Correlation of the Automated Breast Volume Scanner (ABVS) and Hand-held Breast Ultrasound (HHUS) Findings

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OBJECTIVES: To correlate the findings of Automated Breast Volume Scan (ABVS) and Hand-held Breast Ultrasound (HHUS), and to compare the benefits and drawbacks of each system as an adjunct to mammography.

MATERIALS AND METHODS: A total of 212 adult female patients underwent mammography in the Breast Center of Wattanosoth Hospital in 2010 followed by ABVS and HHUS was interpreted and reported by radiologists immediately. ABVS was interpreted and recorded by one radiologist 3 months later.

RESULTS: There were 504 lesions, interpreted as BIRADS 1 in 37 cases, BIRADS 2 (simple cyst) in 77 cases, BIRADS 3 in 63 cases, BIRADS 4 in 31 cases and BIRADS 5 in 4 cases. Both studies agreed in 306 lesions, there was agreement and ABVS showed additional lesions in 13 cases, the studies were not in agreement about 35 lesions. ABVS showed negative but HHUS showed positive in 24 lesions, HHUS showed negative but ABVS showed positive in 104 lesions although there were pitfalls in ABVS results in 24 lesions.

CONCLUSION: In our study, despite having some drawbacks with nipple artifacts, ABVS showed significant improvement in detection of breast cancer in as compared to HHUS, uncovering 12 additional suspicious lesions, and excluding 3 suspicious lesions. Patients also benefit from a shorter, more comfortable examination without exposure to radiation agents or the need to hold their breath.

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Breast cancer has become the most common cancer. Statistics from Siriraj Cancer Center in 2008 showed 1,129 new breast cancers, making up 25.79% of all women's cancers.[1] Since there is no effective way to prevent breast cancer, the best that can be done is to treat the disease at its earliest stage. Breast imaging which includes mammography (MM), ultrasound (US), magnetic resonance imaging (MRI) and radionuclide scintigraphy (RNS), has proven to be the most appropriate method to detect lesions.[2-5] Concerning the cost effectiveness and availability, MM and US are the studies of choice in our country.[6-8]

Statistics of breast tissue composition in 191,169 mammograms performed from 1995-2009 in Siriraj Breast Centre show almost entirely fat in 5.64%, scattered density in 20.36%, heterogeneously dense in 63.18% and extremely dense in 10.82%, therefore, 75% of Thai breasts can be classed as difficult breasts, in which lesions may be completely obscured.[9] Mammography has limitations in detection and evaluation of breast lesions in mammographically dense breasts, palpable mass in young women, pregnant and lactating breasts, acute inflammation, post-operation, trauma, male gynecomastia and assessment of augmented breasts. US has no such

limitation. The masses in MM are notified either as round, oval, lobular, which are less significant or as irregular, microlobular and speculated, which are more suspicion. There might be associated findings, such as the presence of microcalcifications and architectural distortion.[10,11]

US is much more informative in evaluation of breast mass, for its shape (round, oval or irregular), orientation (parallel, non-parallel), margin (circumscribed or not, sub grouped into indistinct, angular, microlobulated or speculated), lesion boundary (abrupt interface or echogenic halo), echo pattern (anechoic, hypoechoic, isoechoic, hyperechoic and complex), posterior acoustic features (no posterior acoustic features, enhancement, shadowing and combined pattern), surrounding tissue (in ducts, straightening or thickening of Cooper's ligament, edema, skin thickening, architectural distortion), vasculature and other specific findings. Therefore, apart from seeing the mass, US can define the mass as:

- Cystic lesion, subgrouped into simple, complicated, complex and cluster of microcysts.
- Solid lesion, subgrouped into benign looking, probably benign, low suspicion and high suspicion of malignancy.

The management of each subgroup is different

We compared results between mammography, pathology and US results. The outcome of using both studies together yielded a much more impressive results, namely that when the mass looked benign, it was true benign in 94.9%, probably benign was benign in 88.57%, indeterminate is 50 +/- 3.49% and malignant was true malignant in 95.78% of cases.[12-15]

Of 26,741 MM with US performed during 1999–2004 in Siriraj Breast Centre, US was able to detect 141 cancers in MM negative (182 US BIRADS 4, 32 US BIRADS 5). Concerning detection of breast mass, there were 13,109 cases that in both MM & US were positive, 14,220 cases that were positive in US, negative in MM.[16]

US of axillary adenopathy is superb, giving more internal architecture details, pathology and including more nodes than can be seen by MM. Fine-Needle Aspiration (FNA) of the abnormal node can be performed in one setting, which is far better than to search and do excisional biopsy of sentinel lymph node, performed in the operating room. Normal nodes were also studied.[17]

US has limitation in detection of microcalcifications, especially those with no associated mass. Of 39,830 screenings in Siriraj Breast Centre in 2004, there were 84 breast cancers. We found 19 cases (22.62%) with microcalcifications alone, which were negative in US, and 106 cases (6.02%) of 1761 cancers in 22,442 diagnostic cases had microcalcifications alone.[18] Those are the cases that will be missed if US was performed without MM. However, if the lesion is extensive, US may show where the lesion is and US guided core needle biopsy (CNB) can be performed, with proven specimen radiograph to show the presence of the microcalcifications.

US has technical drawbacks in limitation of field of view (FOV): it is not reproducible, time consuming, requires high skill/experience, operator dependent, not fit for screening. These problems can be overcome by using an automated breast US volume scan, which is a quick study that provides multiplanar images with very high resolution. It is reproducible, thus very beneficial to be used in a comparison study. The automated breast volume scanner (ABVS), like computed tomography (CT) volume scan provide automated acquisition of a large number of thin two-dimensional (2D) slices to produce a three-dimensional (3D) volumetric data set. A reconstruction by post-processing is instantly performed in multiplanar: sagittal, coronal, radial, anti-radial, cranial-caudal (CC), Mediolateral-oblique (MLO), multislices: thin or thick slices, 3D navigation, tomographic display 3D which allows for correlation with mammography or MRI.[19,20]

Materials and Methods

In 2010, we did a study on Correlation of ABVS and HHUS after mammography in 212 female patients at Breast Center of Wattanosoth Hospital. Their average age was 48.06 years. HHUS was interpreted and reported by radiologists immediately. ABVS was interpreted and recorded by one radiologist 3 months later. The results of both studies were recorded, analyzed and correlated.

There were 504 lesions, interpreted as BIRADS 1 in 37 cases, BIRADS 2 (simple cyst) in 77 cases, BIRADS 3 in 63 cases, BIRADS 4 in 31 cases and BIRADS 5 in 4 cases. Both studies agreed in 306 lesions, there was agreement and ABVS showed additional lesions in 13 cases, the studies were not in agreement about 35 lesions, ABVS showed negative but HHUS showed positive in 24 lesions, HHUS showed negative but ABVS showed positive in 104 lesions and there were pitfalls in ABVS results in 24 lesions. (Table 1)

Table 1: Correlation of ABVS and HHUS findings

Correlation ABVS and HHUS findings	Number of lesions
1. Agree	306
2. Agreement and ABVS shows additional lesions	13
3. Not in agreement	35
4. ABVS negative, HHUS positive	24
5. HHUS negative, ABVS positive	104
6. Pitfalls of ABVS	22
Total	504

Table 2: Correlation of 306 agreed findings by ABVS and HHUS.

Findings	Number of lesions
Solid lesions	208
B*1: Negative	58
B2 / B3: Benign solid (looking/ probably)	121
B2 / B3: Benign & cysts	14
B4: Low suspicion	13
B5: High suspicion	2
Cystic lesions	98
Simple cyst	56
Complicated cyst	21
Complex cyst	5
Multiple cysts	16

*B = BIRADS

Details of the findings in each category are as follows:

1. Both studies agreed in 306 lesions, including: 208 solid lesions and 98 cystic lesions. Among solid lesions, there were 58 BIRADS 1, 121 BIRADS 2/3 (benign looking / probably benign), 14 BIRADS 2/3 (benign looking/probably benign and cysts), 13 BIRADS 4: (Low suspicion), 2 BIRADS5 (High suspicion). Among cystic lesions, there are 56 simple cysts, 21 complicated cysts, 5 complex cysts and 16 multiple cysts (Table 2). The MM, HHUS and ABVS are shown in Figure 1.

2. Both studies agreed and ABVS showed additional lesions in 13 cases which included: 8 benign solid lesions, and ABVS found more cysts, 1 BIRADS 5 lesion and ABVS found 1 more nearby similar BIRADS 5 lesion, 2 simple cysts and ABVS found 1 more complicated cyst and 1 more cluster of microcysts, 1 multiple cyst and ABVS found 1 more benign looking solid lesion and 1 more BIRADS 4 (low suspicion) lesion (Table 3 and Figure 2).

3. Both studies disagreed in 35 lesions, which included the following: HHUS found 19 benign solid lesions, while ABVS showed 2 complex cysts, 14 other cystic lesions, 1 benign solid lesion with cyst, 2 BIRADS 4 (low suspicion). There were 6 benign solid with cystic lesions seen by HHUS, but ABVS showed 2 BIRADS 4 (low suspicion) and 4 simple cysts. Apart from that HHUS noted 2 BIRADS 4 (low suspicion), but ABVS showed 2 simple cysts. HHUS revealed 7 simple cysts, but ABVS revealed 3 solid lesions, 3 simple with complicated cysts and 1 complex cyst. One complex cyst was seen by HH US, but ABVS showed only a simple cyst (Table 4 and Figure 3).

Table 3: The ABVS and HHUS agree findings but ABVS shows 13 more lesions.

ABVS and HHUS agree findings but ABVS shows 13 more lesions		Number of lesions
HH US & ABVS agree finding	ABVS additional findings	
Solid lesions	More cysts	8
BIRADS 5	1 more BIRADS 5	1
Simple cyst	1 more complicated cyst	1
Simple cyst	1 more cluster of microcysts	1
Multiple cysts	1 more benign looking solid lesion	1
Multiple cysts	1 more BIRADS 4 (low suspicion) lesion	1

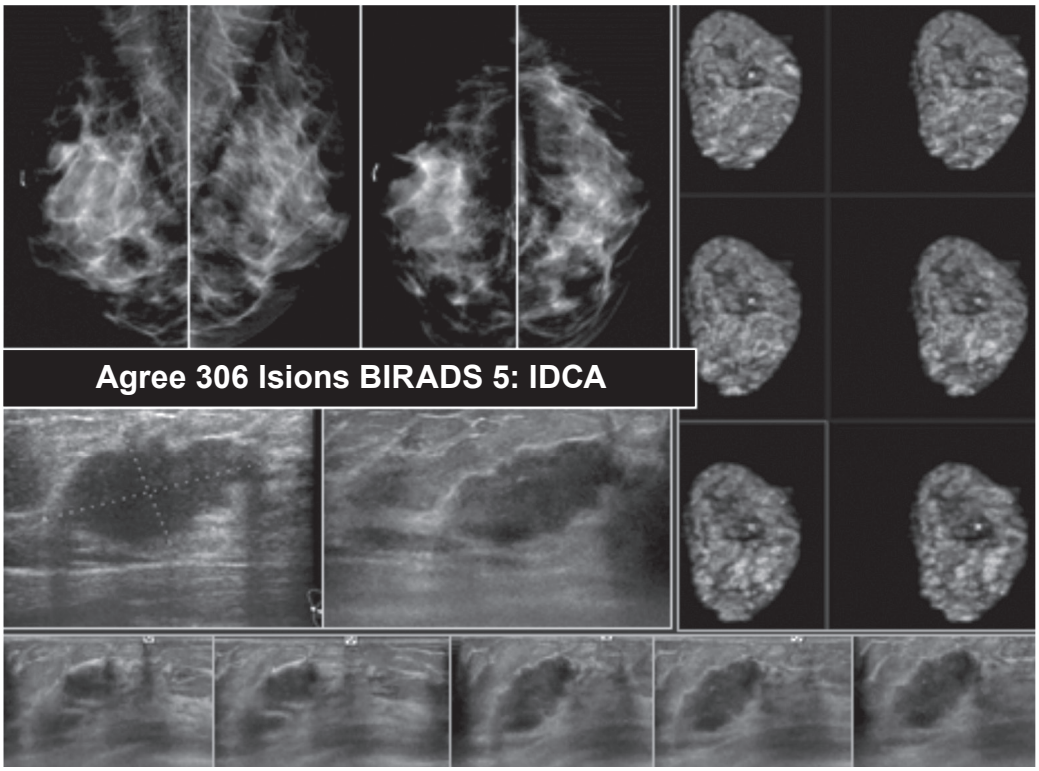

Figure 1: *MM does not show any lesion. HHUS shows a microlobulated solid mass, proven to be invasive ductal carcinoma (IDCA). ABVS shows the same finding in multiple images at 2 mm thickness and multiplanar, including axial, sagittal and coronal planes.*

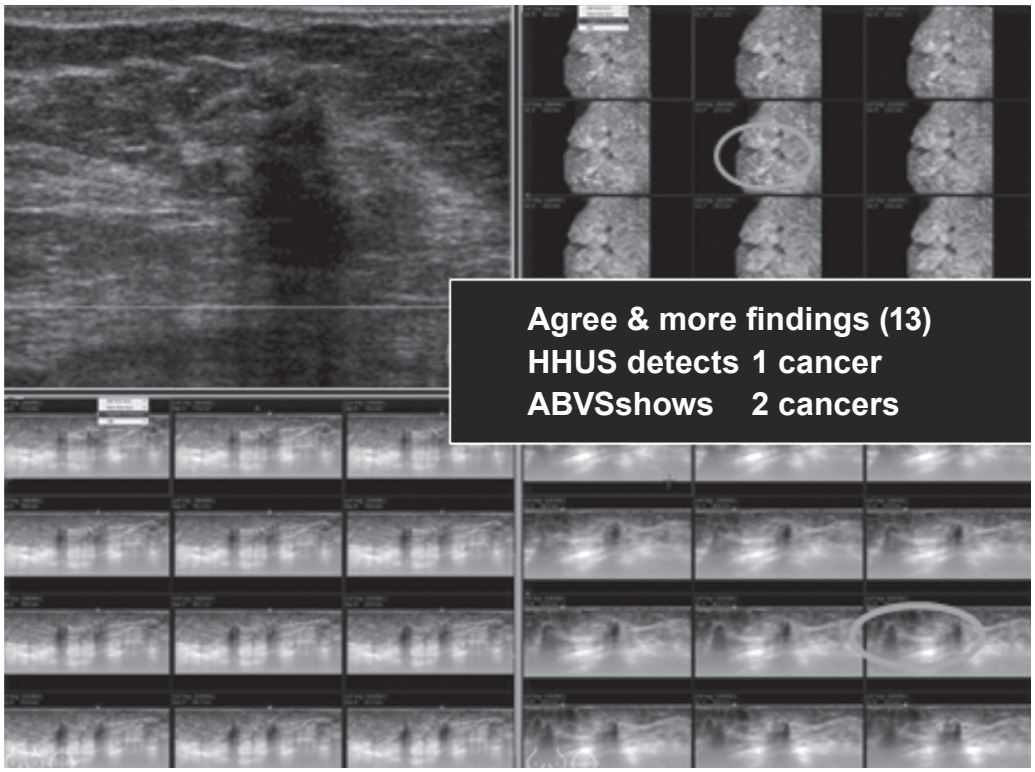

Figure 2: *HHUS shows a small solid mass with increased depth to width ratio and strong acoustic shadowing, proven to be invasive ductal carcinoma. ABVS shows two nearby lesions of the same findings, displayed in multiple images and multiplanar, including sagittal and coronal planes.*

Table 4: The ABVS and HHUS disagreed in 35 lesions.

ABVS and HHUS disagreed in 35 lesions		Number of lesions
HHUS findings	ABVS findings	
Benign solid	Complex cyst	2
Benign solid	Other cystic lesions	14
Benign solid	Benign solid lesions	1
Benign solid	BIRADS 4 (low suspicion)	2
Benign solid & cystic	BIRADS 4 (low suspicion)	2
Benign solid & cystic	Simple cysts	4
BIRADS 4 (low suspicion)	Simple cysts	2
Simple cysts	Benign solid lesions	3
Simple cysts	Simple and complicated cysts	3
Simple cysts	Complex cyst	1
Complex cyst	Simple cysts	1

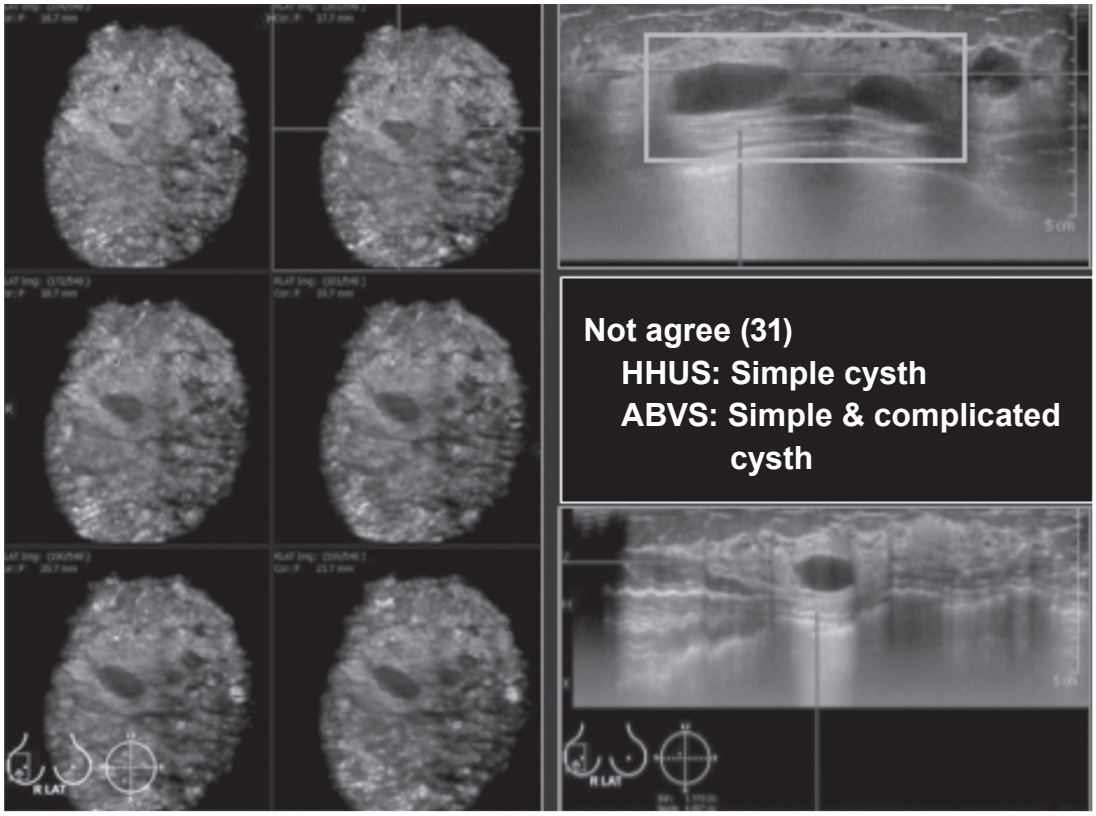

Figure 3: *HHUS shows multiple anechoic simple cysts. ABVS shows some cysts with low echoic contents, compatible with complicated cyst. The large FOV allows good comparison of the lesions in one image, displayed in multiple images and multiplanar, including axial, sagittal and coronal planes.*

Table 5: Negative ABVS but positive HHUS in 24 lesions

ABVS negative and HHUS positive in 24 lesions		Number of lesions
HHUS findings	ABVS findings	
Benign solid	Negative	2
Benign solid & cystic	Negative	14
BIRADS 4 (low suspicion)	Negative	1
Simple cyst	Negative	2
Benign solid & axillary LN*	Negative	2

*LN = Lymph Node

Table 6: Negative HHUS but positive ABVS in 104 lesions.

HHUS negative and ABVSpositive in 104 lesions		Number of lesions
HHUS findings	ABVS findings	
Negative	Benign solid	39
Negative	Benign solid & cystic	2
Negative	BIRADS 4 (low suspicion)	4
Negative	BIRADS 4 (low suspicion)& cyst	2
Negative	BIRADS 5 (high suspicion)	1
Negative	Cystic lesions	56

4. ABVS was negative while HHUS was positive in 24 lesions, including HHUS mistaking fat lobules as benign solids in 12 lesions, as benign solid and cyst in 1 lesion, as BIRADS 4 (low suspicion) in 5, simple cyst in 2 and benign solid with axillary lymph node in 4 lesions (Table 5 and Figure 4).

5. HHUS was negative while ABVS was positive in 104 lesions, including HHUS mistaking lesions for fat lobules or not detecting lesions, while ABVS could identify that there were 39 benign solid lesions, 2 benign solid and cystic lesions, 4 BIRADS 4 (low suspicion), 2 BIRADS 4 (low suspicion) with simple cyst, 1 BIRADS 5 (high suspicion) and 56 cystic lesions (Table 6 and Figure 5).

From our study ABVS showed much more benefit over HHUS. However, ABVS had drawbacks, for example:

- Nipple artifacts, making evaluation markedly limited in 11 cases (Figure 6).
- Motion artifacts in 4 cases (Figure 7).
- Contact artifacts in 3 cases (Figure 8).
- The lesion is out of view in 4 cases (Figure 9).

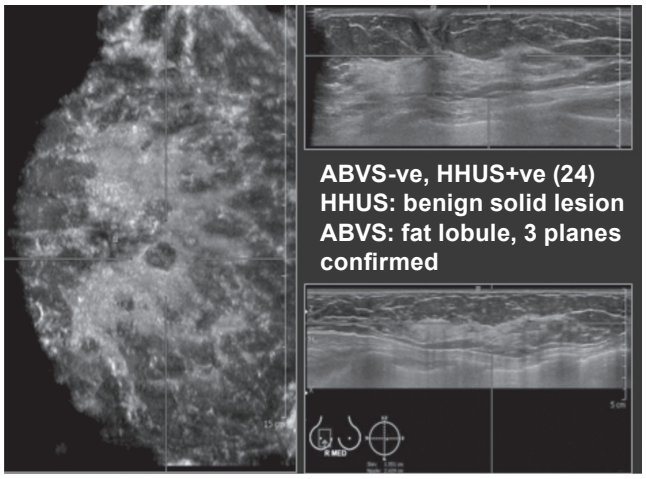

Figure 4: *HHUS shows hypoechoic lesions, while this case, ABVS shows the low echoic lesions continues with subcutaneous fat in another 1 – 2 views, compatible with fat lobule and excluded these false positive lesions seen by HHUS.*

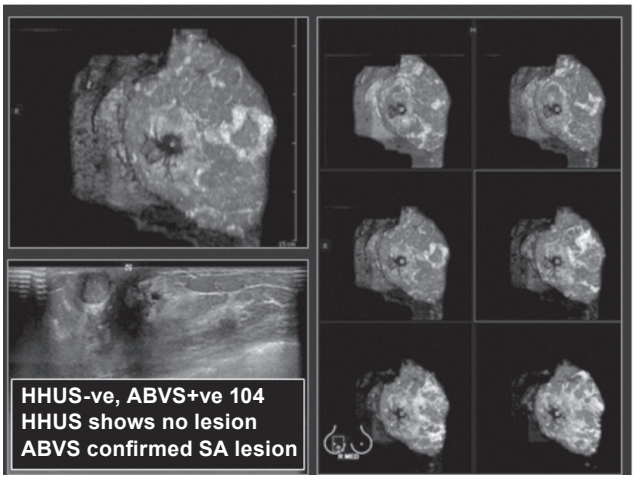

Figure 5: *HHUS detects no lesion. ABVS clearly demonstrates a lobulated hypoechoic solid mass occupied almost entirely inside a cystic lesion, compatible with a complex cystic lesion, confirmed to be a papilloma by core needle biopsy (CNB) and surgical specimen.*

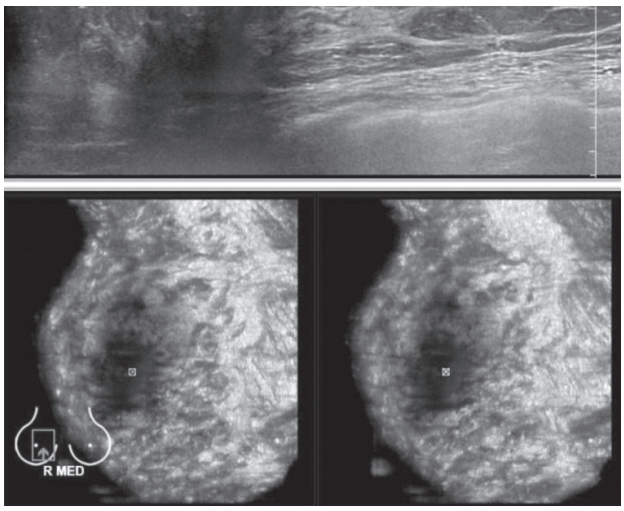

Figure 6: *Shows nipple artifact causing limitation of lesion detected under the nipple.*

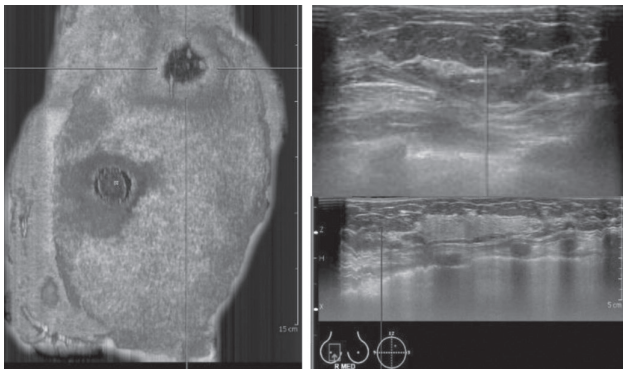

Figure 8: *Shows contact artifact due to air trapped between skin and transducer.*

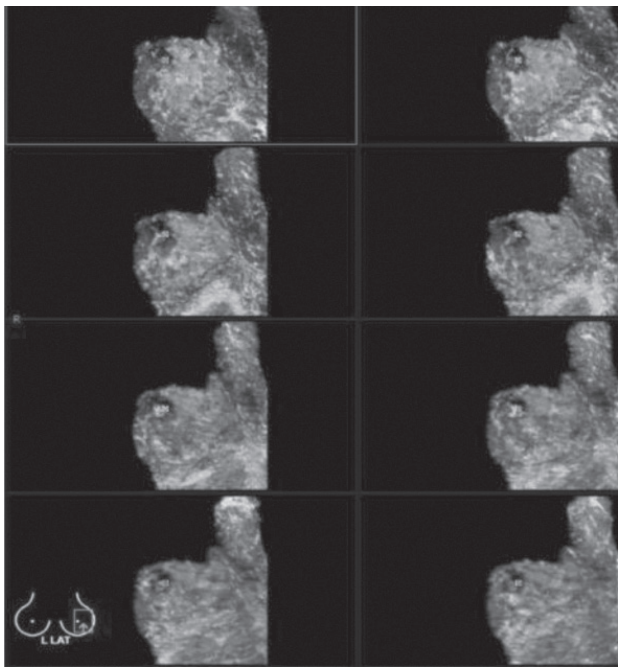

Figure 9: *Shows out of view. The axillary adenopathy seen by mammography and HHUS is not included in the area scanned. Usually axillary lymph node is not totally inside the scanned area.*

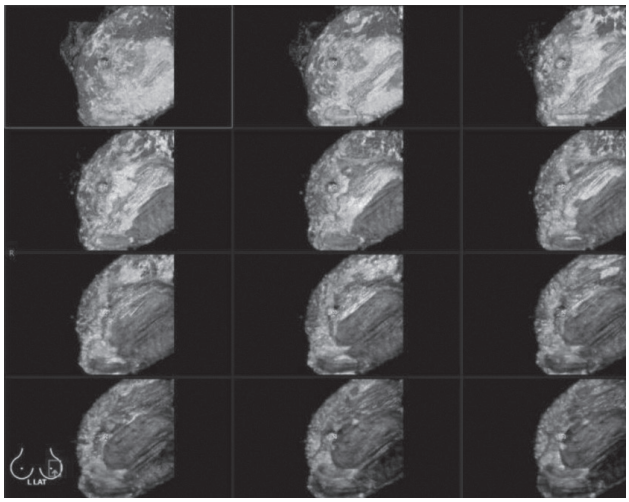

Figure 7: *Shows motion artifact from patient movement during the volume scan.*

Discussion

The result of the correlation of ABVS and HHUS findings were classified into 5 groups: both studies agreed in 306 out of 504 lesions (60.71%), both studies agreed but ABVS showed more lesions in 13 cases (2.58%). Both studies disagreed in 35 cases (6.94%), This was due to ABVS showing more detail and lesions were confirmed with scrolling for the fine details in 3 planes and 2 mm thickness. The echogenicity could be compared, for more confidence of differentiation of simple cysts from solid lesions. ABVS has no operator dependence, unlike HHUS which is known for its operator dependence.

ABVS was negative but HHUS was positive in 24 cases (4.76%), due to ABVS being able to confirm the continuity of fat lobule with subcutaneous fat by scrolling in 3 planes at 2 mm thickness, thus it could exclude the false positive lesions interpretation by HHUS. However, ABVS may not have included lesions in its FOV, due to our trying to limit the scan in order to reduce computer storage space, resulting in ABVS false negative.

HHUS was negative but ABVS was positive in 104 cases (20.63%). This was because HHUS has no multi-slice and multiplanar confirmation and is operator dependent, therefore, the lesions might not have been recognized, while all lesions in area scanned of ABVS were shown in details with confirmation.

From our study ABVS showed benefit over HHUS. Most of the different findings are due to the fact that ABVS has the benefits of a volume scan, whereby the images are readily displayed in multislice and multiplanar. When a lesion is suspected, a cursor is placed at that area and that particular point will be automatically displayed in other views with marker over that point. Scrolling over that point can be applied at 0.5-2.0 mm slice thickness, for

better defining of the area, and confirmation or exclusion of the lesion.

ABVS has a large FOV, covers a large area of the breast, with nipple marking before the automatic volume scan which takes 1 minute for each scan, thus the lesion is standardized, reproducible and take less scanning time. ABVS is actually performed by the experienced technician. ABVS's software adjusts measures and annotates the images on computer screen, and image quality is not different from that of CT volume scan.

However, ABVS had the drawbacks of nipple artifacts thus limiting. Technicians ought to look at the image which comes almost instantly after the scan. If artifacts are noted, technicians should then add a subareolar scan to the already available HHUS. Motion artifacts can be overcome by technicians should stopping, then repeating the scan after requesting the patient's cooperation to remain motionless during the scan.

With contact artifacts, a repeat scan is recommended with more gel filling in the area to avoid air gapping. The technician should note this defect in the work sheet. The lesion may not be included in the scanned area, the out of view. We recommend technicians to check that the FOV includes the breast tissue to the most medial, lateral, superior and inferior parts of the breast, with overlapping scanned area. If mammography shows axillary adenopathy, the technician is urged to add axillary scan.

Conclusion

Overall benefits to patient with ABVS include it being a fast examination; breath holding is not required although the patient must stay completely still during the volume scan. There is no ionizing radiation which is perfect for young or pregnant patients. We did not use contrast agents, thus no related risk to the patient. Apart from that we used minimal compression, so it is more comfortable than mammography.

ABVS has benefits to user as it is a volume scan, with standardized views, and reproducible. ABVS gives a streamlined workflow and the image in coronal plane is more familiar for surgeons and surgical planning, with more diagnostic information captured in less time. It captures volumes with online preview and offline review and manipulation, so it is beneficial in screening (mammography with US), using teleimaging. The technical limitations of HHUS are mostly overcome by ABVS.

References

1. Siriraj Cancer Center, Siriraj Hospital, Mahidol University, Thailand; Statistic Report 2008.
2. Bhothisuwan W, Prabhasawat D, Bhothisuwan K. Lumps in the Breast: Correlation of Ultrasound and Mammography Free Paper in UICC 1986, in K-47: Ultrasound Techniques, Guided Biopsy, article 3728.
3. Bhothisuwan W, Prabhasawat D, Bhothisuwan K. Imaging of Breast Lumps. *Thai Medical Association Annual Meeting 3* 1989:85-7.
4. Bhothisuwan W, Bhothisuwan K. MRI of Breast Lumps. A Correlation with other Breast Imaging, Gross Specimen and Pathology in Educational Lecture in AAR 1994:353.
5. Bhothisuwan W, Bhothisuwan K. Color Displayed MRI of the Breast in Free Paper in SIS in Brazil 1995.
6. Bhothisuwan W. Breast Imaging (in Thai) in Supakorn Rojananin, In Head, Neck and Breast Surgery, Bangkok Ruenkaew Publishing, 1995;1:299-319.
7. Bhothisuwan W, Bhothisuwan K. Breast Imaging and Intervention in Educational Lecture in AOCR 1998 session C07 article 2086.
8. Bhothisuwan W, Bhothisuwan K. Evidence Based Practicing Breast Imaging in Educational lecture: Breast Ultrasound Session, AFSUMB in Thailand 2007.
9. Statistic record and data system from Siriraj Breast Center 1995-2009.
10. Bhothisuwan W: Overview of Breast Imaging, Benefits and Drawbacks in Educational Lecture, WFUMB Center of Excellence Workshop on Breast Ultrasound in Bangladesh 2011.
11. Bhothisuwan W, Bhothisuwan K, Suwanakul P. Correlation of ultrasound with pathology and mammography findings. *J Med Assoc Thai 2004*.
12. McSweeny MB, Murphy CH. Whole breast Sonography, in Symposium on Ultrasound of Small Parts. *Radiol Clin North Am* 1985;23:157-67.
13. Bhothisuwan W. Ultrasound of the Breast in Thailand, from Water Bag Technique to Colour Doppler Ultrasound in Panels and Oral Presentation EP 42 Ultrasound in Breast and Bone Diseases, AFSUMB in China 1995.
14. Bhothisuwan W. Evidence Based Benefits and Drawbacks of Breast Ultrasound in Asian Women, Educational Lecture in 12th World Congress of the World Federation for Ultrasound in Medicine and Biology in Australia 2009.
15. Bhothisuwan W. Correlation of Breast Ultrasound and Mammography in Educational lecture in ABDA with SIS in Indonesia 2010.
16. Bhothisuwan W, Maruekatat N. Early Detection of Breast Cancer Using Breast Ultrasound in Educational Lecture, Fifth Asian Workshop in Ultrasound, AFSUMB Workshop in Philippines 2008.
17. Bhothisuwan W, Bhothisuwan K, Suwanakul P. Axillary Lymph Node Ultrasound with FNA in Breast Cancer in Educational lecture: Indonesia Annual Scientific Meeting in Indonesia 2007.
18. Statistic record and data system from Siriraj Breast Center 2004.
19. Chou Y H, Tiu C M, Chen J, et al. Automated full-field Breast Ultrasonography: The Past and The Present. *J Med Ultrasound* 2007:15:31-44.
20. Bhothisuwan W. Highlight on breast US, new innovation and recent knowledge lesions in Educational Lecture MUST Annual Scientific Meeting in Thailand, 2009.