesions.

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Table 5: ACR BI-RADS Ultrasound.

Fig. 6: Tissue composition. Examples of different background echotextures in ABVS. A-homogeneous-fat, B-homogeneous-fibroglandular, C-heterogeneous.

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Fig. 7: Simple cyst.
**Fig. 8:** Liponecrosis.
Fig. 9: Ductal ectasia.

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Fig. 10: Angioma.

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Fig. 11: Intramammary lymph node.

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Fig. 12: Fibroadenoma.

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**Fig. 13:** Hamartoma.

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**Fig. 14:** Fibrocystic mastopathy and IDC grade 3.

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Fig. 15: Intraductal papilloma.

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Fig. 16: Intraductal papilloma.

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**Fig. 17:** Abriskossoff tumour.

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**Fig. 18:** Sclero-elastotic lesion.

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**Fig. 19:** Lobular carcinoma in situ (+) and atypical lobular hyperplasia (x).

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Fig. 20: Low grade DCIS with hematoma after VAB.

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**Fig. 21:** IDC grade 1.

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**Fig. 22:** Bifocal IDC.

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Fig. 23: IDC with DCIS.

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Fig. 24: Papillary invasive carcinoma.

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**Fig. 25:** Multifocal and multicentric ILC grade 2.

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**Fig. 26:** IDC with mucinous aspects.

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Fig. 27: Invasive mucinous carcinoma. Palpable nodule.

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Conclusion

There is significant overlap of benign and malignant sonographic features demonstrated by ABVS and HHUS. However, ABVS images better demonstrate posterior acoustic features and better enhance spiculated margins of malignant lesions. We have found good image correlation between ABVS reconstructions and FFDM, DBT or MRI images. ABVS as a complementary tool is a promising new method in breast imaging.
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References


