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(Review Article)

Current status of artificial intelligence and machine learning in breast cancer screening: A systematic review

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Abstract

Breast cancer stands as one of the most prevalent forms of cancer. Artificial intelligence (AI) and machine learning have become crucial in accurately identifying and managing various serious illnesses. This development has contributed to improved survival rates by enabling early detection and timely intervention. In our investigation, we conducted a thorough systematic review of the role of AI and machine learning in breast cancer screening. We examined articles from 2015 to 2023 across diverse databases, focusing on the intersection of breast cancer and AI. The integration of AI into existing screening procedures yields more convenient and efficient outcomes. Utilizing AI techniques in breast cancer screening offers numerous benefits, including heightened precision in results. However, the incorporation of AI presents several challenges that need systematic addressing.

Keywords: Breast Cancer; Artificial Intelligence; Machine Learning; Screening; AI; Challenges

1. Introduction

Breast cancer stands as a prominent global cause of mortality in women (1). Benign breast tumors induce only minor structural alterations in the breast (2). In instances of in-situ carcinoma development, the cancer remains confined to the mammary duct lobule system, sparing other organs from its impact (3). Early identification of these types is crucial, as they are amenable to cure when detected promptly. Conversely, invasive carcinoma is acknowledged as the most lethal type of breast cancer due to its ability to metastasize to all other organs (4).

Artificial intelligence (AI) and machine learning (ML) have emerged as powerful tools in the healthcare industry, particularly for breast cancer screening (5). It is crucial to identify breast cancer in a timely manner, as prompt and accurate detection is essential for optimizing therapeutic outcomes.(6,7). The implementation of AI across diverse industries, driven by a desire to enhance productivity, efficiency, and precision, is notably pronounced in healthcare (8,9). AI finds application in various healthcare domains, encompassing medication dispensing (10), hospital administration (11), and patient monitoring (12). The impact of artificial intelligence (AI) on complicated image processing has been undoubtedly stronger (13). Furthermore, AI contributes to mitigating radiation risks associated with breast radiological examinations (14) and automates data collection for quantitative evaluation (15). Accessibility,

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effectiveness, and precision in breast cancer screening could all be enhanced by the application of AI and ML (16-19). Notably, conventional screening methods, such as mammography, exhibit limitations (20). This study, employing a comprehensive literature analysis guided by PRISMA, aims to scrutinize the latest advancements in AI and ML applications for breast cancer screening.

2. Methodology

The systematic review methodology employed in this study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (21). The PRISMA flow chart provided a visual representation of the article selection procedure.

2.1. Data Strategy and keywords

Relevant studies published between 2015 and 2023 were identified through searches on various academic databases, including Springer Link, Science Direct (Elsevier), IEEE Xplore, PubMed, and Web of Science. The search employed specific terms such as "screening," "AI," "breast cancer," and "machine learning." Carefully selected Boolean operators (AND, OR) were applied to combine these terms, formulating a precise and inclusive search strategy.

2.2. Criteria

The inclusion criterion, mandating publication in English, underscored the review's dedication to thoroughness and accessibility. The systematic review encompassed the latest and relevant research in the domain by examining articles released between 2015 and 2023. This temporal restriction facilitated the integration of contemporary artificial intelligence (AI) and machine learning advancements in breast cancer screening, aligning with ongoing research progress.

2.3. Screening of Articles

After obtaining relevant articles from the databases, an evaluation was conducted based on their titles, abstracts, and full-text readings. Ultimately, 12 articles were selected for further scrutiny and quality assessment.

2.4. Quality Appraisal Tools

To assess the reliability of data and identify inherent biases in each study, the CASP technique was employed (22). The evaluation meticulously examined various aspects of the studies, including the quality of data collection methods, the robustness of the research design, and the reliability of the stated conclusions. These criteria played a crucial role in determining the validity and dependability of the chosen studies.

3. Results

The methods for the elimination, systematic review, and article selection are depicted in Figure 1.

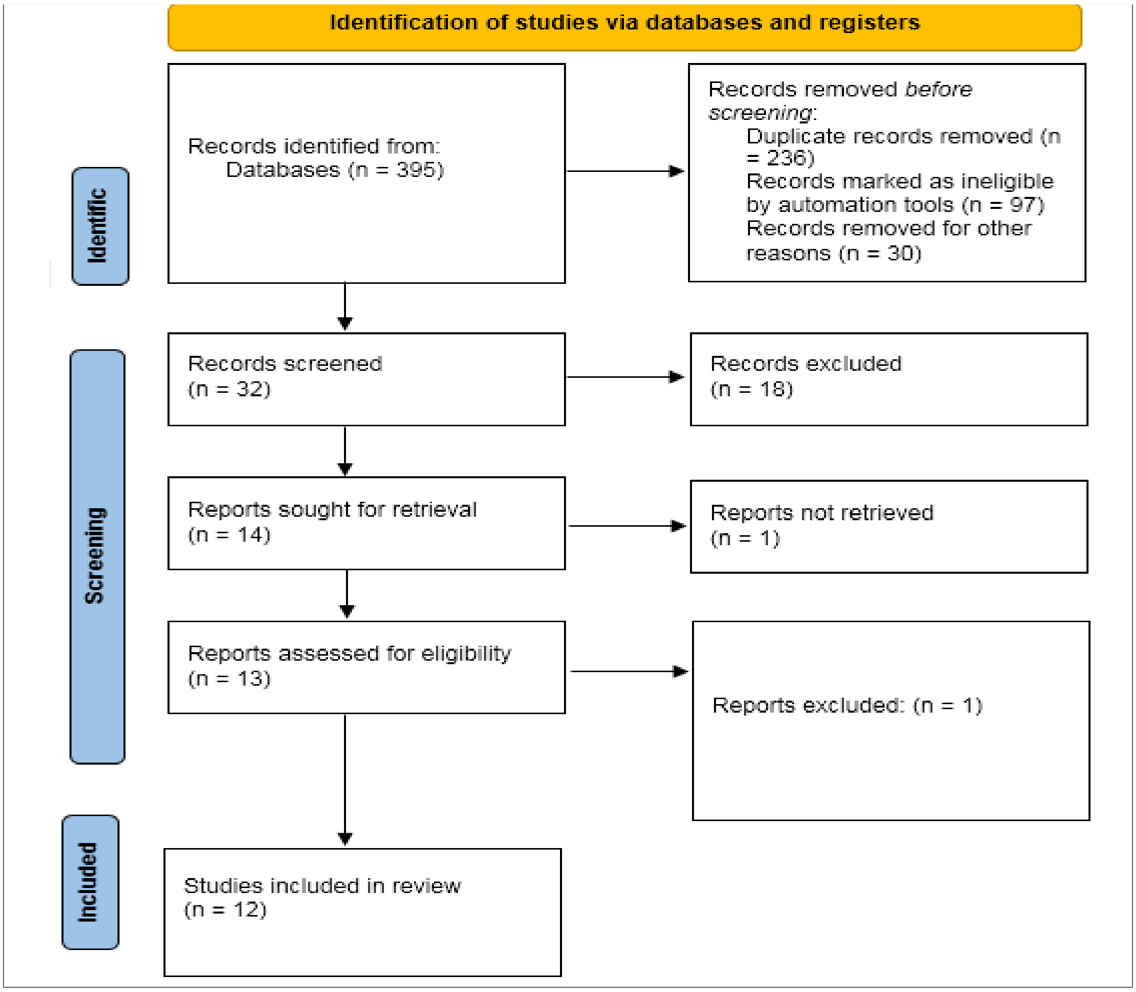

Figure 1 Flow diagram of literature search and study selection

Table 1 represents the main conclusions from the 12 publications that were selected and grouped based on concerns related to AI and machine learning in breast cancer screening.

Table 1 Studies included in the systematic review

No	Author and Years	Aim	Model	Key Findings
1	Singh et al., 2022	Creation of a machine learning algorithm for Boolean classification of breast cancer based on mammograms	Machine Learning Models	The study aimed to develop a machine learning algorithm specifically for the Boolean classification of breast cancer using mammograms. The key findings highlighted the usefulness of mammograms in detecting dangerous malignancies and the cost-effectiveness of machine learning in this context.
2	McKinney et al., 2020	Develop an artificial intelligence system to predict breast cancer from screening mammography	Artificial Intelligence (AI)	The goal was to create an AI system capable of predicting breast cancer more accurately than human experts using data from screening mammography. The key finding was that the AI system outperformed human experts in this predictive task.

3	Houssami et al., 2017	Explore the potential of AI in mammography for breast cancer identification	Operating characteristic curve (AUC-ROC)	The study focused on assessing the potential of AI systems in improving breast cancer identification using mammography. The key finding was an 88% improvement in screening precision achieved by AI systems compared to traditional methods.
4	Tahmooresi et al., 2018	Utilize machine learning techniques for breast cancer detection and diagnosis	Machine Learning	This study employed various machine learning techniques for the detection and diagnosis of breast cancer. The key finding emphasized the improved efficiency of machine learning in diagnosing breast cancer compared to conventional methods.
5	Chan et al., 2020	Utilize deep learning in computer-aided diagnosis (CAD) for breast imaging	Deep Learning (DL)	The study focused on using deep learning techniques in computer-aided diagnosis (CAD) for breast imaging. The key finding was the high precision achieved by deep learning in predicting breast cancer in this context.
6	Elsadig et al., 2023	Develop a machine learning approach to predict breast cancer	Support Vector Machine	This study developed a machine learning approach, specifically a Support Vector Machine (SVM), to predict breast cancer. The key finding was an accuracy of 97.7% in early detection, which significantly enhanced survival rates.
7	Nallamala et al., 2019	Investigate the use of machine learning in discovering fundamental aspects of breast cancer	Machine Learning	The study explored the application of machine learning in discovering fundamental aspects of breast cancer. Key findings included the role of machine learning in fundamental discoveries related to breast cancer.
8	Bataineh et al., 2019	Evaluate the efficiency and effectiveness of automated techniques in breast cancer diagnosis	Automated Techniques	This study evaluated automated techniques in breast cancer diagnosis, focusing on their efficiency and effectiveness. Key findings highlighted the improved efficiency and effectiveness of automated techniques in diagnosing breast cancer.
9	Chugh et al., 2021	Develop computer-aided diagnosis (CAD) techniques for diagnosing breast carcinoma	Computer-Aided Diagnosis (CAD)	The study focused on developing CAD techniques specifically for diagnosing breast carcinoma. Key findings included the effectiveness of CAD techniques in diagnosing this type of breast cancer.
10	Dembrower et al., 2020	Analyze how AI can reduce radiologist workload and increase cancer detection	Machine Learning (ML)	This study analyzed the impact of AI on reducing radiologist workload and improving cancer detection rates. Key findings emphasized the potential of AI in reducing workload and enhancing cancer detection efficiency.
11	Lotter et al., 2021	Investigate deep learning techniques in mammography	Deep Learning (DL)	The study investigated deep learning techniques specifically in mammography for breast cancer detection. Key findings included the effectiveness of deep learning in this imaging context.

12	Sheth & Giger, 2019	Explore the potential use of artificial intelligence (AI) in various tasks in breast imaging	Artificial Intelligence (AI)	This study explored the potential applications of AI in various tasks related to breast imaging. Key findings highlighted AI's potential in multiple areas within breast imaging.

3.1. AI Applications in Breast Cancer Screening

AI and machine learning in various cancer screening and diagnosis have been studied before (23,24). In artificial intelligence (AI) systems, radiomics is a prevalent technique that involves extracting quantitative features from medical images. Typically, pattern recognition algorithms are utilized to identify images and generate a set of numerical values representing quantitative features within the visible area of the image (17). Radiomics operates on the premise that attributes extracted from images capture various processes occurring at the chromosomal and molecular levels (10). According to McKinney et al. (2020), machine learning involves applying computational methods to these radiomic features, enhancing our understanding of disease progression (15). Deep learning, as described by Chugh et al., employs a multi-neural layer or network to process images, similar to supervised machine learning. This approach reduces the image to a set of integers representing features that contribute to the diagnostic process (20). Healthcare practitioners can benefit from improved support in conducting differential diagnoses through the application of supervised machine learning (SML) (12). SML, according to Elsadig et al., utilizes advanced techniques for predicting health issues and issuing warnings to the public about potential dangers (13).

Lotter et al. emphasize that cancer images in mammography serve as labels aiding algorithms in identifying characteristic features of cancer (8). In contrast, unsupervised learning lacks abnormal labels and diagnostic features. According to Houssami et al., in semi-supervised learning, the algorithm's input data is not crucial for training (9).

Table 2 describes various AI methods used in breast cancer screening.

Table 2 AI methods in Breast Cancer Screening

No.	Method	Mode of Functioning
1	ML (Machine Learning)	A computational algorithm that makes use of image features to analyze and classify data.
2	DL (Deep Learning)	Processing of images by a multi-neural layer or network, extracting quantitative aspects for analysis.
3	Radiomics	Extracts quantitative aspects from an image to provide insights into health problems.
4	SML (Sophisticated Machine Learning)	Utilizes sophisticated ways to forecast health problems based on data analysis.
5	Mammography	Involves high-resolution imaging techniques to detect abnormalities in breast tissue.
6	CAD (Computer-Aided Diagnosis)	Uses machine learning algorithms to assist radiologists in interpreting imaging data.
7	MRI (Magnetic Resonance Imaging)	Provides high-resolution images for detailed examination and diagnosis of medical conditions.
8	DBT (Digital Breast Tomosynthesis)	Digital Breast Tomosynthesis is used to reduce reading time and exclude low-risk mammograms.

Mammography stands as the most widely utilized screening technique for breast cancer (7). The outcome is a high-resolution image, storable and applicable across diverse age groups and body sizes (8). Full-field digital mammography systems offer two formats: input (raw images) and output (post-processing). Artificial intelligence (AI) employs image analysis to identify breast masses, breast density, mass segmentation, and cancer risk (14). Computer-aided detection (CAD) systems utilize machine learning (ML) algorithms to assist radiologists in identifying anomalies in mammograms (13). These algorithms analyze large datasets of mammogram images, learning patterns associated with both benign and pathological findings. Consequently, CAD contributes to reducing false positives and negatives while providing radiologists with a valuable second opinion (11).

AI plays a crucial role in enhancing the interpretation of imaging investigations, especially with the integration of automated breast ultrasound and magnetic resonance imaging (MRI) as complementary modalities in breast cancer screening (14). Combining AI algorithms with these modalities can increase sensitivity and specificity, offering a more comprehensive approach to breast cancer detection. Research has demonstrated the high sensitivity achievable through AI-based CAD (1,12). It has the potential to reduce the time required for reading a digital breast tomosynthesis (DBT) scan and serve as a pre-screening method to exclude low-risk mammography cases (10).

3.2. AI Breast Cancer Screening Advantages

Models assessing an individual's breast cancer risk incorporate diverse patient variables, including demographics, medical history, and genetic data (9). Implementation of focused screening and preventive measures based on these models enables healthcare professionals to enhance patient outcomes and optimize resource allocation, particularly for high-risk populations. Additionally, the adoption of artificial intelligence (AI) reduces stress for radiologists (8). Unlike human readers, AI operates tirelessly, providing efficiency in reading mammography images, leading to enhanced accuracy and early cancer detection.

AI's role extends beyond screening to improve medical treatment overall (17). The integration of AI-based diagnostic tools in breast cancer diagnosis has not only elevated radiologists' productivity but also yielded superior results compared to individual efforts (7). AI employs sophisticated machine learning algorithms, enhancing differentiation between structures and image components. However, its application in clinical practice is restricted due to low specificity. Notably, computer-aided detection (CAD) accuracy has improved with the incorporation of AI (20). AI utilizes convolutional neural networks (CNN), a deep learning technology well-suited for image evaluation and classification. Its diagnostic accuracy for cancer detection is comparable to or exceeds that of radiologists (14).

3.3. Challenges and Concerns

AI algorithms utilized in cancer management rely on image data as their foundational component. However, a notable challenge in this domain is the prevalent underutilization, in numerous institutions, of patient histories stored as electronic health records (1). Overcoming this challenge requires building trust among healthcare professionals to embrace AI for decision-making support. Physicians need comprehensive training to effectively leverage AI technologies. In the current era of mobile applications, obtaining data from individuals has become more accessible (14). Smartphone apps facilitate the tracking and retrieval of various parameters, such as blood pressure and heart rate, contributing to increased patient satisfaction and care quality, as highlighted by Elsadig et al. (13). Nevertheless, ethical concerns surrounding AI application persist, encompassing issues related to patient autonomy, privacy violations, data confidentiality, and consent (9). Stringent precautions and legal frameworks should be in place to mitigate confidentiality breaches and monitor malpractice.

The limited integration of radiomics in day-to-day clinical practice poses another obstacle to the widespread adoption of AI for breast cancer screening (15). However, there is a high likelihood that AI will eventually assume many functions performed by radiologists. Even if it does not entirely replace their role, AI is poised to significantly aid radiologists in decision-making (11).

4. Conclusion

Breast cancer poses significant challenges for both patients and the medical community. The early detection of cancer has become more accessible through the integration of AI in various screening methods. AI is utilized in breast cancer screening through advanced techniques such as radiomics, deep learning, and machine learning. These state-of-the-art approaches assist physicians in delivering high-quality patient care and achieving early diagnoses. Artificial Intelligence has the capability to identify calcifications, contributing to patient diagnosis and management. It can also recognize breast masses, density, and tissue segmentation. Overcoming challenges associated with AI appears achievable through additional research and technological advancements. This could lead to increased adoption of AI-based general screening methods, ultimately enhancing the overall quality of life for breast cancer patients.

Compliance with ethical standards

Disclosure of conflict of interest

The Authors declare that there is no conflict of interest

References

[1] Tahmooresi M, Afshar A, Rad BB, Nowshath KB, Bamiah MA. Early Detection of Breast Cancer Using Machine Learning Techniques. Journal of Telecommunication, Electronic and Computer Engineering (JTEC) [Internet]. 2018 Sep 26;10(3-2):21–7. Available from: https://jtec.utem.edu.my/jtec/article/view/4706

[2] Baughan N, Douglas L, Giger ML. Past, Present, and Future of Machine Learning and Artificial Intelligence for Breast Cancer Screening. Journal of Breast Imaging. 2022 Sep 1;4(5):451–9. https://doi.org/10.1093/jbi/wbac052

[3] Malliori A, Pallikarakis N. Breast cancer detection using machine learning in digital mammography and breast tomosynthesis: A systematic review. Health and Technology. 2022 Aug 12;12(5):893–910. https://doi.org/10.1007/s12553-022-00693-4

[4] Hickman SE, Woitek R, Le EPV, Im YR, Mouritsen Luxhøj C, Aviles-Rivero AI, et al. Machine Learning for Workflow Applications in Screening Mammography: Systematic Review and Meta-Analysis. Radiology. 2021 Oct 19; https://doi.org/10.1148/radiol.2021210391

[5] Houssami N, Kirkpatrick-Jones G, Noguchi N, Lee CI. Artificial Intelligence (AI) for the early detection of breast cancer: a scoping review to assess AI's potential in breast screening practice. Expert Review of Medical Devices. 2019 May 3;16(5):351–62. https://doi.org/10.1080/17434440.2019.1610387

[6] Yassin NIR, Omran S, El Houby EMF, Allam H. Machine learning techniques for breast cancer computer aided diagnosis using different image modalities: A systematic review. Computer Methods and Programs in Biomedicine. 2018 Mar;156:25–45. https://doi.org/10.1016/j.cmpb.2017.12.012

[7] Dembrower K, Wåhlin E, Liu Y, Salim M, Smith K, Lindholm P, et al. Effect of artificial intelligence-based triaging of breast cancer screening mammograms on cancer detection and radiologist workload: a retrospective simulation study. The Lancet Digital Health [Internet]. 2020 Sep 1;2(9):e468–74. Available from: https://www.thelancet.com/journals/landig/article/PIIS2589-7500(20)30185-0/fulltext#:~:text=AI%2Dbased%20scoring%20can%20be.

[8] Lotter W, Diab AR, Haslam B, Kim JG, Grisot G, Wu E, et al. Robust breast cancer detection in mammography and digital breast tomosynthesis using an annotation-efficient deep learning approach. Nature Medicine [Internet]. 2021 Feb 1;27(2):244–9. Available from: https://www.nature.com/articles/s41591-020-01174-9

[9] Houssami N, Lee CI, Buist DSM, Tao D. Artificial intelligence for breast Cancer screening: Opportunity or hype? The Breast. 2017 Dec;36:31–3. https://doi.org/10.1016/j.breast.2017.09.003

[10] Nallamala SH , Mishra P , Koneru SV. Breast cancer detection using machine learning approaches. International Journal of Recent Technology and Engineering. 2019;7(5):478–81. https://www.ijrte.org/wp-content/uploads/papers/v7i5s4/E11010275S419.pdf

[11] Chan HP, Samala RK, Hadjiiski LM. CAD and AI for breast cancer—recent development and challenges. The British Journal of Radiology. 2020 Apr;93(1108):20190580. https://doi.org/10.1259/bjr.20190580

[12] Singh G, Chaturvedi P, Shrivastava A, Vikram Singh S. Breast Cancer Screening Using Machine Learning Models [Internet]. IEEE Xplore. 2022. p. 961–7. Available from: https://doi.org/10.1109/ICIEM54221.2022.9853047

[13] Elsadig MA, Altigani A, Elshoush HT. Breast cancer detection using machine learning approaches: a comparative study. International Journal of Electrical and Computer Engineering (IJECE). 2023 Feb 1;13(1):736. https://doi.org/10.11591/ijece.v13i1.pp736-745

[14] Sheth D, Giger ML. Artificial intelligence in the interpretation of breast cancer on MRI. Journal of Magnetic Resonance Imaging. 2019 Jul 25;51(5):1310–24. https://doi.org/10.1002/jmri.26878

[15] McKinney SM, Sieniek M, Godbole V, Godwin J, Antropova N, Ashrafian H, et al. International evaluation of an AI system for breast cancer screening. Nature. 2020 Jan;577(7788):89–94. https://doi.org/10.1038/s41586-019-1799-6

[16] Liu J, Lei J, Ou Y, Zhao Y, Xiaofeng Tuo, Zhang B, et al. Mammography diagnosis of breast cancer screening through machine learning: a systematic review and meta-analysis. Clinical and Experimental Medicine. 2022 Oct 15; https://doi.org/10.1007/s10238-022-00895-0

[17] Bataineh AA. A Comparative Analysis of Nonlinear Machine Learning Algorithms for Breast Cancer Detection. International Journal of Machine Learning and Computing. 2019 Jun;9(3):248–54. https://doi.org/10.18178/ijmlc.2019.9.3.794

[18] Nassif AB, Talib MA, Nasir Q, Afadar Y, Elgendy O. Breast cancer detection using artificial intelligence techniques: A systematic literature review. Artificial Intelligence in Medicine. 2022 May;127:102276. https://doi.org/10.1016/j.artmed.2022.102276

[19] Freeman K, Geppert J, Stinton C, Todkill D, Johnson S, Clarke A, et al. Use of artificial intelligence for image analysis in breast cancer screening programmes: systematic review of test accuracy. BMJ. 2021 Sep 1;n1872. https://doi.org/10.1136/bmj.n1872

[20] Chugh G, Kumar S, Singh N. Survey on Machine Learning and Deep Learning Applications in Breast Cancer Diagnosis. Cognitive Computation. 2021 Jan 30; https://doi.org/10.1007/s12559-020-09813-6

[21] Sarkis-Onofre R, Catalá-López F, Aromataris E, Lockwood C. How to properly use the PRISMA Statement. Systematic Reviews [Internet]. 2021 Apr 19;10(1). Available from:https://systematicreviewsjournal.biomedcentral.com/articles/10.1186/s13643-021-01671-z

[22] Long HA, French DP, Brooks JM. Optimising the Value of the Critical Appraisal Skills Programme (CASP) Tool for Quality Appraisal in Qualitative Evidence Synthesis. Research Methods in Medicine & Health Sciences [Internet]. 2020;1(1):31–42. Available from: https://doi.org/10.1177/2632084320947559

[23] Patel, R., Patel, M., Patel, Z., Kavani, H., Onyechi, A., Ohemeng-Dapaah, J., ... & Yang, C. (2024). Present State and Recent Developments of Artificial Intelligence and Machine Learning in Gastric Cancer Diagnosis and Prognosis: A Systematic Review. Journal of Cancer and Tumor International, 14(1), 1-10.

[24] Patel, R., Patel, M., Patel, Z., & Patel, D. (2024). Current Status of Machine Learning and Artificial Intelligence in Cervical Cancer Screening and Diagnosis: A Systematic Review. Glob Acad J Med Sci, 6.