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Applications of AI (Artificial Intelligence) in Diagnosis of Breast Cancer

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Abstract

Breast cancer is a leading cause of cancer-related deaths worldwide. Early detection and accurate diagnosis are crucial for improving patient outcomes. Artificial intelligence (AI) has emerged as a promising tool in the fight against breast cancer. This research report explores the potential applications of AI in various stages of breast cancer management, including **early detection, diagnosis, treatment planning, and prognosis prediction.** AI algorithms can analyze mammograms and other imaging data to identify suspicious lesions with greater accuracy than traditional methods. Additionally, AI-powered tools can assist in the classification of breast tumors, helping to determine the most appropriate course of treatment. Furthermore, AI can be used to predict the likelihood of recurrence and metastasis, enabling personalized monitoring and follow-up care. This research report presents a comprehensive review of the current state of AI in breast cancer research and highlights the potential benefits and challenges associated with its implementation. By leveraging the power of AI, healthcare providers can improve breast cancer outcomes and enhance the quality of life for patients.

Introduction

The cancer burden in the United States was projected to be 1.7 million new cases and 0.6 million deaths in 2019. (Huang et al., 2020). According to the study conducted by Broach et al., 2016 showed that the risk of breast cancer has increased rapidly. Increased use of modern laparoscopy surgery, robotic surgery, tumor adjuvant therapy, and other new technologies has become crucial in improving survival and reducing local recurrence in light of the rising incidence rate of cancer and its mortality. Delayed detection leads to a decline in quality of life (QOL) and ultimately results in death as the primary cause. (Bhattacharya et al., 2022) A tool that assists in analyzing mammograms with the help of a computer could be extremely beneficial. It could effectively filter out the typical cases, leaving only the doubtful cases for radiologists to examine. (Hazarika & Mahanta, 2018) With the rising prevalence of breast cancer, it is important to focus on developing easier and more efficient ways to detect breast abnormalities early on. This can result in early treatment, reduced costs, and better health outcomes following treatment. (Gangadharan et al., 2023) In developed nations, mammography is utilized for screening the population. Regrettably, mammography is costly and requires a significant amount of resources, including infrastructure to connect screening with further diagnostic procedures. Furthermore, breast cancer often appears in women under 45 years old in low- and middle-income countries (LMICs), where mammography is not advised for screening due to reduced accuracy. There is a pressing need for early detection approaches that do not rely on mammographic screening. (Clanahan et al., 2020) AI systems can operate with greater efficiency and improved dependability, and for extended periods compared to human workers who are compensated for their services. This area of innovation is crucial for healthcare organizations facing staff shortages, rising demand, and tight budgets. Specialists in the field have outlined the extent of AI in tackling long-standing shortcomings in healthcare and enhancing patient care. (Arora, 2020).

Problem Statement:
According to the latest report published by the World health organization found that around 2.3 million women diagnosed with breast cancer and approx. 6,70,00 women died globally due to breast cancer. The report indicates that Breast cancer is a leading cause of mortality among women across the globe but also presents a significant financial burden due to the expensive cost of treatment. The high costs associated with screening, particularly through mammography, make early detection and treatment inaccessible for many women, particularly those belonging to economically disadvantaged backgrounds. The financial barriers to screening contribute to delayed diagnoses and higher mortality rates. Given the potential of Artificial Intelligence (AI) to enhance the cost-effectiveness and accessibility of breast cancer screening, it is imperative to explore how AI integration could address these challenges and improve outcomes for women worldwide.

Research Objectives:
The primary objective of this study is to evaluate the potential of Artificial Intelligence (AI) in reducing the costs associated with breast cancer screening, with a particular focus on mammography.
Additionally, the study aims to explore the challenges and barriers to implementing AI-driven breast cancer screening solutions on a global scale.

Research Questions:
Based on the research objectives the researchers frame the following questions.

a. How can Artificial Intelligence (AI) improve the accuracy of predicting and diagnosing different types of cancer, specifically breast cancer?
b. What is the impact of AI-integrated breast cancer screening on early detection rates and patient outcomes?
c. What are the potential challenges and barriers to implementing AI in breast cancer screening globally?

Literature Review:
The applications of AI (Artificial Intelligence) in Health care Sector:
AI has emerged as a transformative force in the medical field, offering new possibilities for improving patient care, enhancing diagnostic accuracy, and optimizing treatment strategies. The application of AI in medicine spans various domains, including diagnostics, treatment planning, personalized medicine, and healthcare management. One of the most prominent areas where AI has made significant strides is in diagnostic imaging. AI algorithms, particularly deep learning models, have demonstrated exceptional capabilities in analysing medical images. For example, a study by Esteva et al. (2017) showed that a deep-learning algorithm could classify skin cancer with a level of accuracy comparable to that of experienced dermatologists. Similarly, McKinney et al. (2020) demonstrated that an AI model outperformed radiologists in predicting breast cancer from mammograms, highlighting AI's potential to enhance early detection and reduce diagnostic errors. AI helps to revolutionize medicine by improving diagnostic accuracy, enabling personalized treatment, and enhancing patient outcomes.

Concept of AI (Artificial Intelligence)

The concept of artificial intelligence (AI) was first introduced in 1956. The objective of AI was to create machines capable of reasoning and solving complex problems, similar to human cognitive abilities (Huang et al., 2020). AI is typically defined as a computer system's ability to perform tasks involving problem-solving, reasoning, and learning. Among these, autonomous learning is particularly crucial as it reduces the need for constant human intervention to improve system performance (Arora, 2020). AI research has since expanded into various subfields, including expert systems, machine learning, evolutionary computing, fuzzy logic, computer vision, natural language processing, and recommendation systems (Huang et al., 2020).

AI also holds significant potential for enhancing medical devices, especially by working synergistically with robotic technologies to accelerate and broaden their advancements. Recognized as "Software as a Medical Device (SaMD)," AI is increasingly gaining attention from regulators (Arora, 2020). In recent years, AI, particularly machine learning and deep learning, has become more integrated into clinical cancer research, leading to significant breakthroughs in predictive performance (Artificial_intelligence_in_healthcare_0119.Pdf, n.d.). AI is known for its remarkable accuracy in aiding cancer diagnosis and prognosis, often surpassing traditional statistical methods in oncology (Hazarika & Mahanta, 2018; Tran et al., 2019). AI can be used to analyse multifactorial data from various patient examinations to more accurately predict cancer outcomes, including survival time and disease progression (Huang et al., 2020).

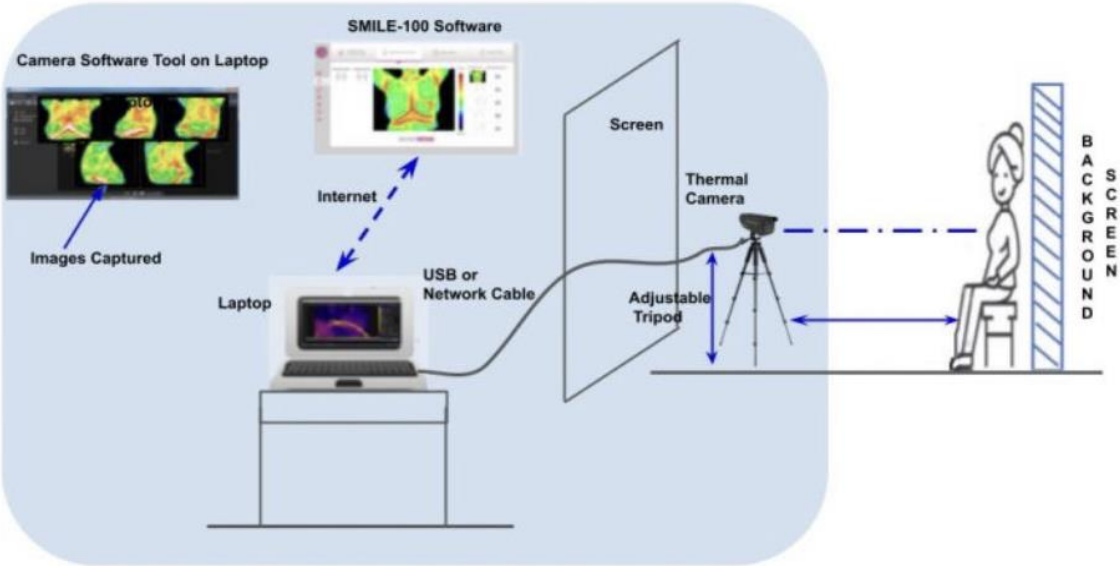
Ethical Consideration Of AI:

To lessen the disparities between the beliefs and objectives of communities and individuals, the ethical concerns of applying AI in healthcare must be considered. (Čartolovni et al., 2022)These may incorporate focuses such as: fairness and equality, under which experts must act within the best interface of their patients, considering the four prerequisites beneath Jonsen's system of common moral issues; Privacy and identity, as technologies such as Brain Computer Interfaces (BCI) raise concerns about the privacy, identity, agency and equality as it involves a direct link between neuronal tissue and artificial devices, emphasising the vitality of avoiding negative consequences; Benefit-risk assessment, this involves assessing the benefits and risks of AI, BCI and robotics to individuals; Guidelines and governance, due to the rapid advancements being made within the field of AI and its applications in healthcare, it is troublesome to to set moral rules for it; Medical Intentions and Patient Preference, understanding how different patients prefer and perceive AI products and understanding their quality of life; trustworthiness and reliability, enabling trustworthy frameworks requires an ethical global framework that elaborates on the roles of government in ethical reviewing and the roles of stakeholders within the moral administration framework; data privacy and security, securing patient data protection and security are pivotal to empower the trust required to interweave AI within the medical field. ("Artificial Intelligence in Healthcare and Medicine," 2019) (Ho et al., 2019) (Mahomed, 2018)

Niramai:

Artificial intelligence has been used by two new companies, UE Life Sciences and Non-Invasive Risk Assessment with Machine Intelligence (Niramai), to create systems that accurately evaluate and identify breast cancer. NIRAMAI has created a new artificial intelligence-driven medical tool that can identify breast cancer far sooner than self-examination or conventional techniques. They developed the SMILE-

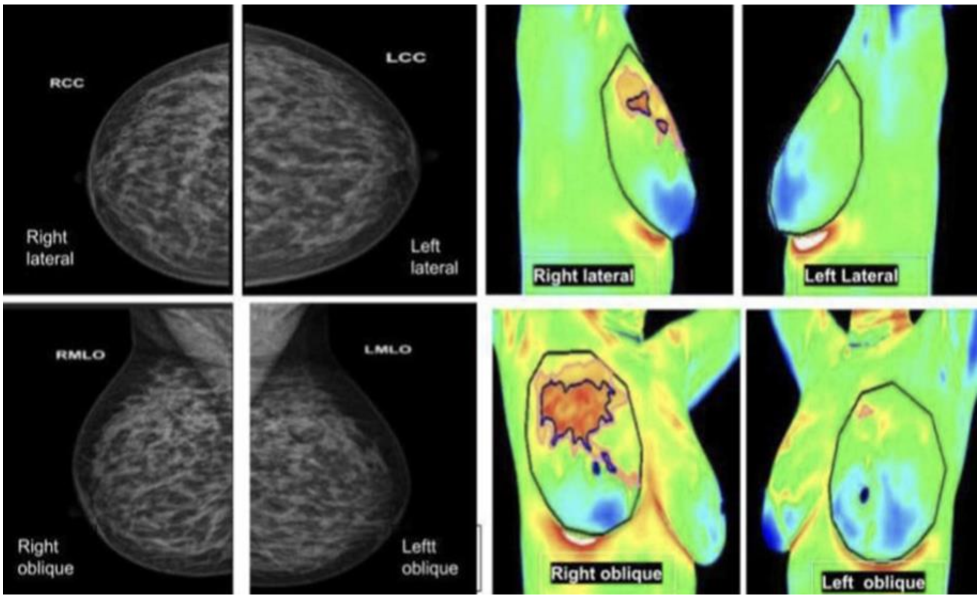
100 System in 2016, a non-invasive, low-cost breast cancer screening method based on the following of body heat integrated with artificial intelligence (Thermalytix) innovation.



SMILE-100 System

In 30 Indian cities, Niramai Thermalytix is accessible at more than 200 hospitals and diagnostic facilities. The Niramai test is also accessible in Kenya, Sweden, the Philippines, the United Arab Emirates, and Turkey. Women of all ages can use the radiation-free, non-touch, painless imaging technique. The unique machine learning algorithms used in the development of the solution's core technology allow for the accurate and dependable identification of breast cancer. This special approach can be applied to large-scale screening in rural and semi-urban regions, as well as cancer diagnosis tests in hospitals and routine preventive health examinations. It is a one of a kind radiation-free, non-contact, and precise breast cancer screening solution, empowering healthcare providers to create more educated decisions with respect to breast cancer screening and diagnosis by speeding up the visualization of high thermal movement patterns on thermal imaging as hotspots. (Bhattacharya et al., 2022) The discharge of nitric oxide encourages the vascular alterations related with malignancy, which raise the temperature within the region of a malignant lesion and deliver peculiar warm thermal patterns encircling the lesion that will be captured with a high-resolution infrared camera. (Observational Study to Evaluate the Clinical Efficacy of Thermalytix for Detecting Breast Cancer in Symptomatic and Asymptomatic Women | JCO Global Oncology, n.d.) In their FDA-cleared SMILE-100 System, AI algorithms check the quality of input thermal images, reducing errors in image capture and enabling use by less skilled healthcare workers. (Singh et al., 2021) It may significantly reduce errors in the acquisition of thermal images, and it even gives less experienced medical personnel the confidence to perform imaging procedures thanks to its own artificial intelligence-based algorithms. This method's thermography could be a supportive apparatus for locating changes in blood perfusion that can be brought on by angiogenesis, inflammation, or other events that may asymmetrically disperse temperature. These contrasts demonstrate a potential issue, as does the presence of hot and cold temperature zones. Indeed in spite of the fact that mammography and ultrasound diagnostics are often performed manually by specialists, automated methods that give an objective reaction that can be utilised as a moment's conclusion are craved. Certain automated methods depend on the study of thermograms, which includes segmenting the picture into pertinent areas and analyzing each region independently. From now on, picture segmentation alludes to the procedure that isolates a digital image into numerous parts and is commonly utilized to recognize areas of interest and information-rich components in digital images. The comparison of thermal asymmetries between the left and right breasts is one of the foremost critical methods for recognizing breast disorders. This strategy can distinguish cancer cells five years before mammography and other intrusive testing. By considering factors such as age, family history, and thermal patterns, the system provides a comprehensive risk assessment. This method makes use of portable technology that costs a tenth of what standard mammography does (Bhattacharya et al., 2022). Additionally, it has shown to be very successful for women with dense breast tissue, in whom conventional mammography frequently fails. (Shimatani et al., 2022) The Thermalytix cancer screening test has been used by more than 100,000 women in 150+ hospitals/diagnostic centers as well as 5000+ screening camps in India. (Niramai – A Novel Breast Cancer Screening Solution, 2024) Amid this assessment, the patient enters a room and is given instructions from outside. The examination is carried out in total privacy. It was afterward found that rural women especially valued the privacy component. As a result, this method has been broadly embraced. Moreover, working this equipment doesn't require a high level of experience. (Clanahan et al., 2020) This strategy too empowers remote radiological consultations through teleradiology. Hence, it cuts hospitals' full-time workforce costs. (Bhattacharya et al., 2022) By leveraging AI and thermal imaging, the company has developed a solution that addresses many limitations of traditional methods while potentially improving accessibility and accuracy. (Pacilè et al., 2020) The extensive clinical validation, regulatory approvals, and patent portfolio underscore the innovative nature of this technology and its potential impact on early breast cancer detection, particularly in regions where access to advanced medical imaging may be limited. (Li et al., 2020)

These facts can also be backed by a case study: A 47-year-old post-menopausal woman displayed a 3-month history of a lump within the right breast at the noon position.



The medical history of the woman was unremarkable, and she had no first-degree relatives with cancer. The Thermalytix test was used to assess the patient. After the test, a clinical breast examination was performed, and the presence of a discernible lump inside the right breast at the noon position was noted. Amid the Thermalytix test, five breast thermal images were captured and examined. Five thermal images were captured during the test, uncovering three hotspots, with a temperature increase of 1.32°C, covering 2.3% of the region of interest. The irregular hotspot coincided with the lump location, creating the impression of a "hot lump." Although there was no overall symmetry in breast temperature distribution, the areolar complex showed 100% symmetry (Gangadharan et al., 2023).

Compared to traditional mammography, Thermalytix offers a radiation-free, non-invasive, and painless imaging technique, making breast cancer screening more comfortable. It eliminates human error, providing accurate results (Rodríguez-Ruiz et al., 2019). Thermalytix has demonstrated significant potential for improving early breast cancer detection, particularly in low-income countries like India, helping to bridge the gap in diagnosis and ultimately saving lives. Technology is an important component in improving healthcare outcomes in such regions (Sharma et al., 2021; Kakileti et al., 2020).

Mammoalert:

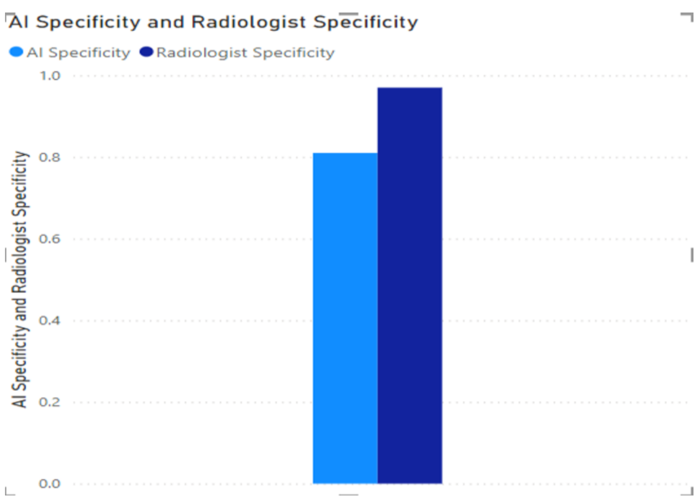
Mammoalert is an additional illustration of an AI-based cancer detection method. With just one drop of blood, it utilizes an immunoassay that runs on Pandora CDx technology to get results as little as 15 minutes after the test. Pandora CDx creates a sample by applying sandwich immunoassays with beads using a special sedimentation process. Four protein markers linked to breast cancer are investigated in this sample. After that, the probability that someone has breast cancer is calculated using an algorithm developed using deep machine learning and artificial intelligence. The test operators(Eg: doctor) and patient receive the results through a smartphone application, and they are available in less than 30 minutes. (Broach et al., 2016) MammoAlert may be run in any remote or impoverished area, at a very low fee, and possibly even earlier than traditional screening. It costs less than $5 for each test and has a specificity and sensitivity of about 85%, as opposed to the typical 70% for mammography. By identifying breast cancer early, this technology can improve the quality of life (QOL) of millions of women globally, even though the exact whereabouts of the tumour still must be validated by mammography or other means. (Bhattacharya et al., 2022)

Issues with AI:

There are threats of automation bias, over-dependence, and long-term personnel issues; AI is carefully studied and utilised gradually. This is on top of the general concerns related to AI that have already been thoroughly documented, like corrigibility, algorithmic biases, and data privacy. (AI ISSUES, n.d.)

AI vs Radiologist Specificity: (Reference: National Library of medicine)

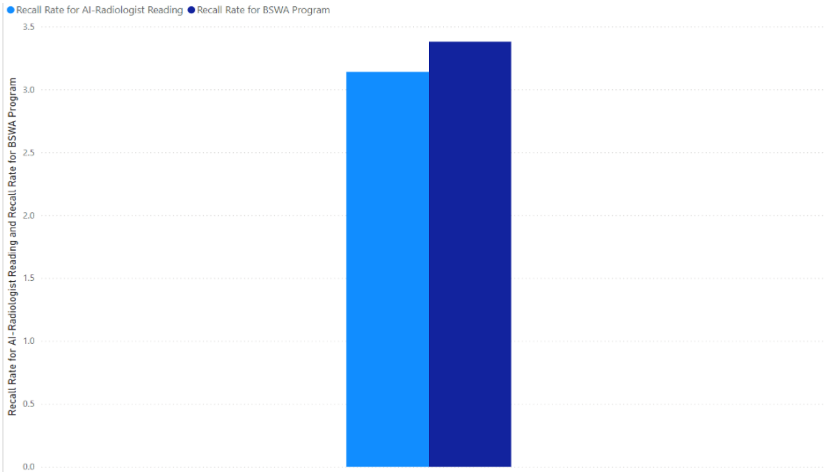
Bigger is better:



Reference: National Library Of Medicine

Specificity, or the "true negative rate," measures the extent of real negatives. A higher specificity means the test is better at identifying those without the condition, reducing the number of false positives. This shows that AI is not properly able to identify those without conditions. (Khan & Arora, 2021)

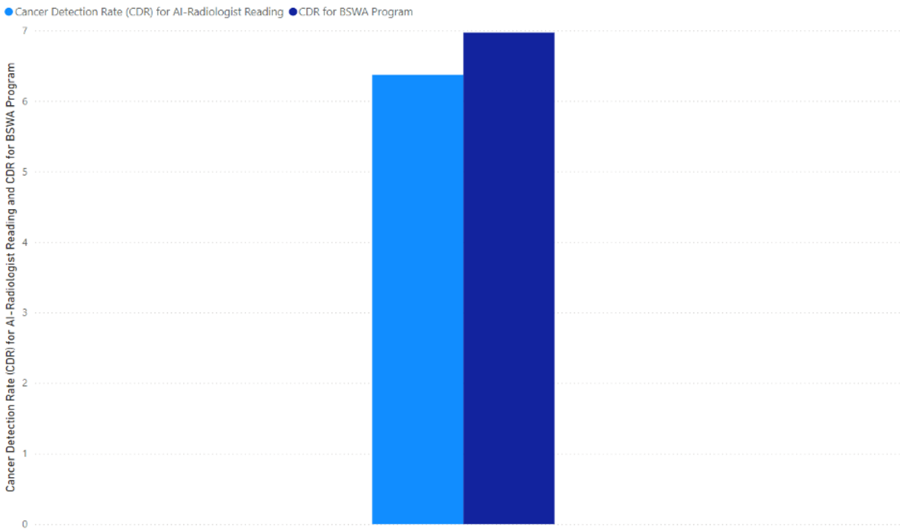
Smaller is better:



Reference: National Library Of Medicine

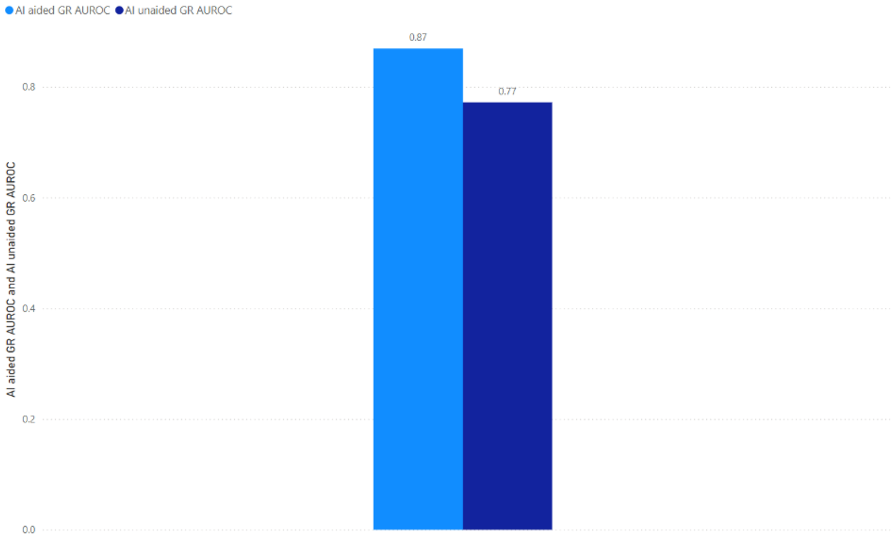
AI-radiologist recall rate is lesser than that of the BSWA program recall rate, it suggests that AI assistance helps radiologists to make more accurate decisions, reducing the number of unnecessary recalls. (Gampala et al., 2020)

Cancer detection rate AI-assisted vs non-AI-assisted: (Reference: National Library of medicine)



The BreastScreen Western Australia (BSWA) program is referred to as the BSWA program. Typically using mammography, this population-based breast cancer screening program in Western Australia aims to identify breast cancer in women who do not exhibit any symptoms at an early stage. In an effort to lower the death rate from breast cancer by promoting early identification and treatment, the program offers free mammograms to qualified women, mostly those between the ages of 50 and 74.

AI vs Non-AI Grade or Risk AUROC:

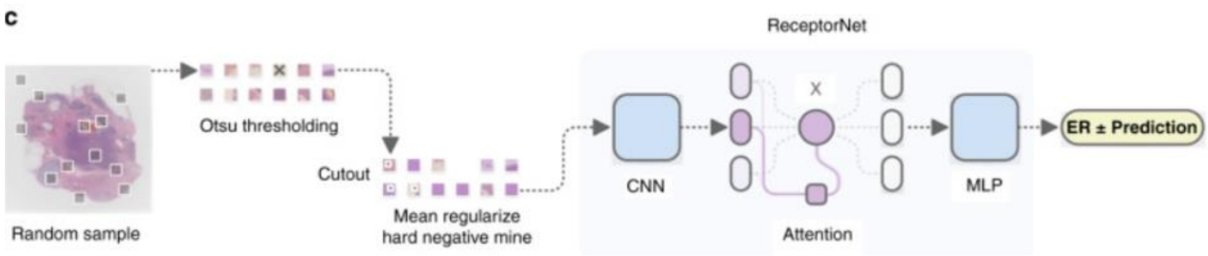


The model's ability to discriminate between the positive and negative classes improves with an AUROC nearer 1. An AUROC of 0.87, for instance, shows that there's an 87% probability that the show will precisely allot an arbitrarily selected positive case a higher priority than an arbitrarily chosen negative instance.

Receptor Net:

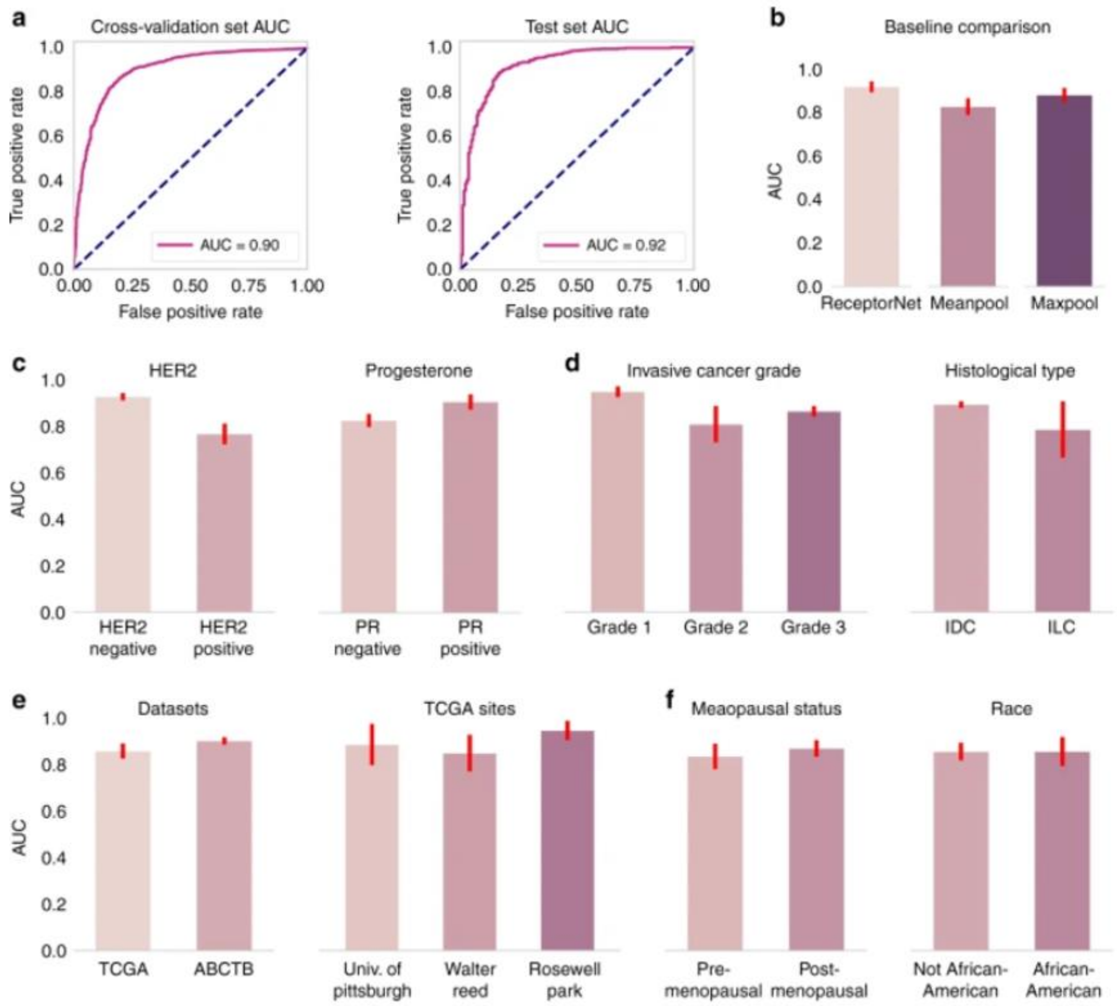
Researchers built a deep learning network called ReceptorNet that uses pathology pictures to directly predict the presence or absence of estrogen receptor (ER) status in breast cancer tumours. Since the ER status determines whether the tumour is likely to respond to hormone therapy, it is essential in deciding on the best course of treatment for patients with breast cancer. ReceptorNet is designed to predict ER+ status from a set of randomly selected tiles from a whole-slide image (WSI) at a resolution of 0.5 µm/pixel. The WSI is divided into non-overlapping tiles of 256 × 256 pixels.

ReceptorNet consists of three interconnected neural networks trained together: an attention module that generates a 512-dimensional aggregate of feature vectors from all the tiles in the set, weighted by their discriminative power; a feature extractor that converts each 256 × 256 tiles into a 512-dimensional feature vector; and a decision layer that uses the aggregate feature vector to calculate the likelihood that the set is positive for ER+ status.

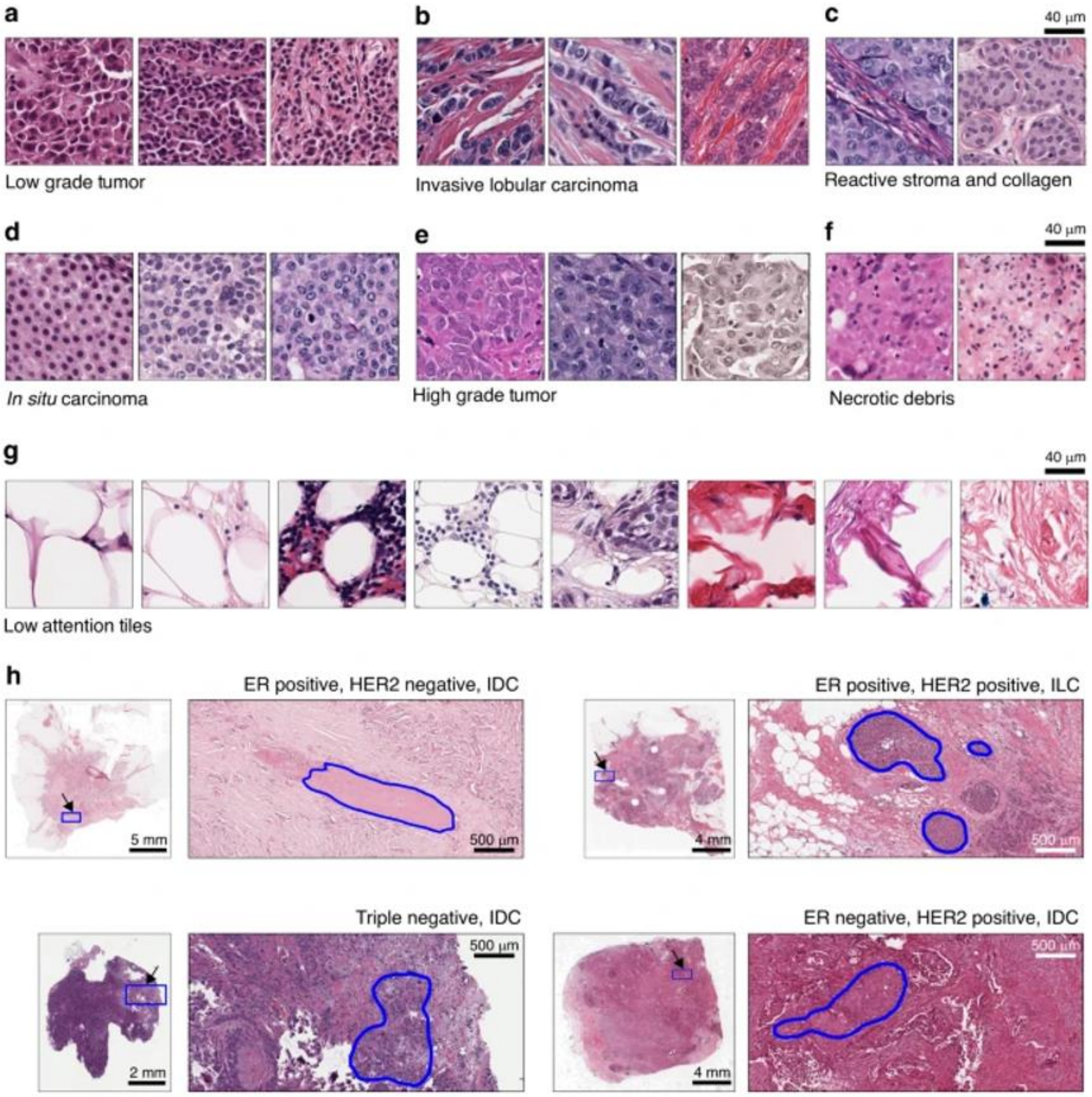


RecptorNet architecture (Reference: Natural Library of medicine)

Fig. 2: ReceptorNet obtains high performance on estrogen receptor status estimation.



ReceptorNet achieved an AUC of 0.90 on cross-validation (N=2,728) and 0.92 on the test set (N=671), outperforming multiple instance learning baselines. Its performance varied with the presence of hormonal receptors (HER2−: N=2,205, HER2+: N=407; PR−: N=852, PR+: N=1,871) and tumour grade (Grade 1: N=297, Grade 2: N=788, Grade 3: N=888), but not with histological type (IDC: N=2,073, ILC: N=371). No significant differences were found across datasets, tissue sources, or demographic groups. Error bars represent 95% confidence intervals, and statistical comparisons were performed using the upper tail F-test and DeLong method.



ReceptorNet automatically identifies several features as predictive of ER status which includes, low-grade tumours, invasive lobular carcinoma, reactive stroma, and in situ carcinoma are associated with ER-positivity, while high-grade tumours and necrotic debris indicate ER-negativity. The model disregards fat tissue, connective tissue with few or no tumour cells, and debris-laden macrophages. Attention weights highlight key regions in whole-slide images used for ERS estimation, with blue outlines marking areas relevant to decision-making.

Conclusion:

Artificial intelligence is gradually spreading to every part of our daily lives, particularly in the field of medicine. The paper's review reveals that researchers are quickly gaining a more profound insight into the obstacles and possibilities brought by AI in the realm of cancer diagnosis and treatment as an intelligent information science. This paper discusses the potential of artificial intelligence in predicting and diagnosing different types of cancer. However, our review is limited by our exclusion of genomic and radiomic data used by artificial intelligence in the development of personalized clinical medicine. We anticipate that AI-driven clinical cancer studies will lead to a significant change in cancer therapy, ultimately leading to a notable increase in patient survival thanks to improved forecasting accuracy. Therefore, it is reasonable to anticipate that AI advancements will resolve the challenges of cancer diagnosis and prognosis in the near future. We determined that utilizing AI for breast cancer screening is crucial in creating a more favourable outcome for breast cancer patients, with an aim to reduce the stage of cancer, and enhance the quality of life for those affected.

Limitations and Future Scope of The study:

The present study has come with certain limitations. In the future, researchers could explore the integration of genomic and radiomic data into AI-driven cancer screening and diagnosis. By combining these data types, researchers can develop more personalized and precise treatment plans, potentially enhancing the accuracy and effectiveness of cancer therapies. In addition, the present study focuses on breast cancer, there is significant potential to apply AI-driven approaches to other types of cancer. Future research could explore how AI can be tailored to predict, diagnose, and treat various cancers, leading to broader applications in oncology. Lastly, future research could also investigate how AI-driven cancer screening and treatment can be made accessible on a global scale, particularly in low-resource settings. Exploring ways to reduce costs and enhance the accessibility of AI technologies will be crucial for ensuring that advancements benefit a wider population.

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