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REVIEW ARTICLES

A Review of Artificial Intelligence in Predicting Outcomes, Complications, and Survival Following Breast Cancer Surgery

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Abstract

Introduction: Artificial intelligence and its applications in medicine have gained significant popularity, coinciding with advances in technology. Breast cancer treatments vary, including surgical interventions. In this review, we aim to evaluate artificial intelligence's ability to predict surgical outcomes, complications, and survival rates after breast cancer surgery by analyzing original research published over the past 5 years.

Materials and Methods: A PubMed search was conducted by two authors from January 1, 2020, to April 13, 2025, using the keywords "Artificial Intelligence" and "Breast Surgery". After excluding duplicates, 14 of the 215 articles were screened for full text, and 9 original articles were selected for inclusion in our review.

Discussion: Artificial intelligence models and systems have significantly impacted the medical field, and breast cancer surgery is no exception. Several original research studies have explored AI's ability to predict surgical outcomes and postoperative results. In this review, we focus on the postoperative aspects of breast cancer surgery and its application of artificial intelligence.

Of the nine articles included in this paper, all reported multiple statistically significant results ($p < 0.05$). Although no prospective studies directly compare artificial intelligence with practicing physicians, artificial intelligence's ability to accurately predict surgical outcomes, complications, and survival has demonstrated higher accuracy and c-index than commonly used prediction methods, as reported in multiple studies.

Conclusion: Artificial Intelligence can be a valuable asset in helping surgeons and physicians worldwide predict prognosis, with improved accuracy, even surpassing that of currently used conservative systems. More research should be conducted on this topic, particularly in comparing Artificial Intelligence systems and models with current systems and evaluation methods.

Keywords: Artificial Intelligence, Breast Cancer Surgery, Outcome, Complication, Survival

Introduction

Artificial Intelligence (AI) is a term coined by John McCarthy in 1955 [1], and AI now broadly includes Machine Learning [ML], Deep Learning [DL], Natural Language Processing (NLP), and many other concepts. Although the term and these technologies are not new, AI has gained increased popularity since the public release of ChatGPT on November 30, 2022 [2].

Nearly every field uses AI in some way, and medicine is no exception. AI is transforming how we study and approach medicine and medical research.

Based on 2022 analytics, Breast Cancer (BC) is the most common cancer worldwide and primarily affects females [3]; therefore, it is a significant health concern globally. Breast Cancer Surgery (BCS) remains a standard treatment option for BC.

BC is a serious issue among women, and accurately predicting the results of BCS can significantly improve prognosis and potentially offer alternative treatment options [4].

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The most commonly used postoperative prognostic methods for BCS include the TNM staging system, histopathological evaluation, the Nottingham Prognostic Index (NPI), and the American Joint Committee on Cancer (AJCC) Staging System. Although these systems and evaluation methods are helpful, they are insufficient, as most have c-indexes below 0.8.

Extensive medical research worldwide is focused on developing more accurate systems for prognostic assessment [5-11]. This is where AI becomes valuable.

If we develop an AI capable of predicting BCS prognosis, it could lead to significantly better surgical outcomes. AI's capabilities are versatile in nearly all areas, including prediction.

Many studies worldwide focus on this topic; therefore, we have compiled a literature review to facilitate access for physicians, surgeons, and medical students.

Material and Methods

A PubMed search was conducted using the phrase ("Artificial Intelligence" AND "Breast Surgery"), including articles published between January 1, 2020, and April 13, 2025.

Of the 215 articles identified in the search results, we excluded non-original and non-related articles, leaving 14 for full-text screening.

This process eliminated another five articles, and the remaining nine were included in our review, as shown in Figure 1.

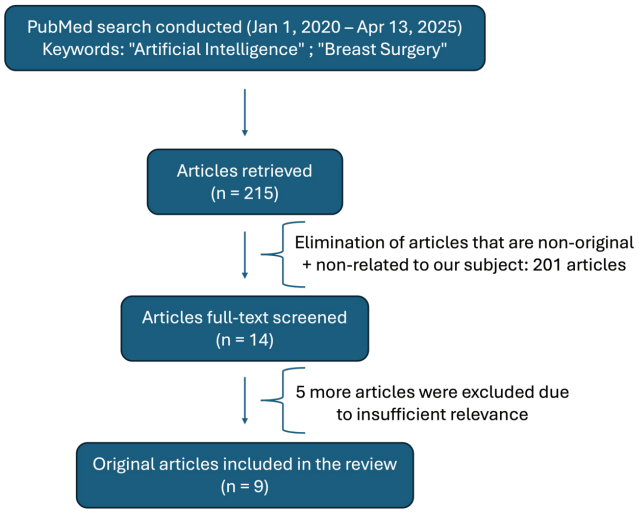

Figure 1. The process of selecting articles

Discussion

Zeng et al. achieved successful results using artificial intelligence models—LSTM, XGBoost, and SVM—developed in Python in a retrospective analysis of breast cancer recurrence risk following surgery. Their study included a training cohort of 1,289 patients and a test cohort of 552 patients, yielding performance accuracies of 0.89, 0.86, and 0.78, respectively.

Notably, the LSTM model outperformed the others. Using an LSTM model to predict the likelihood of patients being classified as low-, intermediate-, or high-risk, they found that individuals expected to be in the high-risk group exhibited greater DNA damage and greater resistance to microtubule-targeting agents than those in the intermediate-risk group.

In this study, all three models successfully predicted breast cancer recurrence after surgery [12].

Concerns about AI-related privacy issues have prompted research to protect the confidentiality of this information. In a study by *Son et al.* using data from 13,117 patients, the performance of a privacy-preserving Gated Recurrent Unit (GRU) model was compared. to that of a standard GRU model in predicting the risk of breast cancer recurrence.

The researchers integrated homomorphic encryption and secure two-party computation techniques into developing their privacy-preserving GRU models. The privacy-preserving GRU model reached an accuracy of 0.893, while the standard GRU model achieved 0.895.

The nearly identical performance of the privacy-preserving model to that of the conventional GRU strongly suggests that implementing artificial intelligence in healthcare is feasible. does not necessarily require compromising patient privacy rights [13].

There are also studies underway to aid breast cancer surgery using AI models during the procedure. *Veluponnar et al.* addressed the limitations of current methods in accurately and reliably determining whether the surgical margins of excised breast cancer tissue are free of tumor cells during breast-conserving surgery.

To minimize the need for additional surgeries or adjuvant treatments and enable more effective and precise resections, they developed a computer-aided ultrasound imaging approach using a deep neural network model created by *Gomez-Flores et al.* [14]. Their system achieved a sensitivity of 96% and a specificity of 75%. Using an ensemble approach, they achieved their best performance, with a Dice score of 0.88. The authors suggest that artificial intelligence can be effectively used intraoperatively to evaluate surgical margins in breast cancer surgery [15].

Larson et al. developed an advanced artificial intelligence system that predicts potential surgical-site complications after surgery and estimates the sNPWT costs required to prevent these complications. For 10 representative open procedures—including orthopedic, abdominal, cardiovascular, cesarean delivery, and breast surgeries—they conducted retrospective analyses using data from the Premier Healthcare Database (2017–2021).

Patients with appropriate demographic information and available clinical attributes were included in the study. Patients who underwent closed procedures, had a documented SSC on the day of the index operation, or received two different surgical procedures within 90 days of

SSC diagnosis were excluded. Surgical site infections were the most common complications.

The patient's age, urgency of the surgery, obesity, and diabetes mellitus are particularly important risk factors that increase the likelihood of complications at the surgical site.

A total of 386,624 patients underwent breast surgery. Among these patients, the most significant predictors of SSC risk were associated with the presence of an underlying breast malignancy. To analyze the relationship between the CP structure, with or without DP, and the risk of sepsis, the model with the highest predictive accuracy for postoperative complication risk was CatBoost.

CatBoost achieved an average area under the curve of 76% with a performance range of 0.73 to 0.81 across surgical subspecialties. The discriminative power of CatBoost is 0.76 for breast surgeries. Although the model is promising, it should be further developed to account for factors such as surgical duration, intraoperative blood loss, the patient's vital signs, and surgeon skill standardization.

The model's results could be further improved by incorporating factors such as surgical duration, intraoperative blood loss, patient vital signs, and surgeon skill standardization during the operation. 66.854 Number of patients included in Simulation of Cost-Effectiveness of sNPWT Across Surgical Populations. Among patients undergoing breast surgery, sNPWT was cost-effective for only 18%. Finally, the specific risk factors of a patient, primarily obesity and breast malignancy status, significantly influenced the cost-effectiveness of sNPWT use.

This study shows that SCC and sNPWT will become more useful and more cost-effective by integrating personalized assessments. Although the study provides valuable information, its insights are limited due to the retrospective design and the possibility that the reported surgical site complications do not accurately reflect the actual situation. values [16].

Saturno et al. conducted a study to evaluate ChatGPT (Version 4) and its ability to assist in decision-making for breast surgery. They submitted a series of clinical questions and compared the answers with recommendations from three major surgical guidelines. These included Reduction Mammaplasty, Breast Reconstruction using Expanders and Implants, and Autologous Breast Reconstruction with DIEP or Pedicled TRAM Abdominal Flaps. After converting the recommendations into questions, a total of 32 questions were created and then submitted to ChatGPT.

The four raters then evaluated the responses and categorized them as "Fully Concordant," "Partially Concordant," or "non-concordant." ChatGPT's responses were rated as 31.3% fully concordant, 40.6% partially concordant, and 28.1% nonconcordant. For Reduction Mammaplasty, 50% of responses were fully concordant, 20% were partially concordant, and 30% were non-concordant. For Breast reconstruction with expanders & implants, 29.4% of responses were fully concordant, 20% were partially concordant, and 30% were non-concordant.

For autologous breast reconstruction with DIEP or pedicled TRAM abdominal flaps, 75% were partially concordant, and 25% were non-concordant responses. This study shows that although ChatGPT has the potential to support breast surgery decisions, it needs further development before it can be fully integrated into surgical practice [17].

Xu et al. conducted a comprehensive retrospective study to evaluate the agreement with the Chinese Society of Clinical Oncology Artificial Intelligence System (CSCO AI). They analyzed data from 537 breast cancer patients treated at the Second Affiliated Hospital of Anhui Medical University between January 2017 and December 2022. The clinical cases from 2017 to 2020 were analyzed using CSCO AI.

The options recommended by CSCO AI and the current treatment used were compared. The recommendations from CSCO AI and the decisions regarding Multidisciplinary Treatment (MDT) are classified as "Consistent" or "Inconsistent."

Suppose the recommendations of CSCO AI and the treatment currently being applied are aligned, meaning they are consistent; otherwise, they are considered inconsistent. The level of consistency was higher among patients in stages I (85.2%) and III (88.2%) than in stage II (76.06%). When comparing recommendations from CSCO AI with currently used treatments, overall agreement was 80.4%. Consistency was higher in stages I (85.02%) and III (88.46%) than in stage II (76.06%).

When comparing MDT-recommended treatment options with CSCO AI decisions, an overall agreement rate is 92.4%. Although CSCO AI has limitations, its advantages and the promise of future developments in breast cancer treatment should not be overlooked. The study could be improved in the future by increasing the sample size and extending the follow-up periods for patients [18].

Yu et al. developed a sophisticated artificial intelligence model, RDeepNet, to predict recurrence-free survival (RFS) and to explore the relationship between radiomics and the biological foundations of treatment and epigenetics. The RDeepNet model, which incorporates both intratumoral and peritumoral radiomic features, was created. They conducted retrospective analyses using data from 1,113 patients with nonmetastatic invasive breast cancer. Of these, 698 patients were assigned to the training cohort, 171 to the validation cohort, and 244 to the testing cohort. The model demonstrated strong predictive performance, achieving high AUC values for 1-, 2-, and 3-year RFS across the training, validation, and test cohorts.

Additionally, the model successfully classified patients into high- and low-risk groups based on molecular subtypes and treatment choices. The model also correlated with immune cell profiles. Therefore, this study demonstrated that MRI-based radiomics can reflect underlying molecular characteristics. This research elucidates how MRI-based radiomics can be linked to molecular traits and its potential

for personalized breast cancer treatment and prognosis prediction.

Although these findings are encouraging, the study's discussion has limitations, including MRI data variability and the need for longer follow-up to improve overall survival.

Future research should explore the connections between radiomic features and genetic traits. Moreover, they should lengthen the follow-up period and assess overall survival outcomes [19].

Ma et al. developed an MRI-based radiomic model (CSS model) to predict surgical margins and examined its association with the tumor immune microenvironment. This study retrospectively analyzed preoperative breast MRI data from 570 patients across three hospitals from January 2011 to January 2020. The patients were divided into three cohorts: training, testing, and external validation.

The model development process involved extracting radiomic features from tumor and peritumoral segments in MRI images and subsequently using these features in train and validate the model. The AUC values of the model were 0.78, 0.88, and 0.76 for the training, validation, and test cohorts, respectively. The model showed surgical margin positivity rates ranging from 0% to 10% in low-risk groups and from 27.3% to 87.2% in high-risk groups.

Additionally, the study showed that surgical margins influence the tumor immune microenvironment. Patients with positive surgical margins had higher infiltration of B cells, immature dendritic cells, and neutrophils. Moreover, epithelial-mesenchymal transition (EMT) levels were linked to surgical margin positivity, and EMT status could be predicted using radiomic models.

However, factors such as family history of breast cancer, T stage, N stage, histological type, ER, PR, HER-2 status, molecular subtype, and Ki67 did not show statistically significant differences in surgical margin status across the four cohorts. Despite the promising results of this study, it has limitations, including its retrospective design and the lack of standardization among the surgeons performing the surgical procedures. Additionally, this model was not tested in patients with multifocal lesions who received neoadjuvant chemotherapy, which is another limitation of this study. In conclusion, this study demonstrates promise as a reliable predictive model for BCS planning and as a tool to optimize new surgical strategies [20].

Conclusion:

Artificial intelligence can be a valuable tool for surgeons and physicians worldwide to more accurately predict prognosis, often surpassing current conservative systems. However, there is limited information on PubMed comparing these two approaches, especially with larger sample sizes. More research is needed to compare AI systems and models with existing systems and evaluation methods.

Abbreviations

AI - Artificial Intelligence; ML - Machine Learning; DL - Deep Learning; NLP - Natural Language Processing; ChatGPT - Chat Generative Pre-trained Transformer; BC - Breast Cancer; BCS - Breast Cancer Surgery; TNM - Tumor, Node Metastasis; NPI - Nottingham Prognostic Index; AJCC - American Joint Committee on Cancer; LSTM - Long Short-Term Memory; XGBoost - eXtreme Gradient Boosting; SVM - Support Vector Machines; DNA - Deoxyribonucleic acid; GRU - Gated Recurrent Unit; sNPWT - single-use Negative Pressure Wound Therapy; SSCs - Surgical site complications; CP - Clinical Parameter; AUC - Area Under Curve; CatBoost - Categorical Boosting; DP - Demographic Data; DIEP - Deep Inferior Epigastric Perforator; TRAM - Transverse Rectus Abdominis Myocutaneous; CSCO AI - Chinese Society of Clinical Oncology Artificial Intelligence System; MDT- Multi-Disciplinary Treatment; RFS - Recurrence-Free Survival; Rdeepnet - Radiomic Deepsurv Net; MRI - Magnetic Resonance Imaging; EMT - Epithelial-Mesenchymal Transition; ER - Estrogen Receptor; PR - Progesterone Receptor; HER2 - Human Epidermal Growth Factor Receptor 2; Ki67 - Proliferative Index

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