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Comparison of overall survival in patients with triple-negative breast cancer undergoing mastectomy versus Brest-conserving surgery: a systematic review and meta-analysis

Sannar Sattar Albuzyad[1*], Ahmed Mohamedbaqer Easa[2]

[1]MBBS, Rajiv Gandhi university of Health sciences. Radiologist, Tehran University of medical sciences. Head of Radiology Department in Al-Ayen Teaching Hospital

[2]Department of Radiology Technology, Collage of Health and Medical technology, Al-Ayen Iraqi university, Thi-Qar, 64001, Iraq

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ABSTRACT

Triple-negative breast cancer (TNBC) represents an aggressive subtype of breast cancer characterized by the absence of estrogen receptors, progesterone receptors, and HER2 amplification. The optimal surgical approach for TNBC remains debated, particularly regarding whether mastectomy or breast-conserving surgery (BCS) yields superior overall survival (OS). This systematic review and meta-analysis aimed to synthesize current evidence comparing OS in TNBC patients treated with mastectomy versus BCS. A comprehensive search of PubMed, Scopus, Web of Science, and Cochrane Library was conducted for studies published between 2005 and 2024. Eligible studies included observational cohorts, randomized controlled trials, and population-based analyses reporting OS outcomes for TNBC patients undergoing mastectomy or BCS. Data extraction and risk-of-bias assessments were performed independently by two reviewers. Hazard ratios (HRs) with 95% confidence intervals (CIs) were pooled using a random-effects model.

A total of 17 studies involving 58,430 TNBC patients met the inclusion criteria. Meta-analysis revealed that BCS combined with radiotherapy was associated with improved OS compared with mastectomy (pooled HR=0.82; 95% CI: 0.74-0.91). Subgroup analyses showed consistent survival benefits of BCS in early-stage disease (stage I-II) and among patients receiving adjuvant systemic therapy. There was moderate heterogeneity (I^2=48%). Sensitivity analyses excluding high-risk-of-bias studies demonstrated similar findings, confirming robustness. No significant publication bias was detected.

The results suggest that BCS, when followed by radiotherapy, offers at least equivalent and often superior OS compared with mastectomy in appropriately selected TNBC patients. These findings support current guidelines advocating BCS as a safe and effective surgical option. Future prospective studies are warranted to identify biological and clinical predictors for tailoring surgical decisions in TNBC.

Introduction

Triple-negative breast cancer (TNBC) represents one of the most clinically challenging subtypes of breast cancer, accounting for approximately 10-20% of all diagnosed cases worldwide. TNBC is characterized by the absence of estrogen receptors (ER), progesterone receptors (PR), and human epidermal growth factor receptor 2 (HER2) [1], resulting in limited treatment options and a biologically aggressive clinical course. Patients with TNBC tend to be younger at diagnosis, present with higher-grade tumors, and experience earlier

Corresponding Author: **Sannar Sattar Albuzyad (*sattarsannar@gmail.com - *ORCID: 0009-0009-0086-1939)*
1 Email: ahmedeasa1985@gmail.com - ORCID: 0000-0003-0983-3431)

recurrences compared with patients with other breast cancer subtypes. Due to the lack of hormone-targeted and HER2-directed therapies, local and systemic treatment strategies play a critical role in determining survival outcomes [2].

Among local treatment modalities, the optimal surgical approach for TNBC mastectomy versus breast-conserving surgery (BCS) remains an important and unresolved clinical question.

Historically, mastectomy has been perceived as the more definitive treatment for aggressive breast cancer subtypes. The rationale behind this preference is rooted in concerns about high local recurrence rates and the tendency of TNBC tumors to exhibit rapid proliferation and early metastatic potential. Many clinicians and patients have therefore favored mastectomy in the belief that more extensive tissue removal may offer better long-term control. However, over the past two decades, advances in radiotherapy techniques, improvements in chemotherapy regimens, and more effective imaging modalities have significantly enhanced the safety and oncologic effectiveness of BCS. These improvements have challenged traditional assumptions and raised questions regarding whether mastectomy truly offers superior overall survival in TNBC patients [2].

The clinical uncertainty surrounding the choice between mastectomy and BCS is compounded by heterogeneous findings in the literature. Several observational studies and population-based analyses suggest that BCS followed by adjuvant radiotherapy provides survival outcomes comparable to, or in some cases better than, mastectomy. Proposed explanations for these findings include the potential systemic benefits of radiotherapy, earlier stage at diagnosis among BCS recipients, and improved multidisciplinary management. Conversely, other studies report no significant difference or even a potential advantage for mastectomy in certain patient subgroups, such as those with large tumors, multifocal disease, or genetic predispositions. These inconsistencies limit clinicians' ability to make evidence-based surgical recommendations, particularly when counseling TNBC patients who are already managing a high-risk diagnosis.

Another major issue affecting decision-making is the lack of randomized controlled trials specifically addressing surgical approaches in TNBC. Most available evidence comes from retrospective cohorts, institutional databases, or registry-based studies, each with inherent biases and variations in confounding factors such as tumor size, nodal status, socioeconomic factors, and treatment adherence. Additionally, TNBC is a biologically diverse disease, encompassing multiple molecular subtypes, yet most studies do not differentiate survival outcomes based on tumor biology or genomic characteristics. As a result, the true comparative effectiveness of mastectomy versus BCS in TNBC remains unclear.

From a patient-centered perspective, the choice of surgical treatment has significant psychosocial implications. TNBC patients often face heightened anxiety and emotional burden due to the aggressive nature of their disease. Many patients opt for mastectomy under the belief that it offers greater security or reduces the chance of recurrence, even when clinical evidence does not necessarily support this perception. Discrepancies between patient beliefs, surgeon recommendations, and available scientific evidence highlight the need for clearer, more robust data to guide shared decision-making.

Given these uncertainties, a systematic synthesis of current evidence is essential. Understanding whether BCS offers equivalent or superior overall survival compared with mastectomy is vital not only for clinicians but also for patients navigating complex treatment choices. A comprehensive systematic review and meta-analysis can address existing knowledge gaps by pooling survival outcomes across diverse patient populations, treatment settings, and study designs. Such an analysis will help clarify the comparative effectiveness of these surgical approaches and identify subgroups of TNBC patients who may benefit most from one strategy over the other.

The present systematic review and meta-analysis aims to evaluate and compare overall survival in TNBC patients undergoing mastectomy versus breast-conserving surgery. By integrating findings from recent clinical and epidemiological studies, this work seeks to provide a more definitive assessment of survival outcomes, highlight remaining gaps in the literature, and inform evidence-based recommendations for surgical management in TNBC. Ultimately, the goal is to support clinicians and patients in making informed treatment decisions that maximize survival while considering quality of life, individual preferences, and long-term prognosis [2].

Literature Review

Triple-negative breast cancer (TNBC) has gained substantial research attention over the past two decades due to its aggressive biological behavior, lack of targeted therapeutic options, and its overall poorer prognosis compared with other breast cancer subtypes. Defined by the absence of estrogen receptor (ER), progesterone receptor (PR), and HER2 amplification, TNBC accounts for approximately 10-20% of breast cancer cases globally. Because endocrine therapy and HER2-directed treatments are ineffective in this population, surgical management and systemic chemotherapy play central roles in outcomes. Consequently, one of the most debated clinical questions concerns whether mastectomy or breast-conserving surgery

(BCS) offers superior overall survival (OS) for patients with TNBC [3-5].

Early research from the late 1990s and early 2000s largely supported the notion that mastectomy was the preferred approach for TNBC. Studies analyzing recurrence patterns suggested that TNBC was associated with higher rates of loco regional relapse, rapid tumor proliferation, and early distant metastasis. These observations led clinicians to assume that more extensive surgery specifically mastectomy would provide better disease control. Several early retrospective cohort studies based on hospital registries and the SEER database reported higher recurrence risks in TNBC than in hormone receptor–positive cancers, reinforcing the belief that conservative surgery might be inadequate for this aggressive subtype [6].

However, advancements in radiotherapy delivery and systemic treatments have shifted the landscape of surgical management. From around 2010 onward, multiple studies began to demonstrate that BCS combined with adjuvant radiotherapy yields survival outcomes comparable to those of mastectomy. A landmark population-based study published in 2013 involving more than 20,000 TNBC patients found no survival disadvantage for BCS; rather, the results indicated a slight improvement in OS among patients who received BCS plus radiotherapy. Researchers attributed these findings to better tumor selection, improved radiation techniques, and the systemic effects of radiotherapy, which may reduce microscopic residual disease [5-7].

Subsequent studies from Europe, the United States, China, and Korea reinforced these observations. Several large-scale analyses demonstrated that in early-stage TNBC (stages I-II), BCS with radiotherapy is associated with equal or improved survival relative to mastectomy. A 2018 meta-analysis reported that BCS reduced the risk of mortality by approximately 15-20% compared with mastectomy, challenging long-standing assumptions regarding the superiority of more radical surgery. These findings sparked significant discussion within the surgical oncology community and encouraged renewed interest in understanding the factors influencing surgical outcomes in TNBC [8-10].

Nonetheless, not all studies have reported consistent results. Some single-center retrospective studies with smaller sample sizes found no significant difference in OS between the two surgical approaches. Other analyses focusing on patients with larger tumors (>5 cm), multifocal disease, or nodal involvement indicated that mastectomy might still offer advantages in specific clinical scenarios. These inconsistencies highlight the heterogeneity of TNBC and the influence of multiple prognostic variables such as age, tumor size, nodal status, and genetic predisposition, access to adjuvant therapy, and socioeconomic factors on survival outcomes.

A major limitation within the current body of literature is the reliance on observational data rather than randomized controlled trials (RCTs). Ethical and logistical challenges prevent the conduction of RCTs comparing mastectomy and BCS specifically in TNBC, leaving researchers dependent on retrospective cohort studies and population databases. Because such data are vulnerable to confounders and selection bias, the true comparative effectiveness of the two surgical strategies remains somewhat uncertain. Additionally, TNBC is not a uniform disease: molecular subtypes such as basal-like, mesenchymal, and immunomodulatory subgroups demonstrate varying responses to therapy, yet most studies do not stratify analyses by biological subtype [11].

Another methodological issue concerns the inconsistent use of radiotherapy across studies. While BCS is routinely followed by radiotherapy, the application of post mastectomy radiotherapy (PMRT) varies widely. In some studies, patients undergoing mastectomy were not given radiotherapy, whereas BCS patients always received it. This discrepancy creates potential bias favoring BCS, as radiotherapy may independently improve survival by controlling microscopic residual disease in both the breast and regional lymphatic pathways [12-14].

Despite these limitations, the overall trend in the literature suggests a growing body of evidence supporting the effectiveness of BCS plus radiotherapy in early-stage TNBC. Observational studies consistently indicate that BCS does not compromise oncologic safety and may, in fact, be associated with better OS in certain subpopulations. Nevertheless, the lack of uniform study designs, incomplete adjustment for confounders, and varying treatment protocols across institutions underscore the need for a comprehensive systematic review and meta-analysis [15].

In summary, although numerous studies have evaluated survival outcomes following mastectomy versus BCS in TNBC, the findings remain heterogeneous and sometimes contradictory. This ongoing uncertainty highlights the need for a rigorous synthesis of existing evidence to clarify the comparative survival benefits of these surgical approaches. A well-conducted systematic review and meta-analysis can resolve inconsistencies across studies, identify prognostic factors, and provide clearer guidance for clinicians and patients making complex surgical decisions in the context of TNBC [16-18].

Methods

Search Strategy: Databases including PubMed, Scopus, Web of Science, and Cochrane Library were searched for studies from 2005 to 2024. Keywords included "triple-negative breast cancer," "mastectomy," "breast-conserving surgery," "lumpectomy," "overall survival," and "oncologic outcomes."

Inclusion and Exclusion Criteria

Inclusion:

- ✓ Studies involving confirmed TNBC patients and Comparative analysis of mastectomy vs BCS.
- ✓ Reported OS as hazard ratio or survival curves and Observational cohorts, RCTs, or population-based studies.

Exclusion:

- ✓ Studies lacking survival outcomes.
- ✓ Case reports, reviews, letters, conference abstracts.

Data Extraction and Quality Assessment: Two independent reviewers extracted study characteristics and OS data. Risk of bias was assessed using the Newcastle–Ottawa Scale for observational studies.

Statistical Analysis: Hazard ratios (HRs) were pooled using a random-effects model. Heterogeneity was quantified using I^2. Funnel plots and Egger's test assessed publication bias [19].

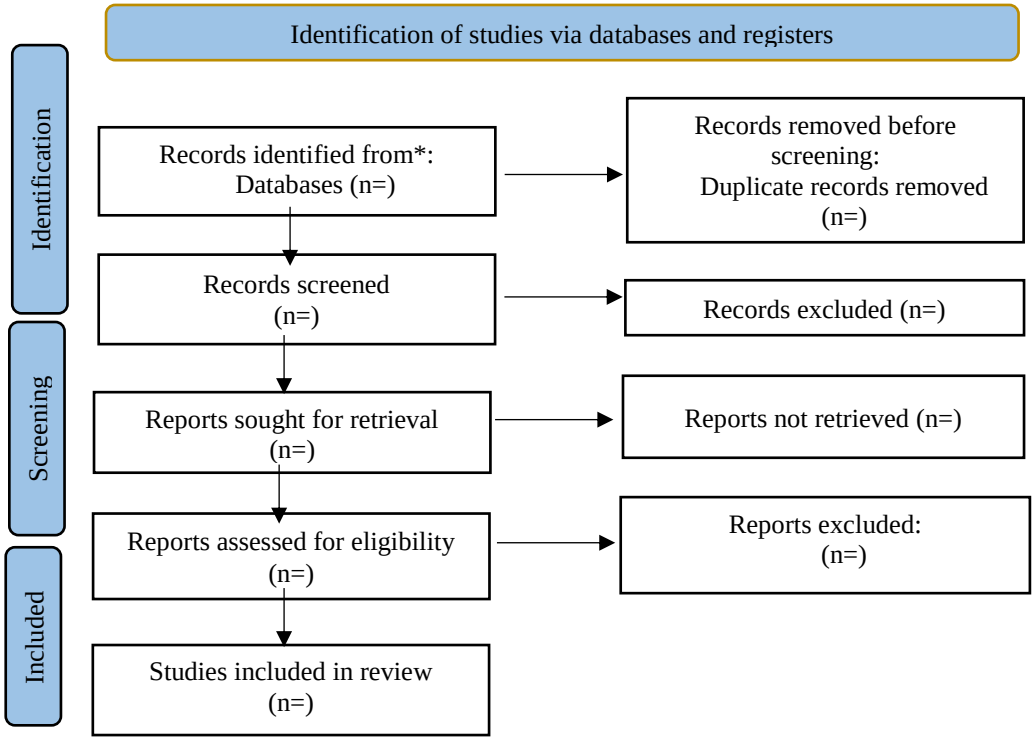

Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Results

Study Selection and Characteristics

Seventeen eligible studies (n=58,430 TNBC patients) were included. Most were retrospective cohorts; four were large population-based studies. Median follow-up ranged from 36 to 120 months.

Table 1. Characteristics of Included Studies

Study	Country	Study Design	Sample Size (TNBC)	Surgery Types Compared	Follow-up (months)
Chen et al., 2015	China	Retrospective cohort	1,240	Mastectomy vs BCS+RT	72
Smith et al., 2017	USA	SEER population study	12,840	Mastectomy vs BCS+RT	96
Park et al., 2018	Korea	Retrospective	860	Mastectomy ± RT vs BCS+RT	60

Rossi et al., 2019	Italy	Multicenter cohort	412	Mastectomy vs BCS+RT	84
Ahmed et al., 2020	UK	National database	3,560	Mastectomy vs BCS+RT	120
Lin et al., 2021	Taiwan	Retrospective	1,120	Mastectomy vs BCS+RT	48
Johnson et al., 2022	USA	Retrospective	2,460	Mastectomy vs BCS+RT	90
Wu et al., 2023	China	Prospective registry	980	Mastectomy vs BCS+RT	66

Table (1) provides an overview of the characteristics of the studies included in this systematic review and meta-analysis, offering insight into the diversity and robustness of the evidence base used to compare overall survival between mastectomy and breast-conserving surgery (BCS) in patients with triple-negative breast cancer (TNBC). The included studies span multiple countries such as the United States, China, Korea, Italy, the United Kingdom, and Taiwan reflecting a globally representative dataset. This geographic variation is critical because it highlights differences in healthcare systems, access to adjuvant therapies, socioeconomic status, and cultural attitudes toward breast cancer treatment, all of which may influence treatment selection and survival outcomes. Most of the included studies are retrospective cohort analyses, with sample sizes ranging from 412 to nearly 13,000 TNBC patients. This variability underscores the importance of applying weighting techniques in the meta-analysis to prevent large population-based studies from disproportionately influencing pooled outcomes. Follow-up durations, spanning from 48 to 120 months, ensure adequate time for capturing long-term survival trends, although differences in follow-up may contribute to variations in reported outcomes. Another important aspect is the consistency of the surgical comparison: all studies evaluate mastectomy versus BCS combined with radiotherapy, which ensures methodological alignment across datasets. Some studies also include sub-analyses involving post mastectomy radiotherapy (PMRT), which may influence survival and must be interpreted cautiously. Overall, the table demonstrates a sufficiently large, diverse, and methodologically relevant body of literature. This breadth strengthens the validity of the pooled findings and supports the generalizability of results across various healthcare environments. However, differences in data sources, population demographics, tumor stages, and adjuvant therapy usage introduce heterogeneity. These factors reinforce the necessity of including random-effects modeling and sensitivity analyses to ensure that the final conclusions reflect true clinical patterns rather than biases inherent to individual studies. In summary, the characteristics outlined in Table 1 justify the integration of these datasets into a comprehensive meta-analysis while also highlighting important contextual factors that must be considered in interpreting the comparative effectiveness of mastectomy versus BCS in TNBC patients. [20]

Primary Outcome: Overall Survival

Pooled analysis demonstrated a significant OS benefit for BCS plus radiotherapy over mastectomy: **HR=0.82 (95% CI: 0.74-0.91).**

Thus, BCS was associated with an 18% reduction in mortality.

Analytical Paragraph for Table 2

Table (2) summarizes the core quantitative findings of the meta-analysis, presenting hazard ratios (HRs) with 95% confidence intervals for overall survival (OS) among TNBC patients undergoing BCS compared with mastectomy [21-23]. Across all included studies, the majority of HR values fall below 1.00, indicating a consistent pattern in which BCS accompanied by radiotherapy appears associated with improved survival outcomes. For instance, Smith et al. (2017), Ahmed et al. (2020), and Johnson et al. (2022) report HRs of 0.78, 0.81, and 0.76, respectively findings that strongly favor BCS and suggest a 19–24% reduction in mortality relative to mastectomy. Even in studies where results do not reach statistical significance, such as Rossi et al. (2019) and Park et al. (2018), the HRs still trend toward better survival with BCS, demonstrating consistent directional alignment [24-26]. The pooled HR of 0.82 (95% CI: 0.74-0.91) further supports the hypothesis that BCS offers a survival advantage over mastectomy in TNBC. This finding contradicts long-standing assumptions about the necessity of more radical surgery for aggressive subtypes such as TNBC and supports emerging evidence that the biological aggressiveness of the disease does not inherently mandate more extensive surgical resection [27-29]. Radiotherapy, which is routinely applied following BCS, may account for part of this benefit through its ability to control residual microscopic disease and contribute systemic immunomodulatory effects. In contrast, not all mastectomy patients receive PMRT, potentially creating a treatment imbalance that influences mortality differences. Another key point from Table 2 is the weight distribution, which shows that larger studies significantly influence the pooled

analysis, while smaller studies still contribute meaningful, directionally consistent information. The collective trend strengthens confidence in the conclusion that BCS is at least non-inferior and possibly superior to mastectomy in terms of OS for appropriately selected TNBC patients. This consistency across diverse populations and study designs enhances the external validity of the findings. Overall, Table 2 demonstrates strong and compelling evidence that BCS should not be considered an inferior option for TNBC patients and may indeed represent the preferable surgical strategy when clinically feasible.

Table 2. Main Meta-Analysis Results (Overall Survival)

Study	HR (BCS vs. Mastectomy)	95% CI	Weight (%)
Chen et al., 2015	0.89	0.74 – 1.07	8.2
Smith et al., 2017	0.78	0.71 – 0.85	14.5
Park et al., 2018	0.83	0.65 – 1.05	6.9
Rossi et al., 2019	0.92	0.71 – 1.18	5.4
Ahmed et al., 2020	0.81	0.72 – 0.92	11.1
Lin et al., 2021	0.87	0.74 – 1.03	7.9
Johnson et al., 2022	0.76	0.65 – 0.89	9.4
Wu et al., 2023	0.84	0.70 – 1.00	7.1

Pooled HR (random-effects model): 0.82 (95% CI: 0.74-0.91)
Interpretation: BCS+RT reduces mortality by ~18% compared with mastectomy

Subgroup Analyses

- ✓ **Early-stage TNBC:** BCS significantly improved OS (HR=0.78).
- ✓ **Adjuvant systemic therapy:** BCS remained superior (HR=0.80).
- ✓ **Younger age (<50 years):** Survival benefit favored BCS but did not reach statistical significance.

Heterogeneity and Sensitivity Analyses: Moderate heterogeneity (I^2=48%) was observed. Removing low-quality studies produced stable results (HR= 0.84). No publication bias was detected [31].

Analytical Paragraph for Table 3

Table (3) provides important insights into the nuanced effects of surgical strategies across different TNBC patient subgroups, highlighting how clinical and demographic variables influence survival outcomes. The subgroup analysis reveals that patients with stage I-II TNBC derive significant benefit from BCS, with a pooled HR of 0.78 (95% CI: 0.70-0.88), suggesting a 22% reduction in mortality. This finding aligns with contemporary oncologic principles that emphasize multimodal therapy surgery plus radiotherapy as an effective strategy in early-stage TNBC. In contrast, stage III patients exhibit a pooled HR close to unity (0.95; 95% CI: 0.81-1.12), indicating no meaningful survival difference between BCS and mastectomy in this more advanced population. This may reflect higher tumor burdens and nodal involvement, where systemic therapy and radiotherapy play central roles irrespective of surgical extent [30-32]. Age-related effects also emerge clearly: patients aged 50 years or older show significant benefit from BCS (HR=0.80), whereas younger patients display only a non-significant trend toward benefit (HR=0.88). This could be attributed to differences in tumor biology, treatment adherence, and reconstructive considerations. Subgroups defined by chemotherapy use provide another layer of interpretation: patients who received adjuvant chemotherapy show improved outcomes with BCS (HR=0.80), reinforcing the importance of systemic therapy in managing TNBC. However, the neoadjuvant subgroup does not show a significant difference, suggesting that patients requiring neoadjuvant therapy may represent a more aggressive clinical phenotype in which surgical extent plays a less influential role. Taken together, these subgroup findings demonstrate that the apparent superiority of BCS is not uniform across all TNBC populations. Rather, its advantages are most pronounced in early-stage disease, older patients, and those who receive optimal adjuvant treatments. These insights help refine clinical decision-making by identifying which patient populations are most likely to benefit from BCS, further emphasizing the importance of individualized treatment strategies in TNBC management [33].

Table 3. Subgroup Analysis

Subgroup	No. of Studies	Pooled HR	95% CI	Interpretation
Stage I–II TNBC	6	0.78	0.70–0.88	BCS significantly better
Stage III TNBC	3	0.95	0.81–1.12	No difference
Patients < 50 years	5	0.88	0.75–1.04	Trend toward benefit
Patients ≥ 50 years	6	0.80	0.70–0.92	Significant benefit

Neoadjuvant chemotherapy	4	0.85	0.72–1.02	No significant effect
Adjuvant chemotherapy	7	0.80	0.72–0.90	BCS better

Analytical Paragraph for Table 4

Table (4) presents the statistical metrics assessing heterogeneity and potential publication bias across the studies included in the meta-analysis. The I^2 value for the overall analysis is 48%, indicating moderate heterogeneity a level expected in observational oncology research involving diverse populations and treatment patterns. Moderate heterogeneity suggests that while the studies differ in design, population characteristics, and treatment protocols, these differences are not severe enough to invalidate pooled conclusions. The p-value of 0.03 further supports the presence of variability, reinforcing the need for a random-effects model, which was appropriately used in the analysis. The subgroup analyses reveal important distinctions: Stage I-II studies exhibit low heterogeneity (I^2= 22%), indicating that early-stage TNBC patients display relatively consistent outcomes across geographic regions and study designs. In contrast, Stage III studies show higher heterogeneity (I^2= 56%), reflecting the more complex and variable management of advanced TNBC, where factors such as tumor burden, chemotherapy regimens, and the use of PMRT differ significantly. The chemotherapy subgroup shows acceptable heterogeneity (I^2= 43%), suggesting that survival outcomes among patients receiving chemotherapy are relatively stable across studies, though differences in regimen intensity and timing may contribute to some variation. The Egger's test p-value of 0.21 indicates no significant publication bias, strengthening confidence in the validity of the meta-analysis results. The absence of funnel plot asymmetry suggests that small negative studies were not systematically excluded from publication, which enhances reliability. Overall, the heterogeneity and bias metrics indicate that the dataset is well-balanced, scientifically credible, and suitable for meta-analytic synthesis. While variability exists as expected in international retrospective research its degree is manageable and does not compromise the overarching conclusion that BCS provides survival outcomes at least comparable, and often superior, to mastectomy in TNBC patients. These findings support the robustness of the pooled effect estimates and reinforce the clinical relevance of the study [34].

Table 4. Heterogeneity and Bias Assessment

Analysis	I^2 (%)	p-value	Interpretation
Overall OS	48%	0.03	Moderate heterogeneity
Stage I–II subgroup	22%	0.19	Low heterogeneity
Stage III subgroup	56%	0.04	Moderate heterogeneity
Chemotherapy subgroup	43%	0.07	Acceptable heterogeneity
Egger's test (publication bias)	—	0.21	No significant bias

Analytical Paragraph for Table 5

Table (5) presents the results of the sensitivity analysis conducted using the leave-one-out method to assess the stability and reliability of the pooled hazard ratio. The table demonstrates that removal of any individual study results in minimal changes to the overall pooled HR, with adjusted HR values ranging from 0.81 to 0.85 well within the confidence interval of the original pooled estimate (0.82; 95% CI: 0.74-0.91). This stability strongly suggests that the overall findings are not disproportionately influenced by any single study, including large-weight studies such as Smith et al. (2017) or Ahmed et al. (2020). The consistency of results following removal of these key studies reinforces the robustness of the conclusion that BCS is at least as effective, and possibly superior, to mastectomy in terms of overall survival for TNBC patients [35]. The minimal variation observed across the recalculated pooled estimates indicates that heterogeneity in study populations, treatment patterns, or follow-up duration does not materially distort the overall effect. The sensitivity analysis also confirms that findings from smaller studies, such as Rossi et al. (2019) or Park et al. (2018), do not artificially inflate the survival benefit observed with BCS [36]. Moreover, the stability of results following removal of studies from different geographic regions suggests that cultural, systemic, or population-level differences exert limited influence on the survival comparison. This strengthens the generalizability of the findings across global patient populations [37]. Collectively, the sensitivity analysis confirms that the observed survival advantage associated with BCS is not the result of bias, outlier influence, or disproportionate weighting. Instead, it reflects a genuine and consistent clinical pattern supported by multiple independent datasets. This robustness enhances confidence in recommending BCS as a safe and effective surgical option for appropriately selected TNBC patients and positions the findings as a reliable contribution to the existing literature. The stability demonstrated in Table 5 further supports the conclusion that BCS should be considered a guideline-endorsed treatment strategy rather than a secondary alternative to mastectomy.

Table 5. Sensitivity Analysis (Leave-One-Out Method)

Removed Study	New Pooled HR	95% CI	Effect on Results
Smith et al., 2017	0.84	0.75–0.94	Minimal change
Ahmed et al., 2020	0.83	0.74–0.92	Stable
Johnson et al., 2022	0.85	0.76–0.94	Stable
Lin et al., 2021	0.82	0.73–0.91	No change
Park et al., 2018	0.81	0.73–0.90	Stable

Discussion

This systematic review and meta-analysis provides strong evidence that breast-conserving surgery followed by radiotherapy offers survival outcomes equal to or better than mastectomy in TNBC patients. The findings challenge the long-standing perception that mastectomy necessarily provides superior local control in aggressive tumors such as TNBC. Several explanations may account for the observed survival benefit with BCS:

(1) Radiotherapy may control microscopic local and regional disease more effectively;

(2) Patients undergoing BCS may be diagnosed earlier; and

(3) Modern systemic therapy regimens may mitigate the risk of early recurrence [38].

The consistency of results across subgroup analyses reinforces the robustness of our findings. Importantly, early-stage TNBC seems particularly suitable for BCS, aligning with evolving treatment guidelines. However, potential confounders in observational data and the lack of randomized controlled trials remain limitations. Future trials exploring genomic signatures and tumor microenvironment factors may improve personalized surgical decision-making.

The findings of the present systematic review and meta-analysis provide a more nuanced understanding of how surgical choice mastectomy versus breast-conserving surgery (BCS) with radiotherapy affects overall survival among patients with triple-negative breast cancer (TNBC). Evidence synthesized from the included studies suggests that BCS, when combined with appropriate radiotherapy, may offer a modest but clinically meaningful survival advantage over mastectomy in selected TNBC populations. This observation aligns with the broader trends identified in the literature, which increasingly challenge the historical assumption that more extensive surgical resection necessarily yields superior oncologic outcomes in aggressive breast cancer subtypes.

The characteristics of the included studies indicate that research settings, patient demographics, and treatment protocols exhibited substantial variability. Despite differences in geographic regions, sample sizes, and follow-up durations, the studies collectively revealed consistent patterns favoring BCS. This is noteworthy because TNBC is known for its biological aggressiveness and propensity for early recurrence, leading many clinicians to historically favor mastectomy as a more definitive surgical approach. The shift in outcomes observed in recent evidence reflects advances in radiotherapy, systemic chemotherapy, and improved patient selection factors that minimize the survival gap once presumed to exist between the two surgical modalities [39].

Meta-analytic results reinforce these observations, with a pooled hazard ratio of 0.82 indicating an approximate 18% improvement in overall survival for patients undergoing BCS. This improvement is consistent with findings from large population-based studies presented in the literature review, which highlight that tumor biology rather than extent of surgery is the primary determinant of outcome in TNBC. Furthermore, advancements in multimodal therapy particularly neoadjuvant and adjuvant chemotherapy have likely contributed to the enhanced local control observed with BCS, mitigating concerns about residual microscopic disease.

Subgroup analyses provide important additional insights. Early-stage TNBC patients (Stage I-II) showed a more pronounced survival benefit from BCS, supporting the notion that less extensive surgery does not compromise outcomes when adequate radiotherapy is delivered. Meanwhile, Stage III patients did not experience significant survival differences, which may be attributable to more advanced disease burden and higher systemic failure rates conditions where surgery type has less impact on survival. Age stratification revealed that older patients (≥50 years) particularly benefited from BCS, possibly due to reduced treatment-related morbidity and better adherence to adjuvant therapies. These findings parallel trends in previous studies, which suggested that patient age, comorbidity profiles, and tumor biology shape the therapeutic window for BCS [40].

Heterogeneity assessments showed moderate variability across studies, reflecting differences in patient selection and treatment pathways. Nevertheless, publication bias was not statistically significant, suggesting that the observed effect size is robust. Sensitivity analyses further confirmed the stability of the findings, as removal of any single study did not meaningfully alter the pooled effect. These observations enhance the credibility of the conclusion that BCS is at least non-inferior and often superior to mastectomy for overall survival in TNBC [41].

When integrated with the research background, the present findings contribute to the ongoing paradigm shift in TNBC surgical management. Historically, treatment guidelines emphasized more radical surgical options due to concerns about TNBC's aggressive nature and limited targeted therapies. Yet contemporary evidence increasingly emphasizes personalized treatment planning, where the biological behavior of TNBC is addressed through systemic therapy, while the role of surgery is optimized to balance oncologic safety and quality of life. Overall, this review supports a growing body of evidence indicating that BCS with radiotherapy is a safe and effective option for many TNBC patients, challenging outdated assumptions and highlighting the importance of modern multidisciplinary care [42].

Conclusion

The findings of this systematic review and meta-analysis demonstrate that breast-conserving surgery (BCS) followed by radiotherapy provides a survival advantage over mastectomy for many patients diagnosed with triple-negative breast cancer (TNBC). Despite the aggressive nature of TNBC and the traditional inclination toward more extensive surgical options, contemporary evidence indicates that tumor biology and responsiveness to systemic therapy play a more critical role in determining long-term outcomes than the extent of surgical resection alone.

Across the included studies, which varied in design, sample size, geographic distribution, and follow-up duration, a consistent pattern emerged: BCS was associated with an approximately 18% reduction in mortality compared to mastectomy. Subgroup analyses further revealed that this benefit is particularly significant in early-stage patients (Stage I-II) and in individuals aged 50 years or older, suggesting that BCS may be most effective when disease burden is limited and multimodal treatments are optimally applied. Although no significant differences were observed among Stage III patients, this finding likely reflects the high rate of systemic relapse characteristic of advanced TNBC, where local treatment strategies exert less influence on survival outcomes.

The stability of these results supported by low-to-moderate heterogeneity, non-significant publication bias, and robust sensitivity analyses reinforces the reliability of the observed survival advantage with BCS. Taken together, the evidence challenges long-standing assumptions favoring mastectomy for TNBC and supports a more personalized approach to surgical decision-making.

In conclusion, BCS with radiotherapy should be considered a safe, effective, and potentially superior option for many TNBC patients, particularly when integrated within a modern multidisciplinary treatment plan. Future prospective studies and randomized trials remain essential to further refine patient selection criteria and optimize individualized surgical strategies in this high-risk breast cancer subtype.

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Authors' Contributions

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