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*Research article*

# Differential diagnosis of breast cancer assisted by S-Detect artificial intelligence system

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**Abstract: Objective:** Traditional breast ultrasound relies too much on the operation skills of diagnostic doctors, and the repeatability in different doctors was low. This study aimed to evaluate the assistant diagnostic value of S-Detect artificial intelligence (AI) system in differentiating benign from malignant breast masses. **Methods:** The ultrasound images of 40 patients who underwent ultrasound examination in our hospital were collected. The conventional ultrasound images, elastic images, and S-Detect mode of breast lesions were analyzed. The breast imaging reporting and data system recommended by the American Society of Radiology (BI-RADS) classification for each breast mass was evaluated both by the doctor and AI. The receiver operator characteristics (ROC) curves were drawn to compare the diagnostic efficiency. **Result:** Among the 40 lesions, 16 were benign, and 24 were malignant. The S-Detect AI system had a high diagnostic efficiency for malignant mass, with sensitivity, specificity, and accuracy of 95.8%, 93.8%, and 89.6%. The accuracy of AI was higher than the elastic image and then than the conventional gray-scale image. With the assistance of the S-Detect AI system, the accuracy of BI-RADS classification was improved significantly. **Conclusion:** The S-Detect AI system will enhance breast cancer diagnostic accuracy and improve ultrasound examination quality.

**Keywords:** ultrasonography; artificial intelligence; breast cancer; S-Detect technique; diagnostic efficiency

## 1. Introduction

The breast tumor is a common clinical disease in women. Ultrasound has always been considered the most appropriate method for breast examination and tumor screening [1]. However, ultrasound has a strong technical dependence on the examiners, and the results of different examiners are different, which has been considered the shortcomings of ultrasound [2]. With the imaging technology development, more and more methods have been used to objectively analyze ultrasound images to help diagnose breast tumors [3], such as elastic ultrasound, computer-aided diagnosis technology, etc.

The S-Detect artificial intelligence system is a set of auxiliary ultrasound imaging in diagnosing a deep learning system [4–6]. This system extracts the morphological features from the breast imaging reporting data system recommended by the American Society of Radiology (BI-RADS). Combined with pathological results of mass, the information can be used to diagnose breast lumps automatically. Two-dimensional breast ultrasound is widely used in diagnosing breast lesions. Still, due to its strong operator dependence, the accuracy and repeatability of BI-RADS classification results between different operators need to be improved [7–9]. Artificial intelligence-assisted diagnosis system eliminates the influence of many human factors. It can carry out image analysis objectively and efficiently to improve doctors' working efficiency and diagnostic efficiency [10–12].

One of the main problems encountered in ultrasound diagnosis is that senior doctors' diagnostic level is significantly higher than that of junior doctors. The training of a junior doctor often takes four years or more. The use of AI will significantly reduce the difficulty of training doctors. The purpose of this study was to evaluate the value of the S-Detect artificial intelligence system in the auxiliary diagnosis of benign and malignant breast masses.

## 2. Materials and methods

### *2.1. Research objects*

From November 2019 to June 2020, the patients with breast masses undergoing ultrasound examination in the ultrasound imaging department of our hospital were randomly collected.

Inclusion criteria: The diagnosis had definite pathological support; adult patients; hospitalized patients.

Exclusion criteria: The mass boundary was not clear; there were blood flow, arrow, and text on the image; patients who can't cooperate with the exam.

Finally, 40 patients were enrolled in the study cohort. All the patients were female, with an age of (50.9 ± 13.9) years old. These patients were diagnosed with single or multiple breast lesions. However, only one typical image was selected from a patient. This study was approved by the ethics committee of the First People's Hospital of Anqing City. The written informed consent was obtained from patients.

### *2.2. Image acquisition*

The Samsung RS80A ultrasonic diagnostic instrument was used to detect the breast, with an L3-12A probe, frequency 3~12MHz.The patient was placed in the supine position, with his hands over his head, to expose the mammary glands and axilla's scanning area as large as possible. The scan was executed by two ultrasound doctors (engaged in breast ultrasound > 3 years) for regular breast two-dimensional (2D) gray-scale and color doppler ultrasound. The 2D images were collected, and the location, size, shape, boundary, internal echo, rear and side, blood flow, and spectrum of the echo were observed. The information was evaluated by the BI-RADS classification.

Then, the S-Detect mammary gland mode was selected to display the 2D horizontal and vertical gray-scale section of the mass. After clicking the center of lesion, the system automatically outlined the lesion boundary as the region of interest. If the border drawn automatically did not match the mass's solid edge, the operator could readjust and sketch the frame. After selecting the most appropriate boundary, the system automatically listed the various characteristics of the mass (size, depth, shape, boundary, internal echo, and so on) and the diagnostic results, which probably benign or malignant (Figures 1–3).

Finally, the model was converted to breast elasticity, and the patient was asked to hold their breath without pressure. Satisfactory elastic images were collected. The color of elastography was divided into green and blue, which reflects the hardness of the tissue. If the lesion is very hard, it is dark blue and tends to be malignant. The lesions were soft, light green, and managed to be benign.

*2.3. Image analysis*

The BI-RADS classification results for each breast mass were divided into the senior physician (engaged in breast ultrasound > 15 years) and the junior group. Both of them were classified into two groups based on whether the auxiliary S-Detect AI were used. One group was the BI-RADS initial classification of each mass by sonographers based on conventional ultrasound images; another group was the BI-RADS classification for each mass again performed for the physician combined with S-Detect assisted diagnosis.

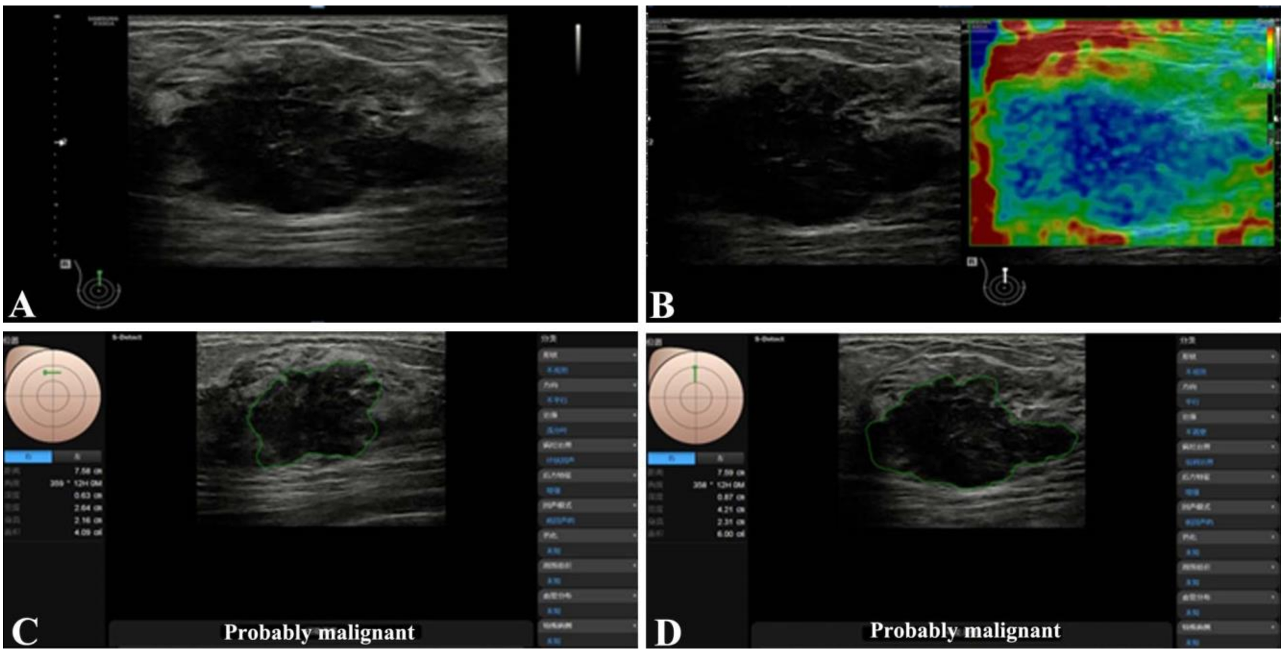


**Figure 1.** Malignant breast mass from a patient with 82 years old. A: Two-dimensional gray-scale ultrasound image; B: Elastic image of nodule; C: Transverse section image in S-Detect system; D: longitudinal section image in S-Detect system. The diagnosis was probably malignant.

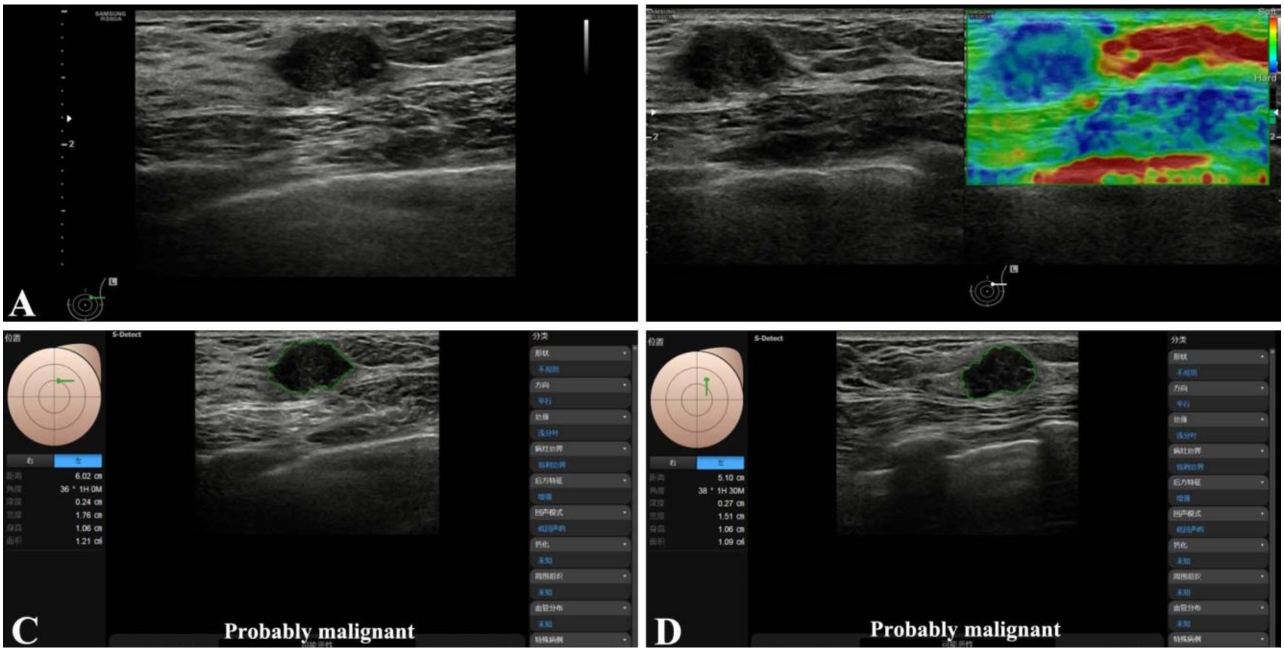


**Figure 2.** Malignant breast mass from a patient with 59 years old. A: Two-dimensional gray-scale ultrasound image; B: Elastic image of nodule; C: Transverse section image in S-Detect system; D: longitudinal section image in S-Detect system. The diagnosis was probably malignant.

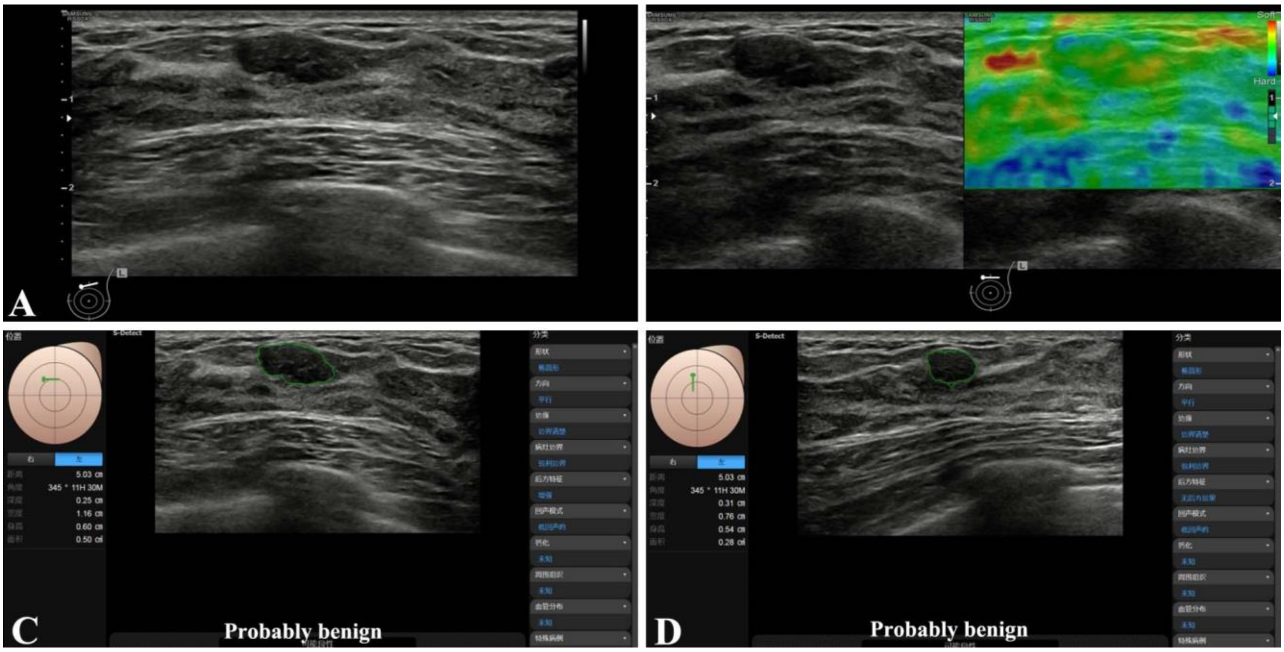


**Figure 3.** Benign breast mass from a patient with 27 years old. A: Two-dimensional gray-scale ultrasound image; B: Elastic image of nodule; C: Transverse section image in S-Detect system; D: longitudinal section image in S-Detect system. The diagnosis was probably benign.

Since each mass was randomly examined more than twice before the final surgical biopsy, the multiple BI-RADS classifications for all lesions obtained by multiple sonographers were defined in this study as a junior set of results. The S-Detect system diagnosis results were also combined with the junior set of products. The BI-RADS classification diagnosis results Category ≤ 4a was defined as benign lesions, while Category ≥ 4b was defined as malignant lesions.

The S-Detect diagnosis of each breast mass in both transverse and longitudinal sections was recorded as B/B, and both areas were likely benign. The diagnosis results of the two regions are different, which was denoted as M/B. Both sections are likely malignant, denoted as M/M. The S-Detect diagnostic result B/B was defined as benign lesions, while the M/B or M/M were defined as malignant lesions.

According to the standards of elastic imaging Guidelines, the Tsukuba score (Elasticity Score) was performed for each breast mass, with the ES value as the ES group data. The ES ≤ 3 points of Tsukuba were defined as benign lesions, while ES ≥ 4 points were defined as malignant lesions.

### *2.4. Statistical analysis*

The SPSS 21.0 software was used for statistical analysis of the data. The qualitative data were presented in terms of rate and the results of different diagnostic methods for the same lesion were compared by paired chi-square test.

Based on the pathological results, the receiver operator characteristics (ROC) curves were drawn for multiple groups of diagnostic products to obtain the area under curve area (AUC), sensitivity, specificity, and diagnostic accuracy. Kappa test was used to analyze the consistency of diagnostic results of different groups of data. The accuracy was calculated by the following formula:

$$\text{accuracy} = \frac{a + d}{n} \times 100\% \tag{1}$$

In the formula, the “*a*” represents the true positive number, “*d*” represents the true negative number, and “*n*” represents the total number.

## 3. Results

### *3.1. Pathological results*

Among the 40 patients, benign lesions accounted for 40.0% (16/40), and malignant lesions accounted for 60.0% (24/40). In the benign lesions, there were 4 cases of mammary gland disease, 8 cases of fibroadenoma, 2 cases of papilloma, and 2 cases of other benign tumors. In the malignant lesions, there were 17 cases of invasive ductal carcinoma, 1 case of mucinous carcinoma, 1 case of papillary carcinoma, 3 case of intraductal carcinoma, 1 cases of invasive lobular carcinoma, and 1 case of intraductal carcinoma in situ..

### *3.2. Diagnostic efficiency of S-Detect AI system*

When the results of pathological examination were used as the gold standard, the S-Detect AI system itself had high sensitivity, specificity, and accuracy (95.8%, 93.8%, 89.6%) for the identification of benign and malignant breast masses. The diagnostic efficiency of two-dimensional gray-scale ultrasound was the lowest, with the sensitivity and specificity was lower than 80%. The elastic image had a relatively high specificity (93.8%) and a relatively lower sensitivity (79.2%). The detail was shown in Table 1 and Figure 4.

**Table 1.** Diagnostic effectiveness of different methods.

| Group | AUC | Sensitivity (%) | Specificity (%) | Accuracy (%) |
|---|---|---|---|---|
| AI | 0.948 | 95.8 | 93.8 | 89.6 |
| Elastic image | 0.865 | 79.2 | 93.8 | 73.0 |
| Gray-scale | 0.719 | 75.0 | 68.8 | 43.8 |

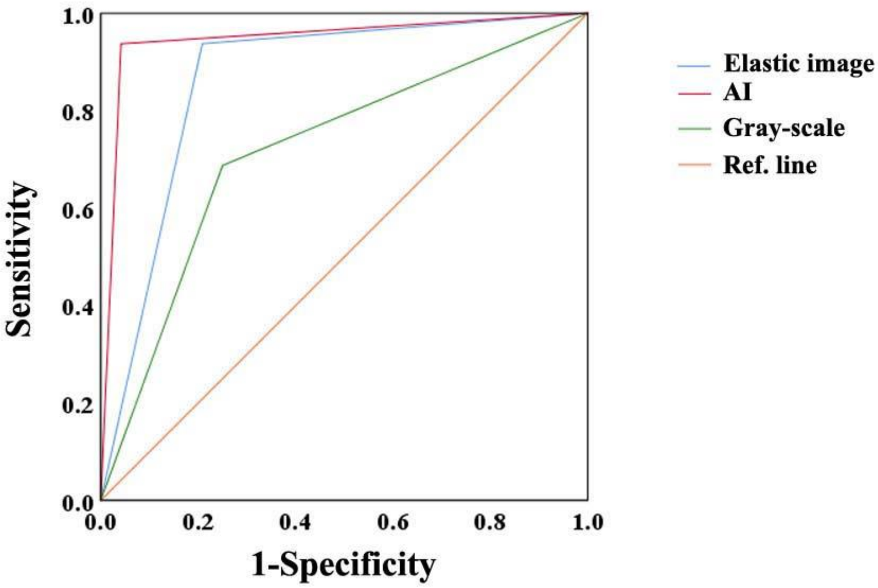


**Figure 4.** The ROC curve of different methods.

**Table 2.** The BI-RADS classification whether S-Detect AI were assisted.

| Before assistance | | S-Detect | | After assistance | |
|---|---|---|---|---|---|
| Category | 8 | B/B | 7 | Category 3 | 8 |
| | | M/B | 1 | | |
| Category4a | 13 | B/B | 6 | Category 3 | 3 |
| | | M/B | 4 | Category 4a | 4 |
| | | M/M | 3 | Category 4b | 4 |
| | | | | Category 4c | 2 |
| Category 4b | 11 | B/B | 2 | Category 4a | 2 |
| | | M/B | 4 | Category 4b | 6 |
| | | M/M | 5 | Category 4c | 3 |
| Category 4c | 6 | M/B | 2 | Category 4c | 6 |
| | | M/M | 4 | | |
| Category 5 | 2 | M/M | 2 | Category 5 | 2 |

*3.3. Auxiliary value of S-Detect AI system in BI-RADS classification*

Before the S-Detect AI system was used, the BI-RADS classification of 40 patients was category 3 in 8 cases, Category 4a in 13 cases, category 4b in 11 cases, and category 4c in 6 cases, and category 5 in 2 cases. From Table 2, doctors primarily use the S-Detect auxiliary system for escalation and degradation of category 4a and class 4b. For BI-RADS3, 4C, and 5 breast lesions, the S-Detect system diagnostic difference did not substantially affect the judgment of doctor.

*3.4. Auxiliary value of S-Detect AI system for junior doctors*

With the assistance of S-Detect AI system, the accuracy of BI-RADS classification was improved significantly. The detail was showed in Table 3 and Figure 5.

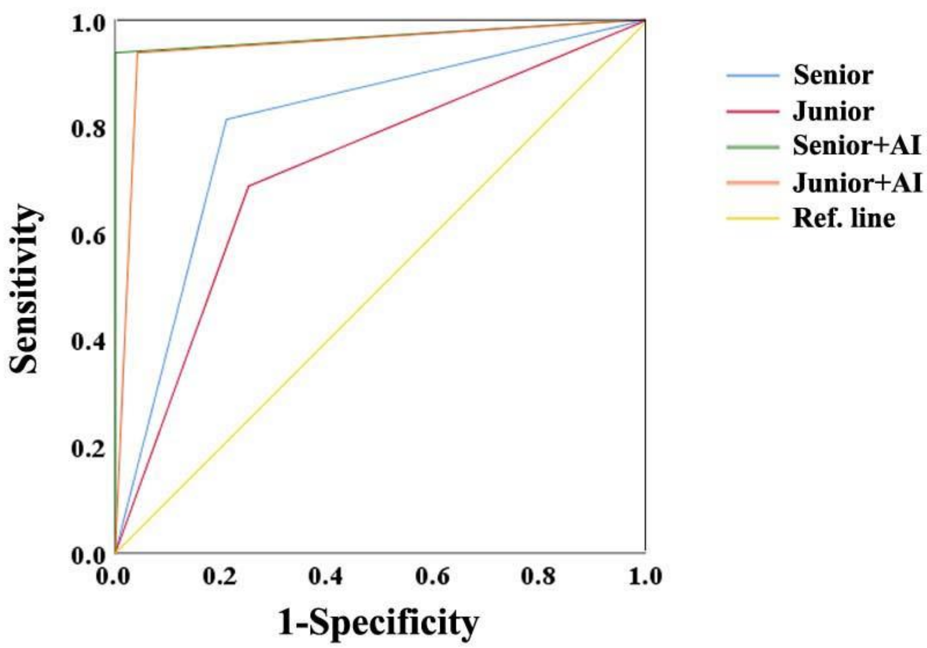


**Figure 5.** The ROC curve of auxiliary S-Detect AI system.

**Table 3.** Diagnostic effectiveness of auxiliary S-Detect AI system.

| Group | Area under ROC curve | Sensitivity (%) | Specificity (%) | Accuracy (%) |
|---|---|---|---|---|
| Senior | 0.802 | 79.2 | 81.3 | 60.5 |
| Junior | 0.719 | 75.0 | 68.8 | 43.8 |
| Senior+AI | 0.969 | 100.0 | 93.8 | 93.8 |
| Junior+AI | 0.948 | 95.8 | 93.8 | 89.6 |

## 4. Discussion

The S-Detect artificial intelligence system can effectively differentiate benign from malignant breast lesions. With the assistance of this technology, the BI-RADS classification diagnostic performance of senior sonographers has been on the rise [13]. The S-Detect auxiliary diagnosis results combined with the results of random ultrasound examination can significantly improve diagnostic accuracy. Therefore, this clinical diagnosis technique can enhance the quality of random breast ultrasound examinations obtained by patients and reduce missed diagnoses and misdiagnosis. The S-Detect technique and the elasticity scoring technique can improve the sonographer's diagnostic efficiency in breast cancer diagnosis. Still, there are some differences between the diagnostic ability and the auxiliary diagnostic ability [14].

Artificial intelligence technology based on big data and deep learning algorithm is widely integrated into the medical field [15–17]. Combining medical imaging with it can reduce the work burden of imaging physicians and improve the overall work efficiency. Computer aided diagnosis system has the advantages of objectivity, stability and high repeatability, and has been used in the early research and application of lung mass, breast mass and cardiovascular disease. The S-Detect auxiliary diagnostic system is intelligent and efficient, using the physico-acoustic characteristics of 2D gray-scale images of breast lesions for rapid differential diagnosis. In this study, the S-Detect technique has a high diagnostic efficiency, with differential diagnosis sensitivity, specificity and accuracy exceeding 90%. With the aid of this technology, the diagnostic efficiency of senior doctors has an upward trend. As a result, the S-Detect technology can provide effective advice and increase diagnostic confidence for junior sonographer in the diagnosis of 2D gray-scale images.

According to the BI-RADS classification standards recommended by the American Society of Radiology, Category3mass for the possibility of malignant 2% or less, Category 4a mass is the possibility of malignant is 2~10%. In this study, of the 16 benign groups, 93.8% (15/16) were classified as Category 3 or 4a, and the pathological findings were mostly adenopathy or fibroadenoma of the breast. The clinician will perform a pathological biopsy or surgical excision of masses classified as Category 4a or above, most of which pathologically turn out benign. The S-Detect technology has higher diagnostic performance for BI-RADS4a and 4B mass upgrades and downgrades, improving the accuracy of the random ultrasound surgeon's diagnosis and reducing unnecessary biopsies and surgeries to BI-RADS4a diagnosis. The operators in 2D ultrasound examination of the breast are highly dependent. The operation technique and image discrimination ability of ultrasound doctors with different years of experience lead to poor repeatability among the operators [18–20]. The S-Detect system automatically analyzes a 2D gray-scale image of a breast mass, allowing for more objective identification of a breast mass, regardless of the operator's years of service, experience, resolution, etc. In this study, to our hospital patients randomized to breast ultrasound, diagnostic accuracy was less than 80%. With the help of artificial intelligence, the joint diagnosis accuracy up to 90%, both in the senior and junior doctor. The results reduced the low qualification doctor with high qualification doctor diagnosis efficiency of the differences, thus improving the hospital's overall quality [10].

Elasticity score technology reflects the hardness characteristics of breast masses [21,22]. It uses the elasticity information of breast masses to improve the diagnostic efficiency of ultrasound doctors. The S-Detect technique uses the same physical-acoustic information and diagnostic classification as conventional breast ultrasound complements and optimizes the two-dimensional information of conventional ultrasound. In this study, the elasticity scoring technique was less sensitive than the S-Detect technique, and the accuracy was similar to the S-Detect technique. Still, the combination of the elasticity scoring with routine breast ultrasound was slightly better than the S-Detect technique, possibly due to the complementarity of physical information from different directions.

## 5. Conclusions

In summary, the S-Detect artificial intelligence system can improve breast cancer diagnosis accuracy by ultrasound physicians and improve the quality of routine breast ultrasound diagnosis. In the future, multi-center and more extensive sample size studies are needed to verify the artificial intelligence system's clinical application prospect. The S-Detect technology has its limitations. Its characteristic analysis does not include important information such as blood flow signals, calcifications, and mass hardness, and the system has errors in the identification of masses <1 cm in diameter.

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## Conflict of interest

All authors declare no conflicts of interest in this paper.

## References

1. R. Singh, S. V. S. Deo, E. Dhamija, S. Mathur, S. Thulkar, To Evaluate the Accuracy of Axillary Staging Using Ultrasound and Ultrasound-Guided Fine-Needle Aspiration Cytology (USG-FNAC) in Early Breast Cancer Patients-a Prospective Study, *Indian J. Surg. Oncol.*, **11** (2020), 726–734.
2. I. González-Huebra, A. Elizalde, A. García-Baizán, M. Calvo, A. Ezponda, F. Martínez-Regueira, et al., Is it worth to perform preoperative MRI for breast cancer after mammography, tomosynthesis and ultrasound?, *Magn. Reson. Imag.*, **57** (2019), 317–322.
3. Y. Huang, F. Li, J. Han, C. Peng, Q. Li, L. Cao, et al., Shear wave elastography of breast lesions: quantitative analysis of elastic heterogeneity improves diagnostic performance, *Ultrasound Med. Biol.*, **45** (2019), 1909–1917.
4. M. Di Segni, V. de Soccio, V. Cantisani, G. Bonito, A. Rubini, G. Di Segni, et al., Automated classification of focal breast lesions according to S-detect: validation and role as a clinical and teaching tool, *J. Ultrasound*, **21** (2018), 105–118.
5. T. V. Bartolotta, A. A. M. Orlando, L. Spatafora, M. Dimarco, C. Gagliardo, A. Taibbi, S-Detect characterization of focal breast lesions according to the US BI RADS lexicon: a pictorial essay, *J. Ultrasound*, **23** (2020), 207–215.
6. T. V. Bartolotta, A. A. M. Orlando, M. L. Di Vittorio, F. Amato, M. Dimarco, D. Matranga, et al., S-Detect characterization of focal solid breast lesions: a prospective analysis of inter-reader agreement for US BI-RADS descriptors, *J. Ultrasound*, **5** (2020), 1–8.

7. R. M. Jales, M. T. Dória, K. P. Serra, M. M. Miranda, C. A. Menossi, K. Schumacher, et al., Power Doppler Ultrasonography and Shear Wave Elastography as Complementary Imaging Methods for Suspected Local Breast Cancer Recurrence, *J. Ultrasound Med.*, **37** (2018), 1493–1501.
8. R. Guo, G. Lu, B. Qin, B. Fei, Ultrasound Imaging Technologies for Breast Cancer Detection and Management: A Review, *Ultrasound Med. Biol.*, **44** (2018), 37–70.
9. J. Geisel, M. Raghu, R. Hooley, The role of ultrasound in breast cancer screening: the case for and against ultrasound, *Semin Ultrasound CT MR*, **39** (2018), 25–34.
10. J. Y. Wu, Z. Z. Zhao, W. Y. Zhang, M. Liang, B. Ou, H. Y. Yang, et al., Computer-aided diagnosis of solid breast lesions with ultrasound: factors associated wth false-negative and false-positive results, *J. Ultrasound Med.*, **38** (2019), 3193–3202.
11. A. S. Tagliafico, M. Piana, D. Schenone, R. Lai, A. M. Massone, N. Houssami, Overview of radiomics in breast cancer diagnosis and prognostication, *Breast*, **49** (2020), 74–80.
12. K. Kim, M. K. Song, E. K. Kim, J. H. Yoon, Clinical application of S-Detect to breast masses on ultrasonography: a study evaluating the diagnostic performance and agreement with a dedicated breast radiologist, *Ultrasonography*, **36** (2017), 3–9.
13. E. Cho, E. K. Kim, M. K. Song, J. H. Yoon, Application of computer-aided diagnosis on breast ultrasonography: evaluation of diagnostic performances and agreement of radiologists according to different levels of experience, *J. Ultrasound Med.*, **37** (2018), 209–216.
14. J. H. Choi, B. J. Kang, J. E. Baek, H. S. Lee, S. H. Kim, Application of computer-aided diagnosis in breast ultrasound interpretation: improvements in diagnostic performance according to reader experience, *Ultrasonography*, **37** (2018): 217–225.
15. W. H. Yuan, A. F. Li, Y. H. Chou, H. C. Hsu, Y. Y. Chen, Clinical and ultrasonographic features of male breast tumors: A retrospective analysis, *PLoS One*, **13** (2018), e0194651.
16. S. H. Yeo, G. R. Kim, S. H. Lee, W. K. Moon, Comparison of ultrasound elastography and color doppler ultrasonography for distinguishing small triple-negative nreast cancer from fibroadenoma, *J. Ultrasound Med.*, **37** (2018), 2135–2146.
17. A. Vourtsis, Three-dimensional automated breast ultrasound: Technical aspects and first results, *Diagn. Interv. Imaging*, **100** (2019), 579–592.
18. D. A. Spak, J. S. Plaxco, L. Santiago, M. J. Dryden, B. E. Dogan, BI-RADS(®) fifth edition: A summary of changes, *Diagn. Interv. Imaging*, **98** (2017), 179–190.
19. X. X. Qu, Y. Song, Y. H. Zhang, H. M. Qing, Value of ultrasonic elastography and conventional ultrasonography in the differential diagnosis of non-mass-like breast lesions, *Ultrasound Med. Biol.*, **45** (2019), 1358–1366.
20. B. L. Niell, P. E. Freer, R. J. Weinfurtner, E. K. Arleo, J. S. Drukteinis, Screening for breast cancer, *Radiol. Clin. North Am.*, **55** (2017), 1145–1162.
21. F. Valdora, N. Houssami, F. Rossi, M. Calabrese, A. S. Tagliafico, Rapid review: radiomics and breast cancer, *Breast Cancer Res. Treat.*, **169** (2018), 217–229.
22. F. Taskin, Y. Durum, A. Soyder, A. Unsal, Review and management of breast lesions detected with breast tomosynthesis but not visible on mammography and ultrasonography, *Acta. Radiol.*, **58** (2017), 1442–1447.