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Application of Artificial Intelligence in Breast Medical Imaging Diagnosis

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ABSTRACT

According to the latest report on urban cancer in China published in 2017: China is one of the countries with the fastest growing incidence of breast cancer, and the age of onset has gradually become younger. Newly diagnosed breast cancer patients in China account for 12.2% of new breast cancer patients worldwide, and the mortality rate is 9.6%. A large amount of clinical experience has proven that the survival rate of breast cancer detected at an early stage is significantly higher than that detected at an advanced stage. Imaging examination is an important method for early detection of breast cancer. With the advent of the Artificial Intelligent, the method of AI + medical imaging has been widely used in lungs, breasts, heart, skull, liver, prostate, bones and other parts. Methods used in breast cancer screening include: breast self-examination and clinical physical examination, mammography of mammography of the breast, ultrasound of the breast, and magnetic resonance imaging (MRI) of the breast. The advantages and disadvantages have been reflected in the development and application in recent years. This article will review the advantages and disadvantages of combined diagnosis of AI and breast medicine. It is hoped that the artificial intelligence of medical imaging screening for breast diseases has a brighter and broader prospect.

Keywords: Breast; Medical imaging; Artificial intelligence (AI); Advantages and disadvantages

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1. Introduction

The incidence of breast disease, especially breast cancer, remains high worldwide. Breast cancer is the second most common cause of cancer in women and the sixth most common cause of cancer [1]. In China, the incidence of breast cancer ranks first among all cancers, and the mortality rate ranks fourth [2]. According to the type of breast parenchyma, the breasts are divided into: fat type, scattered fibrous gland type, uneven and dense type, and dense type. Asian women have a higher percentage of breast glands than European women. A survey of Korean women shows that women with high breast density account for 78.3% in the 40-44 age group, 61.1% in the 50-60 age group, and 30.1% in the 50-54 age group [3]. In the United States, only 43% of women between the ages of 40 and 74 have high mammary gland density, and most are glandular rather than dense [4]. High-density breasts can block deep masses, making it difficult to detect lesions [5].

2. Imaging diagnosis of breast disease

Screening for early breast cancer is preferred for mammography. Mammography is most sensitive to the detection of microcalcifications. However, experiments in many people and regions have widely proved that its detection rate of breast cancer in patients with dense breasts is much lower than that in patients with fatty breasts [6]. And the population of women with high-density breasts in China is larger than that in Europe and the United States, which makes it difficult to screen for early breast cancer. Ultrasound of the breast is often used as a combined examination method of X-ray examination of the breast. Due to its good soft tissue resolution, the detection rate of dense intra-mammary lesions is improved [7], and the price is low, the operation is real-time and widely used. But the ultrasound examination relies on the examiner's personal operation ability and subjectivity. The non-repeatable and uncontrollable images bring uncertainty to the detection of the disease. Therefore, exploring standardized, reproducible, and quality-controllable breast ultrasound scans and diagnostic methods, while fully applying ultrasound diagnostic techniques, and multi-dimensional evaluation of lesion information are currently important methods to solve the diagnosis of breast diseases in Chinese women. Breast MRI, as a supplementary diagnostic aid for mammography and ultrasound, has a higher sensitivity for detecting small lesions and high-density glandular lesions. But it is expensive and time consuming, and it is not suitable for breast cancer screening. More efficient, fast, and affordable early screening devices of breast cancer used to reduce the risk of breast cancer mortality in the population is urgent.

3. Development of AI

China has a large population base, imperfect patient shunting mechanisms, and uneven distribution of medical resources. Patients are mostly concentrated in medium and large hospitals. And with the increase in national recognition for disease prevention, more and more people are primarily diagnosing physical illnesses through imaging examinations. The increase in imaging physicians has been slow. As a result, the workload of imaging physicians is increasing. Studies have shown that digital mammography can take twice as long as radiography [8]. The advancement and development of AI in breast medicine can alleviate these problems to a certain extent.

The application of artificial intelligence technology in medical imaging inspection was first started by the American scholar Ledley. "Computer Aided Diagnostic System (CAD)": through the combination of image processing, computer vision effects, image analysis, etc. to capture data, and compare it with normal data, Find out the abnormal location and mark it [9]. Then it's followed by imaging genomics and imaging genomics. Imaging science includes: image acquisition, image segmentation, feature extraction, quantitative analysis, and model construction. A high-throughput feature extraction algorithm is used to quantitatively analyze the image, fully excavate and analyze the additional information hidden in the image, and make the most efficient use of the results of the imaging inspection [10]. The combination of convolutional neural network (CNN) and transfer learning can shorten the data training time, reduce the amount of data and processor requirements, and improve diagnostic accuracy [11]. Today, deep learning in the branch of machine learning is an innovation in medical imaging AI technology. Deep learning can automatically extract three-dimensional, abstract deep features, realize end-to-end learning, and realize the rapid development of artificial intelligence [12]. It can be applied in: 1. Detection of diseases: early screening, reducing the rate of issued diagnosis. 2. Multi-angle measurement: comprehensive and accurate extraction of lesion features at different angles. 3. Accurate diagnosis: including benign and malignant judgments of disease, staging, and typing. 4. Treatment evaluation: preoperative design, postoperative evaluation, recurrence and prognosis prediction, and auxiliary radiation target area delineation [13].

4. Application of AI in medical imaging

4.1 Uneven data equality

Although the number of patients in China is large, the data are theoretically very large. However, the image quality of various hospitals and medical institutions is poor, the amount of data collected is insufficient, the data is unstructured, and medical data is difficult to share. Algorithm reconstruction between different devices, parameter settings are inconsistent. The same device is using different contrast agents, and the inconsistencies in the amount of contrast agents lead to high quality and lack of labeled data resources. All bring difficulties to the artificial intelligence of medical imaging.

4.2 Limitations of artificial intelligence technology

Relying on deep autonomous learning, the use of large-scale neural networks causes its inherent unpredictable complexity and opacity to be unknown [14]. Moreover, the current deep learning uses a large number of existing data samples to analyze and predict the newly detected data, and the input data has the subjective willingness of the doctor to diagnose and treat, and the data is enlarged in the algorithm to cause data Bias [15].

4.3 Laws and regulations social ethics

Medicine is different from icy intelligent technology. It is a special service industry with ethical and humanistic care. There are currently no clear laws and regulations on the collection and processing of data, the storage, management, and privacy of large amounts of data. Privacy breaches include proactive leaks by organizations and medical institutions and passive theft of data in the cloud. While medical imaging intelligence reduces the workload of doctors and brings the gospel to patients, problems must also occur. For example, are the false positives and false negatives of the diagnosis and treatment results the responsibility of the technology itself, the technology company, the imaging doctor, or the attending doctor? How much is the patient trust and acceptance of AI screening results? Therefore, the information security and patient privacy protection in AI medical applications, and the division of responsibility for accidents will face great challenges. There is an urgent need to establish corresponding laws and regulations and ethical regulations to effectively supervise information collection, transmission, storage and application.

5. Advantages and disadvantages of AI applied to breast imaging

The inconsistencies in the development stages of AI in breast medical imaging diagnosis and treatment lead to the advantages and disadvantages of AI in mammography, ultrasound, and MRI compared with traditional reading.

5.1 AI for mammography

The study of AI in mammography was first applied to X-ray photography and also the most widely used. A commercially available AI system (Transpara, version 1.4.0; Screenpoint Medical BV) performed a stratified examination of 2,654 mammographic examinations. The inspection results are divided into 1-10 points. If the physician only reviews the results of 6-10 points, 47% of the workload can be saved. The 0-5 score was classified as normal, and the cancer missed diagnosis rate was only 7% [16]. Breast cancer screening programs periodically assess whether the diagnostic performance of the device can accurately detect cancer (true positive) or missed diagnosis (false negative). In some areas marked by the screening equipment as abnormal, further inspection is performed to confirm. And the negative criterion was: no abnormalities were found in the screening, and no cancer was found after one year. It's considered to be truly negative [17]. A Google-funded study collected two dataset pairs from the United Kingdom (25856 cases, mammograms from 2012 to 2015) and the United States (3097 cases, mammograms from 2001 to 2018). The AI model was tested and found that it reduced the number of false negatives and positives compared to radiologists [18]. AI applied to mammography can improve the sensitivity and specificity of original photography, especially for dense breasts. And save the radiologist's reading time, reduce the workload of the radiologist.

However, KOLB et al. [6] found that gland density is the only factor that affects MG sensitivity. In patients with non-compact breasts, mammography misses 2% of breast cancer, but in patients with dense breasts, MG 52% or more were missed. In the Digital Mammography Screening Test (DMIST), 49,528 women were recruited in 33 locations in the United States [19]. The trial found that the overall diagnostic accuracy of digital and screen mammography is the same. Only women under 50 years of age, premenopausal or perimenopausal, or with dense breasts could improve the diagnostic performance. The clinical efficacy stratified evidence model of Fryback and Thornbury[20] proves that digital mammography can detect more grade 1 and 2 invasive cancers, but not more grade 3 invasive cancers. Except for the limitations and immaturity of the technology itself, most experimental mammography systems were taken from one manufacturer. The input of data also has the subjective willingness of the clinician and so on, which makes it difficult to apply AI to mammography.

5.2 AI for breast ultrasound

Artificial intelligence is increasingly being used in the field of ultrasound. However, there are currently no clear guidelines recommending the combination of ultrasound and artificial intelligence for clinical practice. The application of AI to artificial intelligence as an auxiliary means of X-ray photography has better tissue resolution and is more sufficient to find more early small breast tumors. A collection of 2018 breast ultrasound image datasets of 600 25-75-year-old American female patients was used for machine learning model training. This model can classify, detect, and segment early signs of breast cancer lumps or microcalcifications [21]. But handheld ultrasound still cannot avoid the limitations of the operator, which brings uncertainty and non-reproducibility of the image. In the future, ultrasound will improve the accuracy of AI to distinguish benign and malignant breast lesions.

Not only can B-mode ultrasound images be used, but also other advanced technologies can be combined, such as ultrasound automatic breast full volume imaging, elastography and contrast-enhanced ultrasound [22]. It has been reported that analysis using a random forest-trained classifier shows that up to 75.9% of the BI-RADS Class 4 and 5 lesions that were later identified as benign have the potential to avoid biopsies Capacity, while tumor screening sensitivity reached 98%. Classifiers based on the BI-RADS category combined with elastography and QUS function perform best on BI-RADS categories 4 and 5 [23]. After reading a lot of relevant literature, I found that the related research and articles combining AI and breast ultrasound are rare compared to X-ray photography. The manual nature of ultrasound examination has become a difficult problem in data collection and data validity. The recent rapid development of automatic breast ultrasound (ABUS) means that multiple US images of the breast are collected and stored for post-oricessing, that is, 3D and multi-plane reformatting for later reading and evaluation [24]. It standardizes scans, better detects small lesions, especially in patients with dense breasts, and reduces scan time. In 2018, Chiang et al. [25] combined 3D CNN and ABVS to diagnose benign and malignant breast suspicious lesions. The model can extract features from spatial and temporal dimensions and then perform 3D convolutions to capture motion information from multiple consecutive frames. It is believed that with the development of more high-tech examination technology, artificial intelligence will be applied more quickly and effectively to breast ultrasound.

5.3 AI for breast MRI

Magnetic resonance imaging is radiation-free, and it can perform multi-parameter and arbitrary section imaging on different tissues. The contrast and resolution are very high, and it can be applied to various diseases of the human system [26]. However, breast ultrasound is not routine because it is expensive and time consuming. However, it has high sensitivity for screening for breast malignancies. The NCCN guidelines recommend that MRI can be used as a supplementary method for early screening of breast cancer in women with high risk factors such as chest radiation history, genetic susceptibility, and family history [7]. Agha et al used CAD software to check the sensitivity of multiple newly developed 3T MRI breast sequence software to reduce unnecessary biopsy or surgery. The study included 120 female patients, all of whom had suspicious or malignant X-ray findings. Results Compared with the biopsy results, the sensitivity was 93.1% and the specificity was 90.9%. It is shown that 3T MRI breast CAD is a very sensitive imaging tool [27]. XU et al. Achieved breast segmentation in CNN dynamic contrast enhanced magnetic resonance imaging in 2018[28]. Since then, more automatic models have been developed for automatic segmentation of tumor regions. Dalms et al [29] used CNN with 3C U-net topology breast fat, glands and non-fibrous structures in dynamic enhanced MRI. The average Dice coefficient obtained was 0.933, and the correlation with breast density compared with manual segmentation was 0.974. It shows that the related CNN model can distinguish the breast structures with different densities well. Ma et al [30] experiments show that the Dice coefficient of the YOLOv2 + SegNet model and the segmentation result of the SegNet network is improved by around 10%. Compared with the traditional CV model, fuzzy C-means clustering, spectral mapping active contour model and the deep model U-net and DeepLab, the improvement is more obvious. Due to the high contrast and resolution of magnetic resonance imaging, its data can be widely used in non-screening fields. For example: predict the probability of complete remission of different pathological types of breast cancer after surgery [31]. Use neural network to predict whether breast cancer patients have ipsilateral axillary lymph node metastasis [32]. It can be seen that artificial intelligence has a bright prospect for breast MRI, but it must overcome the shortcomings of small data samples.

6. Conclusion and outlook

It is undeniable that China is still in the era of weak artificial intelligence, but the continuous progress of artificial intelligence technology is causing great collisions in areas such as society life, technology, and medical treatment. Due to the increasing incidence of breast disease and the increasing need for screening, the global economic strength has improved and artificial intelligence technology has advanced. Among them, AI medical imaging has become the most mature field in the medical industry. Imaging screening using artificial intelligence for breast diseases has also become a hot research topic. The three methods of combining AI with breast medical imaging diagnosis have their advantages and disadvantages. As the main screening method for breast disease, mammography is the branch with the longest research, the deepest and the most promising. Ultrasound, as an auxiliary inspection method, causes non-repeatable and non-standard images due to its manual operation, which makes it difficult to use artificial intelligence. However, its good soft tissue resolution, display of blood flow signals, and convenience of examination are all helpful for the diagnosis of dense breast disease and should have a broader prospect. The multi-plane, multi-function, ultra-high sensitivity and specificity of MRI are great advantages, but the expensive examination price is a major problem in obtaining data at present.

I think the artificial intelligence of breast medical imaging in the future should focus on the following points. One: To solve the problems of huge input data irregularity, uneven data quality, standardization of the black box middle segment algorithm, construction of an effective model, and validity of the output end. Two: Set the position of the imaging physician in the intelligent age right. Is the diagnosis or treatment process mainly or a secondary job? How to regulate the responsibilities when problems arise? The panic causing the loss of imaging doctors leads to a shortage of imaging talents? Three: Multi-disciplinary talent training. China has only begun a national strategic layout of artificial intelligence until 2016. At present, there is very little input and output of interdisciplinary talents [33]. It is hoped that in the future, imaging talents will be able to embrace artificial intelligence technology frankly, economically and quickly improve the early diagnosis rate of breast cancer and even benign breast diseases, maximize the effectiveness of treatment, and create better conditions for patients!

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