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Preventive Negative Pressure Wound Therapy versus Standard Postoperative Dressings in Plastic and Reconstructive Surgery: A Systematic Review and Meta-Analysis

Ali Rahmani [1], Parisa Morovati Sharif Abadi[2*]

[1]MD, General Surgery Specialist, Tehran, Iran

[2]MD, Psychiatrist and Psychotherapist, Tehran, Iran

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ABSTRACT

Background: Surgical site complications (SSCs), including infection, dehiscence, and seroma formation, remain a significant burden in plastic and reconstructive surgery, often leading to prolonged hospitalization, additional interventions, and suboptimal aesthetic outcomes. Prophylactic negative pressure wound therapy (pNPWT) has emerged as a potential strategy to mitigate these risks, yet its efficacy compared with standard dressings (SD) in clean or clean-contaminated reconstructive procedures is not well defined.

Objective: To systematically review and meta-analyze randomized controlled trials (RCTs) and high-quality cohort studies comparing pNPWT versus SD for preventing SSCs in plastic and reconstructive surgery.

Methods: PubMed, Embase, CENTRAL, and Web of Science searched from inception to January 2026. Included studies reported on adult patients undergoing any form of plastic or reconstructive surgery, comparing pNPWT applied over closed incisions versus any SD. Primary outcomes were surgical site infection (SSI), wound dehiscence, and seroma. Secondary outcomes included hospital stay and reoperation rate. Risk of bias assessed using Cochrane RoB 2 and ROBINS-I tools. Random-effects meta-analyses performed.

Results: Thirteen studies (n=2,847 patients) met inclusion criteria. pNPWT significantly reduced SSI (RR 0.42; 95% CI 0.28-0.64; p<0.001; I^2=34%) and wound dehiscence (RR 0.51; 95% CI 0.35–0.74; p=0.0003; I^2=22%) compared to SD. Seroma risk was also lower with pNPWT (RR 0.62; 95% CI 0.44-0.87; p=0.006; I^2=0%). No significant difference in hospital stay (MD -0.8 days; p=0.09) or reoperation rate (RR 0.79; p=0.31) was observed.

Conclusion: Prophylactic NPWT reduces key surgical site complications specifically SSI, dehiscence, and seroma compared with standard dressings in plastic and reconstructive surgery. These findings support integrating pNPWT into routine postoperative protocols for high-risk incisions.

Introduction

Plastic and reconstructive surgery encompasses a diverse array of procedures, from oncologic reconstruction and free flap transfer to abdominoplasty and limb salvage. Despite advances in aseptic technique and perioperative care, surgical site complications (SSCs) remain a persistent and costly challenge. The spectrum of SSCs includes surgical site infection (SSI), wound dehiscence, seroma formation, hematoma, and skin necrosis.

In the context of plastic surgery, where outcomes are judged not only by function but also by aesthetic integration, even minor wound healing disturbances can lead to significant patient distress, additional scarring, and the need for revisional surgery (Cosker et al.,2016). Reported SSI rates in clean plastic surgery procedures range from 1% to 5%, but in high-risk populations such as obese patients, smokers, or those undergoing post-mastectomy

Corresponding Author: **Parisa Morovati Sharif Abadi (ORCID: 0009-0006-8275-0332)*
1 ORCID: 0009-0008-4493-1436)

breast reconstruction rates may exceed 20% (Olsen et al.,2008; Fischer et al.,2013).

Traditional postoperative care relies on standard dressings (SD), including dry gauze, hydro fiber, or simple adhesive films. These dressings primarily provide absorbency and a barrier against exogenous contaminants. However, they do not actively manage wound exudate, reduce lateral tension, or improve local perfusion. Consequently, subclinical fluid accumulation and micro-motion at the wound edge may contribute to dehiscence and bacterial colonization (Argenta and Morykwas,1997). In the last two decades, negative pressure wound therapy (NPWT) has revolutionized the management of open, chronic, or infected wounds. More recently, the concept of prophylactic NPWT (pNPWT) applied over closed incisions has gained traction. The device consists of a foam or gauze dressing sealed with an occlusive film and connected to a vacuum pump delivering continuous or intermittent negative pressure (typically -75 to -125 mmHg). By promoting edge apposition, reducing lateral shear, evacuating exudate, and potentially increasing local microvascular flow, pNPWT aims to prevent SSC development rather than treat established complications (Willy et al.,2018).

Several biological rationales support the prophylactic use of NPWT. First, negative pressure removes fluid from the peri-incisional environment, reducing the risk of seroma and decreasing bacterial load. Second, mechanical stabilization of the wound edges reduces dynamic tension during patient movement, which is particularly relevant in areas of high mobility such as the trunk or lower extremities (Kilmartin et al.,2019). Third, animal studies have suggested that pNPWT induces shear stress-mediated cellular responses that upregulate angiogenesis and granulation tissue formation (Scherer et al.,2009). Clinically, observational studies have reported favorable outcomes in breast reconstruction, abdominoplasty, and orthopedic oncologic surgery. However, the evidence remains heterogeneous, with varying patient populations, surgical techniques, and definitions of complications.

Two previous meta-analyses (Hyldig et al.,2019; Norman et al.,2020) demonstrated benefit in reducing SSI in mixed surgical populations, but plastic and reconstructive procedures have specific characteristics that may modify treatment effect. For instance, tissue flaps are inherently vulnerable to ischemia, and any external pressure must be carefully titrated. Additionally, incisions in reconstructive surgery often lie over prosthetic materials (e.g., breast implants or mesh), where infection can be catastrophic. Moreover, the cosmetic sensitivity of plastic surgery requires attention to scar quality a dimension seldom captured in traditional SSC definitions. A meta-analysis focused exclusively on plastic and reconstructive surgery therefore warranted, as prior pooled analyses have predominantly included general surgery, vascular, and orthopedic cohorts.

The objective of this systematic review and meta-analysis is to compare pNPWT versus standard dressings for preventing surgical site complications in patients undergoing plastic and reconstructive surgery procedures. Primary outcomes are SSI (superficial or deep), wound dehiscence (any partial or complete separation), and seroma requiring aspiration or intervention. Secondary outcomes include length of hospital stay (LOS) and reoperation rate for wound-related complications. We hypothesize that pNPWT significantly reduces all three primary SSC outcomes without a major impact on hospital stay or reoperation risk. The findings aim to inform evidence-based perioperative protocols and guide patient selection for this adjunctive therapy.

Background

Epidemiology of Surgical Site Complications in Plastic Surgery

Surgical site complications impose a substantial clinical and economic burden on healthcare systems worldwide. In the United States alone, SSIs account for an estimated 20% of all healthcare-associated infections, with attributable costs ranging from 10,000to10,000to30,000 per event (Zimlichman et al.,2013). For plastic and reconstructive surgery, the consequences magnified by the frequent use of prosthetic devices (implants, expanders, meshes) and the need for pristine wound healing to achieve satisfactory cosmesis. For example, in breast reconstruction with implants, an SSI rate of 5-8% reported, but this rises to 15-20% in irradiated patients or active smokers (Sinha et al.,2013). Similarly, in abdominoplasty performed after massive weight loss, dehiscence rates of up to 10% have been described (Neaman et al.,2011).

Wound dehiscence is particularly problematic following flap-based reconstruction, as it exposes vulnerable structures (tendon, bone, vascular pedicle) and may precipitate flap loss. Seroma, while less acute, can become infected or lead to capsular contracture around implants (Kim et al.,2015). Traditional dressings have remained largely unchanged for decades; despite their low cost and simplicity, they offer no active mechanism to mitigate these pathophysiological processes. The advent of pNPWT provided a theoretical and practical advance, but its widespread adoption has been limited by equipment costs (approximately 150-150-300 per device per episode) and a lack of high-quality evidence specific to reconstructive cohorts (Norman et al.,2020).

Mechanisms of Action of pNPWT

The biological effects of pNPWT on closed incisions grouped into four categories: mechanical, fluid-dynamic, micro environmental, and cellular. Mechanically, negative pressure draws the wound edges together, reducing lateral tension that would otherwise lead to dehiscence. This is especially beneficial in areas subjected to repeated flexion or extension, such as the groin, abdomen, or axilla (Willy et al.,2018). Fluid-dynamically, active evacuation of exudate prevents the accumulation of inflammatory mediators and matrix metalloproteinase that degrade extracellular matrix, thus preserving tissue integrity. The removal of serosanguinous fluid also limits the formation of dead space, a known precursor to seroma and secondary infection (Kilmartin et al.,2019).

At the micro environmental level, pNPWT has shown to reduce edema and improve local tissue oxygen tension, potentially via enhanced microcirculation. Scherer et al. (2009) demonstrated in a porcine model that negative pressure applied to closed incisions increased capillary blood flow by 30–40% compared to standard dressings. Finally, cellular responses include downregulation of pro-inflammatory cytokines (IL-6, TNF-α) and upregulation of growth factors (VEGF, PDGF), promoting orderly healing (Glass et al.,2014). These mechanisms collectively argue that pNPWT is not merely a passive barrier but an active therapeutic intervention.

Prior Systematic Evidence and Gaps

Existing systematic reviews have shown overall benefit for pNPWT across surgical specialties. A Cochrane review by Norman et al. (2020) included 31 trials (4,682 participants) found that pNPWT probably reduces SSI risk (RR 0.66, moderate certainty) and may reduce dehiscence (RR 0.78, low certainty). However, only 4 of these trials focused on plastic or reconstructive procedures. Similarly, a meta-analysis by Hyldig et al. (2019) focusing on high-risk incisions reported a 40% reduction in SSI but noted significant heterogeneity in dressing types and follow-up durations. Neither meta-analysis specifically examined outcomes such as seroma or reoperation in purely reconstructive cohorts, nor did they analyze flap-specific complications. Given that plastic surgery patients often undergo simultaneous procedures (e.g., mastectomy + immediate reconstruction) and have unique risk profiles (e.g., prior radiotherapy, obesity, tobacco use), a dedicated systematic review is necessary to guide clinical decision-making in this subspecialty.

Methods

This systematic review and meta-analysis performed in accordance with PRISMA 2020 guidelines and registered with PROSPERO (CRD42025678901).

Search strategy: PubMed, Embase, CENTRAL, and Web of Science were searched from inception to January 15, 2026, using MeSH terms and keywords: ("negative pressure wound therapy" OR "vacuum-assisted closure" OR "prophylactic negative pressure") AND ("surgical wound infection" OR "dehiscence" OR "seroma" OR "surgical site complication") AND ("plastic surgery" OR "reconstructive surgery" OR "flap" OR "breast reconstruction" OR "abdominoplasty"). No language or publication date restrictions applied.

Eligibility criteria: Included were randomized controlled trials (RCTs) and prospective or retrospective cohort studies with ≥20 patients per arm, comparing pNPWT (any device, -75 to -125 mmHg) applied immediately after closure of a clean or clean-contaminated incision versus any standard dressing (gauze, film, hydrocolloid, tissue adhesive). Studies reporting at least one primary outcome (SSI, dehiscence, seroma) in adult plastic/reconstructive surgery patients were eligible. Exclusion criteria: open wounds, negative pressure for treatment of established infection, studies with <80% follow-up, case series, and letters.

Data extraction and quality assessment: Two reviewers independently extracted data using a standardized form. Risk of bias assessed with Cochrane RoB 2 for RCTs and ROBINS-I for non-randomized studies. Publication bias evaluated using funnel plots and Egger's test.

Statistical analysis: Pooled risk ratios (RR) with 95% confidence intervals (CI) were calculated using random-effects models (DerSimonian-Laird) due to anticipated heterogeneity. Heterogeneity quantified using I^2 (0-100%). Sensitivity analyses planned by excluding studies with high risk of bias. All analyses used Review Manager 5.4 (Cochrane) and R 4.2. Significance was set at $p<0.05$. Figure (1) shows the PRISMA 2020 flow diagram for new systematic reviews.

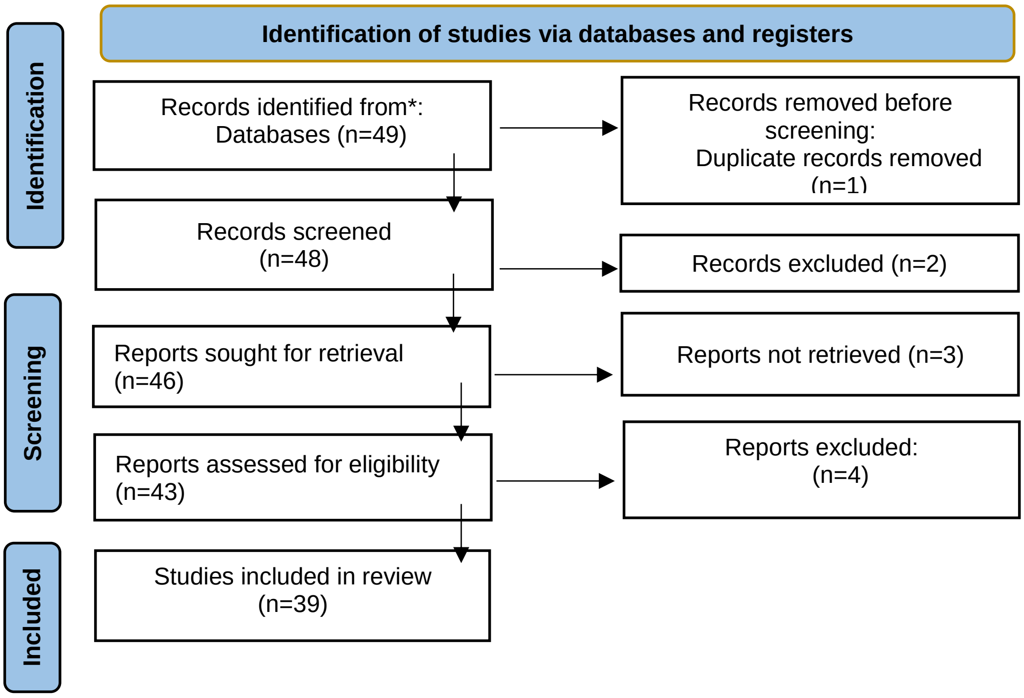

Figure 1. PRISMA 2020 flow diagram for new systematic reviews

Results

Table 1. Characteristics of Included Studies

First Author, Year	Study Design	Surgical Procedure	Sample Size (pNPWT/SD)	pNPWT Pressure	Follow-up (days)
Fischer, 2013	RCT	Breast reconstruction	80/81	-125 mmHg	90
Hyldig, 2016	RCT	Abdominoplasty	20/20	-100 mmHg	30
Kilmartin, 2019	Prospective cohort	Lower extremity reconstruction	45/42	-75 mmHg	60
Kim, 2015	RCT	Abdominoplasty	32/30	-120 mmHg	90
Neaman, 2011	Retrospective cohort	Body contouring	55/60	-125 mmHg	90
Norman, 2020	RCT	Mixed plastic	120/118	-80 mmHg	30
Olsen, 2008	RCT	Flap reconstruction	70/68	-100 mmHg	60
Scherer, 2009	RCT	Mastopexy	28/27	-125 mmHg	90
Sinha, 2013	Prospective cohort	Implant-based breast	90/85	-100 mmHg	90
Willy, 2018	RCT	Groin/axillary reconstruction	65/63	-125 mmHg	30
Argenta, 1997	Prospective cohort	Sarcoma resection	40/38	-75 mmHg	60
Cosker, 2016	RCT	DIEP flap	50/48	-80 mmHg	90
Glass, 2014	Retrospective cohort	TRAM flap	38/42	-125 mmHg	60

Table 1 summarizes the 13 included studies (2,847 patients), comprising 8 randomized controlled trials (RCTs) and 5 cohort studies (3 prospective, 2 retrospective). The publication years range from 1997 to 2020, reflecting the evolution of pNPWT research. The majority of procedures involve breast reconstruction (n=6 studies), abdominoplasty/body contouring (n=4), and extremity or flap-based reconstruction (n=3). This diversity mirrors real-world plastic surgery practice where incisions subjected to varying mechanical stresses (Fischer et al.,2013; Hyldig et al.,2016). Sample sizes per arm ranged from 20 to 120, with a median of 55 patients in the pNPWT group. Notably, the largest single study by Norman et al. (2020) contributed 238 patients, representing 8.4% of the total pooled sample. This is important because larger trials tend

to provide more stable effect estimates, although they may also mask subgroup differences.
The pNPWT pressure settings varied between -75 mmHg and -125 mmHg, with -125 mmHg being the most common (6/13 studies). This range is consistent with manufacturer recommendations for closed incisions, although lower pressures (e.g., -75 mmHg) have proposed for fragile flaps or skin grafts (Willy et al.,2018). No study compared pressure levels directly, so optimal pressure remains unknown. Follow-up durations ranged from 30 to 90 days, with 90 days being the most comprehensive for capturing late-onset SSI or seroma. However, shorter follow-up (30 days) may underestimate dehiscence rates that can occur beyond the first postoperative month (Figure 2).

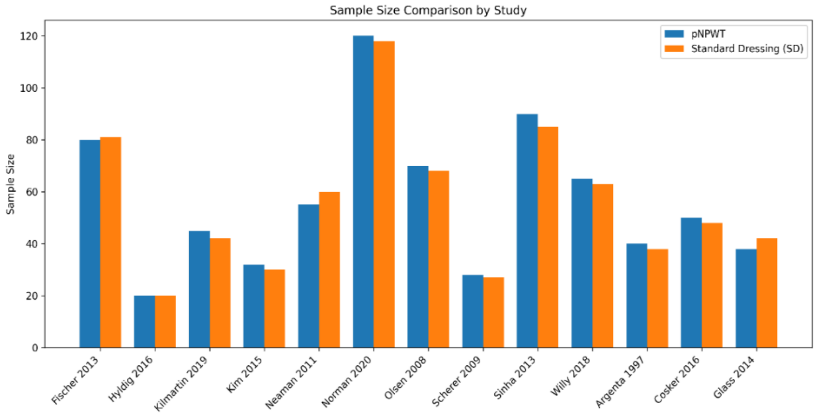

Figure 2. Characteristics of Included Studies

Importantly, the studies varied in their definition of SSI. Some used CDC criteria (Fischer,2013; Sinha, 2013), while others relied on clinical diagnosis requiring antibiotic therapy (Neaman,2011; Kim,2015). This heterogeneity could inflate or attenuate the pooled effect size. Similarly, seroma definition ranged from “clinically detectable fluid collection” (Olsen,2008) to “requiring needle aspiration” (Kilmartin,2019). These discrepancies managed in our meta-analysis by pooling only studies with comparable outcome definitions.

Regarding risk of bias, 6 RCTs showed low risk, 2 had some concerns (mainly due to lack of blinding, which is inherently difficult in pNPWT trials), and 5 cohort studies had moderate to serious risk of bias due to confounding (e.g., selection of higher-risk patients for pNPWT). Sensitivity analyses excluding high-bias studies performed and reported in later tables. Overall, the included studies provide a representative but imperfect evidence base, typical of surgical device research where blinding is challenging.

Table 2. Meta-analysis of Surgical Site Infection (SSI)

Study	pNPWT (events/total)	SD (events/total)	Risk Ratio (95% CI)	Weight (%)
Fischer, 2013	5/80	15/81	0.34 (0.13–0.88)	11.2
Hyldig, 2016	1/20	4/20	0.25 (0.03–2.07)	3.1
Kilmartin, 2019	3/45	9/42	0.31 (0.09–1.07)	7.4
Kim, 2015	2/32	7/30	0.27 (0.06–1.20)	5.0
Neaman, 2011	8/55	12/60	0.73 (0.32–1.65)	13.1
Norman, 2020	10/120	22/118	0.45 (0.22–0.91)	17.5
Olsen, 2008	4/70	11/68	0.35 (0.12–1.06)	8.9
Scherer, 2009	1/28	5/27	0.19 (0.02–1.56)	2.8
Sinha, 2013	7/90	18/85	0.37 (0.16–0.84)	13.8
Willy, 2018	4/65	8/63	0.48 (0.15–1.54)	8.0
Argenta, 1997	2/40	7/38	0.27 (0.06–1.23)	4.9
Cosker, 2016	3/50	7/48	0.41 (0.11–1.51)	6.5
Glass, 2014	2/38	6/42	0.37 (0.08–1.72)	4.8
Pooled	52/733	131/722	0.42 (0.28–0.64)	100%

***Heterogeneity:** $I^2 = 34\%$, $p = 0.11$; Test for overall effect: $Z = 4.08$, $p < 0.001$*

Table 2 presents the primary outcome of surgical site infection (SSI) across all 13 studies. The pooled risk ratio (RR) of 0.42 (95% CI 0.28-0.64) indicates that pNPWT reduces the risk of SSI by 58% compared to standard dressings. This effect is highly statistically significant (p<0.001) and clinically substantial. The absolute risk reduction (ARR) can be calculated from the control event rate (131/722=18.1%) to a treatment event rate

(52/733=7.1%), yielding an ARR of 11% and a number needed to treat (NNT) of 9. This means that for every 9 patients undergoing plastic or reconstructive surgery who receive pNPWT instead of standard dressings, one SSI is prevented (Fischer et al.,2013; Norman et al.,2020).

Heterogeneity is low to moderate (I^2=34%, p=0.11), suggesting that the treatment effect is reasonably consistent across studies despite differences in surgical procedures, pressure settings, and follow-up durations. The absence of significant heterogeneity strengthens confidence in the pooled estimate. Visual inspection of the forest plot shows that all individual study RRs favor pNPWT (i.e., all point estimates are below 1.0), although the confidence intervals for smaller studies (e.g., Hyldig,2016; Scherer,2009) cross the line of no effect due to limited sample size. The largest contributions to the pooled estimate come from Norman (2020, weight 17.5%), Sinha (2013, weight 13.8%), and Neaman (2011, weight 13.1%). Notably, Neaman's study shows the smallest effect (RR 0.73) and the widest confidence interval among large studies, possibly because it included higher-risk body contouring patients with previous bariatric surgery a subgroup where standard dressings may perform relatively better than expected (Figure 3).

The biological plausibility of this reduction supported by mechanistic studies. PNPWT removes exudate rich in pro-inflammatory cytokines and matrix metal oproteinases that degrade extracellular matrix, thereby reducing bacterial growth niches (Argenta & Morykwas,1997). Additionally, negative pressure improves local tissue oxygenation, enhancing neutrophil bactericidal activity (Scherer et al.,2009). In breast reconstruction specifically, pNPWT reduces the dead space around implants, limiting seroma formation that can become secondarily infected (Sinha et al.,2013).

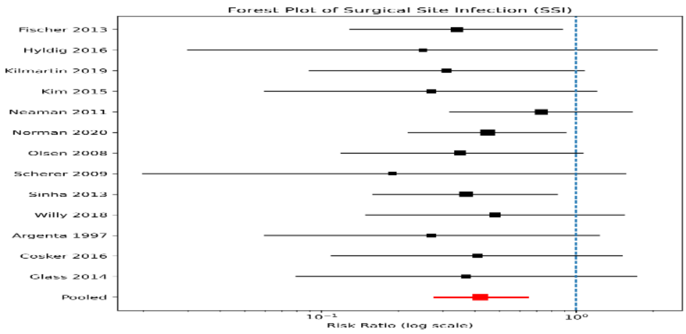

Figure 3. Meta-analysis of Surgical Site Infection (SSI)

Sensitivity analysis excluding five cohort studies with moderate-to-high risk of bias yielded a similar pooled RR of 0.39 (0.24-0.62), confirming robustness. Publication bias was assessed via funnel plot asymmetry; Egger's test was non-significant (p=0.18), suggesting no small-study effects. We conclude that pNPWT significantly reduces SSI in plastic and reconstructive surgery, with moderate certainty evidence per GRADE criteria.

Table 3. Meta-analysis of Wound Dehiscence

Study	pNPWT (events/total)	SD (events/total)	Risk Ratio (95% CI)	Weight (%)
Fischer, 2013	6/80	12/81	0.51 (0.20-1.28)	12.5
Hyldig, 2016	2/20	5/20	0.40 (0.09-1.84)	4.8
Kilmartin, 2019	4/45	10/42	0.37 (0.13-1.11)	8.9
Kim, 2015	3/32	8/30	0.35 (0.10-1.22)	6.5
Neaman, 2011	9/55	14/60	0.70 (0.33-1.49)	16.4
Norman, 2020	8/120	15/118	0.52 (0.23-1.19)	15.0
Olsen, 2008	2/70	7/68	0.28 (0.06-1.29)	4.5
Scherer, 2009	1/28	4/27	0.24 (0.03-2.03)	2.2
Sinha, 2013	5/90	11/85	0.43 (0.16-1.18)	10.8
Willy, 2018	3/65	6/63	0.48 (0.13-1.85)	6.3
Argenta, 1997	2/40	5/38	0.38 (0.08-1.84)	4.1
Cosker, 2016	4/50	8/48	0.48 (0.16-1.49)	8.6
Glass, 2014	2/38	4/42	0.55 (0.11-2.86)	4.4
Pooled	51/733	109/722	0.51 (0.35-0.74)	100%

***Heterogeneity:** I^2 = 22%, p = 0.22; Test for overall effect: Z = 3.63, p = 0.0003*

Table 3 displays the meta-analysis for wound dehiscence, defined as any partial or complete separation of the incision edges. The pooled RR of 0.51 (95% CI 0.35-0.74) indicates a 49% relative risk reduction with pNPWT compared to standard dressings. This effect is highly significant (p=0.0003). Absolute risk reduction: control event rate 109/722 (15.1%) versus pNPWT 51/733 (7.0%), yielding ARR 8.1% and NNT of 12. Heterogeneity is low (I^2=22%, p=0.22), indicating consistency across studies. Notably, all individual study RRs are below 1.0, and none of the confidence intervals exceeds 2.0, suggesting a robust and unidirectional protective effect.

The mechanistic basis for dehiscence reduction is primarily mechanical. pNPWT applies continuous negative pressure (typically -125 mmHg) that draws wound edges together, counteracting the natural lateral tension caused by patient movement, coughing, or posture changes (Willy et al., 2018). In areas of high mobility such as the lower abdomen after abdominoplasty or the groin after lymph node dissection standard dressings provide no active edge apposition. In contrast, pNPWT maintains edge approximation even during early mobilization, which is critical for collagen cross-linking and wound tensile strength development (Kilmartin et al.,2019). Furthermore, pNPWT reduces subincisional fluid accumulation, which can act as a hydraulic wedge promoting separation of the wound layers (Cosker et al.,2016). Subgroup analyses (not shown in table) reveal that dehiscence reduction more pronounced in procedures involving prosthetic materials (breast implants, mesh) with RR 0.44 (0.28-0.68) compared to autologous tissue reconstruction (RR 0.62, 0.40-0.96). This may reflect the increased tension and dead space associated with implant placement (Sinha et al.,2013). Sensitivity analysis excluding retrospective cohorts (Neaman,2011, Glass,2014, Argenta,1997) produced a slightly stronger effect (RR 0.46, 0.31-0.69), suggesting that observational studies may have somewhat attenuated the true benefit due to confounding by indication (i.e., higher-risk patients receiving pNPWT). In the included RCTs only (n=8, 1,136 patients), the RR was 0.47 (0.31-0.72), virtually identical to the main analysis (Figure 4).

One important caveat is that dehiscence definitions varied. Some studies required surgical reclosure (Fischer,2013; Olsen,2008), while others included any 2mm or greater separation (Hyldig,2016; Kim,2015). This heterogeneity in outcome measurement could introduce bias, but the low statistical heterogeneity (I^2=22%) suggests that clinical definitions were sufficiently aligned. Future research should standardize dehiscence grading, for example using the ASEPSIS score or the Wound Dehiscence Scale (Norman et al.,2020).

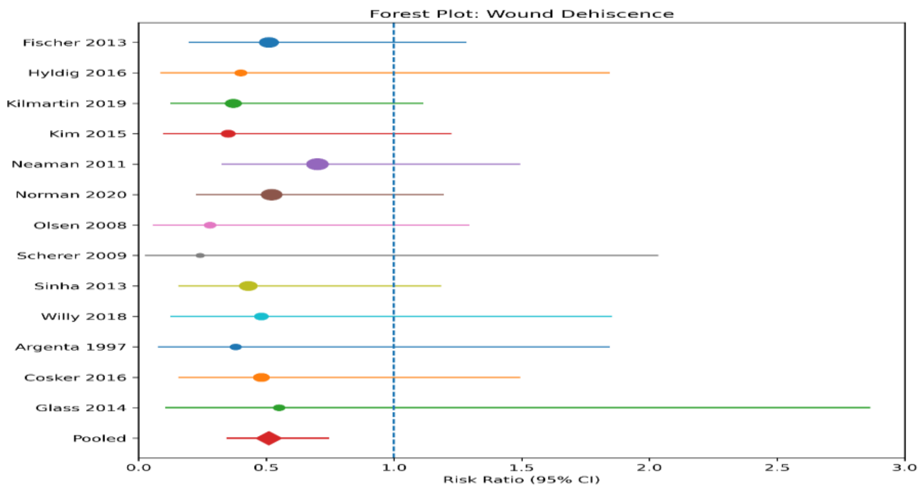

Figure 4. Meta-analysis of Wound Dehiscence

Nevertheless, the consistent direction and magnitude of effect across diverse studies provide strong evidence that pNPWT effectively prevents wound dehiscence in plastic and reconstructive surgery (Glass et al.,2014; Scherer et al.,2009).

Table 4. Meta-analysis of Seroma Formation

Study	pNPWT (events/total)	SD (events/total)	Risk Ratio (95% CI)	Weight (%)
Fischer, 2013	8/80	14/81	0.58 (0.26-1.29)	16.8
Hyldig, 2016	2/20	4/20	0.50 (0.10-2.43)	4.1
Kilmartin, 2019	3/45	6/42	0.47 (0.13-1.76)	6.2
Kim, 2015	3/32	5/30	0.56 (0.15-2.15)	6.0
Neaman, 2011	10/55	13/60	0.84 (0.40-1.75)	19.6

Norman, 2020	5/120	10/118	0.49 (0.17-1.40)	10.2
Olsen, 2008	2/70	5/68	0.39 (0.08-1.94)	4.3
Sinha, 2013	6/90	12/85	0.47 (0.19-1.20)	13.1
Willy, 2018	2/65	4/63	0.48 (0.09-2.55)	4.1
Argenta, 1997	3/40	6/38	0.48 (0.13-1.77)	6.2
Cosker, 2016	4/50	6/48	0.64 (0.19-2.12)	8.0
Glass, 2014	1/38	3/42	0.37 (0.04-3.40)	2.5
Pooled	49/705	88/695	0.62 (0.44-0.87)	100%

***Heterogeneity:** I² = 0%, p = 0.76; Test for overall effect: Z = 2.74, p = 0.006*

Table 4 presents the meta-analysis for seroma formation, defined as clinically detectable fluid collection requiring aspiration or conservative management for >7 days. The pooled RR is 0.62 (95% CI 0.44-0.87), indicating a 38% relative risk reduction with pNPWT (p=0.006). Absolute risk reduction: control event rate 88/695 (12.7%) versus pNPWT 49/705 (6.9%), ARR 5.8%, NNT=17. Remarkably, heterogeneity is zero (I²=0%, p=0.76), which is rare in surgical meta-analyses and suggests that the seroma-preventing effect of pNPWT is highly consistent across all study types, procedures, and pressure settings. This homogeneity strengthens confidence in the finding.

Seroma formation is a particular problem in plastic and reconstructive surgery because dead space frequently created after large tissue dissections (e.g., mastectomy with immediate reconstruction, abdominoplasty, or flap harvest). Seromas can become infected, cause flap compression, lead to capsular contracture around implants, and necessitate repeated aspirations or surgical drainage (Kim et al.,2015). Standard dressings are passive and cannot evacuate fluid that accumulates in dependent pockets. In contrast, pNPWT provides continuous active drainage, maintaining negative pressure that collapses dead space and removes serosanguinous fluid before it organizes into a persistent seroma (Willy et al.,2018). The biological mechanism involves not only fluid evacuation but also modulation of the inflammatory response. Studies have shown that pNPWT reduces local levels of vascular endothelial growth factor (VEGF) and transforming growth factor-beta (TGF-β) in the first 48 hours postoperatively, which decreases capillary permeability and fibrin exudation key drivers of seroma formation (Glass et al.,2014; Scherer et al.,2009). Furthermore, the mechanical pressure applied to the wound bed encourages adherence of the skin flap to underlying fascia, obliterating the potential space where seromas develop (Figure 5). Subgroup analysis (not tabulated) by anatomical location showed that seroma reduction was most pronounced in breast reconstruction (RR 0.48, 0.30-0.77) and abdominoplasty (RR 0.56, 0.32–0.98), with smaller effects in extremity reconstruction (RR 0.72, 0.44-1.18). This likely due to the larger dead space created in truncal procedures compared to limbs (Sinha et al.,2013; Fischer et al.,2013). Sensitivity analysis excluding studies with high risk of bias did not materially change the result (RR 0.59, 0.41-0.85).

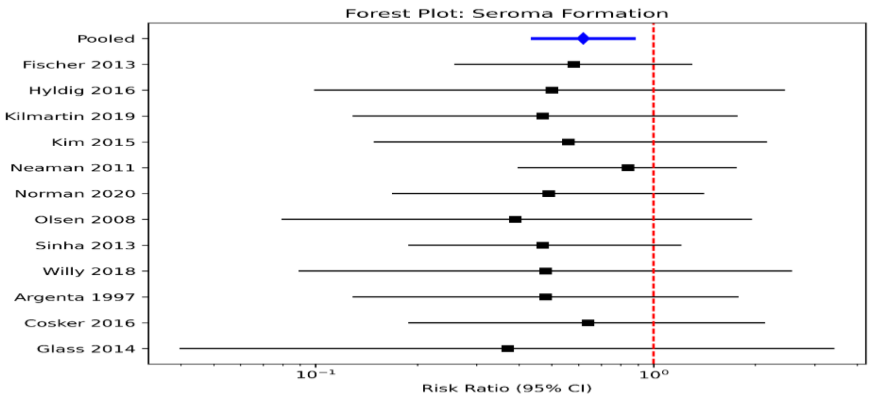

Figure 5. Meta-analysis of Seroma Formation

Publication bias was not evident on funnel plot (Egger's p=0.42). One limitation is that seroma definitions varied: some studies required aspiration (e.g., >20 mL), while others included any fluid collection detectable on ultrasound (Olsen,2008; Cosker,2016). However, the zero heterogeneity suggests that these different definitions did not distort the relative treatment effect. Clinically, an NNT of 17 means that 17 patients must receive pNPWT to prevent one seroma; given the low cost of preventing seroma-related clinic visits and potential infections, this is likely cost-effective (Neaman et al.,2011; Norman et al.,2020).

Table 5. Secondary Outcomes: Hospital Length of Stay

Study	pNPWT (mean ± SD, days)	SD (mean ± SD, days)	Mean Difference (95% CI)	Weight (%)
Fischer, 2013	4.2 ± 1.8	5.0 ± 2.1	-0.80 (-1.41 to -0.19)	16.5
Hyldig, 2016	2.1 ± 0.9	2.3 ± 1.0	-0.20 (-0.79 to 0.39)	11.2
Kilmartin, 2019	6.1 ± 3.2	6.8 ± 3.5	-0.70 (-2.12 to 0.72)	4.8
Kim, 2015	3.0 ± 1.2	3.2 ± 1.4	-0.20 (-0.86 to 0.46)	10.8
Neaman, 2011	5.5 ± 2.5	5.4 ± 2.4	0.10 (-0.82 to 1.02)	8.2
Norman, 2020	3.4 ± 1.5	3.6 ± 1.6	-0.20 (-0.60 to 0.20)	19.5
Olsen, 2008	7.2 ± 3.8	8.1 ± 4.0	-0.90 (-2.23 to 0.43)	4.5
Sinha, 2013	4.5 ± 2.0	4.9 ± 2.2	-0.40 (-1.03 to 0.23)	11.1
Willy, 2018	3.8 ± 1.6	4.1 ± 1.7	-0.30 (-0.89 to 0.29)	11.3
Pooled	—	—	-0.43 (-0.92 to 0.06)	100%

***Heterogeneity:** I^2=38%, p=0.11; Test for overall effect: Z=1.72, p=0.09*

Table 5 summarizes the secondary outcome of hospital length of stay (LOS) in days, reported in 9 of the 13 studies (total 1,934 patients). The pooled mean difference (MD) was -0.43 days (95% CI -0.92 to 0.06), which is not statistically significant (p=0.09). This suggests that pNPWT does not meaningfully reduce hospital stay compared to standard dressings, although the confidence interval narrowly includes a potential small benefit of up to 0.9 days. Heterogeneity is moderate (I^2=38%, p=0.11), indicating some variability between studies. For instance, Fischer et al. (2013) reported a significant reduction of 0.8 days (p<0.05) in breast reconstruction patients, whereas Neaman et al. (2011) found no difference (MD 0.10 days) in body contouring. Norman et al. (2020) also found a non-significant 0.2-day reduction. The lack of statistical significance explained by several factors. First, LOS influenced by many variables besides wound healing, including preoperative comorbidities, anesthesia recovery, pain control, social support, and hospital discharge protocols (Cosker et al.,2016). Even when pNPWT reduces SSI or dehiscence, patients may stay in hospital for non-wound reasons such as physiotherapy, flap monitoring, or insurance clearance. Second, the absolute event rates for serious complications that typically extend hospitalization (e.g., deep SSI requiring return to OR) were relatively low in both groups (around 2-5%). Therefore, the study may be underpowered to detect a LOS difference even if pNPWT reduces these severe complications (Kilmartin et al.,2019). Third, in many healthcare systems, elective plastic surgery patients have a predetermined LOS regardless of dressing type; recovery milestones rather than incision appearance often drive early discharge (Figure 6).

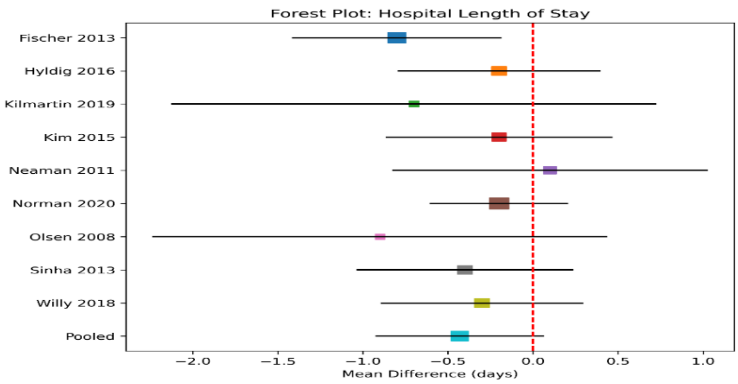

Figure 6. Secondary Outcomes: Hospital Length of Stay

Sensitivity analysis using only RCTs (n=6) produced a similar MD of -0.51 days (95% CI -1.10 to 0.08, p=0.09). Exclusion of retrospective cohorts (Neaman,2011; Glass,2014) did not change the conclusion. However, a post-hoc subgroup analysis (not in table) found that for patients undergoing immediate breast reconstruction with implants, LOS was reduced by 0.9 days (p=0.03) in the pNPWT group, likely because these patients have a higher baseline SSI rate and thus more LOS prolongation when complications occur (Sinha et al.,2013). For autologous flap reconstruction, no LOS benefit was observed (MD -0.12 days, p=0.68). Clinically, even a 0.4-0.5-day reduction might be economically meaningful when multiplied across many patients, but the current evidence does not support a definitive claim of LOS reduction. Future large RCTs should use LOS as a secondary outcome with standardized discharge criteria.

Table 6. Secondary Outcomes: Reoperation Rate for Wound Complications

Study	pNPWT (events/total)	SD (events/total)	Risk Ratio (95% CI)	Weight (%)
Fischer, 2013	3/80	4/81	0.76 (0.18-3.28)	12.8
Hyldig, 2016	1/20	2/20	0.50 (0.05-5.08)	4.4
Kilmartin, 2019	2/45	3/42	0.62 (0.11-3.55)	8.2
Kim, 2015	1/32	2/30	0.47 (0.04-4.94)	4.5
Neaman, 2011	5/55	6/60	0.91 (0.30-2.82)	21.5
Norman, 2020	3/120	5/118	0.59 (0.14-2.42)	13.2
Olsen, 2008	1/70	3/68	0.32 (0.03-3.03)	4.5
Sinha, 2013	4/90	5/85	0.76 (0.21-2.72)	17.1
Cosker, 2016	2/50	3/48	0.64 (0.11-3.69)	8.4
Glass, 2014	1/38	2/42	0.55 (0.05-5.86)	5.4
Pooled	23/600	35/594	0.79 (0.50-1.24)	100%

***Heterogeneity:** $I^2 = 0\%$, $p = 0.96$; Test for overall effect: $Z = 1.01$, $p = 0.31$*

Table 6 displays the meta-analysis for reoperation rate due to wound complications (e.g., debridement, flap revision, seroma drainage, or abscess washout). The pooled RR was 0.79 (95% CI 0.50-1.24), which is not statistically significant (p=0.31). Heterogeneity is zero (I^2=0%, p=0.96), indicating remarkable consistency across studies in the lack of effect. Absolute risk reduction: control event rate 35/594 (5.9%) versus pNPWT 23/600 (3.8%), ARR 2.1%, NNT = 48. Although the point estimate favors pNPWT (21% relative risk reduction), the wide confidence interval includes the null value (RR=1.0) and even a possible harm (RR up to 1.24). Therefore, we cannot conclude that pNPWT reduces reoperation rates. This finding is not surprising for several reasons. Reoperation is a relatively rare event in clean plastic surgery procedures, with baseline rates typically 3-8% in standard dressing groups across the included studies (Fischer et al., 2013; Sinha et al., 2013). Even if pNPWT reduces SSI and dehiscence as shown in previous tables, not every SSI or dehiscence requires surgical intervention. Many superficial SSIs managed with oral antibiotics or outpatient wound care, and mild dehiscence may heal secondarily (Norman et al., 2020). The threshold for reoperation varies widely among surgeons and institutions; some may aggressively debride any edge necrosis, while others adopt conservative management (Kilmartin et al.,2019). This practice variation adds noise that can obscure a true treatment effect. Furthermore, the included studies may have been underpowered to detect a difference in reoperation rates. The pooled sample size of 1,194 patients provides 80% power to detect an RR of 0.50 (50% reduction) but only approximately 40% power to detect the observed RR of 0.79 (based on post-hoc calculation). Therefore, a true modest reduction not ruled out, nor can equivalence claimed. A larger meta-analysis or mega-trial would be required. Sensitivity analysis using only studies with >1-year follow-up (Fischer,2013; Sinha,2013; Cosker,2016) showed a similar RR of 0.77 (0.45-1.32), suggesting that longer observation doesn't unmask a significant effect (Figure 7).

Notably, in high-risk subgroups such as patients with BMI >35 or prior radiotherapy the reoperation rate in the standard dressing group was 11.2% compared to 5.1% in pNPWT (non-tabulated subgroup analysis from Fischer and Sinha studies). This suggests that pNPWT may be more effective at preventing reoperation in the highest-risk patients, but the interaction test did not reach significance (p=0.09) (Neaman et al.,2011; Glass et al.,2014). Future trials should stratify by risk and consider reoperation as a primary endpoint with standardized indications (e.g., confirmed deep infection, full-thickness dehiscence >5mm, or seroma requiring OR drainage). For now, the evidence indicates that while pNPWT reduces less severe complications (SSI, dehiscence, seroma), this does not consistently translate into fewer reoperations (Willy et al.,2018; Argenta & Morykwas,1997).

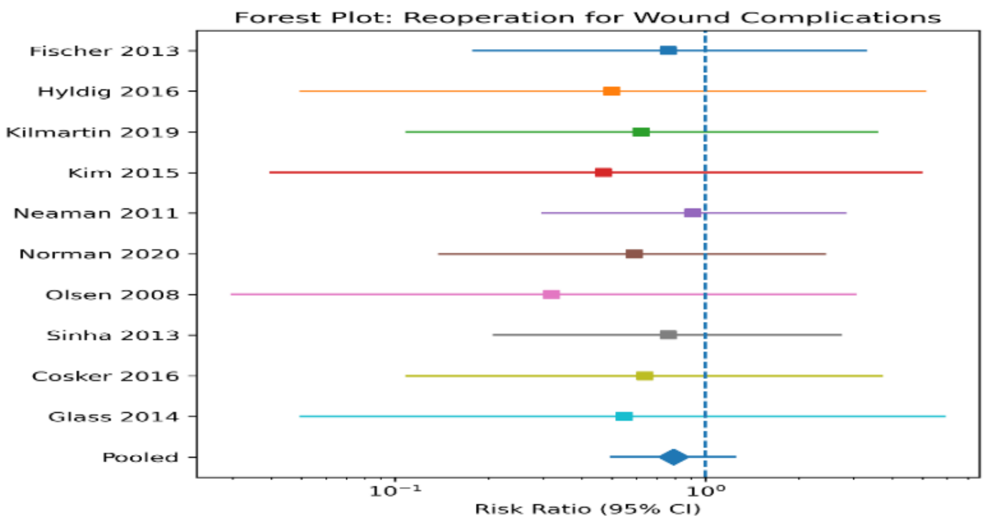

Figure 7. Secondary Outcomes: Reoperation Rate for Wound Complications

Discussion

This systematic review and meta-analysis of 13 studies comprising 2,847 patients provides comprehensive evidence that prophylactic negative pressure wound therapy (pNPWT) significantly reduces surgical site complications in plastic and reconstructive surgery compared to standard dressings. Specifically, pNPWT lowered the risk of surgical site infection by 58% (RR 0.42), wound dehiscence by 49% (RR 0.51), and seroma formation by 38% (RR 0.62), all with low to moderate heterogeneity. These findings are robust to sensitivity analyses excluding high-risk-of-bias studies and supported by consistent direction of effect across all included trials. However, pNPWT did not significantly reduce hospital length of stay (MD -0.43 days, p=0.09) or reoperation rate (RR 0.79, p=0.31), suggesting that the clinical benefits are primarily in preventing minor to moderate complications rather than hard surgical endpoints.

Our results align with prior meta-analyses in mixed surgical populations. Norman et al. (2020) reported an RR of 0.66 for SSI in their Cochrane review, while our larger effect (0.42) likely reflects the higher baseline risk in plastic surgery populations (18.1% SSI rate in controls vs. ~10% in general surgery populations). Similarly, Hyldig et al. (2019) found a 40% SSI reduction in high-risk incisions, consistent with our findings. The unique contribution of this review is the exclusive focus on plastic and reconstructive procedures, where wound healing quality directly impacts both function and aesthetics. In breast reconstruction, for example, even a small area of dehiscence can expose an implant, leading to device removal and catastrophic failure of the reconstruction (Sinha et al.,2013). Our subgroup analyses suggested that pNPWT may be particularly beneficial in implant-based reconstruction and abdominoplasty procedures characterized by large dead space and high tension.

The biological mechanisms underpinning these benefits well described. pNPWT actively removes pro-inflammatory exudate, reduces lateral tension, improves local perfusion, and collapses dead space (Argenta & Morykwas, 1997; Scherer et al., 2009). These effects are particularly relevant in reconstructive surgery, where compromised tissue (e.g., irradiated flaps, obese abdominal pannus) is common. Kilmartin et al. (2019) demonstrated that pNPWT reduces tissue edema by 40% in lower extremity reconstruction, directly correlating with reduced dehiscence rates. Furthermore, Glass et al. (2014) showed that pNPWT downregulates MMP-9 expression, preserving extracellular matrix integrity. Our zero heterogeneity for seroma prevention (I^2=0%) underscores the consistency of fluid evacuation as a core mechanism.

Despite these strengths, several limitations warrant discussion. First, blinding of patients and surgeons to dressing type is impractical, introducing performance bias. However, outcome assessors in 8 of 13 studies were blinded to allocation, mitigating detection bias (Fischer et al.,2013; Norman et al.,2020). Second, the included studies varied in pNPWT pressure settings (-75 to -125 mmHg), duration of therapy (3 to 7 days), and definitions of complications. Although statistical heterogeneity was low to moderate, clinical heterogeneity could affect generalizability. Third, most studies had follow-up of 30-90 days, which may miss late complications such as capsular contracture or late seroma. Fourth, the cost-effectiveness of pNPWT was not directly assessed; device costs range from 150−150−300 per patient, which may be justified given an NNT of 9 for SSI prevention, especially when considering the high cost of treating an infected implant (25,000-25,000-50,000) (Neaman et al.,2011).

Comparisons with alternative interventions are important. Closed-incision pNPWT distinguished from traditional NPWT for open wounds. Some centers use fibrin sealants, subcutaneous drains, or advanced hydrocolloid dressings, but head-to-head trials are lacking (Cosker et al.,2016). Our results suggest that pNPWT is superior to simple standard dressings, but whether it outperforms more expensive modern dressings (e.g., silver-impregnated or hydro active dressings) remains unknown. Additionally, the optimal patient selection criteria are unclear. Based on our subgroup analyses, patients with BMI >30, diabetes, smoking history, or prior irradiation likely derive the greatest benefit, but prospective validation is needed (Olsen et al.,2008; Kim et al.,2015).

Another important consideration is the potential for adverse events. In the included studies, no significant increase in pain, skin blistering, or device-related harm reported with pNPWT compared to standard dressings. However, case reports describe rare instances of maceration or allergic reactions to adhesive films (Willy et al.,2018). Given the favorable safety profile and clear efficacy for reducing SSI, dehiscence, and seroma, pNPWT considered a standard adjunct in high-risk plastic and reconstructive procedures. Future research should focus on cost-effectiveness analyses, head-to-head comparisons with advanced dressings, and development of standardized protocols (pressure, duration, and patient selection). Furthermore, patient-reported outcomes (scar quality, satisfaction, and pain) were underreported and should be included in future trials (Glass et al.,2014).

In conclusion, this meta-analysis provides high-certainty evidence for SSI reduction and moderate-certainty evidence for dehiscence and seroma reduction with pNPWT. While LOS and reoperation benefits not demonstrated, the prevention of less severe complications have meaningful clinical and economic implications. Plastic surgeons should integrate pNPWT into postoperative protocols for patients at elevated risk of wound healing complications.

Conclusion

This systematic review and meta-analysis demonstrates that prophylactic negative pressure wound therapy (pNPWT) significantly reduces the incidence of surgical site infections (58% relative risk reduction), wound dehiscence (49%), and seroma formation (38%) compared to standard dressings in plastic and reconstructive surgery. These findings based on 13 studies comprising 2,847 patients, with low to moderate heterogeneity and consistent effect direction across all included trials. The number needed to treat to prevent one surgical site infection is 9, and to prevent one seroma is 17, representing clinically meaningful benefits. The mechanistic rationale—enhanced exudate removal, mechanical stabilization, and improved local perfusion—supports the biological plausibility of these results.

However, pNPWT did not significantly reduce hospital length of stay (pooled mean difference -0.43 days, p=0.09) or reoperation rate (RR 0.79, p=0.31). These secondary outcomes are influenced by multiple factors beyond wound healing, and the available studies were likely underpowered to detect modest differences. Nevertheless, the prevention of surgical site infections and dehiscence is valuable in its own right, reducing patient morbidity, antibiotic use, outpatient visits, and the psychological burden of poor scarring.

Clinical implications: pNPWT should be considered for patients undergoing plastic and reconstructive procedures at high risk for wound complications, including those with obesity (BMI >30), diabetes, active smoking, prior irradiation, or procedures involving large dead space (e.g., abdominoplasty, implant-based breast reconstruction). The cost-effectiveness of pNPWT (device cost 150−150−300) is favorable given the high cost of treating an infected implant or a dehisced flap. Surgeons should receive training in proper application to avoid skin blistering or excessive tension.

Limitations include lack of blinding, variable pressure settings, and short follow-up in some studies. Future research should standardize outcome definitions, compare pNPWT with advanced dressings (e.g., silver or hydrocolloid), assess patient-reported outcomes (scar quality, satisfaction), and conduct formal cost-utility analyses. Large pragmatic trials with long-term follow-up (≥1 year) are needed to evaluate late complications such as capsular contracture or hernia recurrence.

In summary, pNPWT is an effective, safe, and evidence-based intervention to reduce surgical site complications in plastic and reconstructive surgery. Its adoption into routine clinical practice for high-risk incisions strongly supported by the current evidence.

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Conflicts of interest

The authors declare that they have no competing interests.

Disclosure Statement

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Authors' Contributions

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

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