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ORIGINAL ARTICLE
Breast

Influence of Closed-incision Negative Pressure Wound Therapy on Abdominal Site Complications in Autologous Breast Reconstruction

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Background: Closed-incision negative pressure wound therapy (ciNPWT) has shown promise in reducing surgical wound complications. Among its numerous benefits, it allows for exudate management and tension offloading from wound edges. The purpose of this systematic review and meta-analysis was to assess the efficacy of prophylactic ciNPWT versus conventional dressings on abdominal donor site complications in microsurgical breast reconstruction (MR).

Methods: A systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines in January 2023. PubMed and Embase were searched to identify all relevant studies. Data collected included rates of total wound complications, wound dehiscence, infection, seroma, and length of hospital stay.

Results: A total of 202 articles were screened, and eight studies (1009 patients) met the inclusion criteria. Use of ciNPWT was associated with a significantly lower rate of wound dehiscence (OR, 0.53; 95% confidence interval, 0.33–0.85; $P = 0.0085$, $I^2 = 0\%$). There was no significant difference in the rate of total wound complications [odds ratio (OR), 0.63; 95% CI, 0.35–1.14; $P = 0.12$, $I^2 = 69\%$], donor site infection (OR, 0.91; 95% CI, 0.42–1.50; $P = 0.47$, $I^2 = 13\%$), seroma (OR, 0.74; 95% CI, 0.22–2.49; $P = 0.63$, $I^2 = 57\%$), or length of hospital stay (SMD, 0.089; 95% CI, –0.13–0.35; $P = 0.37$, $I^2 = 29\%$).

Conclusions: Although exudate management by ciNPWT fails to reduce surgical site infection, seroma formation, and overall length of stay, ciNPWT tension offloading properties seem to be associated with lower rates of wound dehiscence when compared with conventional dressings in abdominal-based autologous breast reconstruction.
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INTRODUCTION

Microsurgical reconstruction (MR) of the breast transfers excess donor tissue to the chest to recreate the breast mound after mastectomy. It commonly uses abdominally based flaps (ie, deep inferior epigastric artery perforator (DIEP) flap, muscle-sparing free transverse rectus abdominis musculocutaneous (MS-TRAM) flap, or superficial inferior epigastric artery flap, which offer long-lasting results, natural aesthetics, body weight responsiveness, and the added benefit of body contouring at the donor site.[1] However, morbidity at the donor site remains a problem.[2]

Wound dehiscence, surgical site infection, and seroma formation are notable complications at the abdominal donor site after MR,[3] resulting in elevated morbidity rates and imposing a burden on healthcare systems. The implementation of preventive measures is crucial in mitigating the occurrence of these complications. Recently, the use of closed-incision negative pressure wound therapy (ciNPWT) has shown promise as a prophylactic measure to combat donor site complications. Mechanistically, ciNPWT promotes healing by facilitating wound approximation, angiogenesis, and fluid management, and by decreasing bacterial load.[4] ciNPWT has been investigated in a variety of surgical specialties,[5–9] and its use continues to grow in breast reconstruction. A systematic review and meta-analysis recently demonstrated reduced

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overall wound complications and flap necrosis using ciNPWT in implant-based breast reconstruction, and several reviews have shown benefit in primary wound closure.[10–15] However, the utility of ciNPWT on donor site morbidity in MR has not been systematically reviewed to date. The purpose of this study was to assess the efficacy of prophylactic ciNPWT over standard dressings on abdominal donor site complications in MR.

Takeaways

Question: Does the prophylactic use of closed-incision negative pressure wound therapy (ciNPWT) impact the rate of complications at the abdominal donor site in microsurgical breast reconstruction?

Findings: The use of ciNPWT was associated with a significantly lower rate of wound dehiscence. Rates of total surgical site complications, surgical site infection, and seroma formation were reduced but not significant. The length of hospital stay was not affected.

Meaning: The significant reduction in the rate of wound dehiscence suggests that ciNPWT may be an effective way to reduce wound dehiscence risk.

METHODS

Literature Search

Approval from the institutional review board was not necessary for this systematic review and meta-analysis. A meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[16] A literature search was conducted to identify all articles involving the use of ciNPWT on the abdominal donor site in autologous breast reconstruction. PubMed and Embase were searched on January 17, 2023, using the keywords described in Table 1. All potentially relevant articles were imported into Mendeley Desktop V1.19.8, and duplicates were removed. There were no restrictions on the date range inquiry.

Study Selection

Two authors (B.D. and J.G.) examined the articles for inclusion. Included articles met the following criteria: (1) directly compared the effect of ciNPWT with conventional dressings on abdominal donor site incisions in MR; (2) reported outcomes on the donor site; (3) included a unique patient population; and (4) had an article available in the English language. One article[17] was excluded due to patient population overlap. In this case, factors such as the number of eligible patients, study quality, and temporality were considered when deciding which study to include.

Data Extraction

Data were extracted and verified, including author, year of publication, country, study design, cohort numbers, type of MR, demographics of cohorts, details of ciNPWT, details of control treatment, follow-up duration, study duration, length of hospital stay, and wound healing complications.

Data Analysis

Meta-analysis was performed if five or more studies provided data on an outcome of interest. All analyses were performed in R statistical software (version 2022.12.0 + 353; R Foundation for Statistical Computing). Odds ratios (ORs) and standardized mean differences were used as summary statistics for categorical or continuous outcomes, respectively.

A Mantel-Haenszel random effects model was used to account for methodological variation across studies.[18] A random effects variance component was derived from the variability of effect sizes in each of the collected studies and applied to mitigate weighting of results from larger studies[19,20] over smaller ones.[21,22] Statistical claims of significance are therefore made in a more conservative, generalizable way.

The multiple sources of heterogenicity amid reported studies were calculated using the point estimate I^2. The point estimate I^2 should be interpreted cautiously when a meta-analysis has few studies.[23] As our meta-analysis involves eight studies or fewer, confidence intervals were provided to supplement the biased point estimate I^2 for those statistically significant complications (see Funnel plots below). Finally, to account for the publication bias and minimize the "file drawer problem," funnel plots were used to assess publication bias for those outcomes with statistically significant heterogeneity.

RESULTS

Results of Data Search

A total of 307 articles were identified from PubMed (n = 132) and Embase (n = 175). After duplicate removal, 202 articles were screened for relevance by examination of their title and abstract. Subsequently, 24 articles were selected for full-text evaluation, of which eight met the

Table 1. Search Terms

Search Terms	
PubMed	("negative pressure wound therapy"[MeSH Terms] OR ("negative pressure"[All Fields] AND "wound"[All Fields] AND "therapy"[All Fields]) OR "negative pressure wound therapy"[All Fields] OR ("negative"[All Fields] AND "pressure"[All Fields] AND "wound"[All Fields] AND "therapy"[All Fields]) OR "negative pressure wound therapy"[All Fields]) AND ("breast"[MeSH Terms] OR "breast"[All Fields] OR "breasts"[All Fields] OR "breast s"[All Fields]) AND "ENGLISH"[Language]
Embase	negative AND ("pressure"/exp OR pressure) AND ("wound"/exp OR wound) AND ("therapy"/exp OR therapy) AND ("breast"/exp OR breast) AND [english]/lim

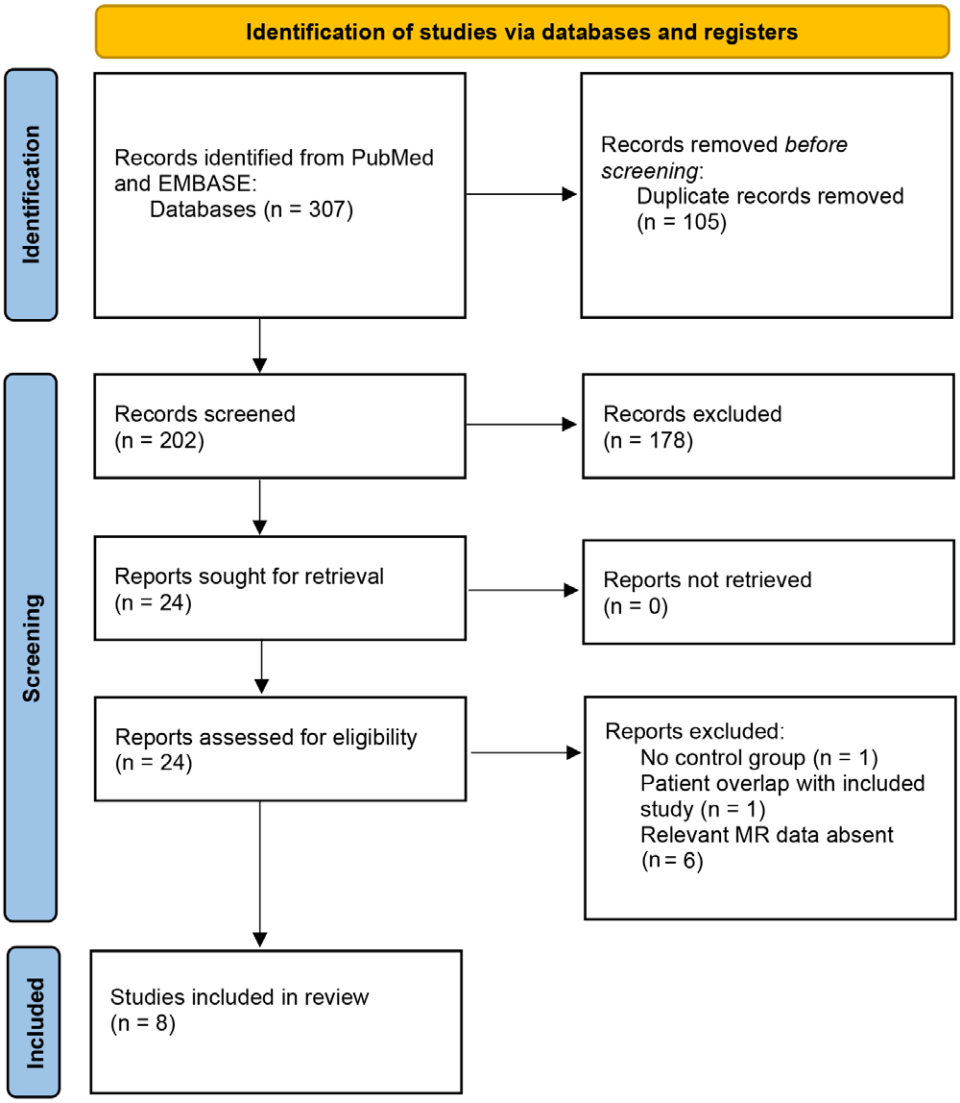

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

inclusion criteria (Fig. 1). One study, which was published within the search date range, was added later because the study[24] was not available in PubMed or Embase at the time of search. All authors agreed on the inclusion of these studies, which accrued a total of 1009 patients.

Overview of Included Studies

Included studies were published from 2020 to 2022. Of the eight studies included, six were retrospective cohorts,[19–22,25,26] one was a retrospective case-control,[24] and one was a single-blinded, randomized clinical trial.[27] Data on 1009 patients were reported, and data on surgery type were corroborated in seven of the studies. Of the 578 patients in the seven studies, 527 underwent DIEP, 28 underwent MS-TRAM, and 23 underwent DIEP/MS-TRAM. The remaining study[19] did not report the patient breakdown based on the type of MR performed, but DIEP flaps represented nearly all of the flaps (96.8%, 676/698). Detailed characteristics of the studies are shown in Table 2.

Meta-Analysis of Outcomes

Seven studies reported outcomes on wound complications (999 abdominal incisions). If a study did not report the total number of wound complications, complications were added together to facilitate comparison. Use of ciNPWT did not significantly impact the rate of total wound complications (Fig. 2) compared with conventional dressings (OR, 0.63; 95% confidence interval, 0.35–1.14; P = 0.12, I^2 = 69%). Heterogeneity was statistically significant.

Data on wound dehiscence were reported in five studies (524 abdominal incisions). Use of ciNPWT was associated with a significant reduction in wound dehiscence compared with conventional dressings (OR, 0.53; 95% confidence interval, 0.33–0.85; P = 0.0085, I^2 = 0%) (Fig. 3). Heterogeneity was not statistically significant.

Data on donor site infection were reported in six studies (957 abdominal incisions). There was no significant difference in the rate of donor site infection with ciNPWT (Fig. 4) compared with conventional dressings (OR, 0.91;

Table 2. Summary of Included Studies

Author, Year	Country	Study Design	n (NPWT/Control)	Type of Surgery	Differences in Demographics between Cohorts	Details of NPWT (Type, Pressure, Duration)	Details of Control Treatment (Type, Duration)	Follow-up Duration	Study Duration
Wang, 2021[26]	Australia	RC	41, 85	DIEP, MS-TRAM	Patients with diabetes and obesity (BMI > 30 g/m^2) were significantly more likely to receive ciNPWT ($P = 0.005$ and $P = 0.002$, respectively)	PREVENA, −125 mm Hg, 5–7 d	Hydrocolloid dressing (Comfeel), until discharge	6 wk	October 2016–April 2021
Fang, 2020[22]	Taiwan	RC	5, 5	DIEP	None	PREVENA, not reported, 6 d	Occlusive hydrocolloid silver dressing (AQUACEL Ag Surgical; ConvaTec), 6 d	12 mo	August 2017–January 2018
Siegwart, 2022[20]	Germany	RC	98, 127	DIEP, MS2-TRAM	Significantly more patients with obesity (29.6 versus 15.8%; $P = 0.01$) and bilateral breast reconstruction (40.8 versus 27.6%; $P = 0.04$) were included in the ciNPWT cohort	Self-made, −120 mm Hg, until discharge	Sterile adhesive strips (Leukosan Strip, BSN Medical) combined with a plaster (Leukomed, BSN Medical), until discharge	66 mo (mean)	November 2007–March 2019
Doval, 2021[21]	USA	RC	24, 18	DIEP	None	PREVENA, −125 mm Hg, not reported	Not reported	5.2 mo (mean; ciNPWT) and 4.8 mo (mean; control)	December 2016–February 2018
Limpiado, 2022[19]	USA	RC	212, 219	DIEP, MS-TRAM, SIEA	None	PREVENA, −125 mm Hg, 10 d	Steri-Strips (3M KCI), Dermabond Prineo (Johnson & Johnson), and Xeroform petroleum gauze (Cardinal Health); 10 d	Not reported	March 2013–March 2020
Kang, 2022[25]	Japan	RC	28, 28	DIEP	BRA score higher in ciNPWT cohort ($P = 0.02$)	PICO, −80 mm Hg, 10 d	Film dressing; 6 d	Not reported	June 2018–May 2020
Muller-Sloof, 2022[27]	The Netherlands	RCT	36, 39	DIEP	None	PREVENA, −125 mm Hg, 5–7 d	Adhesive strips (Steri-Strips; 3M Surgical Products), 5–7 d	12 wk	November 2017–March 2020
Munro, 2022[24]	United Kingdom	RCC	24, 20	DIEP	None	PREVENA, −125 mm Hg, 7 d	Not reported	Minimum 4 mo	March 2017–September 2021

BRA, breast reconstruction risk assessment; RC, retrospective cohort study; RCC; retrospective case-control study; RCT, randomized controlled trial; SIEA, superficial inferior epigastric artery flap.

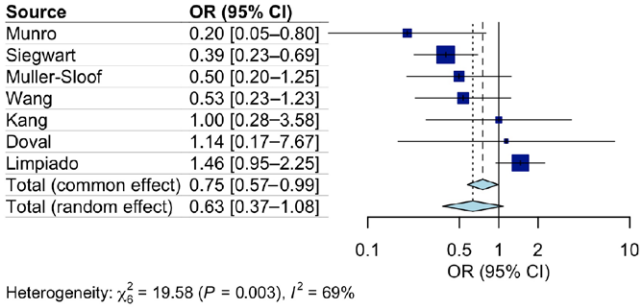

Fig. 2. Forest plot of the effect of prophylactic negative pressure wound therapy compared with conventional dressings on the rate of total surgical site wound complications in closed incisions on the abdominal donor site in autologous breast reconstruction.

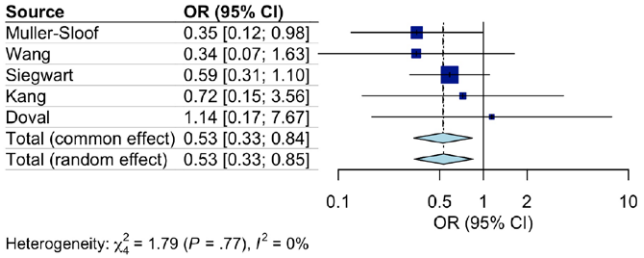

Fig. 3. Forest plot of the effect of prophylactic negative pressure wound therapy compared with conventional dressings on the rate of wound dehiscence in closed incisions on the abdominal donor site in autologous breast reconstruction.

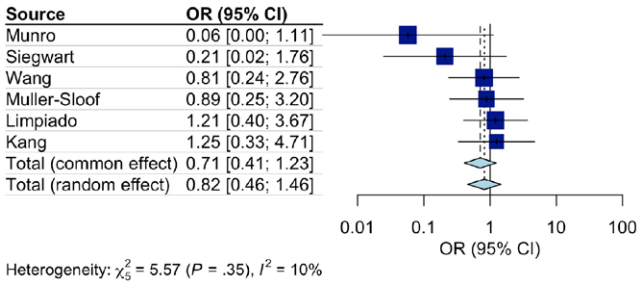

Fig. 4. Forest plot of the effect of prophylactic negative pressure wound therapy compared with conventional dressings on the rate of surgical site infection in closed incisions on the abdominal donor site in autologous breast reconstruction.

95% confidence interval, 0.42–1.50; P = 0.47, I^2 = 13.36%). Heterogeneity was not statistically significant.

Data on seroma were reported in five studies (536 abdominal incisions). There was no significant difference in the rate of seroma with ciNPWT (Fig. 5) compared with conventional dressings (OR, 0.74; 95% confidence interval, 0.22–2.49; P = 0.63, I^2 = 57%). Heterogeneity was statistically significant.

Data on length of hospital stay were reported in five studies (478 abdominal incisions). The national SD of length of hospital stay for DIEP flaps was used to compare the effect of ciNPWT.[28] There was no significant difference in the length

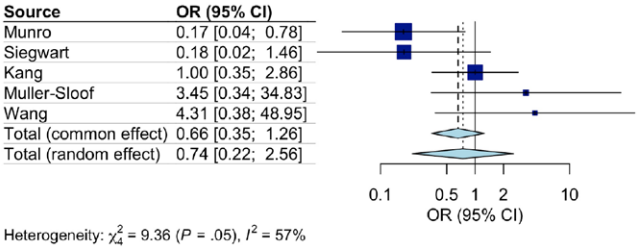

Fig. 5. Forest plot of the effect of prophylactic negative pressure wound therapy compared with conventional dressings on the rate of seroma formation in closed incisions on the abdominal donor site in autologous breast reconstruction. Forest plots (Figs. 2–5) in results were created to depict 95% confidence intervals and relative weights of each study. For the overall summary statistic, mean and 95% confidence interval are represented by the middle point and width of the diamond, respectively.

of hospital stay with ciNPWT (Fig. 6) compared with conventional dressings (standardized mean differences, 0.089; 95% confidence interval, −0.13 to 0.35; P = 0.37).

DISCUSSION

Postmastectomy breast reconstruction aims to replace what was taken away by cancer, and in doing so, improve patients' quality of life and mental well-being.[29] The DIEP flap is the workhorse of abdominally based autologous breast reconstruction due to the readily available tissue, well-described perforator anatomy, and potential to minimize muscle harvest. However, the lengthy lower abdominal incision may be associated with wound complications, including dehiscence, infection, and seroma formation. Recent meta-analyses have shown that prophylactic ciNPWT reduced overall complication rates in breast reconstruction.[11,12,14,30] Here, we present the first meta-analysis to investigate the efficacy of ciNPWT in MR using abdominal donor sites.

Among a sample of 524 abdominal incisions across five studies, decreased wound dehiscence with ciNPWT was observed compared with standard dressings (OR, 0.53; 95% confidence interval, 0.33–0.85; P = 0.0085, I^2 = 0%). Wound dehiscence has been shown to cause significant morbidity, including decreased patient quality of life, prolonged hospital stays, and increased care costs.[17,27,31–42] Our finding is congruent with other studies examining ciNPWT in orthopedic trauma,[5,43] breast surgery,[11,14,15,44] abdominal wall reconstruction,[34,45] laparotomy,[46,47] ventral hernia repair,[48] and reviews combing multiple types of procedures.[36,41,45,49–52] However, results in the literature are mixed, and other studies do not show this relationship.[6–9,13,33,53–58] In the context of DIEP flaps, wound dehiscence is frequently attributed to suturing under tension and the extended length of the incision.[39,59] In this regard, the utilization of ciNPWT holds significant promise in preventing wound dehiscence by offering valuable physical support and functioning as a protective splint against the tensile forces acting on the wound.[60]

No difference in the incidence of surgical site infection on the donor site was detected with ciNPWT compared

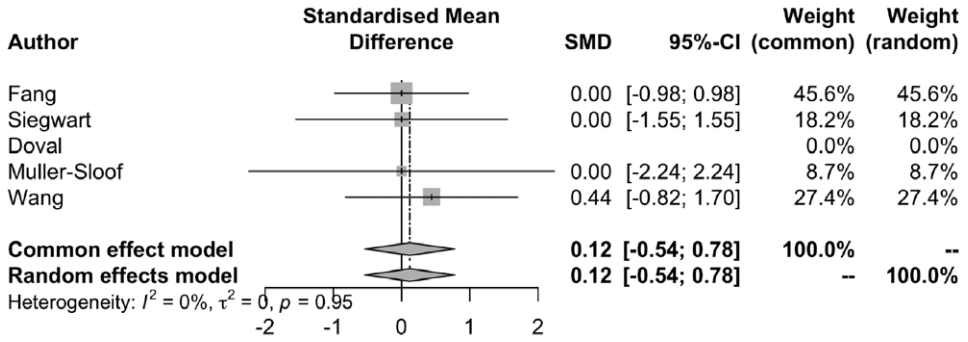

Fig. 6. Standard mean differences for the length of hospital stay.

with standard dressing ($P = 0.47$). This contradicts several studies demonstrating decreased surgical site infection rates with ciNPWT.[5–9,11,13,14,30,33,36,41,43–52,54–58,61–76] However, the occurrence of infection in DIEP flaps is infrequent, with a recent meta-analysis reporting a donor site infection rate of 4.79%.[77] Mechanistically, ciNPWT acts as a barrier that prevents contamination of the surgical site with bacteria before reepithelization, encourages drainage of excess interstitial fluid, increases lymphatic flow, improves blood flow, and induces angiogenesis, theoretically decreasing the risk of infection and expediting healing.[78] In addition, wound dehiscence and infection often occur together and are often reported alone even when they are both present.[27,33,38]

Our findings on seroma rates were similarly not statistically significant ($P = 0.63$). Some studies demonstrate a benefit on rates of seroma with the use of ciNPWT,[11,41,44,49,50,52,54,55,63] but results are mixed.[6–8,13–15,33,45,48,61] Seromas develop as a result of the accumulation of serum in internal spaces. In vivo studies have shown improved fluid flow within 4 days of ciNPWT, resulting in decreased porcine subcutaneous dead spaces and therefore reduced risk of seroma.[79] In addition, ciNPWT has been demonstrated to reduce the volume of seromas by 63% in domestic pigs via increased lymphatic clearance.[79] In humans, seromas may present as increased serous drain output, so ciNPWT's efficacy at decreasing seroma formation may also be gauged by examining the time to drain removal. One of the studies included in this metanalysis investigated this but found no difference between the use of ciNPWT and conventional dressings in the time to drain removal.[20] Seromas can also form after drain removal, but this would occur after the ciNPWT removal, negating any beneficial effects.

Regarding length of hospital stay, no difference was found between ciNPWT and conventional dressings ($P = 0.37$). Similar to seroma, there is controversy here, with some studies reporting that ciNPWT can reduce the length of hospital stay for certain patients,[36,49,63–65,70,71] and other studies reporting no effect.[5,47,56,57,66,80] Notably, it is worth considering that early discharge of select DIEP flap patients, as soon as the first and second postoperative days, has been demonstrated to be safe, and thus, the use of ciNPWT may not be expected to influence length of stay.[81–85]

There are several limitations to this study. The data were derived almost entirely from relatively small (<100 patients in six of eight) retrospective reports, which may carry biases inherent to their designs, such as information bias and publication bias. In the present study, funnel plots were used to assess for publication bias in outcomes with statistically significant heterogeneity. In the total wound complications funnel plot, the most precise studies plotted outside the pyramid support possible publication bias (Fig. 7), whereas the plot for seroma demonstrated relative symmetry, supporting lack of publication bias (Fig. 8). Selection bias within included studies is another likely limitation to this meta-analysis.

Complications at the donor site are associated with many risk factors,[86] so some of the studies preferentially treated patients with certain comorbidities (ie, diabetes, obesity), whereas others left the decision to apply ciNPWT to the operating surgeon.

Significant heterogeneity within the total complication and seroma groups is another limitation. One possible source of heterogeneity is duration of ciNPWT, which ranged from 5 to 10 days in included papers, with some studies removing therapy upon discharge. The type of device was also inconsistent, and offers another possible source of heterogeneity. PREVENA (KCI USA, San Antonio, Tex.) was used in six of eight studies, PICO (Smith & Nephew, Andover, Mass.) was used in one, and the last study used a self-made device. Mean duration of

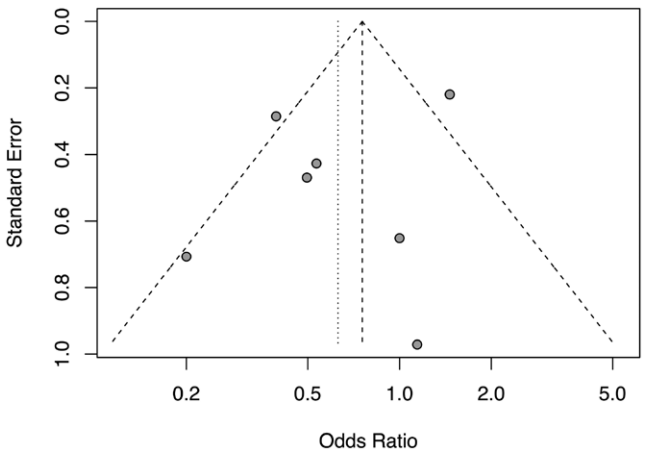

Fig. 7. Funnel plot for total wound complications outcomes.

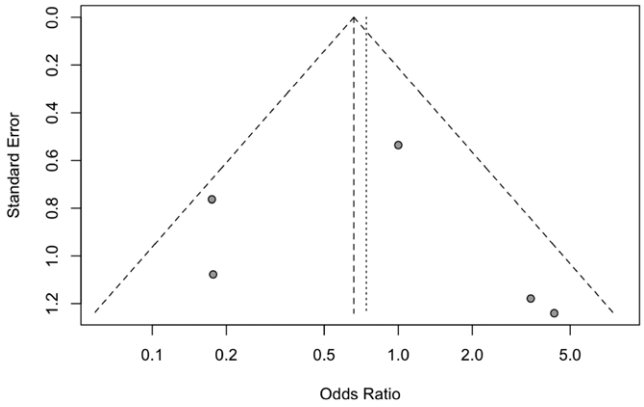

Fig. 8. Funnel plot for seroma formation outcomes. Funnel plots represent decreasing standard errors in ordinates, versus the effect size (OR) along the abscissa of a Cartesian coordinate system. Smaller studies characteristically yield larger standard errors and scatter away from the effect OR (being less precise), whereas larger studies remain closer to the OR and concentrate on the tip of the "funnel." Consequently, studies with high precision will be plotted close to the meta-analysis mean, and studies with low precision will be spread evenly on both sides of the mean, creating a roughly pyramidal distribution. Study variables positioned out of the triangle are suspicious for publication bias. Long segment lines indicate the Mean OR (vertical line) and define a region within which 95% of points might lie in the absence of both heterogeneity and publication bias (oblique lines). The short segment vertical line factors inclusion of the outliers (dots outside the pyramid) and weight of the studies by number of patients. When negative studies are not reported, positive studies scatter only on one side of the funnel, (asymmetry of the funnel plot). Conversely, in lack of publication bias, the effect of the smaller studies scatters symmetrically inside the pyramid. A negative or positive relation between standard error and effect size would imply that smaller studies that found effects in one direction only were more likely to be published and/or to be submitted for publication.

follow-up was variable as well, ranging from 6 weeks to 66 months.

The use of ciNPWT is associated with higher medical costs compared with conventional dressings.[65] The average cost of a PREVENA incision management system is approximately $500.[87] However, ciNPWT has shown promise to promote cost savings through prevention of wound complications in breast surgery,[30,88,89] cesarean section wounds,[90–93] hip/knee replacements,[94] laparotomy,[95] coronary artery bypass grafting,[96] vascular groin incisions,[97,98] ventral hernia repair,[99] and multi-specialty reviews.[50,76] Two of the studies included in our meta-analysis investigated cost effectiveness of ciNPWT. Limpiado et al found that ciNPWT use prevents one major wound healing complication for every six patients treated, resulting in potential cost savings of $3667 per patient annually.[19] In addition, Munro et al found ciNPWT had a mean reduction in cost-per-patient associated with postoperative complications of £420.77 and £446.47 (when accounting for postoperative length of stay).[24] The average cost of hospital readmission to revise an abdominal donor-site complication is $25,000,[19] meaning that prophylactic ciNPWT could result in substantial cost savings if it decreases readmission rates. However, prospective trials with cost-utility analyses are needed to further explore the cost effectiveness of ciNPWT.

CONCLUSIONS

The utilization of prophylactic ciNPWT on the abdominal donor site for MR has demonstrated a notable reduction in the incidence of wound dehiscence compared with conventional dressings, potentially leading to cost savings. Therefore, we recommend considering abdominal donor site ciNPWT for patients at a heightened risk of wound dehiscence. No significant differences were detected in rates of overall wound complications, infection, seroma, and length of hospital stay. It is imperative to conduct further high-quality randomized controlled trials to validate and strengthen the findings presented in this study.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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