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Achievements of artificial intelligence aided diagnosis of breast cancer

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Abstract. Breast cancer has become a major disease threatening women's safety, making people suffer with its high mortality and unbearable pain. The struggle between humans and breast cancer has a history of thousands of years. Even today, with the development of science and technology, breast cancer is still a headache for everyone. The examination and treatment of breast cancer has caused a great medical burden, especially the expensive equipment and examination costs, as well as the test of doctors' professionalism, which makes the poor areas even have insufficient resources to treat. But this struggle has entered a new stage, with the continuous maturity of artificial intelligence and machine learning technology, and the application of artificial intelligence in the medical field, perhaps it can change the current situation. AI can greatly reduce medical costs, and the diagnostic efficiency is much faster than that of doctors. Thanks to AI's low cost and efficiency, the prevention of breast cancer will become easier in the future. This article will mainly introduce AI-assisted diagnosis's achievements in treating and preventing breast cancer in the past four years.

Keywords: Artificial intelligence, breast cancer, medical imaging.

1. Introduction

With the continuous development of technology, people are paying more and more attention to their physical health. From the current medical level, people can completely cure most diseases, but there are still some serious diseases that scientists have not found very effective ways to overcome, such as cancer. Cancer is divided into many kinds, breast cancer is one of them. Before 2020, lung cancer mortality rate is the highest among all cancers. After 2020, breast cancer surpassed lung cancer and became the second highest mortality cancer [1]. Breast cancer accounted for 11.7% of new cases and 6.9% of new deaths [2].

But people are not at a loss when facing cancer. During the long struggle against cancer, scientists and doctors have found that early intervention can slow down the rate of cancer onset and reduce its lethality. Breast cancer is no exception. If we can find signs of breast cancer early and give timely intervention, we can achieve significant results in treating breast cancer. Therefore, early detection and intervention in cancer have become crucial in treating cancer, and determining the ultimate therapeutic effect. Early intervention can effectively reduce the mortality and incidence rate and improve the cure rate [1].

Therefore, how to find the existence of breast cancer early and efficiently and save manpower has become one of the efforts of scientists. Nowadays, there are many mature medical image detection technologies available. Breast cancer can be detected by these imaging techniques: X-ray, ultrasound, and MRI.

X-ray can detect small tumors, so it is more suitable for detecting breast cancer for women who do not feel obvious discomfort [3]. X-ray is a very effective detection technology to reduce breast cancer mortality, even if it will lead to a large proportion of overdiagnosis [1].Ultrasound is also often used for tumor detection, and it is more efficient and cost-effective than X-ray detection. But this is a challenge for operators and requires well-trained operators to perform [1]. Meanwhile, the accuracy of ultrasound imaging is 17% higher than that of X-ray detection [2]. There is also a more high-precision technology called MRI, which performs better than the previous two technologies but is also very expensive.

However, when using these imaging techniques, collecting a large amount of image data is often necessary to obtain diagnostic image data through manual analysis. This significantly increases the workload of diagnostic personnel and greatly tests their professionalism. It has also increased many labor and time costs. In order to solve this situation, the application of AI in processing medical images is very important. Artificial intelligence is an important component of the intelligence discipline and an important tool for developing medical image processing towards intelligence. Research in this field includes robotics, language recognition, image recognition, natural language processing, and expert systems. Since its inception, artificial intelligence has become increasingly mature in theory and technology, and its application fields have expanded. Processing massive medical image data through AI has become a mainstream method and main tool, and has achieved very good results in disease diagnosis and prognosis detection [2]. On the one hand, the introduction of AI greatly reduces the workload of doctors. Moreover, when faced with subtle or blurry image information that is difficult for the human eye to recognize, AI's auxiliary diagnosis and image enhancement functions can also help doctors extract effective information from images, improving the accuracy of diagnosis [1]. On the other hand, a large amount of redundant, fuzzy, and irrelevant information is filtered by AI, which reduces the labor cost of medical treatment and generates excellent socio-economic benefits. This also improves doctors' diagnostic speed and alleviates the medical pressure on society.

This article will introduce and briefly summarize the new research and achievements of AI in medical image processing field since 2019, mainly in AI assisted diagnosis of breast cancer, and the diagnostic performance of the combination of AI and traditional medical imaging methods. This article will not delve too much into the specific technologies of AI in the research, but will focus on the effectiveness of AI application in this field.

2. Several diagnostic methods of breast cancer using AI

The AI technologies mentioned here mainly include machine learning (ML) and deep learning (DL). Machine learning is the process of automatically analyzing data through computers under supervised or unsupervised conditions, discovering certain patterns, and then using these patterns to predict the trend of data changes to guide production [4]. Generally speaking, the larger and more regular the dataset, the better the effectiveness of machine learning. Deep learning is a very important direction in machine learning. Deep learning aims to learn the deep rules of sample datasets, which can better process information in medical image signals. Ultimately, it achieves the function of discovering anomalies and diagnosing diseases like a doctor [4]. In the following, we will discuss in detail how artificial intelligence plays a role in the three main breast cancer diagnosis methods and gradually becomes an important part of modern medical imaging technology.

2.1. AI and mammography

The X-ray examination of the breast mainly uses a technique called breast molybdenum target for imaging examination. Breast molybdenum target imaging is basically not limited by age, and has high

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repeatability, relatively high accuracy, and low cost, making it a non-invasive technology. In a study comparing the accuracy of molybdenum target and MRI, 50 patients with breast cancer and 60 patients with benign breast tumor were tested, and the accuracy reached 79.37% and 87.3% respectively [5].

The combination of AI technology and breast X-ray can improve the diagnostic speed and accuracy to a new level. A study on 114421 female breast X-ray image samples showed that the specificity of mammography with AI participation was only slightly improved compared to without AI participation. However, out of these 114421 images, 71585 were independently completed by AI without the participation of doctors, which means the workload of medical students was reduced by 63%. And 25% of false positives were avoided, with a total of 2107 false positives in all image samples, of which AI and misdiagnosis recognized 529 was avoided [6].

The main purpose of this study is to score each sample through AI. A low score is considered to be a low risk of breast cancer, rather than being sent to a doctor for examination. A high score is considered as a high risk of breast cancer and will be sent to the doctor for further examination. This kind of AI participation is to help doctors exclude people with low breast cancer risk, so that doctors only need to diagnose people with moderate or higher risk. Because the diagnostic difficulty of low-risk populations is low, AI can be used to avoid excessive occupation of doctors' time. The result of this method for the sample is that 791 of 114421 participants (excluding the abnormal part of the data, the abnormal part of the data has been eliminated) were diagnosed with breast cancer, 327 with interphase cancer, 1473 with long-term cancer, and 111830 with health. The probability of false positive in AI testing is about 2.5%, which is higher than the 1.8% false positive probability in manual testing. Figures 1 and 2 show the experimental results of the artificial group and the AI group, respectively [6].

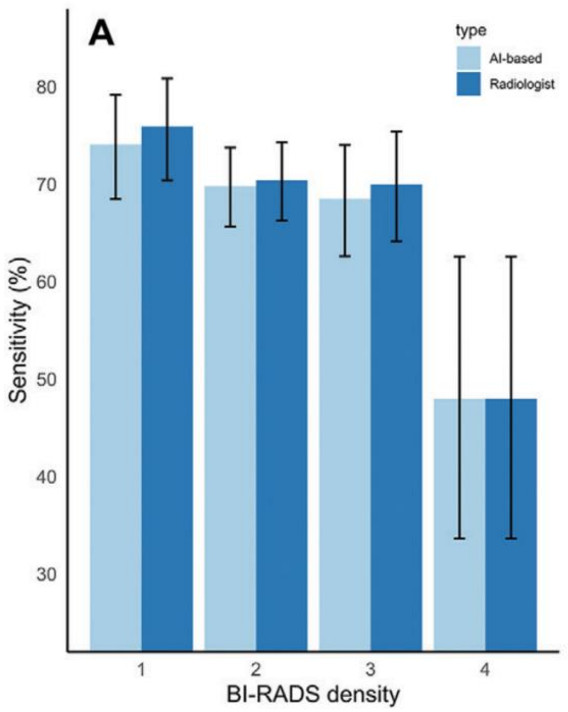

Figure 1. Bar graph shows a comparison of measured radiologist and artificial intelligence-based screening sensitivifies [6].

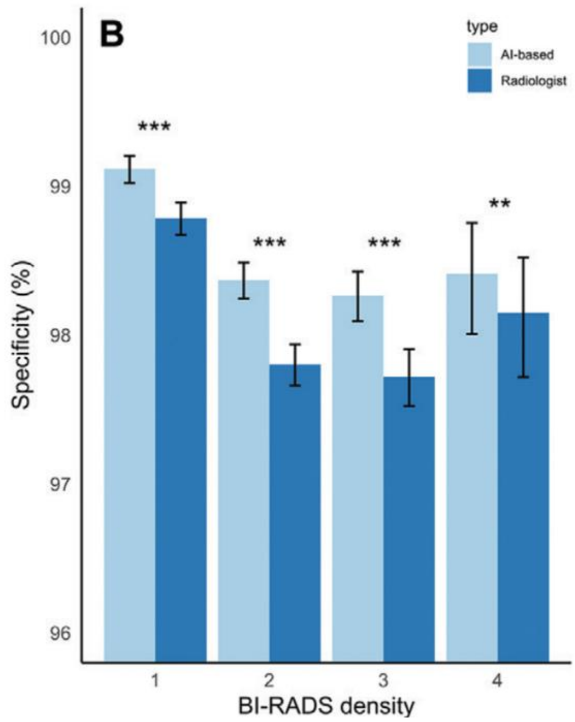

Figure 2. Bar graph shows a comparison of measured radiologist and AI-based screening specificities [6].

However, even though AI has made accurate diagnoses and predictions of the results, most AI cannot provide a corresponding and reasonable explanation for the diagnosis, which means that AI does not know the reason why they make such judgments themselves. Given that the medical field is

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highly sensitive, all doctors cannot fully adopt AI diagnosis. So, allowing AI to use natural language to explain the reasons for diagnosis will undoubtedly accelerate the pace of intelligence in the medical field. The following will present a study on using AI to extract features of breast tumors and convert them into natural language output, which is to use human language to explain what information AI reads from images and make diagnoses [7].

This study used convolutional neural networks and deep neural networks to construct an AI model, but this article will focus on the data and results without excessively explaining the model. In this study, it is believed that breast cancer has a total of 21 characteristics, and the sample data provided includes 878 data, including 611 cases of sarcoma, that is, benign, and 267 cases of cancer, that is, malignant [7].

This study constructed a total of six different models and identified and explained these 21 features, ultimately resulting in a ranking table of the recognition efficiency of the six models for different features.

Table 1. Feature importance ranking [7].

Feature	RF	XGBoost	GBDT	SHAP	TabNet	Causual-TabNet
Skin	15	10	19	21	3	16
Areola	6	3	4	2	8	8
Nipple	16	11	14	11	10	19
Subcutaneous fat	20	12	21	12	16	20
Gland morphology	5	12	8	13	18	18
Gland edge	12	1	3	1	7	3
Increased gland density	10	14	20	10	4	14
Gland shape	19	15	16	15	14	9
Gland distribution	9	9	7	8	21	5
Calcification	21	16	18	16	20	13
Lesion type	13	5	15	6	2	8
Quantity	11	4	9	3	13	10
Position	1	7	1	7	11	17
Shape	2	8	2	5	9	21
Long side	7	6	11	9	5	4
Area	8	17	6	17	1	6
Aspect ratio	4	18	10	18	15	15
Boundary	18	19	13	19	19	1
Edge	3	20	5	20	12	11
Density	17	2	12	4	17	12
Lymph nodes	14	21	17	14	6	2

As shown in Table 1, a lot of information can be obtained. Different models have their advantage intervals, and combining multiple models can be used to achieve better recognition results. For example, boundary feature recognition of tumors is very important for the judgment of benign and malignant tumors, as the edges of benign tumors are smooth, while those of malignant tumors are sharp and have burrs. Finally, by outputting it into natural language, the interpretability of AI in medical image diagnosis can be improved. This interpretability increases the credibility of AI, makes

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AI training easier, and reduces the workload of doctors, which is conducive to improving the social acceptance of artificial intelligence medicine [7].

2.2. AI and ultrasound

Compared with mammography, ultrasound examination for non-prophase breast cancer is more effective. Moreover, for some women with dense breast distribution, the misdiagnosis rate of breast X-ray is over 50%, while the accuracy and specificity of breast ultrasound are very good, and the results have high repeatability and relatively low cost [8]. As early as 2017, Han et al. trained a model that used convolutional neural networks to detect suspicious lesion areas and achieved good results [9]. This has proven the feasibility of AI and deep learning in assisting in diagnosing ultrasound images. Meanwhile, a contrast-enhanced ultrasound technique using micro bubble contrast agents can provide more detailed information than traditional B-mode ultrasound, including the morphological distribution of tumor blood vessels [10].

The following will describe a study on AI assisted diagnosis based on this microbubble contrast-enhanced ultrasound. These studies included 68 cancer cases and 119 benign tumor cases. By training AI models to analyze the image features of tumors and classify benign and malignant tumors. At the same time, there will also be professional doctors to classify AI, as a criterion for evaluating the accuracy of AI classification. This study used five AI models and three fusion models, and the diagnostic specificity working curve obtained is shown in the following figure [8].

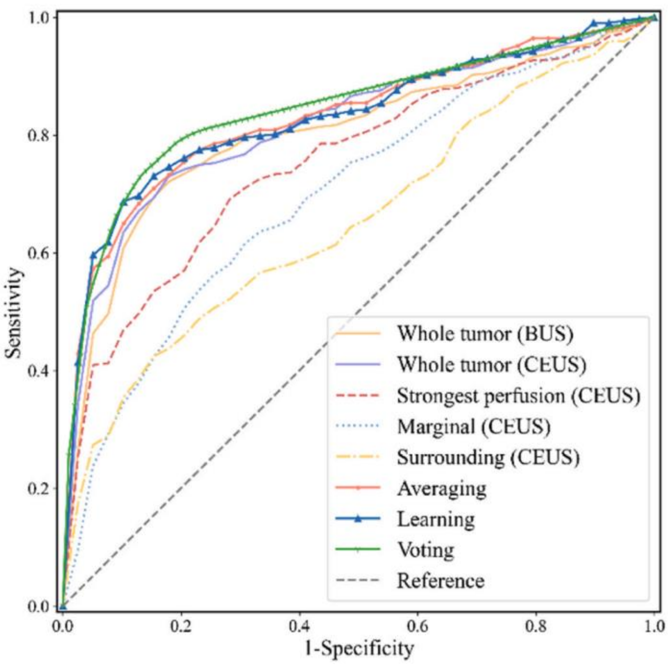

Figure 3. Receiver operating characteristic curves of five single-region models and three fusion models [8].

The data in Figure 3 shows the recognition and diagnostic efficiency of different models for different regions, as well as the diagnostic efficiency of the three fusion models. It can be concluded that the fusion model is usually better than the single model, in which the AI classification of multiple models for bisexual and malignant tumors has good development prospects. Here, the researcher also mentioned that such models may apply to the classification of breast cancer and other diseases that need to recognize image features. This AI assisted classification method has great help in improving medical conditions, especially in underdeveloped areas. However, this study also has a problem with a small sample size, and further validation of the model's feasibility is still needed.

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However, there is a problem that deep learning requires a large number of breast cancer picture materials as a database to achieve good results. If doctors are asked to provide AI with artificial data sets, this will cause serious workload [11]. However, one study shows that metastatic learning can achieve good results in diagnosing breast cancer.

Transfer learning is also a method of deep learning, but it does not rely on a large amount of data like deep learning, and even if the dataset is nonlinear, transfer learning can achieve good results. Specifically, through previous learning, even if the previous learning is not closely related to the current task, transfer learning can inherit some experience and knowledge from the previous learning, thereby reducing the learning cost of the current task. Just like human learning, it is a continuous process. This technology is particularly helpful in digital signal and image processing [12].

The dataset for this transfer learning study comes from 100 images of benign tumors and 100 images of cancer in public databases. Two different transfer learning models are used for AI diagnosis: the traditional transfer learning model(CTL) and the multi-stage transfer learning model(MSTL). This study also used three convolutional neural network optimizers, SGD, Adam, and Adagrad. And compare the diagnostic performance of these two models, as shown in the figure [11].

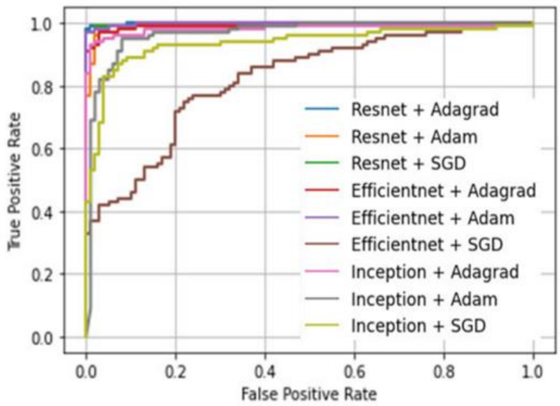

Figure 4. Multistage transfer learning ROC curve[11].

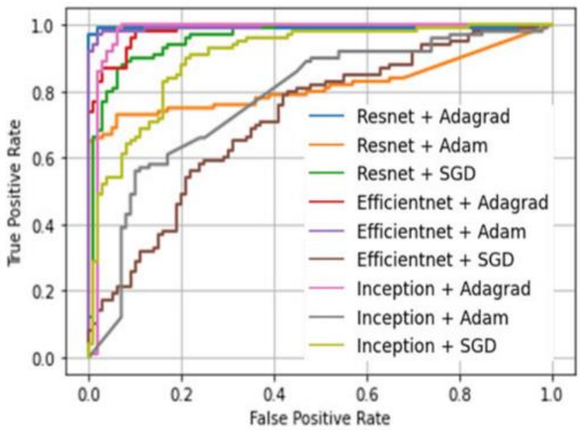

Figure 5. Conventional transfer learning ROC curve. SGD: Stochastic gradient descent[11].

The information read from the Figure 4 and Figure 5 found that the diagnostic performance of multi-stage transfer learning is significantly superior to traditional transfer learning. The significance of this study is that through a small number of breast cancer data sets, it has achieved superior diagnostic performance compared with other AI models in the same period. The cancer cell images used for transfer learning are easy to obtain and can be automatically preprocessed, so this project reduces the time and labor costs required for model training and the requirements for hardware performance. And it can improve clinical decision-making, allowing patients to avoid suffering. However, there is currently a problem of AI suddenly forgetting the learning progress in transfer learning technology, which still needs improvement [11].

2.3. AI and MRI

MRI technology has a better accuracy rate in detecting breast tumors. In detecting 53 patients with breast cancer and 61 patients with benign breast tumors, the accuracy rate reached 84.13% and 90.48% respectively. If combined with other technologies, it will achieve a higher accuracy rate [5]. But MRI technology is often used for detecting severe cases due to its high cost. However, it can provide extremely high resolution, so MRI images are a suitable dataset for AI training [13].

The research introduced below also uses transfer learning methods to further improve AI-assisted MRI diagnosis's specificity. This study used five transfer learning AI models to analyze and diagnose three cancer features. The study sample was 174 breast cancer patients. Similar to the previous transfer learning, it also helps reduce the demand for sample size in the dataset through previous learning of AI. The final results of this study are shown in Figure 6 [14].

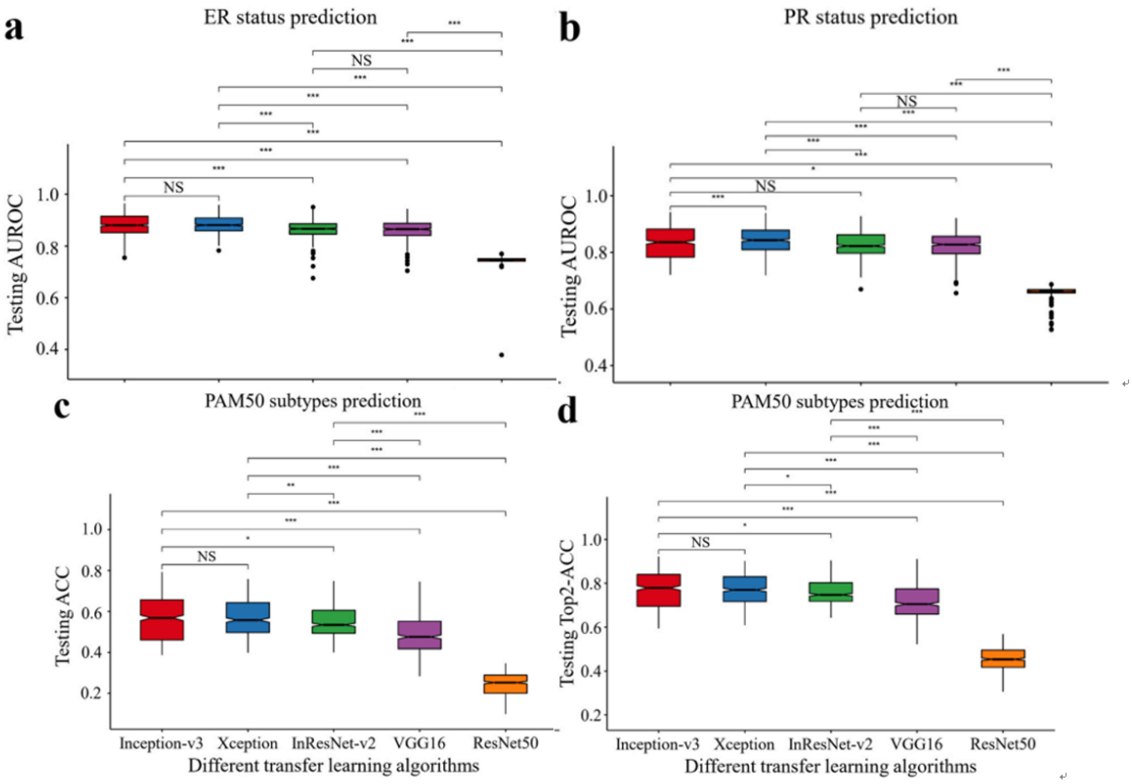

Figure 6. The impact of different transier learning algorithms on model performance [14]

Overall, we can see that the diagnostic performance of this exception model is better than other models. However, the diagnostic effect of PAM50 subtypes is not very good and cannot reach the medical level, even if it is superior to other models. Overall, this study can demonstrate the high medical value and feasibility of the xception model. Moreover, this study has low hardware performance requirements and even has the potential to be used on low-performing devices such as mobile phones [14]. At the same time, it also indicates that MRI technology can be combined with AI to assist medical diagnosis, which has good development prospects and may reduce the high cost of MRI technology.

This is significant for some women with a family history of breast cancer. The breast density of such people is higher than that of ordinary people, which means that the effect of ultrasound and X-ray is not good for such people. The advancement of MRI technology will benefit these people [13].

3. Conclusion

This article reviews and summarizes the research of AI in the field of auxiliary diagnosis of breast cancer in the past four years, and finds that AI has made some achievements in this field and has great potential for development. From the previous research data, some AI models reduced the workload of doctors by more than 60%, which greatly reduced the workload of doctors and improved the diagnostic efficiency of breast cancer. Moreover, breast cancer is a disease with a good early prognosis. Improving efficiency also reduces the cost of breast cancer prevention and increases social welfare. However, AI-assisted diagnosis of breast cancer is still not very mature, and many aspects must be improved. For example, a public breast cancer sample database can be built with the patient's permission to reduce the training cost of AI model and avoid AI training difficulties caused by insufficient data. Moreover, there is a slight gap in the accuracy and specificity of AI diagnosis compared to professional doctors, and it may be necessary to optimize the model's algorithm or a larger sample database to achieve higher accuracy and specificity. Building an open database also helps AI validate its diagnostic performance for later improvement. Finally, people are often very concerned about their own diseases and unwilling to let AI diagnose them. Therefore, after the technology matures, it is necessary to improve the social credibility of AI to reduce patients' resistance.

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