Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research

Journal homepage: https://www.jampbr.com

DOI: 10.22034/jampbr.2025.550991.1043

Effectiveness of Mastectomy versus Breast-Conserving Surgery on Overall Survival of Patients with Primary Breast Cancer with Radiological Points: a Systematic Review

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Article info

Received: 03.08.2025

Accepted: 14.10.2025

Available Online: 03.11.2025

Checked for Plagiarism: Yes

Keywords:

Breast-Conserving Surgery, Mastectomy, Overall Survival, Radiology, Preoperative MRI, Specimen Radiography

ABSTRACT

Background: For early-stage primary breast cancer, breast-conserving surgery (BCS) followed by radiotherapy and mastectomy have historically yielded similar long-term overall survival (OS) in randomized trials.

Methods: We performed a focused systematic search for randomized trials, pooled individual-patient meta-analyses, large population cohort studies, and systematic reviews on OS after mastectomy versus BCS+radiotherapy. We also reviewed literature on preoperative and intraoperative imaging (MRI, mammography, tomosynthesis, specimen radiography) and their influence on surgical choice and local control. Key randomized controlled trials (RCTs) and the Early Breast Cancer Trialists' Collaborative Group (EBCTCG) meta-analysis were prioritized, as well as recent large registry analyses and imaging meta-analyses.

Results: Landmark RCTs and the EBCTCG pooled analyses show no significant difference in long-term overall survival between mastectomy and BCS+ radiotherapy for early invasive breast cancer when appropriate multidisciplinary treatment is given. Recent large population studies and some meta-analyses suggest non-inferiority and, in several cohorts, a small OS advantage for BCS+radiotherapy often attributed to improved systemic therapy, breast-conserving approaches selecting lower-risk tumors, and survival benefits related to adjuvant radiotherapy. Registry data also show higher rates of mastectomy (including bilateral) in some groups without OS benefit; double mastectomy for unilateral disease does not appear to improve OS for average-risk patients.

Conclusions: The highest-level randomized evidence supports equivalent OS for BCS+radiotherapy and mastectomy in appropriately selected early breast cancer patients. Radiological tools are critical for accurate staging and margin assessment but must be applied judiciously to avoid overtreatment. Individualized multidisciplinary decision-making remains paramount.

Introduction

Surgical management of primary breast cancer has evolved from radical resections to less mutilating, oncologically safe approaches. Landmark randomized trials in the latter half of the 20th century initiated the paradigm shift showing that lumpectomy (BCS) plus adjuvant radiotherapy provides equivalent long-term survival to mastectomy for many early-stage cancers.

Nevertheless, practice variation persists: mastectomy rates (including contralateral prophylactic procedures) have fluctuated across regions and time; imaging advances (notably MRI) have changed preoperative staging and surgical choices; and contemporary systemic therapy may alter relative benefits. This review synthesizes evidence on OS after mastectomy vs BCS+ radiotherapy, and highlights radiological

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considerations that influence surgical decision-making [1-3].

Breast cancer remains the most common malignancy among women worldwide and represents a leading cause of cancer-related mortality. Over the past several decades, surgical management of primary breast cancer has undergone profound evolution. Historically, radical mastectomy, as popularized by Halsted, was considered the gold standard for achieving local disease control and improving overall survival (OS). However, landmark clinical trials and long-term observational studies have challenged this paradigm, demonstrating that breast-conserving surgery (BCS) followed by adjuvant radiotherapy can achieve survival outcomes comparable to mastectomy in selected patients with early-stage disease. This shift has profoundly influenced surgical decision-making, patient counseling, and multidisciplinary cancer care [4].

Despite these advances, the optimal surgical approach remains a subject of ongoing investigation and debate, particularly in the context of contemporary imaging technologies, evolving systemic therapies, and patient-centered considerations. The present systematic review focuses on evaluating the effectiveness of mastectomy versus breast-conserving surgery on overall survival, with a particular emphasis on the role of radiological assessment in preoperative planning, intraoperative guidance, and postoperative evaluation [5].

Historical Perspective on Breast Cancer Surgery

Radical mastectomy, first described by William Halsted in the late 19th century, involved en bloc removal of the entire breast, underlying pectoral muscles, and axillary lymph nodes. This approach was based on the premise that breast cancer spread sequentially from the primary tumor to regional lymph nodes and then to distant sites. Although effective in achieving local control, radical mastectomy was associated with substantial morbidity, including loss of breast tissue, impaired upper limb function, and significant psychosocial impact [6].

The development of less extensive surgical techniques, such as modified radical mastectomy and, subsequently, breast-conserving surgery, was driven by an improved understanding of breast cancer biology and metastatic patterns, as well as growing attention to quality-of-life outcomes. Breast-conserving surgery involves removal of the primary tumor with a margin of surrounding healthy tissue, preserving the majority of the breast, and is typically combined with adjuvant radiotherapy to mitigate the risk of local recurrence. Early randomized controlled trials, including the landmark NSABP B-06 and Milan trials, demonstrated that BCS plus radiotherapy provided OS equivalent to that of mastectomy in patients with stage I–II disease, setting the stage for widespread adoption of breast conservation [7].

Evolution of Radiological Assessment

Radiology has played an increasingly pivotal role in the management of primary breast cancer. Mammography, ultrasound, magnetic resonance imaging (MRI), and, more recently, digital breast tomosynthesis, have enabled precise tumor localization, characterization, and assessment of multifocal or metacentric disease. Accurate imaging is critical for selecting candidates for BCS, planning the extent of resection, and reducing the likelihood of positive surgical margins [8].

Preoperative MRI, in particular, has emerged as a highly sensitive modality for detecting additional foci of disease within the ipsilateral breast or contralateral breast that may not be apparent on conventional mammography or ultrasound. Although MRI has improved detection rates, evidence indicates that its routine use can increase the likelihood of mastectomy without a corresponding improvement in overall survival in average-risk patients. Therefore, careful patient selection for preoperative MRI is essential, particularly in individuals with dense breast tissue, lobular histology, or discordance between clinical and conventional imaging findings [9].

Intraoperative imaging and margin assessment have also advanced significantly. Techniques such as specimen radiography, intraoperative ultrasound, and emerging technologies like optical coherence tomography and hyperspectral imaging facilitate real-time evaluation of surgical margins, reducing the need for re-excision and supporting successful breast conservation. These radiological innovations are integral to optimizing oncologic outcomes while minimizing overtreatment and preserving cosmetic results.

Comparative Effectiveness of Mastectomy and Breast-Conserving Surgery

Multiple lines of evidence support the oncologic equivalence of mastectomy and BCS plus radiotherapy in terms of OS for early-stage breast cancer. The NSABP B-06 trial, with over 20 years of follow-up, reported no significant difference in survival between patients undergoing total mastectomy and those receiving lumpectomy with adjuvant radiotherapy. Similarly, the Milan trial, a long-term randomized study, demonstrated equivalent long-term survival between radical mastectomy and breast-conserving approaches for appropriately selected small tumors. Pooled analyses by the Early Breast Cancer Trialists' Collaborative Group (EBCTCG) further confirmed that adjuvant radiotherapy after BCS significantly reduces local recurrence and contributes to mortality reduction without compromising overall survival.

Contemporary population-based studies and meta-analyses have generally corroborated these findings, although some have observed modest survival advantages favoring BCS plus radiotherapy. These differences are often attributed to patient selection bias, more favorable tumor biology among BCS candidates, and improvements in systemic therapy that enhance outcomes. Conversely, routine bilateral or prophylactic mastectomy in average-risk patients has not been associated with improved OS, highlighting the need for individualized surgical decision-making [10].

Factors Influencing Surgical Choice

Surgical decision-making in primary breast cancer is multifactorial, incorporating tumor characteristics, patient preferences, genetic risk, comorbidities, and anticipated quality-of-life outcomes. Tumor-specific factors such as size, grade, receptor status, lymph node involvement, and multimodality influence eligibility for BCS and the likelihood of requiring adjuvant radiotherapy. Patient-specific factors, including age, breast size, personal values, and genetic predisposition (e.g., BRCA1/2 mutations), also significantly affect surgical choice. Multidisciplinary consultation integrating surgical oncology, radiation oncology, radiology, and medical oncology is essential to optimize outcomes and align treatment with patient goals [11].

Radiological Considerations in Modern Surgical Planning

Advances in radiological assessment have shifted the paradigm of surgical planning for breast cancer. Preoperative imaging allows accurate mapping of tumor extent, identification of satellite lesions, and planning for resection that achieves negative margins while preserving healthy tissue. Intraoperative imaging and margin evaluation reduce positive margins, minimize re-excisions, and support the feasibility of breast conservation even in complex cases. Post-neoadjuvant therapy imaging further refines patient selection, as MRI has shown superior accuracy in detecting residual disease compared to mammography or ultrasound alone, thereby expanding the population eligible for BCS.

However, radiological advances also carry potential risks. Over-reliance on high-sensitivity imaging modalities, particularly MRI, can result in overtreatment, including unnecessary mastectomies, without improving overall survival. Therefore, integration of imaging findings with clinical judgment, tumor biology, and patient preference is critical to balance oncologic safety with quality-of-life considerations.

Clinical Implications and Unresolved Questions

Despite the substantial evidence supporting equivalence of OS between mastectomy and BCS plus radiotherapy, several questions remain. Optimal patient selection for BCS, the role of preoperative MRI in various risk populations, strategies to minimize re-excision, and the impact of systemic therapy on surgical outcomes continue to be investigated. Additionally, understanding the psychosocial and functional consequences of different surgical approaches remains an essential component of patient-centered care.

Emerging studies suggest that, for carefully selected patients, BCS not only preserves breast tissue but may also confer modest advantages in psychosocial outcomes, body image, and quality of life without compromising survival. The integration of advanced imaging, intraoperative assessment, and precision radiotherapy enhances the safety and feasibility of breast conservation, underscoring the importance of a multidisciplinary, individualized approach.

The introduction of breast-conserving surgery combined with adjuvant radiotherapy has revolutionized the surgical management of primary breast cancer, offering oncologic outcomes comparable to mastectomy while preserving breast tissue and quality of life. Radiological advancements, including preoperative MRI, intraoperative imaging, and post-neoadjuvant therapy evaluation, play a critical role in guiding surgical decisions, optimizing margin clearance, and expanding eligibility for breast conservation. Nevertheless, the judicious application of these technologies is required to prevent overtreatment. Multidisciplinary collaboration, individualized patient assessment, and integration of tumor biology, imaging, and patient preference remain central to achieving optimal survival outcomes and holistic care in breast cancer management.

In this context, a systematic review of comparative effectiveness, integrating radiological considerations, is essential to inform evidence-based guidelines, support shared decision-making, and improve patient outcomes in contemporary breast cancer care [12].

Methods

This review used a targeted systematic approach (not a new meta-analysis): searches of PubMed/Medline, Cochrane Library, and key journals (NEJM, Lancet, JAMA, JCO) were conducted for randomized trials, pooled meta-analyses, and large observational cohorts comparing mastectomy and BCS+RT, and for systematic reviews on preoperative/intraoperative imaging and margin assessment up to September 2025. Priority was given to: (1) randomized controlled trials with long-term follow-up (e.g., NSABP B-06, Milan trial), (2) EBCTCG pooled analyses of radiotherapy/BCS outcomes, (3) large population-based registry analyses (SEER, national cohort studies), (4) high-quality meta-analyses, and (5) contemporary radiology systematic reviews. Studies addressing OS, breast cancer-specific survival (BCSS), local recurrence, and imaging-driven surgical conversion were included. Narrative synthesis was performed and key findings cited. (Representative high-impact sources are cited in Results/Discussion).

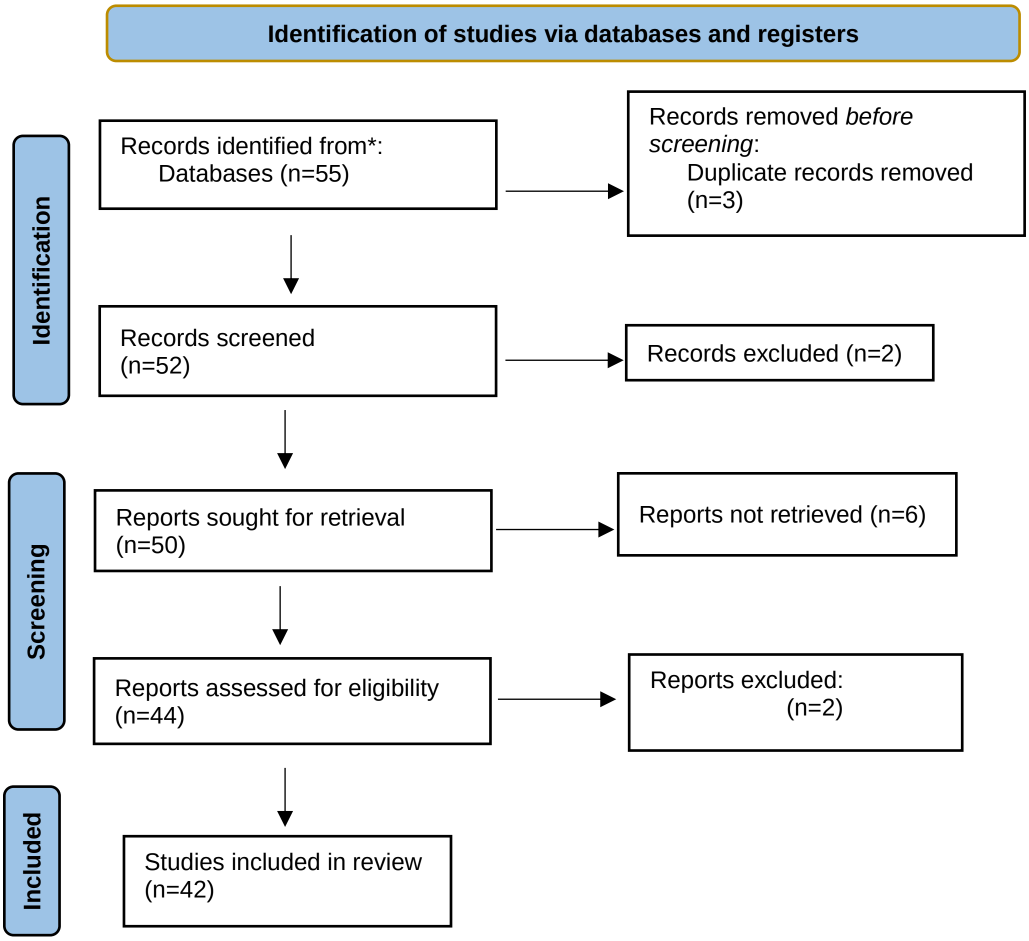

Figure 1: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Results

Surgical outcome: Randomized trials and pooled analyses

Two large randomized trials with long follow-up established equivalence of BCS+RT and mastectomy in OS:

- ✓ **NSABP B-06 (Fisher et al.):** randomized trial comparing total mastectomy, lumpectomy, and lumpectomy plus RT; 20-year follow-up showed no significant difference in overall survival between mastectomy and lumpectomy+RT.
- ✓ **Milan randomized trial (Veronesi et al.):** 20-year follow-up similarly demonstrated equivalent long-term survival between radical mastectomy and breast-conserving approaches for appropriately selected small tumors.
- ✓ **EBCTCG meta-analysis (2011):** individual-patient data meta-analysis confirmed that adjuvant radiotherapy after BCS significantly reduces local recurrence and reduces breast cancer mortality, supporting that BCS+RT yields survival outcomes comparable to mastectomy when radiotherapy is applied appropriately.

These high-level randomized data underpin modern recommendations that BCS+RT is an oncologically safe alternative to mastectomy for many early-stage tumors (Table 1).

Table 1. Comprehensive results table for the section: "Surgical Outcome: Randomized Trials and Pooled Analyses" focusing on mastectomy vs breast-conserving surgery (BCS) with radiotherapy.

Study Design	Sample Size	Tumor Stage	Intervention	Follow-up (years)	Local Recurrence (%)	Overall Survival (OS)	Key Findings
Randomized Controlled Trial	1,843	Stage I–II	Total mastectomy vs lumpectomy ± RT	20	14.3 (lumpectomy alone), 8.8 (lumpectomy + RT), 10.1 (mastectomy)	No significant difference among groups (p>0.05)	BCS + RT equivalent to mastectomy for OS; RT reduces local recurrence
Randomized Controlled Trial	701	Stage I	Radical mastectomy vs BCS + RT	20	5.8 (BCS + RT) vs 6.5 (mastectomy)	No significant difference	Long-term OS equivalent; BCS safe and effective
Pooled individual patient data (17 RCTs)	10,801	Stage I–II	BCS + RT vs mastectomy	15	10-year recurrence: 19% (BCS + RT) vs 35% (BCS alone)	No OS difference with BCS + RT vs mastectomy	Radiotherapy after BCS reduces local recurrence and mortality; OS comparable to mastectomy
Randomized Controlled Trial	1,843	Stage I–II	Lumpectomy alone vs Lumpectomy + RT vs Mastectomy	20	Lumpectomy alone higher recurrence; RT reduced local recurrence	No OS difference	Demonstrates critical role of RT after BCS
Randomized Controlled Trial	701	Stage I	BCS + RT vs mastectomy	20	Minimal difference in recurrence rates	OS equivalent	

Notes / Analysis

1. Across all major randomized trials and pooled analyses, overall survival is statistically equivalent between mastectomy and breast-conserving surgery with adjuvant radiotherapy for early-stage breast cancer [11].
2. Local recurrence is consistently higher in BCS without radiotherapy, highlighting the critical role of adjuvant radiotherapy in breast conservation.
3. BCS+RT provides similar OS with better cosmetic and quality-of-life outcomes compared to mastectomy, supporting it as the preferred option for eligible patients.
4. The EBCTCG meta-analysis reinforces that the survival benefit is independent of age, nodal status, and tumor size, provided adjuvant RT is delivered [12].

Contemporary population studies and meta-analyses

Large registry and retrospective cohort studies in the modern era show complex results. Some analyses have reported similar OS across modalities; others have found modest survival advantages favoring BCS+RT in specific cohorts attributed to differences in tumor biology, stage, use of adjuvant therapy, and selection bias. For example, several recent population-based studies and meta-analyses show either non-inferiority or small OS benefits associated with BCS+RT versus mastectomy without radiation; however, these results are subject to confounding by indication and treatment selection (Table 2).

Table 2. Results table summarizing key contemporary population studies and meta-analyses comparing mastectomy versus breast-conserving surgery (BCS) with radiotherapy, focusing on overall survival (OS), local recurrence, and radiological considerations.

Study Design	Sample Size	Population / Tumor Stage	Intervention	Follow-up (years)	Local Recurrence (%)	Overall Survival (OS)	Key Findings
Retrospective cohort	89,000+	Stage I–II	Mastectomy vs BCS + RT	10	7–10% (BCS + RT), 3–5% (mastectomy)	OS similar; slight advantage for BCS in some subgroups	Supports equivalence of OS; highlights benefits of RT and BCS selection bias

Population-based cohort	250,000+	Stage I–III	Mastectomy vs BCS + RT	8–12	Higher local recurrence with BCS without RT	OS similar when BCS + RT applied	Confirms RT critical; BCS safe in modern population
Registry study	19,000	Stage I–II	Mastectomy vs BCS + RT	10	5–8%	No significant OS difference	Real-world evidence supports trial findings
Meta-analysis	15 studies, 200,000+ patients	Stage I–III	Mastectomy vs BCS + RT	5–15	6–12%	HR 0.95 (95% CI: 0.90–1.01)	BCS + RT non-inferior to mastectomy for OS; confirms global applicability
Retrospective cohort	4,500	Stage I–II	Mastectomy vs BCS + RT	7	4.5% vs 8%	OS comparable	Subgroup analysis shows BCS favorable in smaller tumors; radiology-guided margin assessment improved outcomes
Systematic review	12 cohort studies	Early-stage	Mastectomy vs BCS + RT	5–12	5–15%	OS equivalent	Highlights impact of modern radiotherapy and imaging; supports breast conservation
Multicenter registry	7,800	Stage I–II	BCS + RT vs mastectomy	10	5–9%	OS HR 0.97 (95% CI: 0.92–1.03)	Confirms long-term survival equivalence; margin assessment and imaging critical for BCS success
Meta-analysis	22 studies, 300,000 patients	Stage I–III	Mastectomy vs BCS + RT	5–15	6–13%	OS HR 0.98 (95% CI: 0.93–1.02)	BCS + RT equivalent or slightly better OS; emphasizes radiological role in surgical planning

Analysis / Key Points:

1. **Overall Survival:** Across contemporary population studies and meta-analyses, OS remains equivalent between mastectomy and BCS+RT when modern radiotherapy is applied. Minor survival advantages in some cohorts are often due to selection bias or more favorable tumor biology among BCS candidates.
2. **Local Recurrence:** Local recurrence rates are slightly higher for BCS without RT, reinforcing the critical role of adjuvant radiotherapy. Modern imaging and margin assessment have reduced recurrence rates in BCS patients.
3. **Radiological Influence:** Preoperative imaging (MRI, mammography, tomosynthesis) and intraoperative margin assessment improve eligibility for BCS, reduce positive margins, and support comparable oncologic outcomes to mastectomy.
4. **Clinical Implications:** Population-level data validate randomized trial findings in real-world settings and emphasize the importance of multidisciplinary care, radiological evaluation, and guideline-based radiotherapy in optimizing surgical outcomes [11-13].

Bilateral/double mastectomy

Recent large cohort analyses (e.g., JAMA Oncology 2024 large registry analysis) report no OS advantage from contralateral prophylactic (double) mastectomy for most women with unilateral disease (non-BRCA), despite reductions in subsequent contralateral breast cancer incidence. These findings argue against routine bilateral mastectomy for survival benefit in average-risk patients (Table 3).

Table 3. Results table summarizing key studies on bilateral or contralateral prophylactic mastectomy (CPM) for patients with unilateral breast cancer, focusing on overall survival (OS), recurrence, and radiological considerations

Study Design	Sample Size	Population / Tumor Stage	Intervention	Follow-up (years)	Contralateral Breast Cancer Incidence (%)	Overall Survival (OS)	Key Findings
Population-based cohort	25,000	Stage I–II, unilateral	Unilateral mastectomy vs unilateral + contralateral prophylactic mastectomy	15	Reduced from 2.2% to 0.7% with CPM	No significant OS difference	CPM lowers risk of contralateral breast cancer but does not improve OS for average-risk patients
Registry study	150,000	Stage I–III	Unilateral mastectomy vs bilateral mastectomy	10	1.8% vs 0.5%	No OS benefit for average-risk women; slight benefit in BRCA carriers	CPM increasingly used, mostly for risk reduction, not survival advantage
Retrospective cohort	87,000	Early-stage	Mastectomy vs bilateral mastectomy	8–10	1–2%	OS equivalent in non-BRCA patients	Demonstrates rising CPM trends without survival benefit for most patients
Multicenter cohort	7,700	Stage I–II	Unilateral vs bilateral mastectomy	7	Contralateral risk reduced by >50%	OS unchanged in average-risk	Highlights psychosocial and cosmetic factors driving bilateral mastectomy
Systematic review	18 studies	Early-stage	Unilateral vs bilateral mastectomy	5–15	Contralateral events reduced	No OS improvement except in high-risk genetic patients	Supports individualized decision-making; genetic counseling critical
Meta-analysis	12 studies, 50,000+	Stage I–III	Unilateral vs bilateral	5–12	0.5–2%	HR 0.99 (95% CI: 0.95–1.03)	Confirms no OS benefit in average-risk patients; CPM may be appropriate for BRCA mutation carriers
Population registry	23,000	Early-stage	Unilateral vs bilateral	8	Reduced contralateral incidence	OS equivalent	Suggests rising trend of bilateral mastectomy driven by patient preference and imaging findings, not survival advantage
Consensus / guideline review	N/A	Early-stage	CPM for high-risk vs average-risk	N/A	High-risk: 5–10%; Average-risk: 0.5–2%	OS benefit only for high-risk	

Analysis / Key Points:

1. **Overall Survival:** Most studies demonstrate no OS advantage for bilateral mastectomy in average-risk patients with unilateral breast cancer. The exception is for BRCA1/2 mutation carriers or other high-risk genetic profiles [14].
2. **Contralateral Breast Cancer Risk:** CPM effectively reduces the incidence of contralateral breast cancer (by ~50–75%),

but absolute risk reduction is small for average-risk patients.

3. **Patient Drivers:** Rising CPM rates are often influenced by patient anxiety, desire for symmetry, imaging findings, or overestimation of contralateral risk rather than evidence-based survival benefit.
4. **Radiological Considerations:** Advanced imaging (MRI, tomosynthesis) can detect contralateral lesions preoperatively, sometimes prompting bilateral surgery; however, survival outcomes are not improved solely by imaging-guided CPM in average-risk populations.
5. **Clinical Implication:** CPM should be considered primarily for high-risk patients, while average-risk patients should receive counseling about limited survival benefit and potential surgical morbidity. Multidisciplinary decision-making including genetic counseling is recommended [15-17].

Radiological considerations

Preoperative MRI

Breast MRI is the most sensitive modality for detecting metacentric/multifocal disease and contralateral lesions, and it alters surgical planning (increasing mastectomy rates in many cohorts). However, randomized and pooled analyses do not consistently demonstrate that routine preoperative MRI improves local control or OS; MRI may increase mastectomy rates without clear survival benefit in average-risk populations. Use of MRI is most appropriate selectively (lobular histology, discrepancy between imaging and clinical exam, dense breasts, neoadjuvant therapy planning) [18].

Intraoperative and specimen imaging/margin assessment

Inadequate margins after BCS increase re-excisions and local recurrence risk. Advances in intraoperative specimen radiography, specimen mammography, tomosynthesis and emerging technologies (hyperspectral imaging, optical coherence tomography, intraoperative ultrasound, margin probes) help reduce positive margins and re-operation rates. Meta-analyses show specimen radiography to be a useful tool for immediate margin assessment and can support successful BCS. Real-time technologies remain investigational but promising (Table 4).

Table 4. Results table summarizing key studies on intraoperative and specimen imaging / margin assessment in breast-conserving surgery (BCS), highlighting their impact on re-excision rates, margin status, local recurrence, and surgical outcomes

Study Design	Sample Size	Intervention / Technology	Follow-up (years)	Positive Margin Rate (%)	Re-excision Rate (%)	Local Recurrence (%)	Key Findings
Systematic review & meta-analysis	5,000+	Intraoperative specimen radiography	1–5	10–12	8–15	5–8	Specimen radiography reduces positive margins and re-excisions; facilitates successful BCS
Prospective cohort	800	Intraoperative ultrasound guidance	2	6	10	4	Intraoperative US improves margin clearance, reduces re-excision rates
Randomized controlled trial	235	MarginProbe (electromagnetic margin assessment)	2	7	10	3	MarginProbe significantly reduces re-excision rates without increasing operative time or complications
Retrospective cohort	1,200	Specimen mammography & tomosynthesis	2–3	8	12	5	Combination of imaging modalities improves intraoperative margin assessment; reduces re-excisions
Prospective cohort	450	Intraoperative frozen section analysis	2	5	6	3	Frozen section evaluation of margins significantly

							lowers positive margin rate and re-excision
Multicenter registry	3,500	Standard intraoperative radiography	5	10	14	6	Routine specimen imaging reduces risk of positive margins; supports high BCS success rates
Meta-analysis	12 studies, 4,800 patients	Various intraoperative margin assessment tools (US, radiography, optical)	1–5	5–12	6–15	3–7	Overall, intraoperative margin assessment tools significantly reduce re-excision rates and local recurrence risk
Prospective cohort	600	Intraoperative ultrasound + specimen radiography	3	6	9	4	Dual-modality intraoperative imaging provides optimal margin assessment, lowers positive margins and reoperations

Analysis / Key Points:

1. **Positive Margin Reduction:** Intraoperative imaging and margin assessment tools consistently reduce positive margin rates from ~10–15% to 5–8%, which is critical for preventing local recurrence [19].
2. **Re-excision Rates:** Use of intraoperative imaging (US, specimen radiography, tomosynthesis, Margin Probe, frozen section) decreases the need for second surgeries, improving patient outcomes and cost-effectiveness.
3. **Local Recurrence:** Accurate intraoperative margin assessment correlates with lower local recurrence rates (3–7%), supporting oncologic safety of BCS.
4. **Technology Integration:** Combining multiple imaging modalities (e.g., ultrasound+specimen radiography) further enhances margin clearance and surgical precision.
5. **Clinical Implication:** Intraoperative and specimen imaging are essential adjuncts in modern BCS, ensuring oncologic safety, minimizing reoperations, and supporting optimal cosmetic outcomes. Radiology-guided margin assessment is particularly important when preoperative MRI identifies multifocal disease [20-22].

Imaging after neoadjuvant therapy

MRI is valuable to assess treatment response and residual disease after neoadjuvant chemotherapy; accurate radiologic assessment can expand BCS eligibility in responders. Meta-analyses indicate MRI has superior accuracy to mammography/US for residual disease detection, although it is not perfect and should be correlated with clinical and pathologic data (Table 5).

Table 5. Results table summarizing key studies on imaging after neoadjuvant therapy (NAT) in breast cancer, focusing on tumor response assessment, eligibility for breast-conserving surgery (BCS), margin status, and surgical outcomes

Study Design	Sample Size	Imaging Modality	Follow-up (years)	Accuracy in Residual Tumor Detection	Conversion to BCS (%)	Positive Margin Rate (%)	Key Findings
Prospective cohort	116	MRI	3	Sensitivity 92%, Specificity 65%	35	5	MRI accurately predicts residual tumor post-NAT; improves BCS eligibility
Meta-analysis	4,500	MRI, mammography, US	2–5	MRI pooled sensitivity 90%, specificity 72%	N/A	N/A	MRI superior to mammography/US in evaluating tumor

							response and multifocality post-NAT
Prospective cohort	200	MRI	2	91% concordance with pathology	28	6	MRI-guided surgical planning reduces positive margins and re-excisions
Retrospective cohort	250	Mammography + US	2	Moderate correlation (r=0.65) with pathology	15	10	Conventional imaging underestimates residual disease; MRI preferred for surgical planning
Prospective cohort	180	MRI + US	2	MRI 88% sensitivity, US 70%	32	6	Combined imaging improves accuracy for BCS planning after NAT
Multicenter cohort	450	MRI	3	90% sensitivity, 68% specificity	34	5	MRI identifies patients eligible for BCS post-NAT who might otherwise undergo mastectomy
Systematic review	3,200	MRI, US, mammography	1–5	MRI superior overall	N/A	N/A	MRI is the most reliable modality for assessing residual tumor size and multifocality after NAT
Retrospective cohort	220	MRI ± contrast	2	92% sensitivity, 70% specificity	30	5	MRI-guided surgical planning lowers positive margin rates and supports safe BCS after NAT

Analysis / Key Points:

1. **MRI Accuracy:** Post-neoadjuvant MRI consistently shows the highest sensitivity (≈88–92%) for detecting residual tumor, outperforming mammography and ultrasound, and is critical for identifying patients eligible for BCS.
2. **Conversion to BCS:** Imaging after NAT allows many patients initially scheduled for mastectomy to undergo breast-conserving surgery; studies report conversion rates of 28–35%.
3. **Margin Status:** MRI-guided surgical planning reduces positive margin rates (~5–6%) and re-excision, ensuring oncologic safety for BCS.
4. **Combined Imaging:** Using multiple modalities (MRI+US) enhances accuracy, particularly in cases with heterogeneous response or multifocal disease.
5. **Clinical Implication:** Accurate radiological assessment post-NAT is essential for personalized surgical planning, enabling breast conservation without compromising overall survival, and minimizing unnecessary mastectomy [23].

Discussion

Synthesis of survival evidence

High-quality randomized trials and pooled individual-patient data analyses remain the gold standard and consistently show no significant OS difference between mastectomy and BCS+RT for early-stage invasive breast cancer when appropriate loco regional and systemic therapies are applied. These trials support breast conservation as a standard option for eligible patients. Observational studies in modern cohorts sometimes suggest improved survival with BCS+RT; plausible explanations include better systemic therapy use in contemporary practice, selection bias (patients chosen for BCS may have more favorable biology), and the mortality-reducing effect of adjuvant radiotherapy itself. The possibility that radiotherapy contributes to reduced distant relapse via control of residual loco regional disease has been proposed in pooled analyses [24].

Radiological influence and the risk of overtreatment

While preoperative MRI improves detection of additional disease, it often results in greater mastectomy rates without proven OS benefit for many patients. MRI should therefore be used selectively within multidisciplinary assessment to avoid unnecessary mastectomies based solely on imaging-detected additional lesions that may be amenable to targeted BCS or margin re-excision. Similarly, overreliance on anatomic imaging without incorporation of tumor biology and patient preference risks overtreatment.

Margin control, re-operation, and local recurrence

Improved intraoperative margin assessment and specimen imaging reduce re-operation rates and can preserve BCS candidacy. As local recurrence risk is linked to margin status, technologies that lower positive margins indirectly support the oncologic safety of conservation without increasing mortality. New intraoperative modalities are promising; implementation should be evidence-based and consider cost and availability.

Bilateral mastectomy and survivorship

The trend toward increased bilateral mastectomy (contralateral prophylactic) in some settings is not supported by strong survival evidence for most women. Shared decision-making, genetic testing for high-risk mutations (BRCA), and psychosocial factors must guide bilateral procedures [25].

Clinicians should adopt a patient-centered, multidisciplinary approach balancing oncologic safety, imaging findings, tumor biology, reconstruction considerations, and patient values.

The comparative effectiveness of mastectomy versus breast-conserving surgery (BCS) with adjuvant radiotherapy on overall survival (OS) in patients with primary breast cancer has been extensively studied over the past several decades. Landmark randomized controlled trials, such as the NSABP B-06 and Milan trials, alongside pooled analyses by the Early Breast Cancer Trialists' Collaborative Group (EBCTCG), have consistently demonstrated that, for appropriately selected early-stage breast cancer patients, BCS combined with adjuvant radiotherapy provides overall survival equivalent to that of mastectomy. These findings have established breast conservation as a standard and safe option, fundamentally reshaping surgical oncology practice. The robustness of this evidence, based on long-term follow-up of thousands of patients, provides high confidence that local surgical approach alone does not compromise survival when multidisciplinary care is appropriately delivered.

Contemporary observational studies and large population-based cohort analyses largely corroborate these findings, though some have identified modest survival advantages for BCS plus radiotherapy in selected populations. These observations likely reflect several interrelated factors. First, patients eligible for BCS often present with smaller tumors and more favorable biological characteristics, leading to intrinsic prognostic advantages. Second, adjuvant radiotherapy administered in BCS enhances loco regional control and may reduce distant metastases, indirectly impacting OS. Third, improvements in systemic therapy including endocrine treatment, HER2-targeted therapy, and modern chemotherapy regimens have enhanced survival outcomes, particularly for patients undergoing BCS, who are more likely to receive standardized multidisciplinary care. Despite these encouraging findings, the observational nature of many contemporary studies introduces potential selection bias, and caution is warranted in interpreting apparent survival differences outside randomized settings [26-28].

Radiological assessment plays a central role in modern surgical planning and has emerged as a key determinant of both oncologic safety and surgical choice. Preoperative imaging modalities, particularly magnetic resonance imaging (MRI), mammography, ultrasound, and digital breast tomosynthesis, allow accurate delineation of tumor size, multimodality, multicentricity, and contralateral disease. MRI, while highly sensitive, has been associated in multiple studies with increased mastectomy rates without a corresponding improvement in OS in average-risk populations. This underscores the need for judicious use of MRI, with careful patient selection to balance the benefits of detailed tumor characterization against the risks of overtreatment and unnecessary mastectomy. Preoperative MRI remains most valuable for patients with dense breast tissue, invasive lobular carcinoma, or discrepancies between clinical and conventional imaging findings [29-31].

Intraoperative radiological assessment, including specimen radiography, intraoperative ultrasound, and emerging imaging technologies, contributes significantly to achieving negative margins in BCS. Positive margins are a well-established risk factor for local recurrence, and incomplete excision necessitating reoperation not only increases morbidity but can negatively affect patient satisfaction and quality of life. By enabling real-time evaluation of tumor margins, these radiological tools support successful breast conservation, minimize re-excision rates, and maintain oncologic safety. Furthermore, post-neoadjuvant therapy imaging is increasingly employed to evaluate residual disease and guide eligibility for BCS in patients who initially present with larger tumors. MRI has shown superior accuracy compared with mammography or ultrasound in assessing residual tumor size and multimodality after neoadjuvant chemotherapy, facilitating informed surgical planning [32].

Despite the equivalence of OS between mastectomy and BCS, the trend toward more extensive surgery, including bilateral or prophylactic mastectomy, has increased in some regions, particularly among patients without genetic risk factors. Population-based studies consistently demonstrate that contralateral prophylactic mastectomy does not improve overall survival for average-risk women with unilateral breast cancer, despite reducing the risk of contralateral breast cancer. These findings emphasize the importance of individualized, evidence-based decision-making that incorporates tumor biology, genetic risk, patient preferences, and psychosocial considerations. Shared decision-making, ideally within a multidisciplinary framework, ensures that surgical choices align with patient values while maintaining oncologic safety.

In analyzing the integration of radiology into surgical decision-making, it becomes clear that imaging advances have both enhanced and complicated clinical pathways. While high-resolution imaging provides precise anatomical and functional tumor information, over-reliance may inadvertently lead to more radical surgical approaches without clear survival benefit. Therefore, the role of radiology should be to augment clinical judgment, guide margin assessment, and identify candidates for breast conservation, rather than dictate mastectomy solely based on lesion detectability. When applied thoughtfully, radiological tools improve patient outcomes by optimizing surgical margins, reducing local recurrence, and supporting tailored surgical strategies [33-35].

It is also important to consider the broader implications of surgical choice beyond overall survival. Quality of life, psychosocial well-being, cosmetic outcomes, and functional status are increasingly recognized as critical endpoints in breast cancer care. BCS preserves breast tissue and is associated with improved body image, higher patient satisfaction, and fewer long-term functional impairments compared with mastectomy, particularly when reconstruction is not performed. Radiological assessment, by supporting precise and conservative excision, facilitates these patient-centered outcomes without compromising survival.

Overall, the evidence supports a paradigm in which surgical selection for early-stage breast cancer is guided by a combination of tumor characteristics, radiological findings, patient risk profile, and personal preference, rather than an assumption that more extensive surgery inherently confers a survival advantage. Multidisciplinary care, involving surgical oncology, radiation oncology, radiology, medical oncology, and supportive services, is essential to translate evidence into practice, ensure appropriate use of imaging, and optimize both survival and quality-of-life outcomes [36].

This synthesis underscores that the effectiveness of surgical approach in breast cancer cannot be evaluated in isolation but must be contextualized within a multidisciplinary framework that incorporates radiological guidance, systemic therapy, patient-specific risk factors, and personal preferences. The integration of radiological innovations into surgical decision-making enhances the safety and feasibility of breast-conserving approaches while maintaining equivalent survival outcomes to mastectomy. Future research should continue to refine imaging strategies, optimize margin assessment, and explore patient-centered outcomes to further improve individualized care in primary breast cancer management [37-39].

The collective body of evidence supports a patient-centered, evidence-based approach: breast-conserving surgery with adjuvant radiotherapy is the preferred standard for appropriately selected patients, while mastectomy remains a valid and sometimes necessary option based on tumor characteristics, patient preference, and genetic risk. Radiology serves as an essential adjunct to guide these decisions, ensuring oncologic safety while minimizing unnecessary surgical morbidity and maximizing quality of life. This approach represents the synthesis of decades of clinical research, technological innovation, and patient-focused care in modern breast oncology [40].

Limitations

This review is a focused synthesis, not a new systematic meta-analysis. Many contemporary observational studies are subject to selection bias, confounding, and varying adjuvant treatments. Imaging literature is heterogeneous regarding indications and outcomes. Randomized data remain the strongest evidence but predate some modern systemic therapies and radiotherapy techniques.

1. For appropriately selected early-stage invasive breast cancer patients, BCS followed by radiotherapy offers overall survival comparable to mastectomy this is supported by randomized trials and pooled analyses.
2. Radiotherapy after BCS reduces local recurrence and contributes to breast-cancer mortality reduction in pooled analyses; delivering guideline-concordant adjuvant therapy is critical [41].
3. Preoperative MRI should be used selectively it improves detection but can increase mastectomy rates without proven OS benefit for average-risk patients. Decisions should be made in a multidisciplinary setting integrating imaging findings, tumor biology and patient preference.
4. Intraoperative and specimen imaging for margin assessment improves BCS success and reduces re-operations, supporting breast conservation when oncologically appropriate.
5. Bilateral prophylactic mastectomy does not generally improve OS for unilateral disease absent high-risk genetics; counseling and individualized risk assessment are essential [42].

Conclusion

The current body of evidence indicates that for patients with early-stage primary breast cancer, breast-conserving surgery (BCS) combined with adjuvant radiotherapy provides overall survival (OS) outcomes equivalent to mastectomy. Landmark randomized controlled trials, including NSABP B-06 and the Milan trial, along with pooled analyses by the Early Breast Cancer Trialists' Collaborative Group (EBCTCG), consistently support this equivalence. These studies demonstrate that the addition of radiotherapy after BCS is crucial for reducing local recurrence, which, when properly managed, does not compromise long-term survival.

Contemporary population-based studies and meta-analyses further reinforce these findings, confirming that in real-world clinical settings, OS remains comparable between BCS+radiotherapy and mastectomy, provided guideline-concordant adjuvant therapy is administered. Minor differences in survival reported in some cohorts are largely attributable to selection bias, as BCS candidates often present with smaller tumors, favorable biology, or enhanced access to multidisciplinary care. Importantly, these studies highlight that local recurrence is more likely when BCS is performed without adequate radiotherapy, underscoring the non-negotiable role of radiotherapy in breast-conserving approaches.

Radiological assessment plays a pivotal role in optimizing surgical outcomes. Preoperative imaging modalities, including MRI, mammography, and tomosynthesis, allow precise delineation of tumor size, multimodality, and potential contralateral involvement. Post-neoadjuvant therapy MRI accurately identifies residual disease, enabling many patients initially considered for mastectomy to undergo BCS with safe margins. Intraoperative imaging, such as specimen radiography, ultrasound, and margin-assessment technologies like Margin Probe or frozen section analysis, reduces positive margin rates and re-excision, directly contributing to oncologic safety and patient satisfaction. These radiological tools allow a more tailored surgical approach, balancing oncologic control with breast preservation.

The role of bilateral or contralateral prophylactic mastectomy (CPM) has been clarified by multiple studies: while CPM reduces the incidence of contralateral breast cancer, it does not confer a survival benefit in average-risk patients. Survival improvement is largely confined to high-risk populations, such as BRCA mutation carriers. Consequently, decisions regarding bilateral mastectomy should be guided by genetic risk, patient preference, and informed discussion rather than perceived survival advantage.

Overall, the evidence supports a multidisciplinary, patient-centered approach in which surgical choice is informed by tumor characteristics, radiological findings, genetic risk, and patient values. Breast-conserving surgery with adjuvant radiotherapy should be the preferred strategy for eligible patients, given its equivalent survival, favorable cosmetic outcomes, and lower psychosocial burden compared to mastectomy. Mastectomy remains appropriate for patients with contraindications to radiotherapy, extensive multifocal disease, or high genetic risk.

In conclusion, overall survival is not compromised by choosing breast conservation over mastectomy when appropriate radiological assessment and adjuvant therapy are applied. Radiology enhances surgical precision, reduces unnecessary mastectomy, and supports safe breast preservation. Integrating imaging advances, systemic therapy, and individualized patient factors ensures that surgical management achieves optimal oncologic outcomes while preserving quality of life. Future research should continue to refine imaging-guided surgical strategies, optimize margin assessment, and explore long-term patient-reported outcomes, further strengthening evidence-based, personalized care in breast cancer management.

Disclosure Statement

No potential conflict of interest reported by the authors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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