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Efficacy of mammography in assessing safety margin on surgical specimens

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Abstract

Objectives: This study evaluates the efficacy of mammography in assessing surgical margins in breast cancer patients undergoing breast-conserving surgery (BCS) to minimize reoperation rates. By comparing radiologic assessments with histopathology results, we assess mammography's sensitivity, specificity, and diagnostic performance in determining margin status.

Methods: A retrospective analysis was conducted on patients who underwent BCS at Prince Sultan Military Medical City between 2021 and 2023. Radiology assessments from mammography were compared with pathology results to calculate sensitivity, specificity, and the rates of false positives and false negatives.

Results: The study found a sensitivity of 84%, indicating that mammography successfully identified 84% of cases with positive margins. Specificity was 81.6%, with a false positive rate of 18.4% and a false negative rate of 16%. These findings suggest that mammography provides reasonable accuracy for intraoperative margin assessment, although the presence of false positives and false negatives highlights the need for further optimization.

Conclusion: While mammography offers a relatively effective method for intraoperative margin assessment, improvements are needed to reduce the rates of false positives and false negatives. Advanced imaging technologies, such as digital breast tomosynthesis, may enhance the precision of margin assessments.

Keywords: Breast-Conserving Surgery; Mammography; Sensitivity; Specificity; Image-Guided Biopsy

1. Introduction

Breast cancer is a leading cause of morbidity and mortality worldwide, affecting millions of women each year. In 2020, breast cancer was estimated to account for 2.3 million cases and 685,000 deaths across the globe (1). Due to advancements in breast cancer screening programs and improved public awareness, the rate of early-stage breast cancer detection has increased, allowing more patients to become eligible for breast-conserving surgery (BCS) (2). BCS, which aims to remove cancerous tissue while preserving as much healthy breast tissue as possible, has become a widely preferred treatment option due to its efficacy in achieving favorable cosmetic outcomes and its comparable survival rates to mastectomy when combined with radiation therapy (3). However, the success of BCS largely depends on achieving clear surgical margins, as positive margins are associated with higher rates of local recurrence.

Traditionally, margin status has been assessed through postoperative pathology, which involves examining resected tissue to determine if cancer cells are present at the edges of the specimen (4). Although pathology remains the gold standard for margin assessment, it introduces delays and can lead to additional surgical procedures if positive margins are identified. Reoperations not only increase the physical and psychological burden on patients but also contribute to

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higher healthcare costs and extended recovery times. Consequently, there is a pressing need for real-time, intraoperative methods to assess margins and provide immediate feedback to surgeons (5).

Mammography has emerged as a potential tool for intraoperative margin assessment due to its widespread use in breast cancer screening and its ability to provide quick imaging results (6). However, studies evaluating the effectiveness of mammography for this purpose have reported variable outcomes. Sensitivity rates in identifying positive margins range from 20.6% to 45.45%, while specificity rates are between 85.25% and 94.6% (7-9). These variations are attributed to factors such as the limited resolution of conventional mammography, the challenge of interpreting two-dimensional images of three-dimensional specimens, and difficulties in imaging dense breast tissue (10). Despite these limitations, mammography remains a promising option for intraoperative margin assessment due to its accessibility and familiarity to surgeons and radiologists.

In Saudi Arabia, breast cancer is a significant health concern, accounting for a substantial percentage of cancer diagnoses among women (11). However, there has been limited research on the use of mammography for intraopFerative margin assessment in the region. This study aims to address this gap by evaluating the efficacy of mammography in assessing margin status in patients undergoing BCS at Prince Sultan Military Medical City. By examining the sensitivity, specificity, and rates of false positives and false negatives associated with mammography, this research seeks to contribute valuable insights into the potential of mammography as a tool for intraoperative margin assessment in breast cancer surgeries.

2. Methods

This retrospective study was conducted at Prince Sultan Military Medical City, focusing on patients who underwent BCS between 2021 and 2023. The study included patients diagnosed with invasive ductal carcinoma (IDC) or ductal carcinoma in situ (DCIS) who were eligible for BCS. The primary goal was to assess the efficacy of mammography in determining margin status by comparing radiology reports of specimen radiographs with histopathology results. Ethical approvals were obtained from relevant institutional review boards, and patient confidentiality was maintained throughout the study.

A total of 74 patients who met the inclusion criteria were included in the analysis. Radiologic assessments were conducted using specimen mammography, with radiologists classifying margins based on specific criteria. Positive margins were defined as the presence of visible lesions or calcifications at the cut margin or within 1.5 mm, while free margins were defined as lesions or calcifications located more than 1.5 mm from the cut margin. In cases where lesions demonstrated a complete response to neoadjuvant therapy (NAT) with a tissue marker positioned more than 4 mm from the margin, the margin was also considered free. Cases in which dense parenchymal tissue obscured lesion visibility were classified as inconclusive.

To evaluate mammography's diagnostic performance, we calculated sensitivity, specificity, false positive rate, and false negative rate. Sensitivity was defined as the proportion of true positive margins correctly identified by radiology, while specificity referred to the proportion of true negative margins correctly identified. The false positive rate represented the proportion of cases where radiology indicated positive margins despite negative pathology findings, and the false negative rate indicated cases where pathology confirmed positive margins missed by radiology.

Data analysis was performed using statistical software, with sensitivity and specificity presented as percentages. Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population, providing a comprehensive overview of the patient cohort included in the analysis.

2.1. Ethical Approval and Informed Consent Waiver

This study received ethical approval from the Research Ethics Committee at Prince Sultan Military Medical City (PSMMC). This research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Given the retrospective nature of this study, anonymized patient data were retrieved from the Picture Archiving and Communication System (PACS) database at PSMMC. No direct patient interaction occurred, and no identifiable personal information was used. Therefore, the requirement for informed consent was waived by the PSMMC Research Ethics Committee.

3. Results

This study evaluated 74 patients who underwent BSC at Prince Sultan Military Medical City, with the objective of assessing the accuracy of mammography in determining surgical margin status. Radiologic assessments of surgical

margins were compared with histopathologic findings to determine the efficacy of mammography in identifying positive and negative margins. The outcomes of these assessments are summarized in Table 1.

Table 1 Concordance of radiologic and pathologic margin assessments

Margin assessment category	Radiology (mammography)	Pathology	Frequency
True Positive (TP)	Positive	Positive	21
True Negative (TN)	Negative	Negative	40
False Positive (FP)	Positive	Negative	9
False Negative (FN)	Negative	Positive	4

The diagnostic performance metrics derived from these data include sensitivity, specificity, false positive rate, and false negative rate. These metrics are summarized in Table 2.

Table 2 Diagnostic performance metrics for mammography in margin assessment

Metric	Calculation formula	Value
Sensitivity	TP / (TP + FN)	84%
Specificity	TN / (TN + FP)	81.6%
False positive rate	FP / (FP + TN)	18.4%
False negative rate	FN / (FN + TP)	16%

The sensitivity of mammography for margin assessment was calculated at 84%, indicating its capability to identify true positive margins in 84% of cases with confirmed positive pathology. Specificity was determined to be 81.6%, reflecting the proportion of true negatives correctly identified by mammography. The false positive rate of 18.4% suggests a moderate degree of overestimation, wherein mammography identified some cases as positive despite negative histopathologic findings. The false negative rate of 16% indicates the occurrence of missed positive margins by mammography that were later confirmed by pathology.

4. Discussion

The findings from this study highlight the strengths and limitations of mammography as an intraoperative tool for assessing surgical margins during BSC. The observed sensitivity of 84% suggests that mammography is relatively effective at detecting positive margins, which is critical for minimizing the risk of local recurrence by ensuring that no cancerous tissue remains. In comparison, the specificity of 81.6% indicates a reasonable accuracy in correctly identifying negative margins, although there remains a notable false positive rate of 18.4% and a false negative rate of 16%. These findings align with previous studies, which have reported variable sensitivity and specificity for mammography in intraoperative margin assessment (6, 12), reflecting both the potential and limitations of this imaging modality.

The variability in mammography's sensitivity and specificity across different studies has been attributed to multiple factors, including variations in imaging technology, the experience of radiologists, and patient characteristics such as breast density (13, 14). For example, dense breast tissue has long been recognized as a challenge in mammographic imaging, as it can obscure small lesions and limit visibility of tumor boundaries. This limitation is particularly relevant in the context of intraoperative margin assessment, where accurate detection of even small residual tumor foci is crucial. Studies have demonstrated that higher breast density is associated with decreased diagnostic accuracy in both screening and intraoperative settings (15, 16), highlighting a potential area for improvement in current imaging practices.

Furthermore, the false positive rate of 18.4% observed in this study raises concerns regarding the potential for overtreatment. False positives in margin assessment can lead to the unnecessary removal of additional healthy tissue or even additional surgeries, which may not only affect cosmetic outcomes but also increase the physical and psychological burden on patients (17, 18). The implications of false positives are significant in BCS, where preserving

healthy breast tissue is a key goal. These findings are consistent with literature that underscores the limitations of two-dimensional mammography in providing detailed spatial information, which can lead to overestimation of tumor extent (19). Advanced imaging techniques, such as digital breast tomosynthesis, have shown promise in providing a more three-dimensional view of the breast, potentially reducing false positives by offering improved differentiation between benign and malignant tissue (20).

Conversely, the false negative rate of 16% highlights the risk of undetected positive margins, which can result in local recurrence and subsequent need for reoperation. Intraoperative false negatives can be attributed to several factors, including limited resolution in mammography, challenges in detecting microscopic or diffuse tumor extensions, and the inherent limitations of two-dimensional imaging for assessing three-dimensional specimens (14, 21). False negatives present a critical challenge in BCS, as undetected residual disease may compromise long-term patient outcomes (22). Recent advancements in intraoperative imaging, such as specimen radiography with digital tomosynthesis and optical coherence tomography, have been explored as potential alternatives that may offer higher sensitivity for detecting residual cancerous tissue while reducing false negatives (23). These modalities allow for a more comprehensive visualization of the specimen, potentially improving accuracy in cases where conventional mammography falls short.

While our findings contribute valuable insights into the diagnostic performance of mammography in intraoperative margin assessment, they also highlight the need for continued research and innovation in this area. Future studies could explore the combined use of mammography with adjunctive imaging techniques, such as contrast-enhanced mammography, ultrasound, or magnetic resonance imaging (MRI), to provide a multimodal approach for intraoperative margin assessment. This approach could potentially leverage the strengths of each modality, improving overall accuracy and reducing the rates of both false positives and false negatives. Additionally, integrating computer-aided detection (CAD) and artificial intelligence (AI) algorithms into intraoperative imaging workflows may enhance radiologist performance by providing automated margin assessment and reducing inter-reader variability. Emerging AI models have demonstrated promising results in breast cancer detection and diagnosis, and their application to intraoperative margin assessment represents an exciting avenue for future research (21, 24, 25).

Another area of potential development is the standardization of radiographic criteria for margin assessment. Current practices in intraoperative margin assessment lack standardization, which may contribute to variability in diagnostic performance. Establishing clear, evidence-based guidelines for interpreting mammographic findings in the context of BCS could improve consistency across institutions and reduce discrepancies between radiologic and histopathologic evaluations (26, 27). Such guidelines could incorporate specific criteria for margin assessment, such as threshold distances for determining positive or negative status, to assist radiologists and surgeons in making more informed decisions intraoperatively.

The limitations of this study should also be considered. As a retrospective analysis conducted at a single institution, the findings may not be generalizable to other populations or settings. Additionally, the study relied on conventional mammography, which may not reflect the diagnostic performance of more advanced imaging modalities. Future prospective studies with larger sample sizes and the inclusion of advanced imaging techniques could provide a more comprehensive evaluation of mammography's role in intraoperative margin assessment.

5. Conclusion

while mammography demonstrates reasonable sensitivity and specificity for intraoperative margin assessment, the presence of false positives and false negatives suggests a need for caution in relying solely on this modality. The incorporation of advanced imaging techniques, such as digital breast tomosynthesis, and the exploration of multimodal approaches may hold promise in enhancing diagnostic accuracy. By improving intraoperative margin assessment, healthcare providers can reduce reoperation rates, minimize patient morbidity, and ultimately improve outcomes for patients undergoing BCS.

Compliance with ethical standards

Disclosure of conflict of interest

No competing interests were disclosed.

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Data availability

- Underlying data

Figshare: reasersh margins https://doi.org/10.6084/m9.figshare.28450829.v1 (28)

This project contains the following underlying data:

- reasersh margins.xlsx

Extended data

No extended data were used or generated for this research article. All data used and analyzed are fully presented within the manuscript or made available as underlying data.

Statement of ethical approval

This study received ethical approval from the Research Ethics Committee at Prince Sultan Military Medical City (PSMMC). This research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Given the retrospective nature of this study, anonymized patient data were retrieved from the Picture Archiving and Communication System (PACS) database at PSMMC.

Statement of informed consent

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