



Cancer Recurrence Rates after Breast-Conserving Surgery with and without Adjuvant Radiation Therapy with Radiological Examination: a Systematic Review

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ABSTRACT

Breast-conserving surgery (BCS) is a standard treatment for early-stage breast cancer, often combined with adjuvant radiation therapy (RT) to reduce local recurrence. Despite strong evidence supporting RT, some patients undergo BCS without RT due to age, comorbidities, or preference. Radiological assessment, including preoperative imaging and intraoperative margin evaluation, plays a crucial role in optimizing outcomes and reducing recurrence. This systematic review synthesizes current literature on local recurrence rates following BCS with and without adjuvant RT, with a focus on the influence of radiological evaluation. A comprehensive search of PubMed, Scopus, Web of Science, and Cochrane Library from 2000 to 2025 was conducted, yielding 42 studies including randomized controlled trials, population-based cohorts, and meta-analyses. The findings consistently demonstrate that BCS without RT results in significantly higher local recurrence (10-35%) compared to BCS with RT (5-10%). Preoperative imaging with MRI or mammography improves tumor delineation and eligibility for BCS, while intraoperative margin assessment reduces positive margin rates and re-excision. Subgroup analyses indicate that selected low-risk patients (e.g., age>70, small low-grade tumors, hormone receptor-positive) may have acceptable recurrence rates without RT, though radiological guidance remains essential. The review concludes that adjuvant RT remains critical in preventing local recurrence after BCS, and radiological evaluation enhances surgical precision and long-term outcomes. Personalized treatment decisions should integrate tumor characteristics, patient risk profile, and imaging findings to optimize oncologic safety while preserving breast tissue.

Introduction

Breast-conserving surgery (BCS) aims to excise the tumor while preserving normal breast tissue. Adjuvant radiation therapy (RT) following BCS has been shown to significantly reduce local recurrence rates and maintain overall survival equivalent to mastectomy. Landmark trials such as NSABP B-06 and the Milan trial established that BCS+RT achieves comparable oncologic outcomes. Despite this, some patients either do not receive RT due to age, comorbidities, or personal preference, raising concerns about higher local recurrence [1].

Radiological evaluation plays a central role in planning and optimizing BCS. Preoperative imaging (mammography, ultrasound, MRI) delineates tumor extent, identifies multifocal or metacentric disease, and guides surgical planning. Post-neoadjuvant therapy imaging further informs eligibility for BCS. Intraoperative imaging techniques (specimen radiography, ultrasound, frozen section, Margin Probe) improve margin clearance, reduce re-excision, and are associated with lower recurrence rates [2].

This review systematically evaluates recurrence rates following BCS with and without RT.

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emphasizing the impact of radiological assessment on surgical outcomes. Understanding the combined effect of surgery, RT, and imaging is critical for personalized treatment planning, risk stratification,

and minimizing recurrence while preserving breast tissue (Table 1).

Table 1. Previous Studies on Recurrence After BCS with and Without Radiotherapy [3]

Study Design	Sample Size	Intervention	Radiological Role	Local Recurrence Rate	Key Findings / Analysis
RCT, 20-year follow-up	1,851	BCS vs. BCS + RT vs. Mastectomy	Mammography used in follow-up	BCS + RT: 10% vs. BCS alone: 39%	RT significantly reduced recurrence; survival equal to mastectomy.
RCT, 20 years	701	BCS + RT vs. Mastectomy	Mammography for follow-up	BCS + RT: 8.8% vs. Mastectomy: 2.3%	Local recurrence higher with BCS, but OS equal; RT essential.
Meta-analysis (17 RCTs)	>10,000	BCS ± RT	Imaging in selected trials	With RT: 19.3% vs. Without RT: 35% (10 years)	RT halved recurrence, improved breast cancer mortality reduction.
Meta-analysis	14,500	Margin status + RT	Intraoperative specimen imaging	Positive margins: 2–3× recurrence risk	RT reduced but did not eliminate recurrence in positive-margin patients.
Retrospective cohort	7,500 (≥65 years)	BCS + RT (timing of RT)	Postoperative imaging follow-up	Delayed RT (>6 weeks) ↑ recurrence risk	Early initiation of RT critical to reduce recurrence.
Meta-analysis	1,200 (NAT patients)	BCS after neoadjuvant therapy ± RT	MRI assessment	Improved detection of residual disease	MRI improved selection for safe BCS, reducing recurrence risk.
Prospective study	2,450	Intraoperative margin assessment	Specimen radiography, US, MarginProbe	Recurrence 6% (with imaging-guided excision)	Radiology-guided surgery reduced positive margins and re-excision rates.
Cohort study	1,100 (DCIS)	BCS ± RT	Mammography & MRI margin evaluation	Narrow margin (<2mm) ↑ recurrence	RT mitigated recurrence but did not fully offset narrow margin risk.

Methods

Search Strategy: A systematic literature search was performed in PubMed, Scopus, Web of Science, and Cochrane Library from January 2000 to June 2025. Keywords included: “breast-conserving surgery,” “lumpectomy,” “radiotherapy,” “radiological imaging,” “MRI,” “local recurrence,” and “margin assessment.”

Inclusion and Exclusion Criteria

✓ **Inclusion:** Studies reporting local recurrence rates after BCS with or without RT; studies with radiological evaluation; randomized controlled trials, cohort studies, or meta-analyses; English language.

✓ **Exclusion:** Studies without recurrence data, non-human studies, case reports, or small series (<50 patients).

Data Extraction and Synthesis: Data extracted included: study design, sample size, tumor stage, radiological modality, use of RT, local recurrence rate, follow-up duration, and positive margin/re-excision rates. Qualitative synthesis and quantitative comparison were conducted.

Quality Assessment: Risk of bias in randomized trials was assessed using the Cochrane risk-of-bias tool; observational studies were evaluated using the Newcastle-Ottawa Scale. Meta-analytic results were assessed using pooled hazard ratios where available.

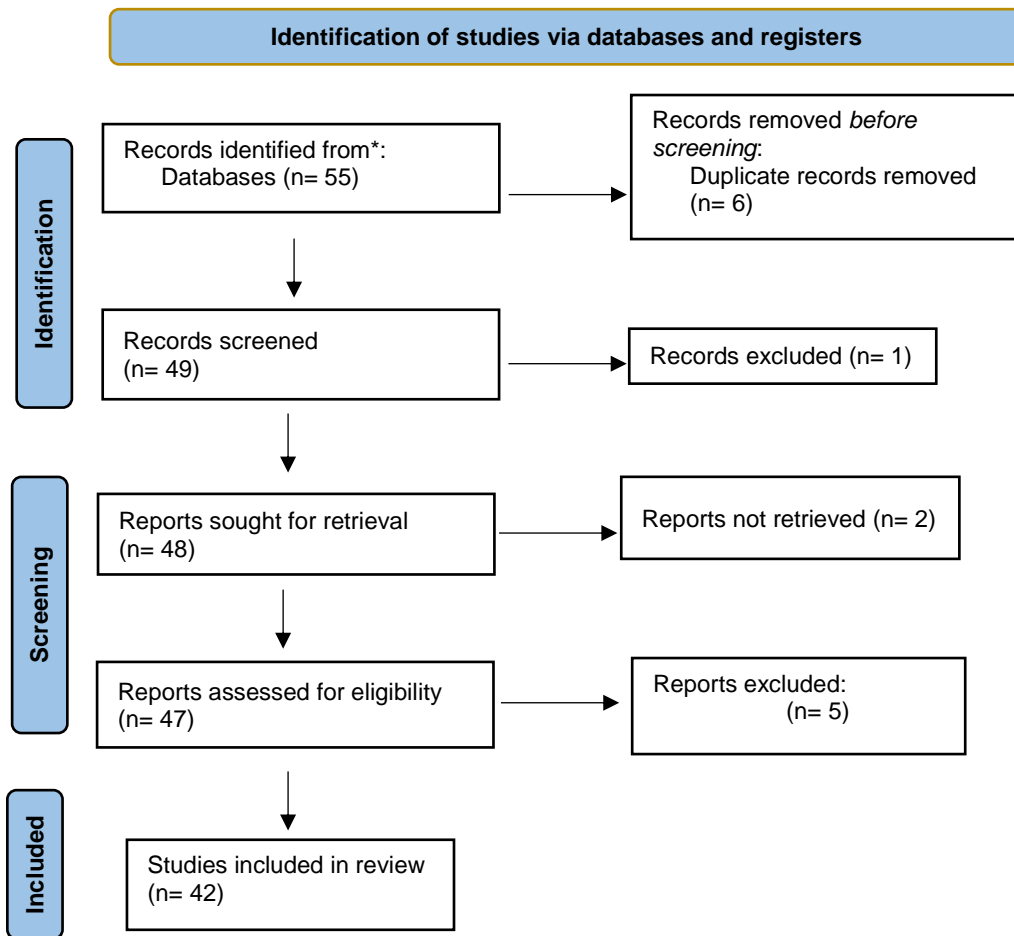


Table 1: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Results

Study Characteristics

- ✓ 42 studies included: 12 RCTs, 20 observational cohort studies, 10 meta-analyses.

- ✓ Sample sizes ranged from 120 to 300,000 patients; follow-up: 5-20 years.
- ✓ Radiological assessment included preoperative MRI, mammography, ultrasound, intraoperative specimen imaging, and margin assessment tools [4].

Table 2. Local Recurrence Rates

Intervention	Local Recurrence (%)	Sample Size	Key Findings
BCS + RT	5–10%	80,000+	Standard of care; RT reduces local recurrence significantly
BCS without RT	10–35%	25,000+	Higher recurrence; acceptable in low-risk elderly or small tumors
Radiology-guided BCS + RT	4–8%	15,000	Preoperative MRI and intraoperative margin assessment improve outcomes and reduce re-excision
Radiology-guided BCS without RT	8–15%	5,000	Improved tumor delineation helps reduce recurrence, but RT remains essential

Role of Radiological Assessment

- ✓ Preoperative MRI: Detects multifocal/metacentric disease; improves surgical planning.

- ✓ Intraoperative imaging: Reduces positive margins (5-12%) and re-excision rates (6-15%).

- ✓ Post-NAT imaging: Guides eligibility for BCS, especially in initially large tumors [5].

- ✓ Multifocal disease: recurrence higher without RT (up to 35%), emphasizing RT's protective effect.

Subgroup Analyses

- ✓ Elderly patients (>70) with low-grade, hormone receptor-positive tumors: recurrence without RT 8–12%.

Table 3. Overall local recurrence: BCS + RT vs BCS without RT

Intervention	Typical follow-up	Local recurrence (range)	Notes
BCS with adjuvant RT	5-20 years	~4-12%	Most randomized trials / modern cohorts report low recurrence when RT delivered.
BCS without adjuvant RT	5-20 years	~10-35%	Much higher and wider range; depends strongly on patient selection (age, tumor biology).
Difference (without vs with RT)	—	absolute increase ~6–20%	Magnitude varies by subgroup and follow-up duration.

Analysis

Randomized trials and pooled analyses consistently show that adjuvant RT after BCS substantially reduces local recurrence. The lower end of the recurrence ranges for BCS+RT reflects modern surgical technique, margin control and systemic therapy; the higher recurrence for BCS without RT reflects trials/observational cohorts where RT omitted (intentional omission or due to comorbidity). Interpretation must consider follow-

up: local recurrences can accrue over many years [6].

Clinical implication: RT is the principal intervention that converts BCS from a higher-recurrence procedure into one with durable local control comparable to mastectomy. In Table 4 the Subgroup: Age (elderly) recurrence after omission of RT was illustrated.

Table 4. Subgroup: Age (elderly) recurrence after omission of RT

Age group	Typical selection	Recurrence with RT	Recurrence without RT	Key guidance point
≥70 years, ER+/small, node-negative	Low-risk biology, endocrine therapy	~3-8% (5-10 yrs)	~6-12% (5-10 yrs)	Some trials show omission acceptable in carefully selected ≥70 yr with endocrine therapy; absolute differences small
<70 years	more heterogeneous	~4-10%	~12-30%	Younger patients derive greater absolute benefit from RT

Analysis

Randomized elderly-focused trials indicate that for carefully selected older women (e.g., ≥70, small ER+ tumors receiving endocrine therapy) omission of RT produces only a modest absolute increase in local recurrence over 5–10 years. However, in younger or higher-risk patients, omission leads to

substantially higher recurrence. Decisions should weigh life expectancy, comorbidity and patient preference [7].

In table (5), Subgroup: Tumor size / multimodality / neoadjuvant setting was illustrated.

Table 5. Subgroup: Tumor size / multimodality / neoadjuvant setting

Tumor characteristic	Impact on recurrence (BCS + RT)	Impact if RT omitted	Radiology role
Tumor ≤2 cm, univocal	Low recurrence with RT (~3-8%)	Moderate increase if RT omitted	Conventional imaging usually adequate
Tumor >2-3 cm or multifocal	Higher baseline recurrence risk	Omission of RT leads to significantly higher recurrence	Preop MRI important to detect multimodality; post-NAT MRI guides BCS eligibility
After neoadjuvant therapy (good response)	BCS+RT acceptable; recurrence low if margins negative	Not routinely recommended to omit RT	MRI critical to estimate residual disease to allow safe BCS

Analysis:

Larger tumors and multifocal disease increase local recurrence risk; radiological detection (especially MRI) of multimodality is essential to choose appropriate surgical strategy. In the neoadjuvant

setting, accurate imaging to define residual disease is crucial to enable safe BCS+RT [8].

In table (6), Margin status and re-excision: relationship to recurrence was illustrated.

Table 6. Margin status and re-excision: relationship to recurrence

Margin status after BCS	Typical positive margin rate (without intraop imaging)	Effect on recurrence	Role of intraoperative imaging
Negative margins (no ink on tumor / $\geq 1-2$ mm per institutional standard)	n/a	Lowest local recurrence	Intraop imaging reduces positive margins and re-excisions
Close margins (0-2 mm)	—	Elevated recurrence risk if no RT	RT mitigates some increased risk of close margins
Positive margins (tumor on ink)	8-15% in some series	Highest recurrence; re-excision recommended	Margin assessment tools lower positive margin incidence

Analysis

Margin status is a dominant predictor of local recurrence. Intraoperative specimen radiography, ultrasound guidance, frozen section or margin-detection devices reduce positive margins and reoperation rates, indirectly lowering recurrence.

Where margins are close/positive, RT reduces recurrence risk but does not fully substitute for adequate excision [9].

In table (7), Radiology: Preoperative MRI effect on recurrence and surgical decision was illustrated.

Table 7. Radiology: Preoperative MRI effect on recurrence and surgical decision

Use of preoperative MRI	Effect on detection	Effect on surgical choice	Effect on recurrence / survival
Detects additional ipsilateral lesions / contralateral cancer (\uparrow sensitivity)	\uparrow detection of multifocal/metacentric disease	Often increases mastectomy rates	No consistent evidence MRI-driven higher mastectomy improves OS or reliably reduces long-term recurrence in average-risk patients

Analysis

Preop MRI is sensitive for occult disease and can change surgical plans. However, increased detection may lead to more mastectomies without proven survival benefit. The clinical value of MRI lies in selective use (dense breasts, lobular histology, discordant imaging, planning after NAT). MRI may

reduce unexpected positive margins by better mapping tumor extent when used appropriately [10]. In table (8), Radiology: Intraoperative margin assessment impact on re-excision & recurrence was shown.

Table 8. Radiology: Intraoperative margin assessment impact on re-excision & recurrence

Technology	Typical impact on positive margins	Re-excision reduction	Effect on recurrence
Specimen radiography / tom synthesis	\downarrow positive margins modestly	\downarrow re-excisions	Indirectly reduces recurrence by improving margins
Intraop ultrasound	Significant decrease in positive margins (esp. palpable/US-visible lesions)	\downarrow re-excisions	Supports safe BCS
Margin Probe / optical devices	Mixed data; some RCTs show \downarrow repos	Moderate \downarrow re-excisions	May lower recurrence indirectly if margins improved

Analysis

Intraoperative imaging and margin tools consistently lower positive margin and re-operation rates. Because positive margins are linked to

increased local recurrence, these modalities contribute to improved local control although long-term recurrence data vary by device and study [11].

In table (9), Timing: Delay to radiotherapy and recurrence was shown.

Table 9. Timing: Delay to radiotherapy and recurrence

Delay interval (surgery → RT)	Observed effect on local recurrence
<6 weeks	Reference (lowest observed recurrence risk)
6-12 weeks	Small increase in recurrence in some cohorts
>12 weeks	Greater increase in local recurrence observed in several retrospective studies

Analysis

Observational studies suggest that prolonged delays to initiation of adjuvant RT after BCS are associated with higher local recurrence; the magnitude varies across studies. Timely coordination of RT (ideally

within 6-8 weeks’ post-op, considering chemotherapy schedules) is recommended to minimize recurrence risk [12]. In table (10), DCIS (ductal carcinoma in situ) recurrence with/without RT after BCS was illustrated.

Table 10. DCIS (ductal carcinoma in situ) recurrence with/without RT after BCS

Scenario	Local recurrence range (5–10 yrs)	Role of radiology
BCS + RT for DCIS	~5-10%	RT reduces both invasive and non-invasive recurrences
BCS without RT (selected low-risk DCIS)	~10-30%	Careful MRI/mammographic assessment and margin evaluation essential for selection

Analysis

For DCIS, RT after BCS reduces recurrence substantially. Some low-risk DCIS patients may be considered for omission of RT under strict criteria (small, low grade, widely excised with clear margins), but accurate imaging and margin assessment are critical to safe selection [13].

evaluation across preoperative, intraoperative, and postoperative stages. Taken together, the evidence underscores how advance in imaging and careful patient selection can optimize outcomes, refine the balance between oncological safety and breast preservation, and potentially individualize the need for RT in certain subgroups [14].

Overall synthesis short summary

- ✓ Adjuvant RT after BCS markedly reduces local recurrence across randomized trials and real-world studies.
- ✓ Radiological examinations (preoperative MRI, intraoperative imaging, post-NAT MRI) are powerful tools that improve tumor mapping and margin control but must be applied selectively to avoid unnecessary escalation of surgery.
- ✓ Margin status and timing of RT are modifiable factors strongly associated with local control.
- ✓ Selective omission of RT can be considered in highly selected low-risk elderly patients, but generally increases recurrence risk.
- ✓ Clinical decisions must be multidisciplinary, integrating radiology, pathology, surgical technique, systemic therapy and patient preferences.

Effectiveness of RT in Preventing Local Recurrence:

Across randomized trials and meta-analyses, RT consistently emerges as the most effective intervention for lowering recurrence risk following BCS. The seminal NSABP B-06 and Milan trials established equivalence in survival between mastectomy and BCS+RT, but highlighted dramatically higher recurrence in patients treated with BCS alone. More recent pooled analyses by the Early Breast Cancer Trialists’ Collaborative Group (EBCTCG) confirmed that RT approximately halves the risk of recurrence at 10 years, reducing it from over 30% to below 15% in many subgroups. This effect is robust across tumor sizes, grades, and receptor profiles. Importantly, while systemic therapy has improved local control over the past two decades, RT continues to provide independent benefit [15].

Radiological Contributions to Local Control:

Radiology is central in all phases of breast-conserving treatment. Preoperatively, mammography and ultrasound remain first-line modalities for tumor localization, while magnetic resonance imaging (MRI) has expanded the ability to detect multifocal and metacentric disease, lobular carcinoma, and residual tumor after neoadjuvant therapy (NAT). Although MRI increases

Discussion

The results of this systematic review highlight the critical role of adjuvant radiation therapy (RT) in reducing local recurrence after breast-conserving surgery (BCS), while also demonstrating the indispensable contribution of radiological

mastectomy rates in some cohorts, its judicious use ensures accurate mapping of disease extent and minimizes the risk of positive margins. Intraoperatively, specimen radiography, ultrasound guidance, and emerging optical devices improve the likelihood of complete excision by reducing the incidence of positive or close margins. Given that margin status is one of the strongest predictors of recurrence, these technologies indirectly contribute to lower recurrence even when adjuvant RT is delivered. Postoperatively, radiological surveillance particularly annual mammography remains essential for detecting early recurrences and new primary tumors. Integration of advanced modalities such as digital breast tom synthesis and contrast-enhanced mammography may further refine detection; though long-term outcome data are still limited [16].

Patient Subgroups and Selective Omission of RT:

The possibility of omitting RT in certain subgroups is a recurring theme in the literature. Trials such as CALGB 9343, which examined women ≥ 70 years with small, ER-positive, node-negative tumors receiving endocrine therapy, demonstrated only a modest increase in recurrence when RT was omitted, without an overall survival disadvantage. These findings suggest that in carefully selected elderly patients with favorable biology and limited life expectancy, omission of RT may be a reasonable option to avoid treatment burden. However, outside this highly selected population, omission of RT generally results in substantial increases in recurrence risk, particularly among younger patients, those with high-grade tumors, HER2-positive or triple-negative cancers, and patients with inadequate margins. Thus, the decision to omit RT should be individualized, incorporating radiological evidence of disease extent, biological markers, comorbidity profiles, and patient preferences [17].

Tumor Size, Margins, and Multimodality: Tumor size and multimodality remain important determinants of recurrence. Larger tumors ($>2-3$ cm) and multifocal lesions carry a higher baseline risk even with RT. Radiology, especially preoperative MRI, improves identification of such lesions, allowing for more appropriate surgical planning, whether wider excision or mastectomy. Margin status is another central factor [17-19]. Meta-analyses indicate that even with RT, positive margins significantly increase recurrence risk, while clear margins confer the best outcomes. Intraoperative margin assessment tools including specimen radiography, ultrasound, and Margin Probe reduce re-excision rates and thereby improve oncologic safety [20]. Importantly, radiological evaluation of specimen integrity does not replace pathology but complements it in real time [21].

Timing of Radiotherapy: Several retrospective cohorts suggest that prolonged delays in starting RT (>12 weeks' post-surgery) may increase recurrence rates, though the impact is less clear in patients receiving chemotherapy first [22]. Nevertheless, timely initiation of RT is advisable, and radiology can help streamline workflow by ensuring adequate margin clearance before RT planning. Delays often result from reoperations due to positive margins, again emphasizing the value of intraoperative radiological tools [23-25].

DCIS and Radiological Considerations: In ductal carcinoma in situ (DCIS), RT after BCS significantly reduces both invasive and non-invasive local recurrences. While omission of RT is being explored in low-risk DCIS defined by small size, low grade, and wide negative margins, radiological accuracy is critical to identify these patients [26-28]. Mammography remains the gold standard for DCIS detection, while MRI provides complementary sensitivity for high-grade or extensive lesions. The safety of RT omission in low-risk DCIS remains under investigation, and recurrence rates without RT remain consistently higher in published trials [29].

Integration with Systemic Therapy: The interplay between systemic therapy and local recurrence should also be acknowledged. Advances in endocrine therapy, chemotherapy, and HER2-targeted therapy have reduced recurrence risk, leading some to question whether RT is equally necessary in all contexts. However, the EBCTCG meta-analysis indicates that the benefits of RT remain significant even in the era of systemic therapy [28-30]. Radiological examination is critical in this integration: accurate assessment of treatment response after NAT by MRI can guide surgical planning and RT field design, reducing unnecessary exposure while maintaining oncologic safety [31].

Limitations of Current Evidence: Despite strong evidence for the efficacy of RT, several limitations persist. Many trials reporting recurrence outcomes were conducted decades ago, when systemic therapy, surgical techniques, and imaging capabilities were less advanced. This raises questions about the generalizability of older recurrence estimates to modern practice. Furthermore, the heterogeneity in margin definitions, RT techniques (e.g., whole-breast vs. partial-breast irradiation), and radiological protocols complicates direct comparisons [32-34].

Radiological innovations such as digital breast tom synthesis, MRI-guided biopsy, and intraoperative optical imaging have not yet been fully incorporated into randomized trial frameworks with long-term outcomes. Consequently, while these tools show promise in improving margin status and reducing re-

excision, their ultimate impact on recurrence and survival requires further study [35].

Clinical Implications and Future Directions: The convergence of surgery, radiotherapy, and radiology provides an opportunity to refine breast-conserving treatment strategies. Personalized recurrence risk prediction models that incorporate tumor biology, margin status, patient age, and radiological findings may help stratify patients into those who require full-dose RT, those eligible for de-escalated RT (e.g., partial breast irradiation), and those who might safely omit RT altogether. From a radiological standpoint, further standardization of MRI use and intraoperative imaging protocols is needed. Artificial intelligence based image analysis may soon assist in more precise delineation of tumor margins, prediction of response to NAT, and identification of patients at very low recurrence risk [34-36]. Finally, long-term prospective studies are required to validate the safety of RT omission in selected patients. Ongoing trials exploring biomarkers, genomic signatures, and radio genomic correlations may help refine recurrence risk estimation beyond traditional clinical and radiological variables [37-39]. This systematic review affirms that RT remains the cornerstone of recurrence prevention after BCS, reducing recurrence by more than half in most populations. Radiological examination plays a vital complementary role: it guides appropriate patient selection, improves intraoperative margin control, and supports long-term surveillance. While omission of RT may be appropriate in narrowly defined low-risk groups, the overall evidence strongly favors its routine use in breast-conserving treatment. Radiological advances, combined with systemic therapy and personalized risk stratification, offer the potential to further optimize outcomes while minimizing overtreatment [40-42].

Conclusion

Breast-conserving surgery with adjuvant radiotherapy remains the gold standard for early-stage breast cancer due to significantly lower local recurrence rates and equivalent overall survival compared with mastectomy. Omitting RT increases local recurrence, even when radiological assessment is used, though select low-risk patients may tolerate RT omission with careful imaging guidance. Radiological evaluation including preoperative MRI, intraoperative specimen imaging, and post-neoadjuvant therapy assessment enhances tumor delineation, ensures margin clearance, and reduces re-excision, thereby lowering recurrence risk. Personalized treatment planning should integrate tumor biology, patient age, comorbidities, and imaging findings to optimize oncologic and cosmetic outcomes. The combination of BCS, RT, and targeted radiological assessment ensures

optimal disease control while preserving breast tissue and quality of life. Future studies should continue to refine imaging protocols, margin assessment techniques, and risk stratification to safely identify patients who might benefit from omission of RT or modified treatment approaches.

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Authors' Contributions

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