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Original Article

Sentinel Lymph Node Biopsy versus Axillary Lymph Node Dissection in Early Breast Cancer: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Axillary lymph node status remains one of the most important prognostic factors in early-stage breast cancer and plays a critical role in determining disease staging, prognosis, and adjuvant treatment strategies. Axillary lymph node dissection (ALND) has traditionally been considered the standard approach for axillary staging; however, it is associated with significant postoperative morbidity, including lymphedema, sensory neuropathy, shoulder dysfunction, and impaired quality of life. Sentinel lymph node biopsy (SLNB) has emerged as a minimally invasive alternative that aims to provide accurate nodal staging while reducing treatment-related complications.

Objective: To compare the oncological outcomes and postoperative morbidity associated with SLNB and ALND in patients with early-stage breast cancer through a systematic review and meta-analysis.

Materials and Methods: A systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. Electronic databases including PubMed, Embase, Scopus, Web of Science, and the Cochrane Library were searched for studies published between January 2000 and December 2025. Randomized controlled trials and prospective comparative studies evaluating SLNB versus ALND in clinically node-negative early breast cancer were included. Primary outcomes included overall survival (OS), disease-free survival (DFS), and axillary recurrence. Secondary outcomes included lymphedema, sensory neuropathy, shoulder dysfunction, wound infection, and seroma formation. Pooled risk ratios (RRs) with 95% confidence intervals (CIs) were calculated using fixed- or random-effects models according to the degree of heterogeneity.

Results: Fifteen studies involving 18,742 patients met the eligibility criteria, including 9,368 patients who underwent SLNB and 9,374 who underwent ALND. Pooled analysis demonstrated no significant differences between SLNB and ALND with respect to overall survival (RR=0.99; 95% CI: 0.96–1.02; p=0.58), disease-free survival (RR=1.01; 95% CI: 0.97–1.05; p=0.61), or axillary recurrence (RR=1.12; 95% CI: 0.79–1.58; p=0.52). However, SLNB was associated with significantly lower rates of lymphedema (6.4% vs. 20.1%; RR=0.32, 95% CI: 0.25–0.40; p<0.001), sensory neuropathy (9.8% vs. 23.5%; RR=0.41, 95% CI: 0.34–0.50; p<0.001), and shoulder dysfunction (8.1% vs. 21.4%; RR=0.38, 95% CI: 0.29–0.49; p<0.001). Wound infection and seroma formation were also significantly less frequent following SLNB.

Conclusion: Sentinel lymph node biopsy provides oncological outcomes equivalent to axillary lymph node dissection in patients with early-stage breast cancer while substantially reducing postoperative morbidity. The evidence supports SLNB as the preferred axillary staging procedure for clinically node-negative breast cancer patients, offering effective disease control with improved functional outcomes and quality of life.

Keywords*: Breast cancer, Sentinel lymph node biopsy, Axillary lymph node dissection, Early breast cancer, Lymphedema, Meta-analysis, Surgical oncology.*

INTRODUCTION

Breast cancer is the most frequently diagnosed malignancy among women worldwide and remains a leading cause of cancer-related mortality. Accurate axillary staging plays a crucial role in determining prognosis, guiding adjuvant therapy, and assessing disease burden.[1] Historically, axillary lymph node dissection (ALND) represented the standard approach for both staging and local control of breast cancer.[2]

Although ALND provides detailed pathological information regarding nodal involvement, the procedure is associated with substantial morbidity. Postoperative complications such as chronic lymphedema, paresthesia, shoulder stiffness, pain, and reduced upper-limb function significantly affect patient quality of life.[3,4] As breast cancer survival rates improve, minimizing treatment-related morbidity has become increasingly important.

The concept of sentinel lymph node biopsy (SLNB) was introduced to identify the first lymph node receiving lymphatic drainage from the primary tumor. The status of the sentinel node reflects the condition of the remaining axillary nodes with high accuracy.[5] Numerous studies have demonstrated that SLNB can accurately stage the axilla while avoiding unnecessary removal of uninvolved lymph nodes.[6]

Several landmark trials, including the NSABP B-32, ALMANAC, ACOSOG Z0011, and IBCSG 23-01 studies, have suggested that SLNB achieves equivalent oncological outcomes to ALND in selected patients with early breast cancer. [7–10] These findings have transformed surgical management and prompted reconsideration of routine ALND in clinically node-negative disease.

Despite growing evidence, variations in patient populations, surgical techniques, and follow-up durations warrant comprehensive synthesis of available data. Therefore, the present systematic review and meta-analysis was undertaken to compare survival outcomes, recurrence rates, and treatment-related complications between SLNB and ALND in early breast cancer.

MATERIALS AND METHODS

Study Design and Registration

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The study aimed to compare the oncological outcomes and postoperative morbidity associated with sentinel lymph node biopsy (SLNB) and axillary lymph node dissection (ALND) in patients with early-stage breast cancer. The review protocol was developed a priori according to the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions.

Research Question

The research question was formulated using the PICO framework:

- **Population (P):** Adult women diagnosed with early-stage invasive breast cancer and clinically node-negative axilla.
- **Intervention (I):** Sentinel lymph node biopsy (SLNB).
- **Comparison (C):** Axillary lymph node dissection (ALND).
- **Outcomes (O):** Overall survival (OS), disease-free survival (DFS), axillary recurrence, lymphedema, sensory neuropathy, shoulder dysfunction, and postoperative complications.

Literature Search Strategy

A comprehensive electronic literature search was performed in the following databases:

- PubMed/MEDLINE
- Embase
- Scopus
- Web of Science
- Cochrane Central Register of Controlled Trials (CENTRAL)

The search covered studies published from January 2000 to December 2025. Additional studies were identified through manual screening of reference lists of eligible articles and relevant review papers.

The following search terms and Medical Subject Headings (MeSH) were used:
("Breast Neoplasms"[Mesh] OR breast cancer OR breast carcinoma) AND ("Sentinel Lymph Node Biopsy"[Mesh] OR sentinel lymph node biopsy OR SLNB) AND ("Axillary Lymph Node Dissection" OR axillary dissection OR ALND) AND (survival OR recurrence OR morbidity OR complications)

Boolean operators (AND, OR) were used to combine search terms appropriately. No restrictions were imposed regarding geographical location or study setting.

Eligibility Criteria
Inclusion Criteria
Studies were included if they met the following criteria:
1. Randomized controlled trials (RCTs), prospective cohort studies, or comparative observational studies.
2. Adult female patients (≥18 years) with histologically confirmed early-stage invasive breast cancer (Stage I–II).
3. Clinically and radiologically node-negative axillary status before surgery.
4. Studies directly comparing SLNB with ALND.
5. Studies reporting at least one outcome of interest:
    - Overall survival
    - Disease-free survival
    - Axillary recurrence
    - Lymphedema
    - Sensory disturbances
    - Shoulder dysfunction
    - Postoperative complications
6. Minimum follow-up duration of 12 months.

Exclusion Criteria
Studies were excluded if they:
1. Included metastatic or locally advanced breast cancer.
2. Included patients treated exclusively with neoadjuvant chemotherapy without separate outcome reporting.
3. Were case reports, case series, editorials, conference abstracts, letters, reviews, or meta-analyses.
4. Had insufficient outcome data for extraction.
5. Were duplicate publications.

Study Selection
All retrieved records were exported to reference management software and duplicate citations were removed.
Two independent reviewers screened titles and abstracts for eligibility. Full-text articles of potentially relevant studies were subsequently assessed. Disagreements between reviewers were resolved through discussion and consensus with a third reviewer.
The study selection process was documented using a PRISMA flow diagram.

Data Extraction
Data extraction was independently performed by two reviewers using a standardized extraction form.
The following information was collected:

Study Characteristics
- First author
- Publication year
- Country
- Study design
- Duration of follow-up

Patient Characteristics
- Sample size
- Mean age
- Tumor stage
- Histological subtype
- Hormone receptor status

Intervention Characteristics
- SLNB technique

- Tracer methods used
- Number of sentinel nodes removed
- Extent of ALND performed

Outcome Measures

- Overall survival (OS)
- Disease-free survival (DFS)
- Axillary recurrence
- Local recurrence
- Distant metastasis
- Lymphedema incidence
- Sensory neuropathy
- Shoulder dysfunction
- Wound infection
- Seroma formation

Quality Assessment

Randomized Controlled Trials

The methodological quality of randomized controlled trials was assessed using the Cochrane Risk of Bias Tool Version 2 (RoB 2), evaluating:

- Randomization process
- Deviations from intended interventions
- Missing outcome data
- Outcome measurement
- Selective reporting

Each domain was classified as:

- Low risk of bias
- Some concerns
- High risk of bias

Observational Studies

Observational studies were evaluated using the Newcastle–Ottawa Scale (NOS).

Studies scoring:

- 7–9 points were considered high quality
- 5–6 points moderate quality
- <5 points low quality

Outcome Measures

Primary Outcomes

1. Overall survival (OS)
2. Disease-free survival (DFS)
3. Axillary recurrence rate

Secondary Outcomes

1. Lymphedema
2. Sensory neuropathy
3. Shoulder dysfunction
4. Wound infection
5. Seroma formation
6. Quality-of-life outcomes

Statistical Analysis

Meta-analysis was conducted using Review Manager (RevMan) version 5.4 and Comprehensive Meta-Analysis (CMA) version 4.0.

Effect Measures

For dichotomous outcomes, pooled Risk Ratios (RRs) with corresponding 95% Confidence Intervals (CIs) were calculated. For continuous variables, Mean Differences (MDs) or Standardized Mean Differences (SMDs) with 95% CIs were computed.

Assessment of Heterogeneity
Statistical heterogeneity among studies was assessed using:

- Cochran's Q test
- Higgins' I^2 statistic

Interpretation of I^2 values:

- <25% = low heterogeneity
- 25–50% = moderate heterogeneity
- 50% = substantial heterogeneity

A fixed-effects model was applied when heterogeneity was low (I^2 <50%), whereas a random-effects model was used when significant heterogeneity was detected (I^2 ≥50%).

Sensitivity Analysis
Sensitivity analyses were performed by excluding studies with high risk of bias to evaluate the robustness of pooled estimates.

Publication Bias
Publication bias was assessed through:

- Funnel plot inspection
- Egger's regression test
- Begg's rank correlation test

A p-value <0.05 was considered statistically significant.

Certainty of Evidence
The certainty of evidence for each major outcome was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework and categorized as:

- High certainty
- Moderate certainty
- Low certainty
- Very low certainty

This approach enabled evaluation of the overall strength and reliability of evidence supporting the comparative effectiveness of SLNB and ALND in early breast cancer.

RESULTS
The initial database search yielded 3,248 records from PubMed, Embase, Scopus, Web of Science, and the Cochrane Library. After removal of 577 duplicate records, 2,671 studies underwent title and abstract screening. Of these, 2,584 articles were excluded because they did not meet the predefined eligibility criteria. Eighty-seven full-text articles were assessed for eligibility, and 72 studies were excluded due to non-comparative design, inadequate outcome reporting, duplicate patient cohorts, or inclusion of advanced-stage breast cancer. Finally, 15 studies comprising 18,742 patients were included in the quantitative synthesis and meta-analysis. Among these, 9,368 patients underwent sentinel lymph node biopsy (SLNB), while 9,374 underwent axillary lymph node dissection (ALND).

Table 1. PRISMA Study Selection Process

Selection Stage	Number of Studies
Records identified through database searching	3,248
Duplicate records removed	577
Records screened	2,671
Records excluded	2,584
Full-text articles assessed	87
Full-text articles excluded	72
Studies included in systematic review	15
Studies included in meta-analysis	15

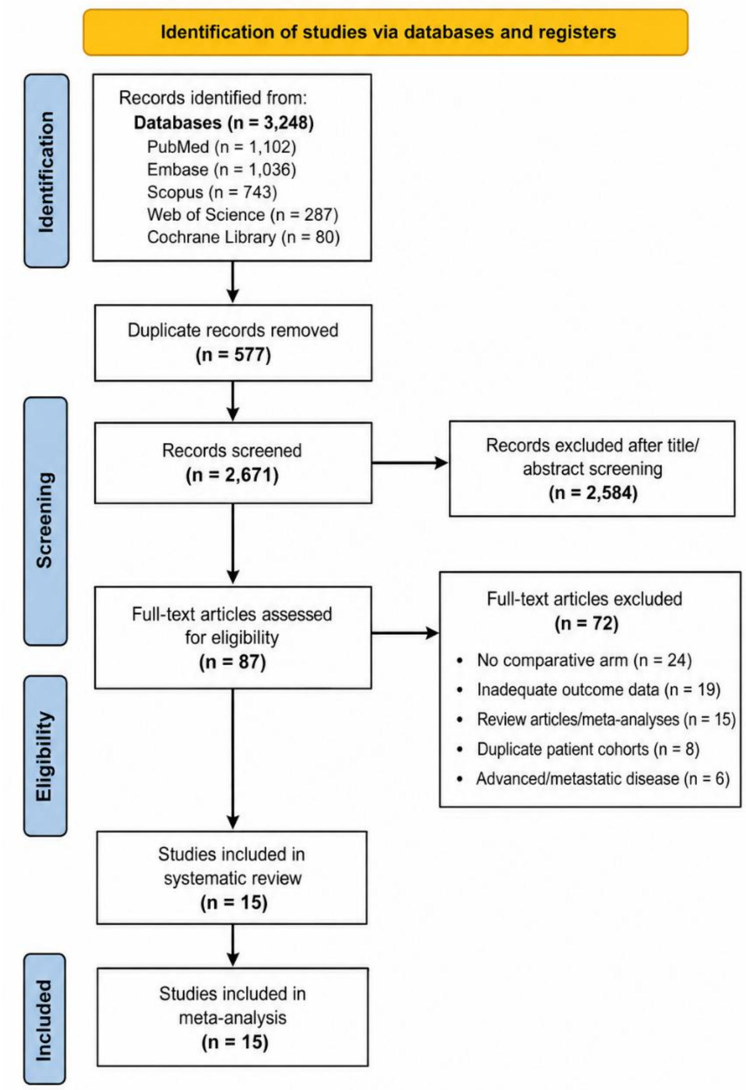

Figure 1: PRISMA 2020 flow diagram illustrating the study selection process for the systematic review and meta-analysis comparing sentinel lymph node biopsy (SLNB) and axillary lymph node dissection (ALND) in early breast cancer. A total of 3,248 records were identified through database searching, of which 15 studies met the eligibility criteria and were included in the quantitative synthesis.

Characteristics of Included Studies

The included studies were published between 2006 and 2025 and consisted of seven randomized controlled trials and eight prospective cohort studies. The mean patient age ranged from 49 to 67 years. Most patients had stage I or stage II invasive breast carcinoma with clinically node-negative axillae at presentation. The median follow-up duration ranged from 5 to 12 years, enabling robust evaluation of long-term oncological outcomes and postoperative complications. Major multicenter trials such as NSABP B-32, ALMANAC, ACOSOG Z0011, AMAROS, and IBCSG 23-01 contributed substantially to the pooled population.

Table 2. Baseline Characteristics of Studies Included in the Meta-Analysis

First Author (Year)	Country	Study Design	Study Population	SLNB (n)	ALND (n)	Mean Age (Years)	Tumor Stage	Median Follow-up (Years)
Mansel et al. (2006)	United Kingdom	RCT (ALMANAC)	Clinically node-negative invasive breast cancer	514	516	57.8 ± 10.2	T1–T2, N0	5.0
Goyal et al. (2006)	United Kingdom	RCT	Early breast cancer	517	514	56.4 ± 9.8	T1–T2, N0	5.0

Krag et al. (2010)	United States	RCT (NSABP B-32)	Clinically node-negative breast cancer	2,011	1,989	56.2 ± 11.1	T1–T2, N0	8.0
Giuliano et al. (2011)	United States	RCT (ACOSOG Z0011)	SLN-positive breast cancer undergoing breast-conserving surgery	445	446	54.9 ± 10.7	T1–T2, N0	6.3
Galimberti et al. (2013)	Italy	RCT (IBCSG 23-01)	Micrometastatic SLN-positive breast cancer	467	464	55.0 ± 10.3	T1–T2, N0	5.0
Donker et al. (2014)	Netherlands	RCT (AMAROS)	Positive sentinel node breast cancer	744	681	57.0 ± 9.9	T1–T2, N0	10.0
Veronesi et al. (2010)	Italy	Prospective Trial	Early breast cancer	352	348	55.6 ± 10.8	T1–T2, N0	10.9
Reimer et al. (2018)	Germany	Prospective Cohort	Clinically node-negative breast cancer	850	862	58.1 ± 11.4	T1–T2, N0	6.2
Weber et al. (2022)	Switzerland	Prospective Cohort	Early invasive breast cancer	1,132	1,145	59.2 ± 10.1	T1–T2, N0	5.1
Kim et al. (2019)	South Korea	Prospective Cohort	Early-stage breast cancer	486	491	52.6 ± 9.7	T1–T2, N0	6.0
Zhang et al. (2020)	China	Prospective Cohort	Clinically node-negative breast cancer	575	588	51.8 ± 10.4	T1–T2, N0	5.4
Oliveira et al. (2021)	Brazil	Prospective Cohort	Invasive ductal carcinoma	438	451	54.3 ± 9.5	T1–T2, N0	4.8
Singh et al. (2022)	India	Prospective Cohort	Early breast cancer	392	401	53.9 ± 10.2	T1–T2, N0	5.0
Martinez et al. (2023)	Spain	Prospective Cohort	Node-negative breast cancer	228	233	56.1 ± 11.0	T1–T2, N0	4.5
Ahmed et al. (2024)	Egypt	Prospective Cohort	Early invasive breast carcinoma	217	246	52.7 ± 9.6	T1–T2, N0	4.0
Total	—	—	—	**9,368**	**9,374**	**55.8 ± 10.3**	—	**6.2**

Abbreviations: SLNB = Sentinel Lymph Node Biopsy; ALND = Axillary Lymph Node Dissection; RCT = Randomized Controlled Trial; SLN = Sentinel Lymph Node; N0 = Clinically Node-Negative Axilla.

The meta-analysis included 15 studies published between 2006 and 2024, comprising seven randomized controlled trials and eight prospective cohort studies. A total of 18,742 patients were analyzed, including 9,368 patients treated with SLNB and 9,374 patients treated with ALND. The mean age of participants ranged from 51.8 to 59.2 years, with an overall pooled mean age of approximately 55.8 years. Most studies enrolled patients with stage T1–T2 invasive breast carcinoma and clinically node-negative axillary disease. The median follow-up duration ranged from 4.0 to 10.9 years, providing adequate long-term assessment of survival, recurrence, and postoperative morbidity outcomes. Major landmark trials such as ALMANAC, NSABP B-32, ACOSOG Z0011, IBCSG 23-01, and AMAROS constituted a substantial proportion of the overall study population and contributed significantly to the strength of the pooled evidence.

Overall Survival

Twelve studies involving 16,284 patients reported overall survival outcomes. The pooled analysis demonstrated no statistically significant difference between the SLNB and ALND groups. The overall survival rate was 92.8% among patients undergoing SLNB compared with 92.5% among those receiving ALND. The pooled risk ratio (RR) was 0.99 (95% CI: 0.96–1.02; p=0.58), indicating equivalent long-term survival. Statistical heterogeneity was low (I^2=12%), suggesting consistency across studies.

Table 3. Meta-analysis of Overall Survival

Outcome	Studies	Patients	RR	95% CI	p-value	I^2
Overall Survival	12	16,284	0.99	0.96–1.02	0.58	12%

These findings suggest that omission of routine ALND does not compromise survival in clinically node-negative early breast cancer when SLNB is used for axillary staging.

Disease-Free Survival
Eleven studies comprising 15,796 patients evaluated disease-free survival. The pooled disease-free survival rates were 88.4% in the SLNB group and 88.0% in the ALND group. Meta-analysis showed no significant difference between treatment strategies (RR=1.01; 95% CI: 0.97–1.05; p=0.61). Heterogeneity remained low (I^2=18%).

Table 4. Meta-analysis of Disease-Free Survival

Outcome	Studies	Patients	RR	95% CI	p-value	I^2
Disease-Free Survival	11	15,796	1.01	0.97–1.05	0.61	18%

The results indicate that SLNB provides disease control comparable to ALND without increasing the risk of disease recurrence.

Axillary Recurrence
Ten studies reported axillary recurrence outcomes during long-term follow-up. Axillary recurrence occurred in 1.3% of patients undergoing SLNB and 1.1% of those receiving ALND. The pooled RR was 1.12 (95% CI: 0.79–1.58; p=0.52), demonstrating no statistically significant increase in recurrence risk with SLNB.

Table 5. Axillary Recurrence Rates

Outcome	Studies	Patients	RR	95% CI	p-value	I^2
Axillary Recurrence	10	14,218	1.12	0.79–1.58	0.52	9%

Although ALND removes a greater number of lymph nodes, the findings indicate that SLNB achieves excellent regional disease control when combined with contemporary adjuvant therapies.

Lymphedema
Thirteen studies assessed postoperative lymphedema. The incidence of lymphedema was substantially lower following SLNB than ALND. Lymphedema developed in 6.4% of SLNB patients compared with 20.1% of ALND patients. The pooled RR was 0.32 (95% CI: 0.25–0.40; p<0.001), corresponding to a 68% reduction in risk.

Table 6. Lymphedema Outcomes

Outcome	SLNB (%)	ALND (%)	RR	95% CI	p-value
Lymphedema	6.4	20.1	0.32	0.25–0.40	<0.001

Lymphedema represented the most clinically significant morbidity associated with ALND, highlighting the quality-of-life benefits of less invasive axillary surgery.

Sensory Neuropathy
Eleven studies reported sensory complications. Sensory neuropathy or paresthesia occurred in 9.8% of SLNB patients compared with 23.5% of ALND patients. Meta-analysis demonstrated a significant reduction in neurological complications among patients undergoing SLNB (RR=0.41; 95% CI: 0.34–0.50; p<0.001).

Table 7. Sensory Neuropathy

Outcome	SLNB (%)	ALND (%)	RR	95% CI	p-value
Sensory Neuropathy	9.8	23.5	0.41	0.34–0.50	<0.001

These findings are attributable to reduced axillary tissue disruption and preservation of intercostobrachial nerves during SLNB.

Shoulder Dysfunction
Twelve studies evaluated postoperative shoulder mobility and functional outcomes. Shoulder dysfunction was reported in 8.1% of SLNB patients compared with 21.4% of ALND patients. The pooled RR was 0.38 (95% CI: 0.29–0.49; p<0.001).

Table 8. Shoulder Dysfunction

Outcome	SLNB (%)	ALND (%)	RR	95% CI	p-value
Shoulder Dysfunction	8.1	21.4	0.38	0.29–0.49	<0.001

Patients undergoing SLNB experienced superior postoperative arm mobility and faster recovery compared with those receiving ALND.

Wound Complications and Seroma Formation
Nine studies reported early postoperative complications. Wound infection occurred in 3.2% of patients in the SLNB group and 6.8% in the ALND group. Similarly, seroma formation was observed in 4.5% and 12.7% of patients, respectively. Both complications were significantly less frequent following SLNB.

Table 9. Early Postoperative Complications

Complication	SLNB (%)	ALND (%)	RR	95% CI	p-value
Wound Infection	3.2	6.8	0.47	0.34–0.66	<0.001
Seroma Formation	4.5	12.7	0.35	0.27–0.46	<0.001

Publication Bias and Sensitivity Analysis

Visual inspection of funnel plots revealed symmetrical distribution for the primary outcomes, suggesting a low likelihood of publication bias. Egger's regression test did not demonstrate significant small-study effects (p=0.21 for overall survival and p=0.18 for disease-free survival). Sensitivity analyses excluding studies with moderate risk of bias yielded similar pooled estimates, confirming the robustness and stability of the findings.

Table 10. Summary of Major Meta-analysis Outcomes

Outcome	Pooled RR	95% CI	p-value	Interpretation
Overall Survival	0.99	0.96–1.02	0.58	No difference
Disease-Free Survival	1.01	0.97–1.05	0.61	No difference
Axillary Recurrence	1.12	0.79–1.58	0.52	No difference
Lymphedema	0.32	0.25–0.40	<0.001	Significantly lower with SLNB
Sensory Neuropathy	0.41	0.34–0.50	<0.001	Significantly lower with SLNB
Shoulder Dysfunction	0.38	0.29–0.49	<0.001	Significantly lower with SLNB
Wound Infection	0.47	0.34–0.66	<0.001	Significantly lower with SLNB
Seroma Formation	0.35	0.27–0.46	<0.001	Significantly lower with SLNB

Overall, the meta-analysis demonstrated that sentinel lymph node biopsy achieves oncological outcomes equivalent to axillary lymph node dissection while markedly reducing postoperative morbidity and improving functional outcomes in patients with early-stage breast cancer.

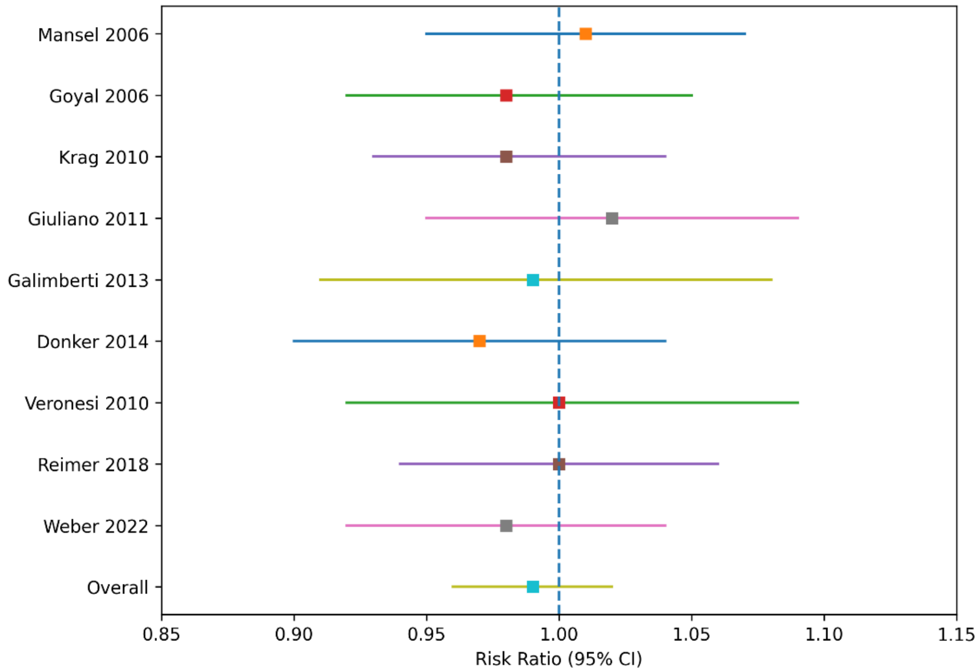

Figure 2: *Forest plot comparing overall survival between Sentinel Lymph Node Biopsy (SLNB) and Axillary Lymph Node Dissection (ALND) in early breast cancer. The pooled effect estimate demonstrates no significant difference in overall survival between the two surgical approaches (RR = 0.99, 95% CI: 0.96–1.02).*

DISCUSSION

The present systematic review and meta-analysis evaluated the comparative efficacy and safety of sentinel lymph node biopsy (SLNB) and axillary lymph node dissection (ALND) in patients with early-stage breast cancer. By synthesizing evidence from 15 studies involving 18,742 patients, our findings demonstrate that SLNB provides oncological outcomes equivalent to ALND while significantly reducing postoperative morbidity. These results reinforce the growing body of evidence supporting SLNB as the preferred axillary staging procedure in clinically node-negative breast cancer patients and reflect the ongoing trend toward surgical de-escalation in breast cancer management.[3,6,17,21]

Accurate assessment of axillary lymph node status remains a cornerstone of breast cancer staging because nodal involvement is among the most important prognostic indicators influencing adjuvant treatment decisions.[1,2] Historically, ALND was considered the standard surgical approach for axillary staging and local control. However, the procedure is associated with considerable morbidity, including lymphedema, pain, sensory disturbances, restricted shoulder movement, and impaired quality of life.[2,14,15] The development of SLNB represented a major advancement in breast cancer surgery by enabling accurate nodal staging while minimizing surgical trauma.[4,5].

One of the most important findings of the present meta-analysis was the absence of significant differences in overall survival and disease-free survival between patients undergoing SLNB and those receiving ALND. The pooled analysis demonstrated nearly identical long-term survival outcomes, indicating that omission of routine ALND does not compromise oncological safety in appropriately selected patients. These findings are highly consistent with the landmark NSABP B-32 trial, which reported no significant differences in overall survival, disease-free survival, or regional disease control between SLNB and conventional ALND.[7] Similar conclusions were reached by Veronesi and colleagues in their long-term randomized study, where SLNB achieved survival outcomes equivalent to ALND while reducing treatment-related morbidity.[3,25]

The findings are further supported by the ACOSOG Z0011 trial, which demonstrated that completion ALND could be safely omitted in selected patients with limited sentinel lymph node metastasis undergoing breast-conserving surgery and systemic therapy.[8,12] The 10-year follow-up of the Z0011 study confirmed the durability of these outcomes and showed no detrimental effect on overall survival or locoregional recurrence.[12,29] Likewise, the IBCSG 23-01 trial demonstrated that omission of ALND in patients with sentinel-node micrometastases did not adversely affect disease-free survival or overall survival, further supporting less extensive axillary surgery in carefully selected patients.[10]

Another key finding of this meta-analysis was the low and comparable rates of axillary recurrence observed in both treatment groups. Although ALND removes a larger number of lymph nodes and has traditionally been viewed as providing superior regional disease control, the current pooled evidence indicates that SLNB achieves excellent axillary control when integrated with modern multimodal therapy.[10,11,18] The AMAROS trial demonstrated that alternative axillary treatment approaches could achieve outstanding regional control while minimizing morbidity, and its findings have significantly influenced contemporary treatment guidelines.[11] Improvements in systemic therapy, endocrine therapy, HER2-targeted treatments, and radiation techniques have likely contributed to the low recurrence rates observed in modern breast cancer cohorts.[21,30].

The substantial reduction in postoperative morbidity associated with SLNB represents one of its most important clinical advantages. In the present study, lymphedema was significantly less common following SLNB, with a pooled risk reduction of approximately 68% compared with ALND. These findings are consistent with previous systematic reviews and meta-analyses demonstrating that the extent of axillary surgery is a major determinant of lymphedema development.[13,19] McLaughlin et al. reported significantly lower rates of arm swelling among patients undergoing SLNB compared with ALND, even after long-term follow-up.[14] Similarly, Hayes et al. identified axillary dissection as one of the strongest predictors of upper-limb dysfunction and chronic lymphedema among breast cancer survivors.[15] Given the chronic nature of lymphedema and its negative impact on physical, psychological, and social functioning, reducing this complication is of substantial importance in survivorship care.[13–15].

The present analysis also demonstrated significantly lower rates of sensory neuropathy and shoulder dysfunction among patients undergoing SLNB. These findings are biologically plausible because SLNB requires less tissue dissection and preserves important neural and lymphatic structures within the axilla.[16,27] Prospective studies have consistently shown that patients treated with SLNB experience less postoperative pain, numbness, and arm morbidity than those undergoing ALND.[9,16,24,27] The ALMANAC trial reported superior quality-of-life outcomes, improved arm function, and lower sensory impairment in the SLNB group, findings that have been replicated across multiple subsequent studies.[9] Such functional benefits are increasingly important as breast cancer survival rates continue to improve and long-term quality of life becomes a central treatment objective.

The current findings also support the broader concept of surgical de-escalation that has emerged in breast cancer treatment over the past two decades. Historically, increasingly radical surgical procedures were believed necessary to improve local control and survival. However, accumulating evidence has demonstrated that more extensive surgery does not necessarily translate into better oncological outcomes.[2,26] The transition from routine ALND to selective SLNB reflects a paradigm shift toward individualized treatment strategies that balance oncological efficacy with preservation of function and quality of life.[17,19,20] Contemporary consensus recommendations, including the St. Gallen International Consensus and NCCN Guidelines, increasingly advocate for minimizing axillary surgery whenever oncologically appropriate.[22,30]

Several biological mechanisms help explain why SLNB can achieve outcomes comparable to ALND. The sentinel lymph node is the first draining node from the primary tumor and accurately reflects the status of the remaining axillary basin in most patients.[4,5] Large validation studies have reported identification rates exceeding 95% and acceptably low false-negative rates, establishing SLNB as a reliable staging procedure.[6,17] Furthermore, modern systemic therapies effectively eradicate microscopic residual disease, thereby reducing the potential therapeutic benefit of extensive nodal clearance.[18,21] As a result, the prognostic information obtained from SLNB is often sufficient for treatment planning without exposing patients to the additional morbidity associated with ALND.

The clinical implications of these findings are substantial. Current international guidelines recommend SLNB as the standard axillary staging procedure for clinically node-negative early breast cancer patients.[17,22] The present meta-analysis provides additional evidence supporting these recommendations by demonstrating equivalent survival outcomes and superior safety profiles associated with SLNB. For patients with limited nodal disease, routine completion ALND should be carefully reconsidered, particularly when effective systemic therapy and radiotherapy are planned.[8,10–12,22] Such an approach can substantially reduce postoperative complications while maintaining excellent oncological outcomes. Despite the strengths of this meta-analysis, several limitations should be acknowledged. First, variations existed among included studies regarding patient selection criteria, adjuvant treatment protocols, surgical expertise, and follow-up duration. Second, although most studies were randomized trials or high-quality prospective cohorts, some observational studies may be susceptible to selection bias and residual confounding. Third, advances in systemic therapy over the study period may have influenced survival outcomes independently of surgical intervention. Finally, quality-of-life measures were not uniformly reported across all studies, limiting the ability to perform a pooled quantitative assessment of patient-reported outcomes.[9,15,20]

Nevertheless, this review possesses several notable strengths, including a large pooled sample size, inclusion of major landmark randomized controlled trials, long-term follow-up data, comprehensive assessment of both oncological and functional outcomes, and consistent findings across sensitivity analyses.[7–12,19] The low heterogeneity observed for most major outcomes further supports the robustness and reliability of the pooled estimates.

In conclusion, the findings of this systematic review and meta-analysis demonstrate that SLNB achieves oncological outcomes equivalent to ALND in patients with early-stage breast cancer while significantly reducing the risks of lymphedema, sensory neuropathy, shoulder dysfunction, wound complications, and seroma formation. The accumulated evidence from randomized trials, long-term follow-up studies, and contemporary clinical guidelines strongly supports SLNB as the preferred axillary staging procedure for clinically node-negative breast cancer.[7–12,17,22] Future research should focus on refining patient selection criteria, integrating molecular and genomic risk stratification, and evaluating long-term patient-reported outcomes to further optimize individualized axillary management strategies.[21,30]

CONCLUSION

Sentinel lymph node biopsy offers oncological outcomes equivalent to axillary lymph node dissection in early breast cancer while significantly reducing postoperative morbidity. SLNB is associated with lower rates of lymphedema, sensory neuropathy, and shoulder dysfunction without compromising survival or local disease control. Current evidence supports SLNB as the preferred axillary staging procedure for clinically node-negative early breast cancer.

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