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Patient-reported outcomes of automated breast ultrasound: considerations for screening modality selection, based on a prospective observational survey

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Purpose: This study aimed to evaluate patient-reported experiences with automated breast ultrasound (ABUS) and identify patient characteristics associated with discomfort, to inform screening modality selection and improve resource use.
Methods: A survey was prospectively conducted on 140 patients who underwent ABUS for breast cancer screening. The survey assessed patient satisfaction, discomfort, and pain before and after the procedure. Factors such as age, breast density, and body mass index (BMI) were analyzed to determine their impact on patient experiences.
Results: The majority of patients expressed satisfaction with ABUS. However, younger patients, those with small or dense breasts, and those with a low BMI reported lower satisfaction and higher pain scores.
Conclusion: Based on patient-reported outcomes, ABUS could complement handheld ultrasound in breast screening. Selecting modalities by age, BMI, breast size, and density may enhance satisfaction and resource use. Personalized strategies may improve screening experience and efficiency.
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Key Words: Automated breast ultrasound, Mass screening, Breast neoplasms/diagnosis, Breast density, Patient reported outcome measures

INTRODUCTION

Breast cancer remains the most prevalent malignancy among women worldwide [1]. Mammography has played a pivotal role in reducing breast cancer mortality by facilitating early detection [2,3]. However, its diagnostic sensitivity is limited in women with dense breast tissue, a known independent risk factor for breast cancer [4,5]. To address this, the American College of Radiology recommends adjunctive ultrasound screening for women with dense breasts, as it may detect cancers that are not visible on mammography [6,7].

In Korea, the prevalence of dense breasts among women aged over 40 years exceeds 50%, which is higher than in Western populations. Since 2021, the Korean National Health Insurance Service of Korea has provided reimbursement for breast ultrasound in eligible patients [8,9], resulting in a substantial increase in its utilization as a supplemental screening tool.

Handheld ultrasound (HHUS) has traditionally been the

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modality of choice for adjunctive screening, but its widespread use is constrained by operator dependency, interobserver variability, and limitations in scalability [10,11]. Automated breast ultrasound (ABUS) was developed to overcome these limitations by providing standardized image acquisition and separating image capture from interpretation [11]. Several studies have demonstrated diagnostic performance comparable to that of HHUS [12-15].

Despite its increasing adoption, little is known about how patients perceive ABUS [16], particularly in terms of discomfort, preference, and compliance. This study aimed to assess patient-reported experiences with ABUS and to identify characteristics associated with discomfort or dissatisfaction. These insights may support evidence-based selection of screening modalities tailored to individual patient profiles.

METHODS

Ethics statement

This prospective study was conducted with approval from the Institutional Review Board of Yongin Severance Hospital (No. 2020-0171-001). All participants provided written informed consent, and the study adhered to the principles of the Declaration of Helsinki and Good Clinical Practice guidelines.

Study design and population

Between July and December 2020, 140 women who underwent ABUS for breast cancer screening at our institution were recruited. Exclusion criteria included age below 19 years, history or diagnosis of breast cancer, or any mental health conditions interfering with study participation. Participants completed a baseline questionnaire before ABUS and a follow-up questionnaire immediately afterward.

Automated breast ultrasound procedure

ABUS was performed using a dedicated system (Invenia ABUS 2.0, GE Healthcare) equipped with a 6–15 MHz wideband transducer. Patients were positioned supine with proper support to optimize breast spreading. Acoustic gel was applied, and compression was adjusted based on image quality. At least 3 standard views—anteroposterior, medial, and lateral—were acquired per breast. Images were reconstructed in coronal and sagittal planes, and interpretation was performed by a radiologist using a dedicated workstation.

Questionnaire and variables

Patient-reported outcomes were assessed using pre- and post-examination questionnaires developed based on the validated Testing Morbidities Index (TMI). The pretest survey gathered demographic and medical information, including age, education, breast size, and medical history. The posttest survey captured discomfort, pain (rated 0–10), and preference for ABUS. TMI scores (range, 5–25) were calculated from responses to questions addressing physical and emotional distress before, during, and after the exam. A lower score indicated greater tolerability [17-19]. Satisfaction with ABUS after the examination was assessed using a 4-point Likert scale, with higher scores indicating more positive responses; for analysis, responses of 1 and 2 were categorized as "uncomfortable," and responses of 3 and 4 as "comfortable."

Statistical analysis

Continuous variables were analyzed using independent t-tests or Wilcoxon rank-sum tests, depending on normality (assessed by the Shapiro-Wilk test). Categorical variables were compared using the chi-square or Fisher exact tests. The McNemar test was used to compare satisfaction levels before and after the examination. Multivariable logistic regression was performed to identify predictors of discomfort, and results were visualized using a nomogram. Statistical analyses were performed using SAS software ver. 9.4 (SAS Institute) and R software ver. 4.1.1 (R Foundation for Statistical Computing).

RESULTS

Clinical characteristics

After administering the ABUS surveys, participants were categorized into a discomfort group (group A) and a comfort group (group B) based on their satisfaction levels. The mean age in group A was 45.31 ± 10.72 years, which was significantly younger than that of group B (53.47 ± 12.08 years). A significantly higher proportion of premenopausal women was observed in group A ($P < 0.05$). The time between the last normal menstrual period and the test date did not differ between the 2 groups. The mean BMI was lower in group A (20.98 kg/m^2) compared to group B (24.86 kg/m^2), and the proportion of underweight patients was significantly higher in group A ($P < 0.05$). Breast size and density also differed significantly between the 2 groups ($P < 0.05$). Patients with smaller breast size and higher density were more likely to report discomfort during ABUS. Pain scores measured using a numeric rating scale were significantly higher in group A (3.58 ± 1.65) than in group B (1.01 ± 1.27). No significant differences were found between the 2 groups in terms of other examination experiences, personal history, or family history (Table 1).

Patient experience

The TMI scores also showed significant differences between the groups. Group A had a significantly higher total TMI score (10.19 ± 2.06) compared to group B (8.25 ± 1.43). This difference was primarily attributed to increased physical and emotional

Table 1. Clinical characteristics

Characteristic	Satisfaction		P-value
	Uncomfortable	Comfortable	
Patient characteristics			
No. of patients	26	114	
Age (yr)	45.31 ± 10.72	53.47 ± 12.08	0.002[a]
Body mass index (kg/m^2)	20.98 ± 2.39	24.86 ± 3.43	<0.001[a]
History of examination			0.103[c]
No	5 (19.2)	7 (6.2)	
Within 1 year	13 (50.0)	65 (57.5)	
Over 1 year	8 (30.8)	41 (36.3)	
Insurance status			>0.999[b]
No	2 (7.7)	12 (10.5)	
Yes	24 (92.3)	102 (89.5)	
Breast size			0.001[b]
A cup or smaller	19 (73.1)	43 (38.1)	
B cup or larger	7 (26.9)	70 (62.0)	
Breast density			0.016[c]
Low (1, 2)	1 (4.8)	31 (29.8)	
High (3, 4)	20 (95.2)	73 (70.2)	
Past history (underlying breast disease)			
Mammography experience (X-ray)			0.350[b]
No	5 (19.2)	14 (12.3)	
Yes	21 (80.8)	100 (87.7)	
Breast ultrasound experience			0.273[c]
No	6 (23.1)	39 (34.2)	
Yes	20 (76.9)	75 (65.8)	
Breast lesion diagnosis			0.249[c]
No	13 (50.0)	71 (62.3)	
Yes (without cancer)	13 (50.0)	43 (37.7)	
Breast lesion treatment			>0.999[b]
No	12 (92.3)	39 (90.7)	
Mammotome	1 (7.7)	2 (4.7)	
Surgery	0 (0)	2 (4.7)	
Family history			
Family history of cancer			0.727[c]
No	15 (57.7)	70 (61.4)	
Yes	11 (42.3)	44 (38.6)	
Family history of benign breast disease			>0.999[b]
No	24 (92.3)	105 (92.1)	
Yes	2 (7.7)	9 (7.9)	
Before ABUS examination			
Recognition of ABUS			>0.999[b]
No	23 (88.5)	102 (89.5)	
Yes	3 (11.5)	12 (10.5)	
Pre-understanding of ABUS			0.794[b]
Very likable	0 (0)	1 (0.9)	
Likable	3 (11.5)	11 (9.7)	
Unlikable	16 (61.5)	76 (66.7)	
Very unlikable	7 (26.9)	26 (22.8)	
About menstruation			
Menopause			<0.001[c]
Yes	7 (26.9)	78 (68.4)	
No	19 (73.1)	36 (31.6)	
Recent menstruation			0.685[c]
Within 2 wk	10 (52.6)	21 (58.3)	
Ago 2 wk	9 (47.4)	15 (41.7)	
Pain Scale	3.58 ± 1.65	1.01 ± 1.27	<0.001[a]

Values are presented as number only, mean ± standard deviation, or number (%).
ABUS, automated breast ultrasound.
[a]Independent 2-sample t-test, [b]Fisher exact test, [c]chi-square test.

Table 2. Questionnaire entries

Variable	Satisfaction		P-value
	Uncomfortable (n = 26)	Comfortable (n = 114)	
Total process			
Total score sum (7–35 points)	10.19 ± 2.06	8.25 ± 1.43	<0.001[a]
Preparation			
Sum of score during preparation (2–10 points)	2.73 ± 0.96	2.43 ± 0.61	0.137[a]
Physical discomfort during preparation			0.227[b]
None (1 point)	21 (80.8)	102 (89.5)	
A little (2 points)	4 (15.4)	11 (9.7)	
Normal (3 points)	1 (3.9)	1 (0.9)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Emotional discomfort during preparation			0.011[b]
None (1 point)	16 (61.5)	78 (68.4)	
A little (2 points)	7 (26.9)	36 (31.6)	
Normal (3 points)	3 (11.5)	0 (0)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
During examination			
Sum of score during examination (3–15 points)	5.38 ± 1.42	3.78 ± 0.99	<0.001[a]
Physical discomfort during examination			<0.001[b]
None (1 point)	2 (7.7)	68 (59.7)	
A little (2 points)	15 (57.7)	42 (36.8)	
Normal (3 points)	5 (19.2)	4 (3.5)	
Much (4 points)	4 (15.4)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Shyness during examination			0.015[b]
None (1 point)	15 (57.7)	92 (80.7)	
A little (2 points)	10 (38.5)	21 (18.4)	
Normal (3 points)	1 (3.9)	0 (0)	
Much (4 points)	0 (0)	1 (0.9)	
Very much (5 points)	0 (0)	0 (0)	
Emotional discomfort during examination			0.002[b]
None (1 point)	16 (61.5)	99 (86.8)	
A little (2 points)	8 (30.8)	15 (13.2)	
Normal (3 points)	1 (3.9)	0 (0)	
Much (4 points)	1 (3.9)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
After examination			
Sum of scores after examination (2–10 points)	2.08 ± 0.27	2.04 ± 0.25	0.544[a]
Physical discomfort after examination			>0.999[b]
None (1 point)	26 (100)	113 (99.1)	
A little (2 points)	0 (0)	1 (0.9)	
Normal (3 points)	0 (0)	0 (0)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Emotional discomfort after examination			0.309[b]
None (1 point)	24 (92.3)	110 (96.5)	
A little (2 points)	2 (7.7)	4 (3.5)	
Normal (3 points)	0 (0)	0 (0)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	

Values are presented as mean ± standard deviation or number (%).
[a]Independent 2-sample t-test, [b]Fisher Exact test.

discomfort during the examination. However, no significant differences were noted in pre- or posttest discomfort (Table 2). As shown in Table 3, the relationship between perception (dislike/favourability) and satisfaction before and after ABUS did not reach statistical significance (P = 0.063).

Table 3. Satisfaction according to automated breast ultrasound (ABUS) preference

Before examination	Satisfaction		P-value
	Uncomfortable (n = 26)	Comfortable (n = 114)	
ABUS			0.063[a]
Unlikable	3 (2.1)	12 (8.6)	
Likable	23 (16.4)	102 (72.9)	

Values are presented as number (%).
[a]McNemar test.

Patients with a changed preference for automated breast ultrasound

To evaluate the potential influence of preconceived notions on satisfaction, additional analyses were performed in patients whose preferences regarding ABUS changed before and after the test (Table 4). Patients who initially had a favorable view of ABUS but reported discomfort after the test had a lower mean BMI (21.06 ± 2.52 kg/m^2) and significantly higher TMI and pain scores. When the TMI scores were divided into before, during, and after the test, no significant differences were observed before and after the test; however, physical discomfort during the examination was significantly higher (P < 0.05). No significant differences were found in age, breast size, breast density, menopausal status, and the interval from the last

Table 4. Factors of change in liking and satisfaction

Factor	Satisfaction		P-value
	Unlikable to comfortable (n = 12)	Likable to uncomfortable (n = 23)	
Patient characteristics			
Age (yr)	53.00 ± 13.52	45.30 ± 11.36	0.084[a]
Body mass index (kg/m^2)	25.08 ± 2.93	21.06 ± 2.52	<0.001[a]
Breast size			0.135[b]
A cup or smaller	4 (36.4)	16 (69.6)	
B cup or larger	7 (63.6)	7 (30.4)	
Breast density			0.139[b]
Low (1, 2)	3 (27.3)	1 (5.6)	
High (3,4)	8 (72.7)	17 (94.4)	
About menstruation			
Menopause			0.079[b]
Yes	7 (58.3)	6 (26.1)	
No	5 (41.7)	17 (73.9)	
Recent menstruation			>0.999[b]
Within 2 weeks	3 (60.0)	10 (58.8)	
Ago 2 weeks	2 (40.0)	7 (41.2)	
Total process			
Total score sum (7–35 points)	8.00 (8.00–8.50)	9.00 (9.00–12.00)	0.004[c]
Preparation			
Sum of score during preparation (2–10 points)	3.00 (2.00–3.00)	2.00 (2.00–3.00)	0.591[c]
Physical discomfort during preparation			>0.999[b]
None (1 point)	10 (83.3)	18 (78.3)	
A little (2 points)	2 (16.7)	4 (17.4)	
Normal (3 points)	0 (0)	1 (4.4)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Emotional discomfort during preparation			0.079[b]
None (1 point)	4 (33.3)	14 (60.8)	
A little (2 points)	8 (66.7)	6 (26.1)	
Normal (3 points)	0 (0)	3 (13.0)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	

Table 4. Continued

Factor	Satisfaction		P-value
	Unlikable to comfortable (n = 12)	Likable to uncomfortable (n = 23)	
During examination			
Sum of score during examination (3–15 points)	3.00 (3.00–4.00)	5.00 (4.00–6.00)	<0.001[c]
Physical discomfort during examination			<0.001[b]
None (1 point)	10 (83.3)	1 (4.4)	
A little (2 points)	2 (16.7)	14 (60.9)	
Normal (3 points)	0 (0)	4 (17.4)	
Much (4 points)	0 (0)	4 (17.4)	
Very much (5 points)	0 (0)	0 (0)	
Shyness during examination			0.806[b]
None (1 point)	9 (75.0)	14 (60.8)	
A little (2 points)	3 (25.0)	8 (34.8)	
Normal (3 points)	0 (0)	1 (4.4)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Emotional discomfort during examination			0.063[b]
None (1 point)	12 (100)	14 (60.8)	
A little (2 points)	0 (0)	7 (30.4)	
Normal (3 points)	0 (0)	1 (4.4)	
Much (4 points)	0 (0)	1 (4.4)	
Very much (5 points)	0 (0)	0 (0)	
After examination			
Sum of scores after examination (2–10 points)	2.00 (2.00–2.00)	2.00 (2.00–2.00)	0.327[c]
Physical discomfort after examination			>0.999[b]
None (1 point)	12 (100)	23 (100)	
A little (2 points)	0 (0)	0 (0)	
Normal (3 points)	0 (0)	0 (0)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Emotional discomfort after examination			0.536[b]
None (1 point)	12 (100)	21 (91.3)	
A little (2 points)	0 (0)	2 (8.7)	
Normal (3 points)	0 (0)	0 (0)	
Much (4 points)	0 (0)	0 (0)	
Very much (5 points)	0 (0)	0 (0)	
Pain scale	0.50 (0.00–1.50)	4.00 (2.00–5.00)	<0.001[c]

Values are presented as mean ± standard deviation, number (%), or median (interquartile range).
[a]Independent 2-sample t-test, [b]Fisher exact test, [c]Wilcoxon rank-sum test.

menstrual period to the test date (Table 4). Interestingly, most patients with initially negative perceptions of ABUS reported satisfaction after the examination, whereas those who were initially favorable experienced some discomfort during the test.

DISCUSSION

This study aimed to assess patient experiences with ABUS—a valuable tool for breast cancer screening—and to identify factors associated with discomfort and decreased compliance, thereby enabling more efficient resource allocation. Our results demonstrated that younger patients, as well as those with lower BMI, smaller breast size, and higher breast density (category C, heterogeneously dense or D, extremely dense), were more likely to report discomfort. This group also had significantly higher test-induced pain scores. Interestingly, most patients who initially had negative preconceived notions about ABUS reported increased satisfaction following the examination.

Although patient discomfort has been previously reported, ABUS remains a promising alternative to HHUS in screening settings [10,20]. In our study, the primary source of discomfort was pain experienced during the examination, a finding consistent with earlier research [21]. This discomfort likely results from the technical characteristics of ABUS: it uses a

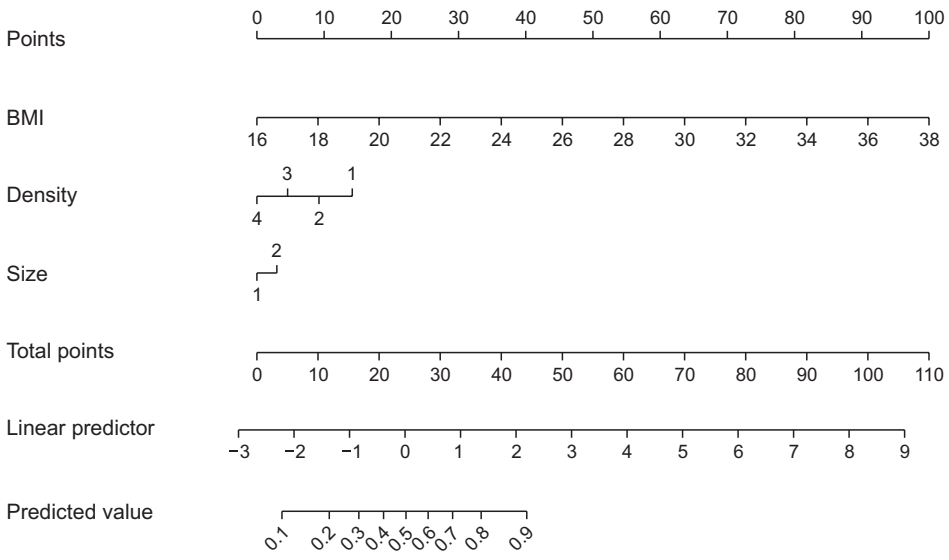

Fig. 1. Nomogram for predicting patient satisfaction with automated breast ultrasound (ABUS). Each individual's satisfaction with ABUS is assigned a point corresponding to the value of each variable. Calculate the total point by summing the points of the variables ((body mass index [BMI, kg/m^2], density, size) and check the predicted value corresponding to the total point. The higher the predicted value, the higher the satisfaction with ABUS.

broader transducer than HHUS, applies sustained compression across the entire breast, requires acquisition of a greater number of images, and takes a longer time to complete. These factors may contribute to increased pain in certain patients. While younger women in our study tended to report lower satisfaction with ABUS, De Giorgis et al. [21] found that compliance actually decreased in women older than 40 years. This discrepancy may reflect the fact that younger women tend to have denser breasts, leading to greater compression-related pain, whereas women with small breasts may experience localized pressure and discomfort due to inadequate cushioning during compression [20].

To enhance diagnostic accuracy in breast cancer screening, ultrasonography is commonly used in conjunction with mammography [22,23]. However, HHUS has notable limitations, including operator dependence, low reproducibility, limited standardization, labor intensiveness, high false recall rates, and low inter-reader reliability [22,24]. In response to these challenges, ABUS was developed and has been approved as a viable alternative [10,20,25].

In Korea, the incidence of breast cancer continues to rise, and since breast ultrasound has been reimbursed under the national insurance system as of 2021, demand for breast ultrasonography is expected to increase further. Although HHUS has traditionally been the primary modality, ABUS is now increasingly being adopted. This study explored patient responses to ABUS, with the goal of identifying specific characteristics associated with reduced tolerance, and incorporated Test-related Mental and Physical Impact scores to guide resource planning. Consistent with previous findings, the predominant source of discomfort was pain during the procedure, and contributing factors included younger age, premenopausal status, lower BMI, small breast size, and dense breast tissue. Nevertheless, most patients expressed overall satisfaction with the test, and even those with initial skepticism reported improved perceptions afterward. While ABUS is broadly applicable, clinicians should recognize its potential limitations in younger women with small, dense breasts. In such cases, HHUS may remain an appropriate and preferable alternative.

To facilitate personalized test assignment, we developed and presented a nomogram (Fig. 1) that predicts patient satisfaction with ABUS based on 3 variables: BMI, breast size, and breast density. The nomogram assigns points for each variable; the total score corresponds to a predicted satisfaction level. For instance, patients with a BMI ≥26 kg/m^2 generally have a predicted satisfaction rate exceeding 90%, regardless of breast size or density. Conversely, those with lower BMI are more likely to experience discomfort, and HHUS may be more appropriate in such cases.

This study has several limitations. First, the sample size was relatively small, and a direct head-to-head comparison between ABUS and HHUS was not performed. However, the study was well-organized and rigorously conducted in a prospective manner at an academic medical center. The sample size was also sufficient for statistical comparisons between subgroups. As breast ultrasonography becomes increasingly standardized and automated, ABUS is expected to gain wider adoption, while HHUS may be used more selectively. Identifying patient-specific factors that influence tolerance and satisfaction may assist in optimizing the allocation of screening modalities and improving the overall patient experience.

In conclusion, although a subset of patients experienced discomfort with ABUS, the majority reported overall satisfaction with the examination. Based on patient-reported outcomes, ABUS could be considered a complementary screening tool to HHUS, particularly in settings where standardized imaging is prioritized. Tailoring the choice of modality according to patient characteristics—such as age, BMI, breast size, and breast

density—may help improve overall satisfaction and optimize screening resource allocation.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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