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Post-operative complications and surgical outcomes of minimal access vs conventional Nipple-Sparing Mastectomy in breast cancer: Meta-Analysis

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Abstract

Background

Conventional nipple-sparing mastectomy (C-NSM) is an important surgical method for breast cancer, but minimal access nipple-sparing mastectomy (M-NSM) have now emerged as a cutting-edge focus within breast surgery. However, there remains a scarcity of comprehensive studies evaluating the overall advantages and limitations of minimally invasive breast surgery.

Materials and Methods

A comprehensive literature search was conducted across four major databases (PubMed, Embase, Web of Science, Cochrane Library) from their inception to August,7,2025. Studies comparing the efficacy of M-NSM and C-NSM in patients with breast cancer were included.The meta-analysis evaluated multiple clinical outcomes, including operative time, length of hospital stay, blood loss, total complication, specific complications, recurrence, metastasis, patient satisfaction and medical cost.

Results

A total of 20 studies involving 5908 patients were included. M-NSM exhibited statistically significant advantages over C-NSM in terms of recurrence and distant metastasis rate. Furthermore, M-NSM showed superior outcomes in overall complications, incision length, seroma formation, skin necrosis, and had higher patient satisfaction.Blood loss in the M-NSM group was lower than that observed in the C-NSM group with no significant difference. However, M-NSM was associated with longer operative and hospitalization durations, including total mastectomy with implant reconstruction time, mastectomy time, and hospital stays.Additionally, the medical costs associated with M-NSM were significantly higher than those for C-NSM.No statistically significant differences were observed between the two groups in terms of infection, NAC necrosis, hematoma, wound dehiscence, implant loss, and capsular contracture.

Conclusion

M-NSM represents a valuable surgical option that enhances oncological safety and operative feasibility for breast cancer.

Introduction

Breast cancer remains the most frequently diagnosed malignancy among women worldwide, accounting for approximately 24.5 per cent of all female cancer cases. With over 2.3 million new diagnoses and more than 665,000 deaths annually, it represents a major global health burden in terms of both incidence and mortality [1, 2]. Mastectomy continues to be a cornerstone in the surgical management of breast cancer. In South Korea, for instance, around 32 per cent of breast cancer patients undergo mastectomy [3]. Conventional open surgery, while established as a standard approach and effective for oncological resection, is associated with significant drawbacks including substantial tissue trauma, conspicuous scarring, and altered breast contour, all of which can profoundly impact postoperative quality of life and psychosocial recovery. In recent years, increasing emphasis has been placed not only on oncological efficacy but also on aesthetic outcomes and patient satisfaction. C-NSM has emerged as a valuable technique that combines reliable oncological safety with improved cosmetic results, thereby enhancing quality of life [4, 5]. Nevertheless, C-NSM still necessitates large incisions that result in visible scars, and some patients report dissatisfaction with aesthetic outcomes. Additionally, the procedure carries a considerable risk of nipple-areolar complex necrosis[6]. In response to these limitations and growing patient demand for less invasive interventions, clinical focus has shifted toward techniques that minimize surgical trauma without compromising oncological safety. Endoscope-assisted and robot-assisted nipple-sparing mastectomy (E-NSM and R-NSM, respectively) represent such innovations aimed at reducing invasiveness while preserving aesthetic integrity.

Endoscopic techniques were first applied in capsulectomy for breast implant contracture in 1992 [7], and later extended to axillary lymph node dissection[8]. In 1995, Professor Friedlande first proposed the use of endoscopic techniques for mastectomy and immediate autologous breast reconstruction[9]. However, due to the absence of a natural cavity in the dense breast parenchyma, significant challenges such as difficulty in creating and maintaining a working space, instrument crowding, and prolonged operative time hindered its widespread adoption. Progress remained slow until recent years, when advances in high-definition imaging, development of specialized instruments, innovations in space-making theories, and refinements in surgical techniques gradually overcame these technical barriers[10–12]. Endoscopic breast cancer surgery has now emerged as a cutting-edge focus within breast surgery, providing further theoretical and technical groundwork for the rise of robotic-assisted procedures. Currently, minimally invasive techniques are being increasingly employed in breast surgery. However, concerns have been raised regarding their oncological safety, particularly the potential risk of tumor dissemination[13]. Additionally, these approaches may be associated with longer operating times and increased costs[14]. Furthermore, there remains a scarcity of comprehensive studies evaluating the overall advantages and limitations of minimally

invasive breast surgery[15]. The application of M-NSM in breast cancer treatment continues to be debated, necessitating further validation of its safety and efficacy.

To address these questions, we conducted a meta-analysis comparing the efficacy and safety of M-NSM versus C-NSM in patients with breast cancer.

Materials and methods

A systematic review was conducted in accordance with PRISMA guidelines and registered with PROSPERO, the international prospective register of systematic reviews (CRD420251128389). A comprehensive literature search was performed utilizing the PubMed, MEDLINE, EMBASE, and Web of Science databases to identify eligible articles published prior to August 7, 2025.The search strategy was developed according to the PICOS framework and combined Medical Subject Headings terms with unrestricted text phrases. Keywords included, but were not limited to," Breast Neoplasm", "Robot Assisted Surgery", "Endoscopy", "Nipple-Sparing Mastectomy", among others. A complete overview of the search record is provided in Supplementary Material 1.

Inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) patients diagnosed with breast cancer; (2) the intervention group underwent robotic or endoscopic nipple-sparing mastectomy; (3) the control group received conventional nipple-sparing mastectomy; (4) Types of included studies: Randomized controlled trials (RCT), retrospective studies (RS), and prospective studies (PS);(5) at least one of the following outcomes was reported: operative time, length of hospital stay, blood loss, total complication, incision length, hospital cost, seroma, skin necrosis, infection, NAC necrosis, hematoma, wound dehiscence, implant loss, capsular contracture, recurrence, metastasis, or patient satisfaction.

Exclusion criteria were as follows: (1) case reports, protocols, letters, editorials, commentaries, reviews, or meta-analyses; (2) studies not involving breast cancer patients; (3) lack of comparison between minimally access and conventional surgical approaches; (4) duplicate publications; (5) insufficient data for extraction; (6) Animal studies, in vitro studies.

Selection of studies

The literature screening process was performed using EndNote software (Version 20; Clarivate Analytics) to remove duplicate records. Two independent reviewers conducted the initial screening by assessing titles and abstracts to determine relevance. Each study was categorized as included or excluded based on this evaluation. Consensus was reached through discussion between the reviewers, and any disagreements were resolved by a third reviewer.

Data extraction

Data extraction was performed independently by two reviewers. The extracted data encompassed the following categories:(1) Study characteristics: first author, country of origin, and year of publication;(2) Baseline characteristics: patient age, sample size, and tumor stage;(3) Outcome measures: operative time (including total procedure time for mastectomy with immediate prosthetic reconstruction and mastectomy time alone), length of hospital stay, intraoperative blood loss, overall complications, incision length, hospital cost, seroma formation, skin necrosis, infection, NAC necrosis, hematoma, wound dehiscence, implant loss, capsular contracture, recurrence, distant metastasis rate, and patient satisfaction evaluation.

Quality assessment

Two independent reviewers assessed the quality of the included studies. The Newcastle-Ottawa Scale (NOS) was used to evaluate the quality of retrospective and prospective cohort studies. The Cochrane-recommended tool was applied to assess the risk of bias in randomized controlled trials. Any discrepancies in ratings were resolved through discussion to reach consensus.

Statistical analysis

Meta-analysis was performed using RevMan software (version 5.4). Continuous variables were expressed as mean difference (MD), while dichotomous variables were analysed using risk ratio (RR), both with 95 per cent confidence intervals (c.i). The statistical heterogeneity among the included studies was assessed using the Cochrane's Q test and the I^2 index. A fixed-effect model was applied if no significant heterogeneity was observed ($P > 0.10$, $I^2 < 50$ per cent). In cases of significant heterogeneity ($P \leq 0.10$, $I^2 \geq 50$ per cent), sources of heterogeneity were explored, and subgroup analyses were conducted to identify potential contributing factors. A P-value of less than 0.05 was considered statistically significant. Publication bias was evaluated using funnel plots.

Rresults

The initial search yielded 864 articles. All records were imported into EndNote 2025 for screening. After removing duplicates and excluding studies based on title and abstract review, 30 articles remained. Of these, 10 studies were excluded for not meeting the inclusion criteria. A detailed flow diagram of the study selection process is provided in Fig. 1.

Study characteristics and quality assessment

A total of 20 studies were included in this meta-analysis, comprising one randomized controlled trial, two prospective studies, and 17 retrospective studies. These studies enrolled 5908 patients, with 2076 undergoing M-NSM and 3832 undergoing C-NSM. The investigations were conducted across multiple countries, including China, Japan, Italy, and South Korea, among others.

Among the 20 studies assessed using NOS for methodological quality, five yielded a score of 9, five scored 8, two scored 7, six scored 6, and one scored 5. The included randomized controlled trial was deemed to be of low quality, as three key domains were rated as high risk of bias. Detailed results of the study characteristics and quality assessment are presented in Table 1.

Table 1
Characteristics and quality assessment of the included studies.

Study,year	Country/Region	Design	Study period	Patients(n) M-NSM/C-NSM	Age(Mean ± SD) M-NSM/C-NSM	TNM stage	Selection	Comparability	Outcome	Total score
Kuo *et al.*2024[16]	Taiwan	RS	2016–2023	123/123	45.01 ± 6.99 / 45.37 ± 8.83	0□□□ □□□□□	4	2	3	9
Gui *et al.*2021[17]	China	RS	2006–2021	292/205	42 (22–65) / 43 (23–64)	0□□□□	3	1	2	6
Sae-lim *et al.*2024[18]	Taiwan	RS	2011–2022	357/371	NA	□□□□□	4	1	2	7
Lee *et al.*2021[19]	Korea	RS	2017–2020	20/25	47.2 ± 9.5 / 44.6 ± 9.6	0□□□ □□□	3	1	2	6
You *et al.*2025[20]	Korea	RS	2021.01-2021.12	8/49	51.3 (38–60) / 48.3 (27–66)	0□□□ □□□	2	1	2	5
Huang *et al.*2021[21]	Taiwan	RS	2018–2020	22/41	44.1 ± 9.5 / 46.2 7.4	0□□□ □□□	4	2	3	9
Lai *et al.*2024[22]	Taiwan	PS	2019–2021	160/73	NA	0□□□ □□□	3	1	2	6
Toesca et al.2022[23]	Italy	RCT	2017–2018	40/40	44.5 (30–60)/45.5 (29–62)	0□□□ □□□□□	-	-	-	-
Kim *et al.*2023[24]	Korea	RS	2019–2021	153/423	45.6 ± 7.8 / 46.4 ± 8.0	0□□□ □□□	3	1	2	6
Lee *et al.*2025[25]	Korea	RS	2016–2020	162/239	44.76 ± 7.81 / 46.75 ± 8.34	0□□□ □□□	3	1	2	6
Zhang *et al.*2025[26]	China	RS	2017–2022	76/40	41.7 ± 8.8 / 41.2 ± 8.1	0□□□□	4	2	3	9
Lee *et al.*2020[27]	Korea	RS	2016–2019	41/270	44 ± 10.0 / 46 ± 8.0	0□□□ □□□	4	1	3	8
Houvenaeghel *et al.*2021[28]	Italy	PS	2016–2020	87/142	NA	NA	4	1	3	8
Lai *et al.*2021[29]	Taiwan	RS	2011–2020	84/188	51 ± 10.2 / 50.9 ± 11.5	0□□□ □□□□□	4	1	3	8
Moon *et al.*2021[30]	Korea	RS	2018–2020	40/41	46 ± 8 / 49 ± 10	□□□□□	4	1	2	7
Lai *et al.*2020[14]	Taiwan	RS	2011–2019	54/62	48 ± 9.3 / 49 ± 11	0□□□ □□□	4	2	3	9
Kim *et al.*2024[15]	Korea	RS	2021–2024	227/1356	45.41 ± 7.99 / 45.47 ± 8.56	NA	4	2	3	9
Liu *et al.*2023[31]	China	RS	2014–2018	71/214	52.6 ± 10.6 / 56.7 ± 8.7	□□□	4	1	3	8
Wang *et al.*2023[32]	China	RS	2014–2019	38/26	43.50 ± 11.12 / 47.83 ± 14.83	NA	4	1	3	8

Study,year	Country/Region	Design	Study period	Patients(n) M-NSM/C-NSM	Age(Mean ± SD) M-NSM/C-NSM	TNM stage	Selection	Comparability	Outcome	Total score
Kitamura *et al.*2002[33]	Japan	RS	1998–2001	21/25	43.4 ± 7.6 / 44.3 ± 7.3	□□□	4	1	1	6

RS, Retrospective study; PS, Prospective study; RCT, Randomized controlled trials; M-NSM, minimally access nipple-sparing mastectomy; C-NSM, conventional nipple-sparing mastectomy; NA, not available.

Clinical outcomes

- NSM demonstrated significant advantages in several outcomes, including overall complications (OR = 0.58,95 per cent c.i. 0.40 to 0.83,P = 0.003; I^2 = 76 per cent), seroma(OR = 0.49,95 per cent c.i. 0.35 to 0.69,P < 0.0001; I^2 = 20 per cent), skin necrosis (OR = 0.48,95 per cent c.i. 0.35 to 0.65,P < 0.00001; I^2 = 44 per cent), and incision length (MD = -6.05,95 per cent c.i. -9.14 to 2.96,P < 0.0001)(FIGURE 2).

With respect to blood loss, the initial analysis of nine studies showed no significant difference between the two groups (MD = -12.50,95 per cent c.i. -25.48 to 0.49,P = 0.06; I^2 = 90 per cent).The funnel plot suggested possible publication bias, which was primarily attributed to the study by Kitamura et al[33]. After excluding this study, intraoperative blood loss was significantly lower in the M-NSM group than in the C-NSM group (MD = -14.22,95 per cent c.i. -26.80 to 1.64,P = 0.03; I^2 = 91 per cent)(FIGURE 3).

No significant differences were observed between the groups in hematoma (OR = 1.03,95 per cent c.i. 0.72 to 1.48,P = 0.87; I^2 = 0 per cent), NAC necrosis (OR = 0.73,95 per cent c.i. 0.39 to 1.35,P = 0.31; I^2 = 65 per cent), wound dehiscence (OR = 0.69,95 per cent c.i. 0.32 to 1.47,P = 0.33; I^2 = 0 per cent), implant loss (OR = 0.66,95 per cent c.i. 0.42 to 1.04,P = 0.07; I^2 = 0 per cent), capsular contracture (OR = 0.63,95 per cent c.i. 0.36 to 1.09,P = 0.10; I^2 = 25 per cent), or infection (OR = 1.15,95 per cent c.i. 0.82 to 1.61,P = 0.42; I^2 = 42 per cent)(FIGURE 4).

Regarding oncological safety, the M-NSM group showed significantly lower rates of recurrence (OR = 0.58,95 per cent c.i. 0.42 to 0.80, P = 0.0009; I^2 = 0 per cent) and metastasis (OR = 0.58,95 per cent c.i. 0.38 to 0.89, P = 0.01; I^2 = 54 per cent) compared to the C-NSM group(FIGURE 5).

However, the C-NSM group was associated with higher surgical and recovery efficiency: mastectomy time (MD = 60.12,95 per cent c.i. 41.52 to 78.72,P < 0.00001; I^2 = 95 per cent),total procedure time for mastectomy with immediate reconstruction (MD = 55.52,95 per cent c.i. 36.09 to 74.96,P < 0.00001; I^2 = 90 per cent), and length of hospital stay (MD = 1.56,95 per cent c.i. 0.87 to 2.26,P < 0.0001; I^2 = 91 per cent) were all significantly shorter in the C-NSM group(FIGURE 6).

Discussion

This study provides a comprehensive comparison of clinical outcomes between minimally access (including endoscopic and robotic-assisted techniques) and conventional in nipple-sparing mastectomy (NSM), based on a systematic analysis of multi-institutional data. By focusing on key indicators such as surgical complications, efficiency and oncological safety, this landmark meta-analysis offers robust evidence to support the broader adoption of minimally invasive NSM in clinical practice.

International studies have demonstrated that minimally invasive breast surgery is comparable to conventional open surgery in terms of oncological safety, supporting its feasibility and safety profile. Sakamoto et al.[34] reported that among 404 patients with 421 breasts followed for a median of 61 months, local recurrence occurred in 11 patients, including one case with lymph node metastasis and one with distant organ metastasis. The recurrence rate was 2.6 per cent, consistent with rates reported for non-endoscopic approaches. Similarly, Hung-Wen Lai et al.[29] found no significant differences in local recurrence, disease-free survival, or overall survival between C-NSM and M-NSM, and multivariate analysis did not identify minimally invasive surgery as a risk factor for disease recurrence. A retrospective analysis by Andi Wan et al.[35] of 2412 patients showed that the 10-year local recurrence-free survival (93.3% vs 96.3%) and metastasis-free survival (81.0% vs 82.0%) rates were similar between the minimally invasive and open surgery groups. No statistically significant differences were observed in disease-free or overall survival at 5, 10, or 15 years.

The present study yielded clinically significant findings: the minimally invasive group exhibited superior outcomes in key prognostic measures, including local recurrence and distant metastasis. It is noteworthy that in two of the included studies, patients in the open surgery group had more advanced tumor stages than those in the minimally invasive group, which may have introduced some bias. However, the oncological advantage of minimally invasive surgery remained statistically significant even after exclusion of these studies. It should be noted that the overall quality of evidence in the included studies was moderate, with a predominance of retrospective analyses. The only RCT reporting oncological outcomes showed no significant difference in overall survival or disease-free survival between the R-NSM and C-NSM groups after a median follow-up of 42 months[23]. In conclusion, current evidence indicates that M-NSM is a safe surgical approach that does not increase the risk of tumor recurrence or metastasis, and may in fact offer superior oncological outcomes compared to open surgery.

A pivotal aspect of comparing C-NSM and M-NSM is whether the latter is associated with lower rates of postoperative complications. The findings of this study indicate that M-NSM offers significant advantages over open surgery across several perioperative outcomes. Specifically, the minimally invasive approach was linked to a significant reduction in total complications, as well as a lower incidence of seroma and skin necrosis. Initial analysis of nine studies showed no significant difference in blood loss1 between the two groups. Funnel plot asymmetry suggested possible publication bias, largely attributable to the study by Kitamura et al.[33].Contributing factors may include: (1) the study was conducted during the early "learning curve" phase of endoscopic surgery, where suboptimal proficiency may have prolonged operative time and increased bleeding; (2) while the first two cases utilized pneumoperitoneum-which offers some tamponade effect-the subsequent 19 cases employed a traction technique, which may have compromised surgical exposure and haemostasis, particularly along the medial breast region. After excluding this study, blood loss was significantly lower in the M-NSM group. Technical refinements have further optimized outcomes. Wang et al.[32] introduced liposuction and fat dissolution techniques through the retromammary space, which improves exposure of the anatomical layers between the pectoral fascia and breast tissue, allowing better visualization of vessels and more precise haemostatic control. Additionally, preoperative injection of adrenaline-containing tumescent solution induces vasoconstriction, thereby reducing blood loss. In contrast, C-NSM typically requires larger visible scars on the breast surface and carries a considerable risk of NAC necrosis-even with inframammary fold incisions[36] -with reported ischemia rates as high as 64.1 per cent[37].Larger incisions not only increase the risk of surgical site infection but also heighten tension during implant placement, raising the likelihood of complications such as wound dehiscence and implant exposure[38].The endoscopic approach provides magnified visualization, enabling surgeons to identify and preserve perforating vessels more effectively and perform more precise glandular dissection. Moreover, M-NSM often utilizes discrete incisions, such as in the axilla, which are remote from the NAC vascular territory, further reducing the risk of NAC ischemia. This approach avoids long or multiple scars on the breast, thereby decreasing the potential for infection, wound breakdown, and implant loss. This meta-analysis found no statistically significant differences between the two groups in rates of infection, implant loss, NAC necrosis, hematoma, wound dehiscence, or capsular contracture. These results suggest that while M-NSM does not demonstrate superiority over C-NSM in preventing these specific complications, it does not appear to increase the risk thereof.

With growing emphasis from both patients and breast surgeons on postoperative aesthetic outcomes, "scar-reduced surgery" has become an increasing focus in clinical practice. This concept prioritizes the concealment of incisions and preservation of a natural breast contour without compromising oncological safety, thereby addressing patients' psychosocial and aesthetic needs more effectively. Against this background, breast cancer surgery has progressively evolved from conventional open procedures to endoscopic techniques, marking a significant advance toward minimally invasive approaches in breast surgery. Building on endoscopic foundations, robotic surgical systems have further expanded the capabilities of minimally invasive surgery. The high-resolution three-dimensional visualization enhances precision and spatial awareness, while articulated instruments provide greater flexibility and range of motion, enabling more complex and detailed dissection. Moreover, the seated console operation significantly improves ergonomics and reduces surgeon fatigue. Multiple studies have confirmed that minimally invasive techniques are not only oncologically safe but also yield superior cosmetic outcomes[29, 39]. This meta-analysis demonstrates that the minimally invasive group had significantly shorter incisions (MD=-6.05,95 per cent c.i. -9.14 to -2.96,P < 0.0001),which were discreetly placed in the axillary region, resulting in better cosmetic appearance. Patient-reported satisfaction was evaluated in five studies, four of which utilized the BREAST-Q scoring system. Consolidated results indicated that the minimally invasive approach was associated with better outcomes across multiple domains. Toesca et al.[23] reported higher scores in breast satisfaction and psychosocial well-being; Kim et al.[24] noted improved sexual well-being following prosthetic reconstruction and superior physical well-being after autologous flap reconstruction; Liu et al.[31] found advantages in breast satisfaction, chest well-being, psychosocial function, and sexual health; and Wang et al.[32] also documented better outcomes in breast satisfaction, psychosocial status, and physical comfort. Furthermore, Lai et al.[14] emphasized that patients undergoing minimally invasive surgery reported higher overall satisfaction, citing preferable incision location, shorter scar length, and improved cosmetic appearance of scars compared to the open approach.

Notably, several limitations impede the broader adoption of minimally invasive techniques, including prolonged operative time, increased reliance on specialized equipment, and higher associated costs[22, 40, 41], areas in which conventional open surgery retains comparative advantages. This meta-analysis revealed a significantly shorter mean hospital stay in the open surgery group. Additionally, open procedures were considerably more cost-effective. Hung-Wen Lai et al.[14] reported that R-NSM was associated with significantly higher expenses across national insurance coverage, out-of-pocket payments, and total medical costs compared to C-NSM,with an average difference of approximately $5,174.Similarly,Wang et al.[31] observed that the average cost of endoscopic surgery was higher than that of conventional open mastectomy ($3,693 ± 927 vs $3,386 ± 774,P = 0.006).With regard to operative efficiency, open surgery demonstrated significantly shorter procedure times for both mastectomy alone (60.12min vs 78.72min) and mastectomy with immediate prosthetic reconstruction (55.52min vs 74.96min).Several factors may contribute to these differences: firstly, minimally invasive surgery requires additional time for equipment setup, such as docking and calibration of the robotic system and sterilization of specialized instruments; secondly, the learning curve for mastering endoscopic or robotic techniques is notably steep, and surgeons must overcome this through accumulated experience[42].For instance, Ahn et al.[43] documented that the first case of robot-assisted nipple-sparing mastectomy with immediate expander implantation required 107 minutes, whereas the subsequent three cases were completed in approximately 80 minutes each. This suggests that although minimally invasive techniques may initially demand more time and resources, surgical duration can decrease substantially as the team gains proficiency and standardizes workflows beyond the learning curve.

This study has several limitations that should be considered. Primarily, the majority of the included studies were non-randomized controlled studies, which carries an inherent risk of publication bias and provides a relatively weak evidence base. Furthermore, some studies were characterized by a

short follow-up duration and a failure to adequately adjust for key confounding variables, such as regional disparities, varying inclusion criteria, and differences in diagnostic and therapeutic techniques. These factors may have contributed to the observed heterogeneity and bias, thereby potentially compromising the reliability of the findings.

Conclusion

M-NSM represents a safe and feasible surgical approach that offers significant benefits for selected patients. Future research should focus on standardizing technical procedures, optimizing the learning curve, and evaluating cost-effectiveness. Further validation of its long-term oncological safety through high-quality, prospective studies with extended follow-up is strongly recommended.

Declarations

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Contributions

Hongwei Wang(Conceptualization, Data curation,Validation, Formal analysis, Project administration, Writing—original draft, Methodology,Writing—review & editing) and Fan Zhang (Conceptualization, Validation, Writing& editing).Liang Zhang (Conceptualization, Data curation, Writing—review & editing). All authors have read and approved the final manuscript.

Data availability

All crude data available upon request.

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Figures

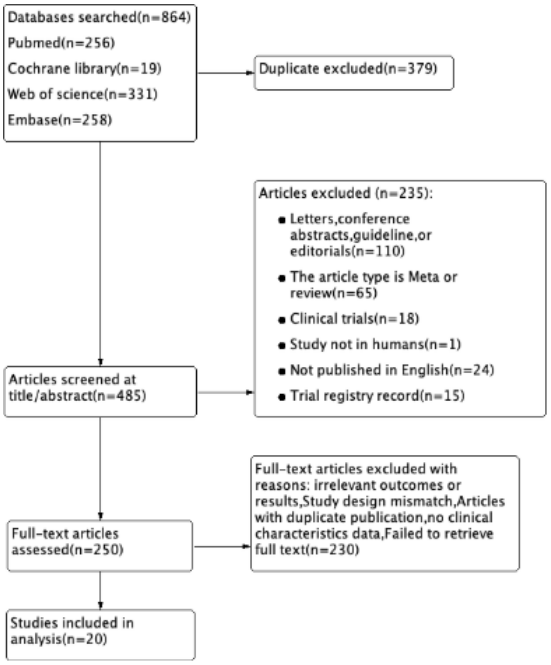


Figure 1

Flow chart of literature search strategies.

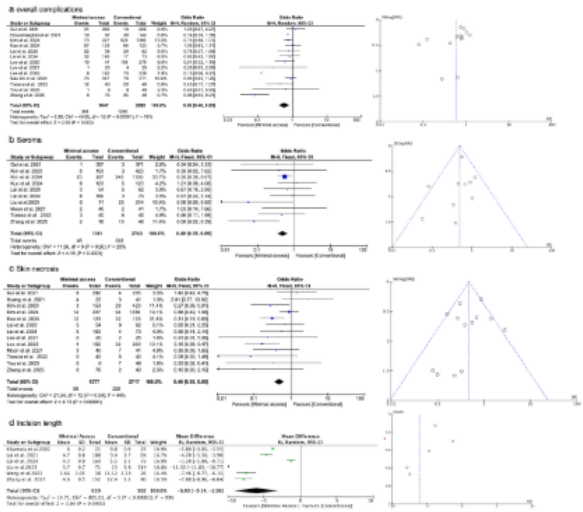


Figure 2

Forest plots comparing crude event numbers between minimally access and conventional nipple-sparing mastectomy, and funnel plots assessing publication bias. a Overall complications. b Seroma. c Skin necrosis. d Incision length. Minimal access, minimal access nipple-sparing mastectomy; Conventional, conventional nipple-sparing mastectomy.

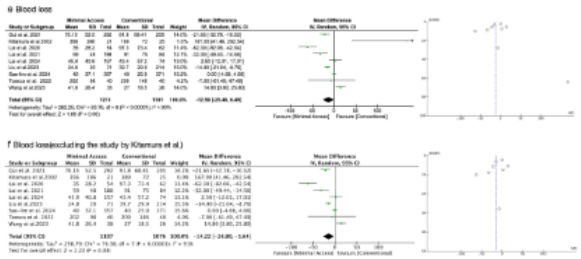


Figure 3

Forest plots comparing crude event numbers between minimally access and conventional nipple-sparing mastectomy, and funnel plots assessing publication bias. e Blood loss. f Blood loss(excluding the study by Kitamura et al). Minimal access, minimal access nipple-sparing mastectomy; Conventional, conventional nipple-sparing mastectomy.

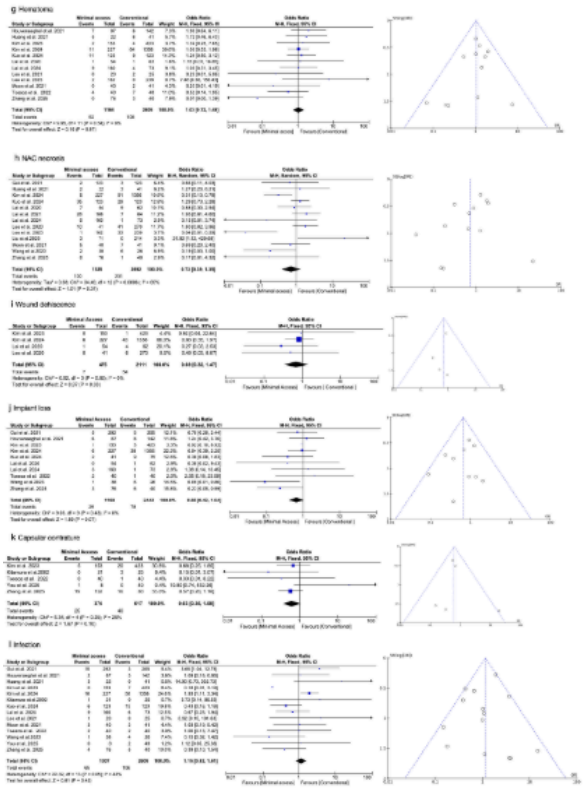


Figure 4

Forest plots comparing crude event numbers between minimally access and conventional nipple-sparing mastectomy, and funnel plots assessing publication bias. g Hematoma. h NAC necrosis. i Wound dehiscence. j Impiant loss. k Capsular contratur. l Infection. Minimal access, minimal access nipple-sparing mastectomy; Conventional, conventional nipple-sparing mastectomy.

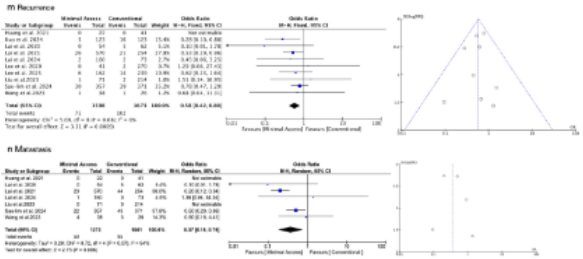


Figure 5

Forest plots comparing crude event numbers between minimally access and conventional nipple-sparing mastectomy, and funnel plots assessing publication bias. m recurrence. n metastasis. Minimal access, minimal access nipple-sparing mastectomy; Conventional, conventional nipple-sparing mastectomy.

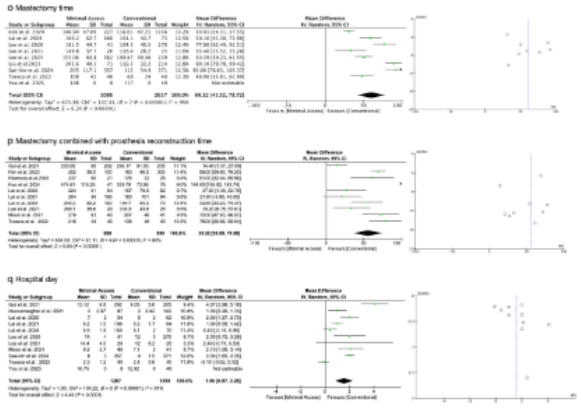


Figure 6

Forest plots comparing crude event numbers between minimally access and conventional nipple-sparing mastectomy, and funnel plots assessing publication bias. o Mastectomy time. p Mastectomy combined with prosthesis reconstruction time. q Hospital day. Minimal access, minimal access nipple-sparing mastectomy; Conventional, conventional nipple-sparing mastectom.