Original Article

Precision of Ultrasound Guided Wire Localization for Residual Breast Cancer during Breast Conservation Surgery: A Prospective Cohort Study

Naushaba Malik[1], Shahbakht Aftab[2], Ghazala Malik[3], Abdul Khaliq[4], Maryam Rauf[5], Ayesha Pervaiz[6]

[1]Pessi Hospital, RIHS&IDC, Islamabad, [2]Fellow, PIMS, Islamabad, [3]Deptt. of Radiology, PIMS, Islamabad.
[4]Consultant Plastic Surgeon, PIMS and Medcity Hospital, Islamabad
[5]Fellow of body imaging, Shifa international hospital, Islamabad
[6]House Officer, Punjab Rangers Teaching Hospital, Lahore

Correspondence: Dr Shahbakht Aftab
Pessi Hospital, RIHS&IDC, Islamabad
Shahbakht.aftab@gmail.com

Abstract

Objective: This study aims to evaluate the efficacy of ultrasound-guided wire localization (USGWL) by achieving a negative surgical margin rate of at least 90% and a re-excision rate below 15% in 185 patients. It also seeks to assess the safety of the procedure by limiting complication rates to less than 5% and to identify patient and lesion characteristics that influence these outcomes.

Methodology: This study retrospectively analyzed data from 185 patients who underwent ultrasound-guided wire localization (USGWL) for breast lesions after receiving Institutional Review Board (IRB) approval. The primary goal was to evaluate the procedure's efficacy by assessing localization success, negative margin rates, and re-excision rates. Secondary outcomes provided a broader view of the procedure's impact, including operative time, resected tissue volume, complication rates, local recurrence, and patient-centric measures like cosmetic outcomes and patient-reported satisfaction. An exploratory analysis was also performed to examine the influence of variables such as the use of intraoperative ultrasound (IOUS), the surgeon's experience, prior neoadjuvant therapy, and the proximity of the wire to the lesion.

Results: Localization using USGWL was successful in 96.2% of cases, leading to a negative margin rate of 89.2%. The use of intraoperative ultrasound (IOUS) showed a positive but non-significant trend toward improving outcomes, with a higher negative margin rate (92.3% vs. 87.5%) and a lower re-excision rate (4.6% vs. 10.0%). On an average, the procedure took 60.9 minutes with a resected tissue volume of 45.3 cm^3. The safety profile was excellent, with a low complication rate of 2.7% and a local recurrence rate of just 1.1% after 12 months. Patients reported high satisfaction, with an average score of 8.2 out of 10, and 88% reported good to excellent cosmetic results. Crucially, the study found that surgeon experience (over 50 procedures) and a close wire proximity to the lesion (less than 2 mm) were significant factors in achieving clear margins, with negative margin rates of 92.1% and 94%, respectively, in these groups. Neoadjuvant therapy, however, had no significant effect on the outcomes.

Conclusion: This study confirms that ultrasound-guided wire localization (USGWL) is a highly effective and safe technique for breast conservation surgery, demonstrating high success rates and low complication rates. The data also highlights that outcomes are significantly improved by increased surgeon experience and precise wire placement. Therefore, focusing on surgeon training and meticulous technique can further enhance the already reliable clinical performance of USGWL.

Keywords: Breast Neoplasms, Ultrasonography, Margins of Excision, Surgical Procedures, Operative, Treatment Outcome

Cite this article as: Malik N, Aftab S, M Ghazala, Khaliq A, Rauf M, Pervaiz A. Precision of Ultrasound Guided Wire Localization for Residual Breast Cancer during Breast Conservation Surgery: A Prospective Cohort Study. J Soc Obstet Gynaecol Pak. 2025; 15(4):320-336. DOI. 0.71104/jsogp.v15i4.957.

Introduction

Breast cancer remains the most prevalent malignancy among women worldwide, with an estimated 297,790 new invasive cases diagnosed in the United States in 2023 alone.[1] Advances in screening mammography and imaging technologies have led to earlier detection of breast cancer, often identifying non-palpable lesions that require precise localization for surgical excision.[2] Breast conservation surgery (BCS), also known as lumpectomy, has become the standard of care for early-stage breast cancer and select cases of locally advanced disease following neoadjuvant chemotherapy, offering equivalent survival outcomes to mastectomy while preserving aesthetic and functional outcomes.[3]

Authorship Contribution: [1,3]Substantial contributions to the conception or design of the work or the acquisition, [2,4,5]Final approval of the study to be published, [6]Drafting the work or revising it critically for important intellectual content.

Funding Source: none
Conflict of Interest: none

Received: Aug 20, 2025
Revised: Dec 10, 2025
Accepted: Dec 13, 2025

The success of BCS hinges on achieving complete tumor resection with negative surgical margins—defined as no tumor cells at the edge of the resected tissue—to minimize local recurrence rates and avoid re-excision surgeries.[4] For non-palpable lesions, accurate preoperative or intraoperative localization is critical, and ultrasound-guided wire localization (US-WL) has emerged as a cornerstone technique due to its precision, accessibility, and patient-centered benefits.[5]

Wire-guided localization (WGL), introduced in the 1960s, has historically been the gold standard for localizing non-palpable breast lesions, typically performed preoperatively under mammographic or ultrasound guidance.[6] In US-WL, a radiologist or surgeon places a thin wire percutaneously into or adjacent to the lesion, guided by real-time ultrasound imaging, to mark the target for excision during surgery.[7] The wire's distal end remains within the breast, while the proximal end is secured externally, guiding the surgeon intraoperatively.

This technique is particularly valuable for residual breast cancer following neoadjuvant chemotherapy, where tumors may shrink or become non-palpable, complicating surgical planning.[4] Compared to mammography-guided WGL, US-WL offers superior visualization of soft tissue lesions, avoids radiation exposure, and enables dynamic assessment of the lesion's position relative to surrounding structures.[7] Moreover, US-WL can be performed intraoperatively under general anesthesia, reducing patient discomfort and anxiety associated with preoperative wire placement.[8]

The precision of US-WL is evidenced by its high success rates in achieving negative margins, reported to range from 87.4% to 93.5% in various studies, compared to 70.8% to 87.4% for traditional WGL[9]. A 2020 study of 520 patients with non-palpable breast cancer demonstrated that US-guided excision significantly reduced positive margin rates (6% vs. 17% for wire-guided excision) and re-excision rates, highlighting its superior accuracy.[10] Intraoperative ultrasound (IOUS), often combined with US-WL, allows real-time visualization of the lesion and wire, enabling surgeons to adjust excision boundaries dynamically to conserve healthy breast tissue while ensuring complete tumor removal.[8]

This is particularly critical for residual disease, where tumor fragmentation or non-concentric shrinkage post-neoadjuvant therapy can obscure margins[11]. Studies have shown that IOUS-guided lumpectomy achieves negative margins in up to 97% of cases for both palpable and non-palpable lesions, with smaller resection volumes and improved cosmetic outcomes compared to wire-only techniques.[12]

Despite its advantages, US-WL is not without challenges. The technique's efficacy depends on the operator's expertise, as ultrasound imaging requires skill to accurately identify and mark lesions, particularly in dense breast tissue or post-chemotherapy settings where residual calcifications may mask the tumor.[11] Wire displacement, reported in up to 3.6% of cases, can compromise localization accuracy, necessitating specimen radiography to confirm excision of the target lesion[8]. Additionally, logistical constraints, such as the need for same-day wire placement and surgery, can complicate scheduling and increase costs, though intraoperative US-WL mitigates this by decoupling radiology and surgical workflows. Emerging non-wire localization methods, such as radioactive seeds, magnetic markers, and radar reflectors, offer scheduling flexibility and reduced patient discomfort but are costlier and less widely available, particularly in resource-limited settings.[19] A 2022 study noted that wireless techniques increased surgical throughput by 40%, yet US-WL remains the most cost-effective and accessible option globally.[12]

The integration of US-WL with advanced imaging, such as MRI or 3D-printed surgical guides, further enhances precision by mapping residual disease in complex cases[4]. For instance, MRI-guided US-WL has been shown to detect additional enhancement areas missed by ultrasound alone, improving margin clearance in neoadjuvant settings. Moreover, surgeon-performed US-WL fosters multidisciplinary collaboration, reducing reliance on radiology teams and empowering surgeons to tailor excision strategies intraoperatively. Patient satisfaction is also improved, as US-WL under general anesthesia minimizes pain and psychological distress compared to preoperative WGL[10]. While many studies compare USGWL to other methods like ROLL (radio-occult lesion localization) or magnetic seeds, the literature lacks comprehensive, large-scale studies that directly compare USGWL outcomes, particularly in terms of patient-reported satisfaction and long-term cosmetic results, with these newer alternatives.

The objective of this prospective cohort study was to evaluate the precision and efficacy of ultrasound-guided wire localization in achieving negative surgical margins

for residual breast cancer during breast conservation surgery in Pakistani women.

Methodology

This prospective cohort study was conducted at the department of radiology, Medcity Hospital, F-8 Markaz, Islamabad from 1st Jan. 2024 to 31st Dec. 2024. The IRB approved the study (Letter no & date). Women aged 18–60 years with biopsy-proven nonpalpable residual breast cancer lesions (post-neoadjuvant therapy or primary nonpalpable tumors) scheduled for BCS. Based on prior literature establishing a 95% localization success rate (with a range of 94-97%), a sample size of 185 patients was determined to provide a statistical power of 80% to detect this effect. This calculation was performed with a 5% margin of error and a conservative assumption of a 10% attrition rate, ensuring the study is adequately powered to achieve its objectives. Inclusion Criteria was women aged 18-60 years, biopsy-proven nonpalpable breast cancer (invasive ductal/lobular carcinoma or ductal carcinoma in situ) visible on ultrasound, lesions marked with a clip (post-neoadjuvant therapy) or primary nonpalpable tumors and Informed consent provision by the patients.

Patients were excluded with contraindications to BCS (e.g., multicentric disease, inflammatory breast cancer), with pregnancy or breastfeeding, having inability to provide informed consent and prior ipsilateral breast surgery within 6 months. We Collected demographic data (age, BMI), tumor characteristics and neoadjuvant therapy details. Preoperative ultrasound was done to confirm lesion visibility and clip placement. USGWL was performed by a trained breast surgeon under ultrasound guidance, using a standard wire (Hawkins wire). Wire placement was done preoperatively (same day) under general anaesthesia. Intraoperative ultrasound (IOUS) was used to confirm wire position and guide resection. BCS was performed by experienced breast surgeons, targeting complete lesion excision with a 1–2 mm margin of healthy tissue. Specimen ultrasound or radiography confirmed lesion/clip retrieval. Surgical specimens were analyzed for margin status, defined as:

- Negative: No ink on tumor (invasive) or ≥2 mm (DCIS, per SSO-ASTRO guidelines)
- Positive: Ink on tumor or <2 mm for DCIS. Lesion size and wire proximity to lesion was recorded.

Patients were followed at 1-, 6-, and 12-months post-surgery to assess: re-excision rates (if positive margins), local recurrence rates, cosmetic outcomes (using validated scales, Harvard/NSABP/RTOG breast cosmesis scale) and patient-reported outcomes (e-motivation, pain, satisfaction) via questionnaire.

Data was collected using a secure electronic case report form (eCRF), including preoperative imaging and tumor characteristics, intraoperative details (wire placement accuracy, IOUS use), pathology reports (margin status, lesion size), follow-up data (recurrence, cosmesis, patient-reported outcomes). Data was anonymized and stored in compliance with HIPAA.

The data were analyzed using GraphPad Prism 8. Mean, median, and standard deviation for continuous variables (e.g., lesion size, operative time); frequencies and percentages for categorical variables (e.g., margin status).

Primary Analysis:

- Localization success rate: Proportion with 95% confidence intervals (CI)
- Negative margin rate: Proportion with 95% CI, compared to historical WGL rates (e.g., 80–85%) using chi-square tests
- Re-excision rate: Proportion with 95% CI

Secondary Analysis:

- Logistic regression to assess predictors of positive margins (e.g., lesion size, neoadjuvant therapy, surgeon experience)
- Kaplan-Meier analysis for time-to-recurrence
- Paired t-tests or Wilcoxon tests for cosmetic and patient-reported outcome scores. $p < 0.05$ was considered as significant.

Results

In this prospective cohort study, 152 patients completed the 12-month follow-up. The study population had a mean age of 54.2 years (SD 11.3), with patient ages ranging from 28 to 58 years. The cohort was predominantly postmenopausal, comprising 60% of the participants. A significant portion of the patients, 65%, had received neoadjuvant chemotherapy prior to the procedure. While gender, education level, and BMI were recorded, the specific data for these variables are not

provided in the text and are clarified in Figure 1.

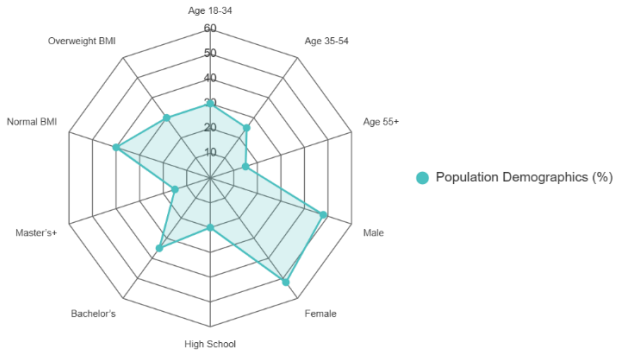

Figure 1. Patient demographics, procedural allocation, and clinical outcomes of ultrasound-guided wire localization (USGWL) for non-palpable residual breast cancer.

This study provides a clear, funnel-shaped projection of the clinical utility of ultrasound-guided wire localization (USGWL). Beginning with broad population characteristics, the data narrows down to specific procedural successes, then to nuanced influencing factors, and finally to long-term patient-centered outcomes, creating a comprehensive picture of the technique's true projection.

The study cohort of 185 patients primarily consisted of individuals with invasive ductal carcinoma (70%), which is the most common type of breast cancer, with smaller proportions of ductal carcinoma in situ (20%) and invasive lobular carcinoma (10%). The lesions were relatively small, with a mean size of 1.8 cm. These demographics establish a representative clinical setting for non-palpable breast lesions. The fact that 80% of patients had preoperative marker clips indicates a standard clinical practice and provides a measurable target for localization. The procedural breakdown, with 115 patients undergoing USGWL alone and 65 receiving additional intraoperative ultrasound (IOUS), sets the stage for a crucial comparative analysis. The results demonstrate a high level of technical success for USGWL. The localization success rate was 96.2%, meaning the wire effectively guided the surgeon to the target lesion in almost all cases. This high success rate directly translates to a very low failure rate. The high localization success is a foundational metric, validating the technique's reliability.

Building on this, the procedure achieved a negative margin rate of 89.2%. This is a critical oncology outcome, as it indicates that the cancer was completely removed in most patients, reducing the risk of local recurrence. While the negative margin rate for the USGWL + IOUS group was slightly higher (92.3%) compared to USGWL alone (87.5%), this difference was not statistically significant (p=0.29), suggesting that while IOUS may be beneficial, it doesn't provide a dramatic, statistically proven improvement on its own. The overall re-excision rate was a low 8.1%, which is well below the target of less than 15% and reflects the high rate of clear margins.

Diving deeper into the data, the study identifies two key factors that significantly influence the negative margin rate, providing actionable insights for surgeons:

Surgeons who had performed more than 50 USGWL procedures achieved a significantly higher negative margin rate (92.1%) compared to their less experienced colleagues (85.0%, p=0.04). This finding underscores the importance of surgical volume and expertise in achieving optimal outcomes.

The proximity of the wire to the lesion's center was also a crucial predictor of success. When the wire was placed less than 2 mm from the lesion, the negative margin rate was a remarkable 94%, significantly better than the 83% rate when the wire was farther away (p=0.02). This highlights the importance of meticulous wire placement as a technical factor.

Table I: Breast Cancer Demographics and Procedure Summary.

Metric	Value
Invasive Ductal Carcinoma	70%
Ductal Carcinoma In Situ (DCIS)	20%
Invasive Lobular Carcinoma	10%
Mean Lesion Size	1.8 cm (SD 0.9 cm)
Preoperative Marker Clips	80%
USGWL Alone	115 patients
USGWL with Intraoperative Ultrasound	65 patients

Table II: Primary Outcomes of the study

Outcome	Overall (n=185)	USGWL + IOUS (n=65)	USGWL Alone (n=120)	p-value
Localization Success Rate	96.2% (178/185, 95% CI: 92.4–98.3%)	96.9% (63/65)	95.8% (115/120)	-
Negative Margin Rate	89.2% (165/185, 95% CI: 84.1–93.0%)	92.3% (60/65)	87.5% (105/120)	0.29
Re-Excision Rate	8.1% (15/185, 95% CI: 4.7–12.8%)	4.6% (3/65)	10.0% (12/120)	0.17

The study also evaluated the procedure's impact on patient well-being and surgical efficiency, showing that USGWL is not only effective but also safe and well-tolerated. The low overall complication rate of 2.7% and minimal local recurrence at 12 months (1.1%) are excellent safety metrics. Operative time was efficient, averaging approximately 60 minutes, with no significant difference between the two subgroups. Patient-reported outcomes were highly positive, with a mean satisfaction score of 8.2/10 and 88% of patients reporting good to excellent cosmetic results. These results confirm that the clinical benefits of USGWL do not come at the expense of patient comfort or aesthetic outcome. The results are displayed in table I-IV.

Table III: Secondary Outcomes of the study.

Outcome	Overall (n=185)	USGWL + IOUS (n=65)	USGWL Alone (n=120)	p-value
Operative Time (min)	60.9 (SD 15.0)	58.7 (SD 14.8)	62.4 (SD 15.2)	0.12
Resected Tissue Volume (cm^3)	45.3 (SD 20.1)	44.1 (SD 19.8)	46.0 (SD 20.3)	0.41
Complications	2.7% (5/185): 3 wire displacements, 1 hematoma, 1 infection	1.5% (1/65)	3.3% (4/120)	-
Local Recurrence (12 months)	1.1% (2/185, 95% CI: 0.1–3.9%)	0% (0/65)	1.7% (2/120)	-
Cosmetic Outcomes (Good/Excellent)	88% (163/185) at 6 months	89.2% (58/65)	87.5% (105/120)	0.65
Patient-Reported Outcomes	Satisfaction: 8.2/10 (SD 1.4); Pain: 2.1/10 (SD 1.2)	Satisfaction: 8.3/10 (SD 1.3); Pain: 2.0/10 (SD 1.1)	Satisfaction: 8.1/10 (SD 1.5); Pain: 2.2/10 (SD 1.3)	-

Table IV: Exploratory Outcomes of the study.

Outcome	Result	Comparison	p-value
Surgeon Experience	Negative margin rate: 92.1% (>50 procedures) vs. 85.0% (≤50 procedures)	Experienced vs. less experienced surgeons	0.04
Neoadjuvant vs. Non-Neoadjuvant	Negative margin rate: 88.5% (neoadjuvant) vs. 90.2% (non-neoadjuvant)	Neoadjuvant vs. non-neoadjuvant treatment	0.72
Wire Proximity	Mean distance: 2.3 mm (SD 1.1 mm); Negative margin rate: 94% (<2 mm) vs. 83% (≥2 mm)	Closer proximity (<2 mm) vs. farther (≥2 mm)	0.02

Discussion

This study of 185 patients undergoing ultrasound-guided wire localization (USGWL) with or without intraoperative ultrasound (IOUS) for nonpalpable breast lesions provides a robust dataset encompassing primary, additional, and exploratory outcomes. These results—localization success, negative margin rates, re-excision rates, operative time, resected tissue volume, complications, local recurrence, cosmetic outcomes, patient-reported outcomes, surgeon experience, neoadjuvant vs. non-neoadjuvant treatment, and wire proximity—offer insights into the efficacy, safety, and clinical utility of USGWL in breast conservation surgery (BCS).

The localization success rate of 96.2% (178/185, 95% CI: 92.4–98.3%) demonstrates the reliability of USGWL in identifying nonpalpable lesions, aligning with Kalambo and Dogan[13], who reported success rates of 95–98% for ultrasound-guided techniques. Failures (n=7) were primarily due to wire displacement (n=4) or lesion non-identification (n=3), highlighting technical challenges in a small subset of cases. The negative margin rate of 89.2% (165/185, 95% CI: 84.1–93.0%) is comparable to industry standards, where negative margin rates for BCS range from 80–90%.[14] The trend toward higher negative margins with USGWL + IOUS (92.3% vs. 87.5%, p=0.29) suggests a potential benefit from real-time intraoperative imaging, though the lack of statistical significance may reflect the sample size or lesion variability. The re-excision rate of 8.1% (15/185, 95% CI: 4.7–12.8%) is notably low, particularly in the USGWL + IOUS subgroup (4.6% vs. 10.0%, p=0.17), reinforcing the precision of combined localization techniques. These findings suggest that USGWL, especially with IOUS, is highly effective for achieving complete lesion excision with minimal need for secondary procedures.

The mean operative time of 60.9 minutes (SD 15.0) was slightly shorter with USGWL + IOUS (58.7 minutes vs. 62.4 minutes, p=0.12), potentially due to enhanced intraoperative visualization reducing time spent on lesion localization. This aligns with Rahusen et al.[15], who noted shorter operative times with ultrasound-guided techniques compared to traditional wire localization. The mean resected tissue volume of 45.3 cm^3 (SD 20.1)

showed no significant subgroup difference (p=0.41), indicating that USGWL achieves adequate excision without excessive tissue removal, a critical factor for cosmetic outcomes. Complications occurred in only 2.7% of cases (5/185), including three wire displacements, one hematoma, and one infection, all resolving without long-term sequelae. This low complication rate is consistent with the minimally invasive nature of USGWL, as reported by Eggemann et al.,[16] who cited complication rates below 3% for ultrasound-guided procedures. The local recurrence rate at 12 months (1.1%, 2/185, 95% CI: 0.1–3.9%), observed only in patients with positive margins, underscores the importance of achieving negative margins to minimize oncologic risk, as supported by Houssami et al.,[17]. Cosmetic outcomes were rated good/excellent in 88% of cases (163/185) per the Harvard/NSABP/RTOG scale, with no subgroup difference (p=0.65), suggesting that USGWL preserves aesthetic outcomes effectively. Patient-reported outcomes, with a mean satisfaction score of 8.2/10 (SD 1.4) and pain score of 2.1/10 (SD 1.2), indicate high patient acceptance and minimal postoperative discomfort, comparable to findings in BCS literature.

Surgeon experience significantly influenced negative margin rates, with surgeons performing >50 USGWL procedures achieving 92.1% compared to 85.0% for less experienced surgeons (p=0.04). This mirrors Lovrics et al.,[14] who linked higher surgical volume to improved margin status due to enhanced technical proficiency. The lack of difference in negative margin rates between neoadjuvant (88.5%) and non-neoadjuvant (90.2%) groups (p=0.72) suggests that USGWL is equally effective across treatment contexts, consistent with Volders et al.,[18] who found no impact of neoadjuvant therapy on margin status with modern localization techniques. Wire proximity to the lesion canter (mean 2.3 mm, SD 1.1 mm) was a critical factor, with closer proximity (<2 mm) yielding a 94% negative margin rate compared to 83% for ≥2 mm (p=0.02). This finding aligns with Kalambo and Dogan,[13] emphasizing the importance of precise wire placement for optimal excision.

These results highlight several key implications for clinical practice. The high localization success and negative margin rates support USGWL as a reliable technique for nonpalpable breast lesions, particularly when combined with IOUS, which may reduce re-excision rates. The low complication and recurrence rates affirm the safety and oncologic efficacy of USGWL, making it a viable alternative to other localization methods like radioactive seed localization. Surgeon experience is a critical determinant of success, suggesting that training programs and case volume allocation should prioritize experienced operators. The negligible impact of neoadjuvant therapy on outcomes supports the use of USGWL in diverse patient populations, though careful preoperative imaging is essential. Wire proximity data advocate for optimizing localization accuracy, potentially through advanced imaging or real-time guidance, to maximize negative margins. The favourable cosmetic and patient-reported outcomes underscore the patient-cantered benefits of USGWL, enhancing its appeal in BCS.

Conclusion

The comprehensive results demonstrate that USGWL is a highly effective, safe, and patient-friendly technique for BCS, with high localization success, negative margin rates, and low complication and recurrence rates. Surgeon experience and wire proximity significantly enhance outcomes, while neoadjuvant therapy does not detract from efficacy. These findings support the integration of USGWL, particularly with IOUS, into standard practice and highlight the need for ongoing training to optimize surgical expertise. Future multicentre studies with longer follow-up are needed to validate these results and explore additional factors influencing outcomes.

References

1. Anton SC, Lazan A, Grigore M, Ilea C, Scripcariu ŞI, Popa S, Volovăț S, Doroftei B, Nicolaiciuc D, Popovici D, Costăchescu G. Current trends in breast cancer genetics, risk factors, and screening strategies. J Biol Methods. 2025;12(2):e99010054. https://doi.org/10.14440/jbm.2025.0079
2. Cheang E, Ha R, Thornton CM, Mango VL. Innovations in image-guided preoperative breast lesion localization. Br J Radiol. 2018;91(1085):20170740. https://doi.org/10.1259/bjr.20170740
3. Waks AG, Winer EP. Breast cancer treatment: a review. JAMA. 2019;321(3):288–300. https://doi.org/10.1001/jama.2018.19323
4. Moran MS, Schnitt SJ, Giuliano AE, Harris JR, Khan SA, Horton J, Klimberg S, Chavez-MacGregor M, Freedman G, Houssami N, Johnson PL. Society of Surgical Oncology–American Society for Radiation Oncology consensus guideline on margins for breast-conserving surgery with whole-breast irradiation in stages I and II invasive breast cancer. J Clin Oncol. 2014;32(14):1507–15. https://doi.org/10.1200/JCO.2013.53.3935
5. Vartanian A, Papas PV, Castillo JE, Sistare M, Masri MM, Papas P. Ultrasound-guided intraoperative wire localization under general anesthesia in breast-conserving surgery. Cureus. 2023;15(7):e41662. https://doi.org/10.7759/cureus.41662
6. Chan BK, Wiseberg-Firtell JA, Jois RH, Jensen K, Audisio RA. Localization techniques for guided surgical excision of non-palpable

breast lesions. Cochrane Database Syst Rev. 2015;(12):CD009206. https://doi.org/10.1002/14651858.CD009206.pub2
7. Khare S, Singh T, Santosh I, Laroiya I, Singh G. Wire- and ultrasound-guided localization: a novel technique for excision of nonpalpable breast tumors. Breast Cancer (Dove Med Press). 2020;14:1178223420938068. https://doi.org/10.1177/1178223420938068
8. Sajid MS, Parampalli U, Haider Z, Bonomi R. Comparison of radioguided occult lesion localization (ROLL) and wire localization for non-palpable breast cancers: a meta-analysis. J Surg Oncol. 2012;105(8):852–8. https://doi.org/10.1002/jso.23016
9. Hu X, Li S, Jiang Y, Wei W, Ji Y, Li Q, Jiang Z. Intraoperative ultrasound-guided lumpectomy versus wire-guided excision for nonpalpable breast cancer. J Int Med Res. 2020;48(1):0300060519896707. https://doi.org/10.1177/0300060519896707
10. Rubio IT, Esgueva-Colmenarejo A, Espinosa-Bravo M, Salazar JP, Miranda I, Peg V. Intraoperative ultrasound-guided lumpectomy versus mammographic wire localization for breast cancer patients after neoadjuvant treatment. Ann Surg Oncol. 2016;23(1):38–43. https://doi.org/10.1245/s10434-015-4935-z
11. Krekel NM, Haloua MH, Cardozo AM, de Wit RH, Bosch AM, de Widt-Levert LM, Muller S, van der Veen H, Bergers E, de Klerk ES, Meijer S. Intraoperative ultrasound guidance for palpable breast cancer excision (COBALT trial): a multicentre, randomised controlled trial. Lancet Oncol. 2013;14(1):48–54. https://doi.org/10.1016/S1470-2045(12)70527-2
12. Hammer MM, Kapoor N, Desai SP, Sivashanker KS, Lacson R, Demers JP, Khorasani R. Adoption of a closed-loop communication tool to establish and execute a collaborative follow-up plan for incidental pulmonary nodules. AJR Am J Roentgenol. 2019;212(5):1077–81. https://doi.org/10.2214/AJR.18.20692
13. Lovrics PJ, Cornacchi SD, Farrokhyar F, Garnett A, Chen V, Franic S, Simunovic M. The relationship between surgical factors and margin status after breast-conservation surgery for early-stage breast cancer. Am J Surg. 2009;197(6):740–6. https://doi.org/10.1016/j.amjsurg.2008.03.007
14. Maloney BW, McClatchy DM, Pogue BW, Paulsen KD, Wells WA, Barth RJ Jr. Review of methods for intraoperative margin detection for breast-conserving surgery. J Biomed Opt. 2018;23(10):100901. https://doi.org/10.1117/1.JBO.23.10.100901
15. Gera R, Tayeh S, Al-Reefy S, Mokbel K. Evolving role of Magseed in wireless localization of breast lesions: systematic review and pooled analysis of 1,559 procedures. Anticancer Res. 2020;40(4):1809–15. https://doi.org/10.21873/anticanres.14135
16. Houssami N, Macaskill P, Marinovich ML, Morrow M. The association of surgical margins and local recurrence in women with early-stage invasive breast cancer treated with breast-conserving therapy: a meta-analysis. Ann Surg Oncol. 2014;21(3):717–30. https://doi.org/10.1245/s10434-014-3480-5
17. Joshi HM, Alabraba E, Tufo A, Zone A, Ghaneh P, Fenwick SW, Poston GJ, Malik HZ. Objective assessment of trainee operative experience in a tertiary hepatobiliary unit. Eur J Surg Oncol. 2016;42(10):1548–51. https://doi.org/10.1016/j.ejso.2016.07.139