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Role of Prophylactic Negative Pressure Wound Therapy in Reducing Surgical-Site Infections in Spine Surgery – A Systematic Review and Meta-Analysis

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Abstract

Study Design: Systematic Review and Meta-analysis.

Objective: To evaluate the prophylactic efficacy of incisional negative pressure wound therapy(NPWT) in mitigating the postoperative complications following primary spine surgery.

Methods: A comprehensive search of the databases (PubMed, Embase, Scopus and Web of Science) was performed until October 2025 since inception. Studies comparing incisional NPWT vs standard wound dressing after primary spine surgery were included if at least one of the relevant outcome measures was reported. While the primary endpoint was surgical site infection(SSI), the evaluated secondary outcomes included wound complications, reoperations, readmissions, length of hospital stay(LOS), and cost-effectiveness. Random-effects meta-analysis with Knapp-Hartung adjustment was employed to calculate pooled odds ratios(ORs) and mean differences(MD). The risk of bias assessment was made using the Cochrane ROB2 tool and Newcastle Ottawa Scale.

Results: Thirteen studies comprising 7619 patients(851NPWT and 6,768controls) were analysed. NPWT significantly mitigated the SSI rates[OR = 0.42, 95%CI(0.28-0.63)$P < 0.001$;$I^2 = 78\%$) and wound complications[OR = 0.51,95%CI(0.33-0.78) $P = 0.03$;$P = 0.03$;$I^2 = 0\%$]. In contrast, reoperation rates[OR = 0.68,95%CI(0.39-1.18)], readmissions[OR = 0.76,95%CI(0.45-1.29)], and LOS [MD = −1.05days,95%CI(−2.16,0.07)] demonstrated non-significant trends, indicating the clinical implications of these secondary outcomes remain uncertain. Two studies reported marked cost savings, with up to $12.9 saved for per $1 spent on NPWT. No significant publication bias was observed.

Conclusion: Prophylactic incisional NPWT is associated with reduced SSI and wound complications in spine surgery. Given the predominance of retrospective studies, protocol heterogeneity, and limited cost-effectiveness data, these findings should be interpreted cautiously. Current evidence suggests NPWT may be most beneficial in selected high-risk patients, with larger multicentric RCTs needed to confirm routine use and economic value.

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Keywords
spine surgery, negative pressure wound therapy, surgical site infection, wound complications, prophylactic VAC, cost effectiveness

Introduction

Surgical site infection (SSI) remains a major source of morbidity following spinal surgery, with the reported incidence ranging between 0.7% and 12%, depending upon the complexity of the procedure and patient comorbidities.[1,2] SS1s account for approximately 50% of all readmissions following spinal fusion, and are associated with a 4-fold increase in treatment expenditure.[1-3] Given the substantial morbidity and healthcare burden associated with surgical site infections, the development of effective prophylactic strategies to reduce their incidence remains a critical priority in spine surgery.[4-6]

A variety of prophylactic measures have been implemented to mitigate the incidence of postoperative wound complications. The standard strategies include meticulous surgical technique, perioperative antibiotic prophylaxis, maintenance of normothermia, and stringent glycemic control.[7-9] In the postoperative setting, wound dressings serve a vital role in protecting the incision from external contamination, maintaining a moist environment conducive to healing and facilitating epithelialization.[10] Conventional non-occlusive dressings, such as sterile gauze or adhesive strips, are simple and breathable but prone to strike-through contamination and frequent dressing changes.[11] On the other hand, occlusive and semi-occlusive dressings, such as hydrocolloids, polyurethane films, alginates, and silver-impregnated barrier materials, create a sealed microenvironment that helps to prevent bacterial ingress and promote uniform healing.[12,13] However, despite such advancements, no single dressing has consistently demonstrated superiority in preventing SSI following spine surgery, underscoring the need for more reliable, evidence-based prophylactic solutions.[14]

In this context, incisional negative pressure wound therapy (NPWT) has emerged as a promising adjunct aimed at mitigating postoperative wound complications. Unlike conventional dressings, NPWT applies controlled sub-atmospheric pressure across a closed incision, enhancing local perfusion, minimising seroma and hematoma formation, as well as providing continuous mechanical stabilization of wound edges.[3,15-17] The sealed system also acts a barrier against external contamination, while maintaining an optimal microenvironment for tissue repair.[18] These advantages have resulted in its growing application in high-risk spine surgeries, particularly those involving extensive soft tissue dissection, instrumentation or patients with significant comorbidities.[2,19] Nevertheless, the evidence supporting its prophylactic use remains heterogeneous, with variation in study design, pressure settings and patient selection. The current systematic review and meta-analysis was therefore undertaken to comprehensively evaluate the efficacy, safety and cost-effectiveness of incisional NPWT in preventing postoperative complications following spine surgery.

Methods

Study Design and Reporting Standards

This systematic review and meta-analysis was conducted to evaluate the prophylactic efficacy of incisional NPWT in reducing postoperative complications following primary spine surgeries. The study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, reproducibility, and methodological rigor throughout the review process.[20] The protocol followed established best practices for systematic review methodology and meta-analytic synthesis.[21]

Eligibility Criteria

Studies were eligible for inclusion if they investigated NPWT as a prophylactic intervention applied immediately after wound closure in primary spine surgeries. Oncology and trauma cases were categorized as primary when NPWT was used at the index procedure. Revision surgeries and therapeutic NPWT applications were excluded from quantitative synthesis, though occasionally referenced for contextual discussion. Eligible designs included randomised controlled trials (RCTs), prospective cohort studies, and retrospective comparative studies. The inclusion criteria required a comparison between NPWT and standard wound dressings with extractable data for at least one predefined outcome, such as surgical site infection (SSI), wound complications (such as dehiscence, seromas, etc.), reoperation rates, length of hospital stay (LOS), readmission rates, or cost-effectiveness. Studies were excluded if NPWT was used as a therapeutic measure for existing wound complications or infections or revision scenarios, lacked a comparator group or extractable outcome data or had a sample size <10 patients, as such studies provide insufficient power and reliability.[1,6]

Search Strategy and Study Selection

A comprehensive literature search was performed in PubMed, Embase, Scopus, and Web of Science databases from inception through October 2025. The search combined controlled vocabulary (MeSH/Emtree) and free-text terms related

to *"negative pressure wound therapy," "vacuum-assisted closure," "spine surgery," "prophylactic," "surgical site infection,"* and *"wound complications"*. The detailed Boolean strategy was developed according to PRISMA-S and PRESS recommendations.[22,23] The reference lists of eligible studies and prior reviews were manually screened to capture additional studies not retrieved by the electronic search. Two independent reviewers screened the titles and abstracts, followed by full-text evaluation. Disagreements were resolved by consensus or arbitration from a third reviewer.

Data Extraction

Data were extracted independently by two reviewers using a standardised pre-piloted template. The extracted variables included: study characteristics (author, year, country, design and sample size), patient demographics (age, sex, BMI, comorbidities), surgical details (procedure type, use of instrumentation, and indications), NPWT protocol (device type, pressure settings, duration of application), and outcome measures (SSI, wound complications, reoperations, LOS, readmissions, cost-effectiveness). The primary outcome was SSI, defined as any superficial or deep infection requiring medical or surgical intervention, in accordance with the CDC criteria.[24] However, follow-up windows varied across studies (30-90 days), which may affect comparability of reported incidence. The secondary outcomes included wound complications (eg, dehiscence, seroma, hematoma), reoperation rates, LOS, readmissions, and cost-effectiveness metrics.

Risk of Bias Assessment

The methodological quality was independently assessed by two reviewers. RCTs were evaluated using the Cochrane Risk of Bias 2.0 tool, addressing random sequence generation, allocation concealment, blinding, incomplete outcome data, and selective reporting.[25] Observational studies were using the Newcastle-Ottawa Scale (NOS) covering cohort selection, comparability and outcome ascertainment.[26] Each study was categorised as low, moderate, or high risk of bias based on cumulative domain scores. Sensitivity analyses were planned to assess the robustness of pooled results following the exclusion of high-risk studies.

Statistical Analysis

Meta-analysis was performed using a random-effects model to account for between-study heterogeneity. The DerSimonian–Laird estimator was applied to estimate between-study variance (τ^2), and Knapp-Hartung adjustment was implemented to improve precision, particularly in smaller sample or moderate heterogeneity settings.[27,28] For binary outcomes (eg, SSI, wound complications, reoperations), pooled odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. For continuous outcomes (eg, LOS), pooled mean differences (MDs) with 95% CIs were computed. Heterogeneity was quantified using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively.[29] Prediction intervals were additionally reported to indicate the plausible range of true effects in future studies. Subgroup analyses were performed based on study design (RCT vs observational), NPWT pressure settings (eg, −75 to −80 mmHg vs −100 to −125 mmHg), and surgical indication (eg, deformity correction, trauma, pediatric scoliosis). Publication bias was assessed using the funnel plot, Galbraith plot asymmetry and Egger's regression test.[30] All analyses were performed using Stata version 17.0 (StataCorp LLC, College Station, TX, USA).

Results

Study Characteristics

Thirteen studies met the inclusion criteria, comprising two RCTs,[3,16] two prospective cohort studies,[31,32] and nine retrospective comparative studies[1,2,5,6,15,17,19,33-36] as shown in Figure 1. Collectively, these studies included 7619 patents (851 patients treated with NPWT and 6768 controls receiving standard wound dressings). Oncology and trauma cases were included when NPWT was applied at the index procedure. Revision surgeries were excluded from pooled analysis but may be referenced in the discussion for contextual relevance. The methodological quality and characteristics of the included studies are presented in Table 1. Surgical procedures encompassed posterior spinal fusion, non-instrumented decompressive surgeries, spinal trauma stabilisation, as well as adult and pediatric deformity correction surgeries. NPWT protocols varied across studies, with pressure settings ranging from −75 to −125 mmHg, and application durations spanning 3 to 14 days. Most studies employed commercially available closed-incision systems such as PREVENA, PICO, or VAC, applied immediately after wound closure as shown in Tables 2 and 3. Across included studies, NPWT was often applied in patients with higher baseline risk factors, including obesity, diabetes, multilevel fusion, extensive instrumentation, and longer operative duration. These differences may contribute to observed heterogeneity and confounding.

SSI

Twelve studies reported SSI outcomes. Pooled analysis demonstrated a significant reduction in infection rates with NPWT compared to standard dressings, with an OR of 0.42 (95%CI:0.28-0.63), $P < 0.001$, as shown in Figure 2A. Considering the high heterogeneity ($I^2 = 78.3\%$), subgroup analysis was done with the study design of included studies and pressure used in the NPWT systems analysed. However, the prediction interval (0.21-0.84) confirmed consistent benefit across various populations and settings. Clinically, this

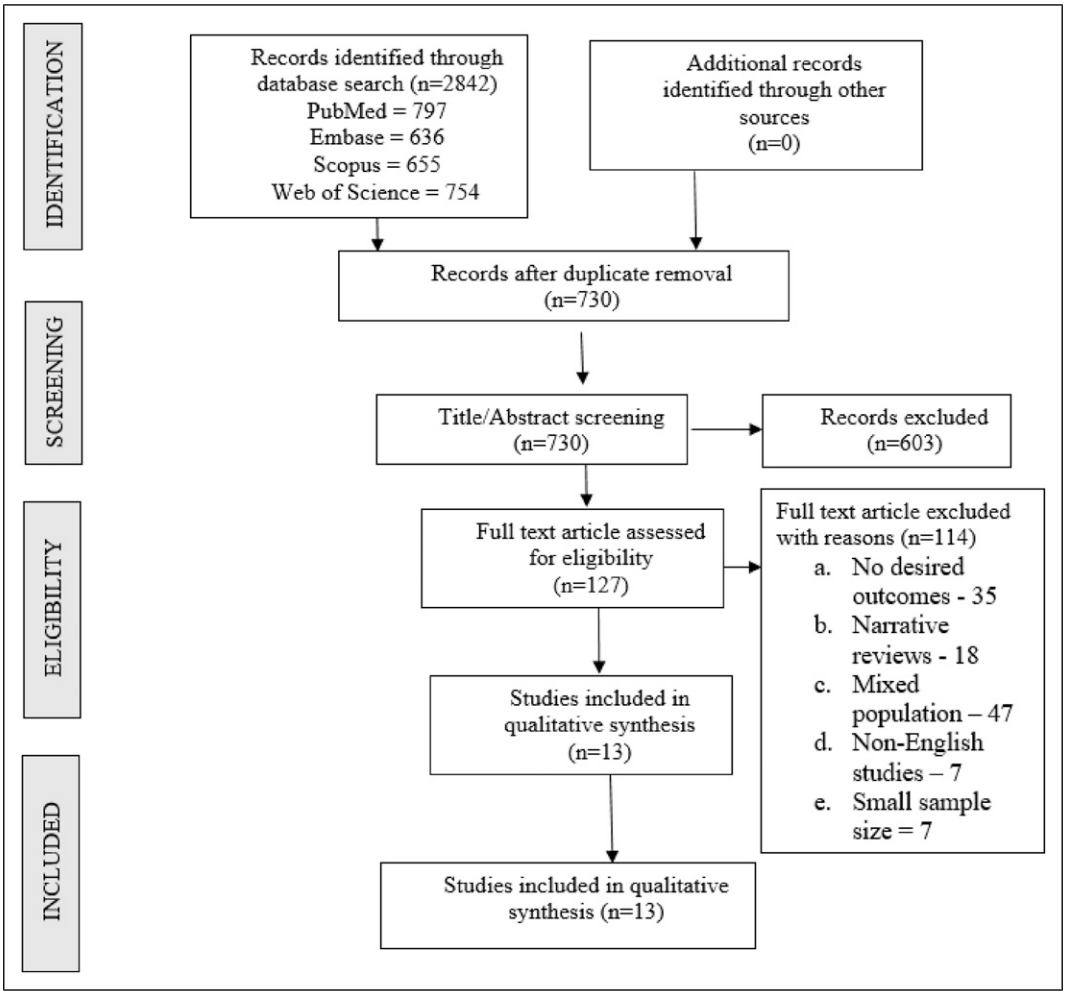


Figure 1. PRISMA flow diagram of inclusion of studies in the analysis

corresponds to a 58% relative reduction in SSI risk, particularly in high-risk cohorts such as multilevel fusion and patients with diabetes and obesity. Individual studies, such as Kramer et al[19] and Mehkri et al,[15] reported absolute risk reductions of 12-15%, and numbers-needed-to-treat (NNT) as low as 8 to prevent one SSI.

Wound Complications

Five studies reported data on wound complications, including dehiscence, seroma, and superficial breakdown. NPWT use was associated with a significant (49%) reduction in such events [OR = 0.51 (95%CI: 0.33-0.78) $P = 0.03$; $I^2 = 0\%$, low heterogeneity] as shown in Figure 2B. The most pronounced benefit was observed in the paediatric scoliosis cohort of Pérez-Acevedo et al,[16] where the complication rates significantly decreased from 38.5% to 7.7% ($P = 0.009$). These findings suggest that NPWT provides greater benefit in cases involving fragile soft tissue envelopes, extensive instrumentation or challenging wound geometry, resulting in enhanced incision integrity, lower dressing changes, and reduced nursing workload.

Reoperation Rates

Five studies provided reoperation data. The pooled effect did not reach statistical significance (OR = 0.68, 95%CI(0.39-1.18), $P = 0.05$; $I^2 = 57\%$) as shown in Figure 3A. Although several studies, including Vidalis et al,[17] reported fewer returns to the operating room in the NPWT group, the variability in the indications for reoperations, such as hardware failure, infection, neurological deterioration and other systemic parameters, likely diluted the pooled effect. While the data suggest that NPWT may reduce wound-related reoperations, its overall impact on global reoperation rates still remains inconclusive.

LOS

Three studies provided data on LOS. The pooled analysis revealed a non-significant trend towards shorter hospitalisation

Table 1. Study and Patient Characteristics From Studies Included in the Review

Study details	Study Design	Risk of bias (NOS/ ROB2)	Sample size (NPWT vs control)	Mean age (NPWT vs control)	Population/Surgery type	Intervention (NPWT details)	Comparator (standard dressing)	Male % (NPWT/ Control)	BMI or obesity rate (NPWT/ Control)	Comorbidities (key ones)	VAC pressure/duration
Adogwa et al (2014)/ USA/	RCS	Low	160 (46/114)	65.3 ± 11.2/ 63.3 ± 14.1	Long-segment thoracolumbar fusion (≥4 levels) for deformity correction	Incisional NPWT (−80 mmHg continuous, 3 days) post-closure	Standard dressing (Xeroform + gauze + tape)	34/28	28.4 ± 5.7/ 28.6 ± 6.8	HTN 67.9%, DM 17%, smokers 46.9%	−80 mmHg/3 days
Akhter et al (2021)/USA	RCS	Low	84 (42/42)	59.7 ± 9.4/ 57.5 ± 10.8	Posterior spinal fusion	PREVENA ciNPT post-closure	Standard occlusive dressing	47.6/ 47.6	~31/29	Obesity, DM, smoking controlled	−80 mmHg/7 days
Dyck et al (2019)/USA	PCS	Low	64 (21/43)	59 (mean)	Posterior lumbar interbody fusion (high-risk)	VAC device after closure	Standard dressing	NR	NR	Mixed comorbidities	−125 mmHg/5-7 days
Imtiaz et al (2024)/UK	RCS	Moderate	50 (50/5630)	32.7 (13-81)	Mixed spinal surgeries	PICO ciNPT (single-use)	Historical control	60	NR	ASA 1-3	−80 mmHg/6.7 ± 5.9 days
Kramer et al (2024)/USA	RCS	Moderate	229 (144/85)	61.8 ± 12.2/ 58.5 ± 11.5	Posterior instrumented spinal fusion	Closed-incisional NPWT (renasys Touch, −100-120 mmHg) until POD7 or discharge (~6.6 days)	Primapore adhesive dressing (POD2 removal)	54.9/ 43.5	31.7 ± 8.3/ 30.7 ± 8.5; obesity 55.6/ 50.6	DM 36.8/23.5; steroids 8.3/ 11.8; smokers ~32	−100 to −120 mmHg/ ~7 days
Mascarenhas et al (2023)/ USA	RCS	Low	71 (41/30)	14.3/14	Neuromuscular scoliosis (pediatric)	Incisional NPWT	Standard dressing	51/70	29.9 ± 7.4/ 27.2 ± 6.8	29.9 ± 7.4/27.2 ± 6.8	VAC (−125 mmHg assumed)/5-7 days
Mehkri et al (2023)/USA	RCS	Low	208 (96/112)	55.5 ± 17.4/ 49.8 ± 20.0	Posterior spinal fusion (trauma)	VAC post closure	Standard dressing	81/70	29.9 ± 7.4/ 27.2 ± 6.8	DM 8/22	VAC used; − pressure NR
Mueller et al (2021)/USA	PCS	Low	274 (118/156)	61.5 ± 11.4/ 63.6 ± 12.1	Open posterior spine surgery (degenerative, deformity, trauma)	Incisional NPWT −125 mmHg for 7 days	Standard island dressing (Telfa + Tegaderm)	55/48	32.2 ± 7.1/ 31.1 ± 7.5	DM 37, obesity 61.9, smokers 47	−125 mmHg/7 days
Naylor et al (2020)/USA	RCS	Moderate	469 (76/393)	NR	Instrumented fusion (anterior & posterior)	NPWT (V.A.C. −75 mmHg cont.) median 5 days	Primapore standard closure	NR	BMI ~29-31	DM, obesity, smoking, malignancy	−75 mmHg/5 days
Nordmeyer et al (2016)/ Germany	RCT	Moderate	20 (10/10)	52.3 ± 16.3/ 57.8 ± 15.2	Spinal fractures treated with fixation	PICO™ ciNPWT (−80 mmHg, 5 days)	Standard dry wound dressing	NR	NR	Normal coagulation	−80 mmHg/5 days

(continued)

Table 1. (continued)

Study details	Study Design	Risk of bias (NOS/ ROB2)	Sample size (NPWT vs control)	Mean age (NPWT vs control)	Population/Surgery type	Intervention (NPWT details)	Comparator (standard dressing)	Male % (NPWT/ Control)	BMI or obesity rate (NPWT/ Control)	Comorbidities (key ones)	VAC pressure/duration
Pérez-Acevedo et al (2024)/ Spain	RCT	Low	52 (26/26)	11.9 ± 3.2/ 12.0 ± 4.8	Pediatric non-idiopathic scoliosis	ciNPWT (−80 mmHg, 7 days)	Hydrofibre + hydrocolloid silver dressing	53.8/ 80.8	18.6 ± 5.1/ 20.1 ± 5.6	ASA II 42%/27%; ASA III 58%/ 73%	−80 mmHg/7 days
Vidalis BM et al (2022)/ USA	RCS	Moderate	42 (28/14)	65.2 ± 9.8/ 61.2 ± 14.3	Decompression ± stabilization for metastatic spine disease	Incisional NPWT (5 days)	Standard dressing (historical)	68/50	27.4 ± 5.4/ 30.3 ± 4.1 (P = 0.085)	27.4 ± 5.4/30.3 ± 4.1 (P = 0.085)	−125 mmHg/5 days
Woldesenbet et al (2025)/ USA	RCS	Low	266 (153/113)	56.4 ± 14.0	Posterior thoracolumbar/ lumbar surgery	PREVENA (−125 mmHg continuous, 1-2 weeks)	Standard dressing (pre-2014 care)	46/54	29.6 ± 7.2 (overall)	Tobacco 46.6%, DM 20.3%, steroids 13.5%, cancer 7.9%, HIV 2.6%	−125 mmHg/1-2 weeks

NPWT = Negative Pressure Wound Therapy; ciNPWT = Closed Incisional Negative Pressure Wound Therapy; VAC = Vacuum-Assisted Closure; PCS = Prospective cohort study; POD = Postoperative Day; RCS = Retrospective Cohort study; RCT = Randomized Controlled Trial; USA = United States of America; UK = United Kingdom; ASA = American Society of Anesthesiologists physical status classification; HTN = Hypertension; DM = Diabetes Mellitus; NR = Not Reported.

Table 2. Summary of Reported Outcome Measures in the Included Studies

Study details	Follow-up period (days)	Surgical site infection (n/N)	Wound complic-ation (n/N)	Reoperation (n/N)	Length of hospital stay (mean ± SD, days)	Readmission (n/N)	Time to wound healing (mean ± SD, days)	Patient-reported pain/ comfort	Important conclusions
Adogwa et al (2014)/USA/	90	5/46 vs 17/114 (P = 0.04)	3/46 vs 14/ 114 (P = 0.02)	6/46 vs 12/114 (P = 0.07)	7.29 ± 4.26 vs 8.08 ± 7.00 (P = 0.16)	9/46 vs 21/114 (P = 0.48)	NR	NR	↓ SSI & dehiscence; no LOS/readmission difference
Akhter et al (2021)/USA	30	0/42 vs 3/42 (P = 0.034)	3/42 vs 6/42	1/42 vs 3/42	NR	21.4% vs 21.4%	NR	NR	SSI ↓ significantly; no LOS/ readmission difference
Dyck et al (2019)/USA	365	2/21 vs 9/43 (10% vs 21%)	NR	Some infections reoperated	Median 16 days both	NR	NR	NR	Trend toward ↓ SSI; underpowered
Imtiaz et al (2024)/UK	30	2/50 (4%)	2/50 (4%)	0/50	NR	0/50	NR	NR	No difference vs historical; no return to theatre
Kramer et al (2024)/USA	540 (17.7 ± 18 months)	12/144 (8.3%) vs 18/85 (21.2%), P = 0.005	31/144 (21.5%) vs 29/85 (34.1%), P = 0.036	21/144 (14.6%) vs 21/85 (24.7%), P = 0.056	Mean LOS NR; SSI readmission LOS ≈8	All SSI readmitted	NR	NR	↓ SSI (−60.7%), ↓ dehiscence (−36.9%); NNT = 8; cost saving $21,662/SSI
Mascarenhas et al (2023)/ USA	90	2/41 vs 2/30	4/41 vs 5/30	NR	4.3 ± 1.2 vs 4 ± 1.5	NR	NR	NR	No difference; small pediatric sample
Mehkri et al (2023)/USA	90	8/96 (8%) vs 22/ 112 (20%), P = 0.021	NR	2/96 vs 8/112 (P = 0.089)	NR	NR	NR	NR	↓ SSI; cost savings $163,492/100 pts
Mueller et al (2021)/USA	60	4/118 (3.4%) vs 17/ 156 (10.9%), P = 0.02	NR	NR	No LOS difference	NR	NR	NR	↓ SSI esp. In instrumented; cost-effective high-risk
Naylor et al (2020)/USA	90	0/23 vs 3/15 (P = 0.01 ALIF); posterior 5.7% vs 5.6% (NS)	5.7% vs 5.6%	NR	NR	Similar	NR	NR	↓ SSI/dehiscence in anterior fusions
Nordmeyer et al (2016)/ Germany	10	NR	Seroma: 0 vs 1.9 mL (Day5); P = 0.0007	NR	NR	NR	NR	NR	↓ seroma volume, ↓ wound secretion, ↓ nursing time
Pérez-Acevedo et al (2024)/ Spain	180	0/26 vs 2/26 (deep SSI)	2/26 (7.7%) vs 10/26 (38.5%), P = 0.009	0 vs 2 implant removals	8.19 ± 10.13 vs 4.96 ± 8.51	NR	Median 7 days	NR	↓ SWC & cost; $1 NPWT → $12.93 saved

(continued)

Table 2. (continued)

Study details	Follow-up period (days)	Surgical site infection (n/N)	Wound complic-ation (n/N)	Reoperation (n/N)	Length of hospital stay (mean ± SD, days)	Readmission (n/N)	Time to wound healing (mean ± SD, days)	Patient-reported pain/ comfort	Important conclusions
Vidalis BM et al (2022)/USA	90	0/28 vs 3/14 (P = 0.032)	2/28 (7%) vs 0/14 (P = 0.545)	0/28 vs 3/14	10.8 ± 1.7 vs 12.4 ± 2.6 (P = 0.606)	NR	NR	NR	↓ deep SSI & dehiscence; more pre-op radiation tolerated
Woldesenbet et al (2025)/ USA	30	19/153 (12.4%) vs 16/113 (14.1%), P = 0.69	NR	NR	NR	NR	NR	NR	↓ SSI only in ≥2 comorbidity subgroup (P < 0.01)

SSI = Surgical Site Infection; LOS = Length of Stay; NR = Not Reported; SD = Standard Deviation; NNT = Number Needed to Treat; ALIF = Anterior Lumbar Interbody Fusion; SWC = Surgical Wound Complication; UK = United Kingdom; USA = United States of America.

in the NPWT group [MD = −1.05 days, 95% CI −2.16 to 0.07; P = 0.19, I^2 = 39%] as shown in Figure 3B. The studies by Adogwa et al[6] and Vidalis et al[17] reported modest reductions in LOS, particularly among patients with fewer wound complications. Although not statistically significant, these findings suggest potential resource savings and earlier mobilisation, especially within enhanced recovery protocols.

Readmissions

Readmission rates were inconsistently reported across the studies. The pooled OR was 0.76 (95% CI: 0.45-1.29), indicating no significant difference between groups. However, Kramer et al[19] noted that all SSI required readmission for operative treatment, emphasising the indirect role of NPWT in mitigating unplanned readmissions by preventing index wound infections.

Cost-Effectiveness

Two studies explicitly evaluated cost outcomes. Mehkri et al[15] reported a mean cost saving of $163,492 per 100 patients treated with NPWT, driven by reduced SSI-related interventions and prolonged hospitalisations. Pérez-Acevedo et al[16] demonstrated that each $1 spent on NPWT yielded $12.93 in downstream savings, primarily through reduced wound complications and material use. Preliminary data suggest that NPWT may offer economic value, particularly in high-risk and pediatric populations. However, these findings are highly context-dependent, influenced by health system structure, device acquisition cost, and definitions of SSI. They should be considered preliminary and hypothesis-generating until validated by larger, multicentric cost-effectiveness analyses.

Sensitivity and Publication Bias Analysis

Sequential exclusion of individual studies (sensitivity analyses) did not materially affect the direction or magnitude of pooled estimates, thereby confirming the stability of the results. Subgroup analyses demonstrated consistent benefit across study designs and NPWT pressure protocols. For protocols using −75 to −80 mmHg, the pooled OR was 0.19 (95% CI 0.12-0.80), indicating an 81% reduction in SSI risk as shown in Figure 4. Higher-pressure protocols (−100 to −125 mmHg) yielded an OR of 0.36 (95% CI 0.13-0.83), while studies with unspecified pressure settings had a pooled OR of 0.25 (95% CI: 0.09-0.54). Heterogeneity across all subgroups was minimal (I^2 = 0%), and no significant intergroup differences were observed (Q = 1.29, P = 0.52). These subgroup findings are exploratory and may be confounded by differences in device type, duration of application, and patient population. Therefore, no definitive conclusions can be drawn regarding pressure settings. Funnel plot and Galbraith plot inspection revealed mild asymmetry as shown in Figure 5, and Egger's test was non-significant (P = 0.34), indicating low risk of publication bias.

Table 3. Summary of Meta-Analysis Results From the Analysis of Outcomes in the Included Studies

Outcome	No. Of studies	Effect measure	Pooled estimate (95% CI)	Heterogeneity (I^2)	Interpretation
Surgical site infection (SSI)	12	Odds ratio	0.42 (0.28-0.63)	78%	58% reduction in SSI risk with NPWT
Wound complications (dehiscence, seroma)	5	Odds ratio	0.51 (0.33-0.78)	0%	49% reduction in wound-related events
Reoperation	6	Odds ratio	0.68 (0.39-1.18)	57%	Non-significant trend favouring NPWT
Length of stay (LOS; days)	3	Mean difference	−0.94 (−2.01 to 0.13)	39%	Non-significant shorter LOS
Readmission	4	Odds ratio	0.76 (0.45-1.29)	32%	Non-significant reduction
Cost-effectiveness	2	Cost ratio	$1 → $12.9 savings	-	Demonstrated economic benefit

SSI = Surgical Site Infection; LOS = Length of Stay; CI = Confidence Interval; NPWT = Negative Pressure Wound Therapy; OR = Odds Ratio.

Discussion

Principal Findings of Our Study

This systematic review and meta-analysis synthesising 13 clinical studies encompassing 7619 patients, demonstrates that prophylactic incisional NPWT significantly reduces the incidence of SSI and wound complications after primary spine surgery. The pooled OR for SSI (0.42, 95% CI: 0.28-0.63) translates to a 58% reduction, with consistent benefit across study designs and NPWT pressure settings. Furthermore, NPWT lowered the odds of wound-related complications by nearly half, while showing favourable trends towards shorter hospital stay and improved cost-effectiveness. Although reductions in reoperation and readmission rates did not reach statistical significance, these outcomes were directionally consistent, suggesting potential clinical benefit beyond infection control. Sensitivity and subgroup analyses confirmed the robustness of these findings, with no significant heterogeneity or publication bias. While NPWT is associated with reduced SSI and wound complications, the included studies span diverse procedures, patient risk profiles, and device protocols. Baseline risk factors such as obesity, diabetes, number of levels fused, instrumentation use, and operative duration varied across included studies. This heterogeneity limits generalizability, and routine use in standard degenerative spine surgery cannot be recommended at present. For clinicians, the current evidence suggests that prophylactic NPWT is most justified in high-risk patients—such as those undergoing multilevel fusion, deformity correction, oncology or trauma stabilisation, or those with obesity and diabetes. In routine degenerative spine surgery, the benefit remains uncertain, and NPWT should be considered selectively rather than universally.

Evolution of Prophylactic NPWT in Spinal Surgeries

Since its introduction in the 1990s, NPWT, also known as vacuum-assisted closure (VAC), has revolutionised the treatment of complex and non-healing wounds.[37,38] The protective effect of NPWT against SSI has been previously validated in high-risk surgical domains. Meta-analyses in cardiac, colorectal and orthopaedic (especially arthroplasty) populations have reported infection risk reductions ranging between 40 and 60%, mirroring the extent of benefit observed in the present analysis.[39,40] These consistent cross-speciality findings underscore a broadly-applicable biological mechanism of benefit rather than a procedure-specific effect. Diverse synergistic mechanisms have been collectively described to explain the efficacy of NPWT in promoting wound stability, perfusion and healing as shown in Table 4[41,42].

In recent years, incisional NPWT has been developed as a modification of the traditional open-wound system and increasingly adopted as a prophylactic measure in clean or clean-contaminated surgical wounds.[43,44] Such an approach has especially been recommended in situations involving complex wound situations in spinal surgeries, such as obese individuals, wounds with high tension across the sutures, or long-segment posterior constructs (involving extensive dissection of the paraspinal musculature).[45-49]

Early Clinical Evidence in Spine Surgery

Previous studies have demonstrated the clinical benefit of NPWT in spine procedures. In the study by Adogwa et al,[6] there was a 50% reduction in wound dehiscence ($P = 0.02$) and 29% lower SSI rates ($P = 0.04$) following the use of prophylactic NPWT in long-segment TL fusion. In 2019, Dyck et al[5] observed SSI reduction from 21% to 10% in posterior spinal fusion for high-risk patients [significantly higher malnourishment ($P = 0.02$), longer surgical procedures ($P < 0.001$) and longer postoperative ICU admissions ($P = 0.039$) in the NPWT group]. In 2021, Akhter et al[33] confirmed that when NPWT protocols were employed following posterior spinal fusion, the SSI rates were substantially mitigated ($P = 0.035$). There was significantly lower rate of superficial dehiscence, seroma formation, as well as a lower need for additional outpatient care or operative revision in the NPWT group. Naylor et al[1] observed complete elimination of

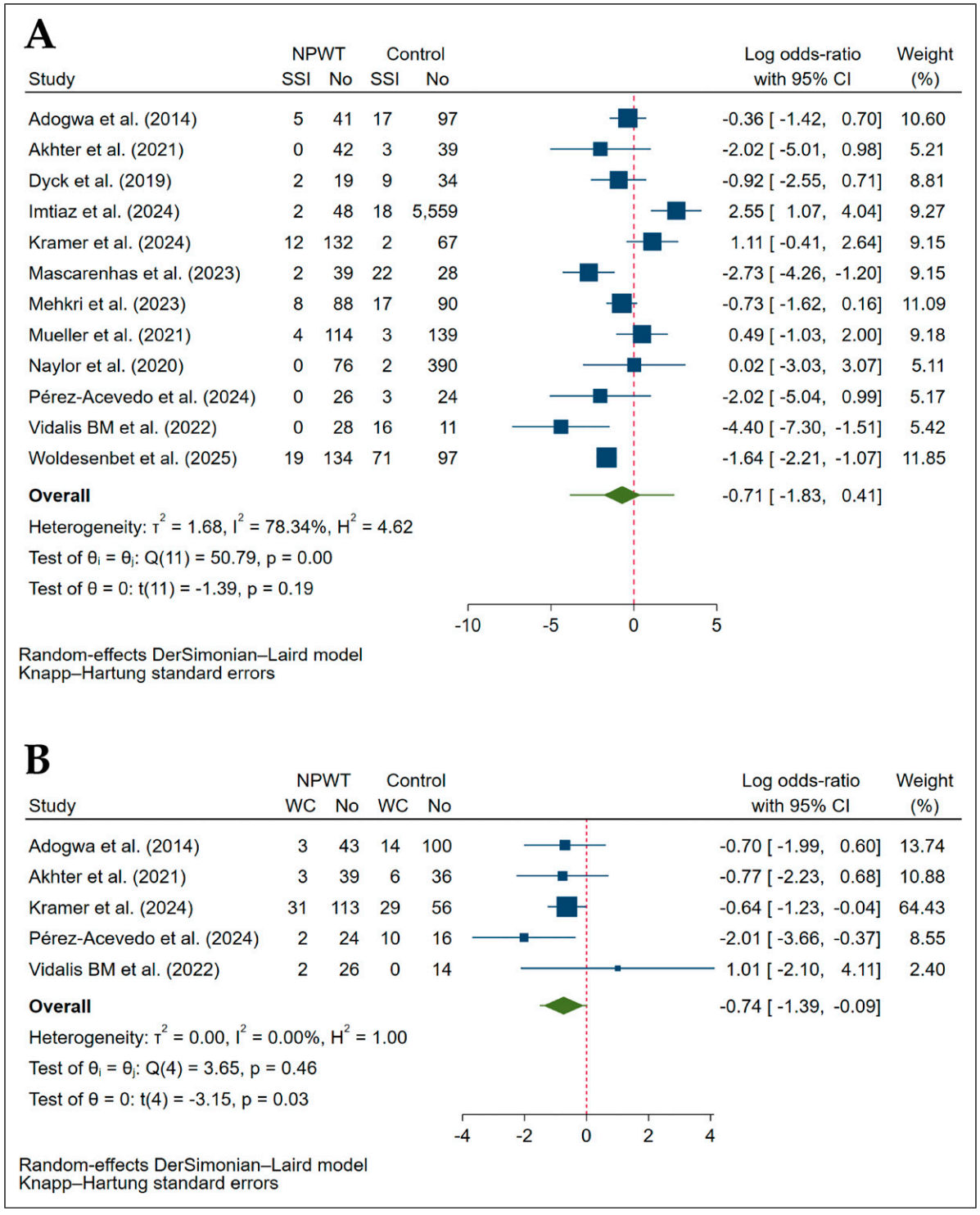


Figure 2. Forest plot of analysis of (A), surgical site infection and (B), wound complication outcomes in the included studies

dehiscence and SSI following the use of NPWT after anterior lumbar fusion surgeries [wound dehiscence or SSI in 3/15 (20%) patients in non-NPWT vs 0/23 (0%) in NPWT group]. They highlighted that NPWT was preferentially more utilised in patients at high risk for wound-related complications (such as spinal neoplasia, osteomyelitis or discitis, revision surgery and longer constructs).

In the study by Vidalis et al,[17] NPWT demonstrated a 0% incidence of SSI in metastatic spine disease (as against 21% in the

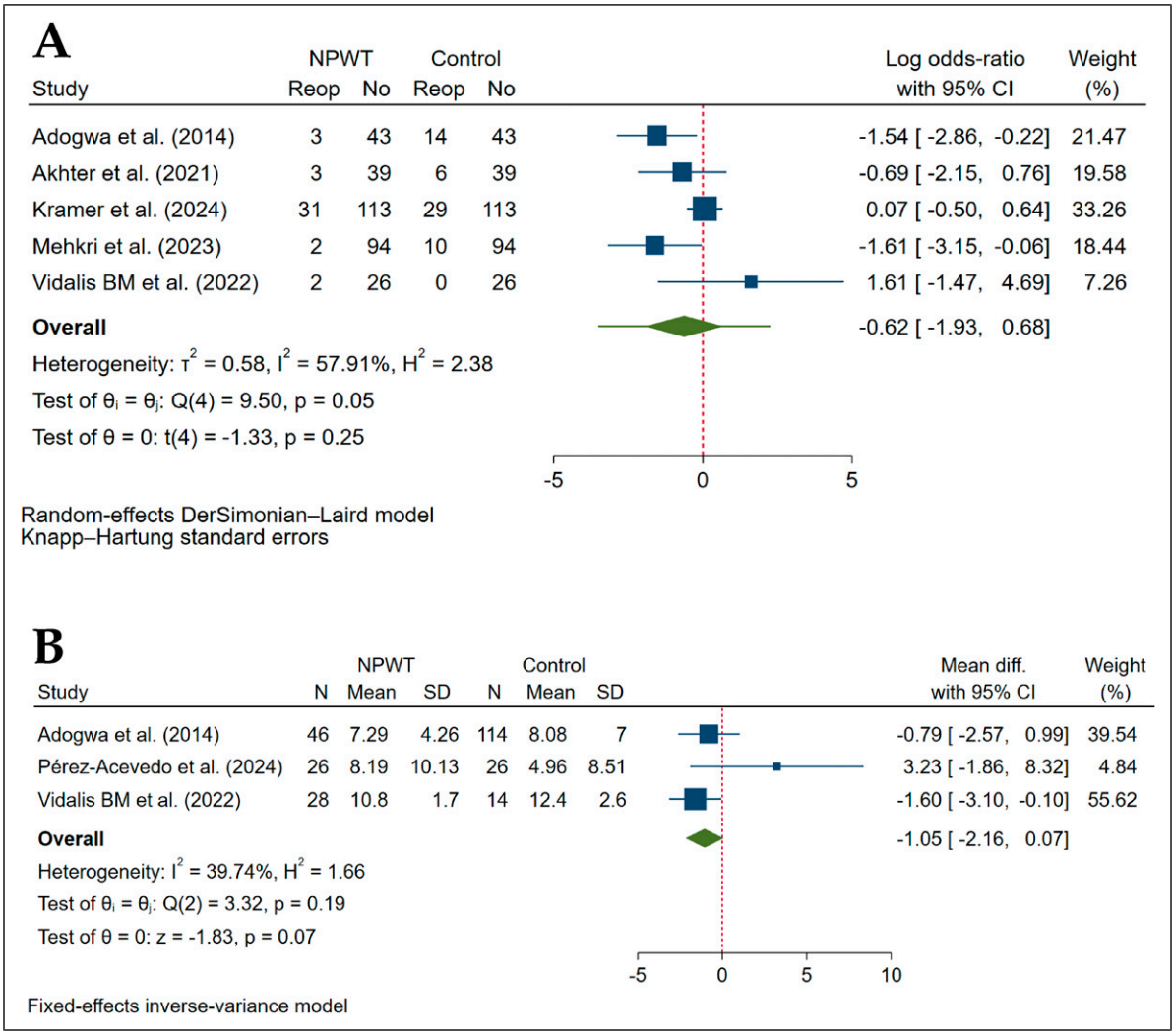


Figure 3. Forest plot of analysis of (A), reoperation rates; (B), length of stay outcomes in the included studies

non-NPWT group), despite prolonged radiation exposures and longer constructs. In the study by Mehkri et al,[15] the annual cost savings of $163,492 per 100 patients were reported, emphasising its health-economic benefit. Beyond infection rate reduction, the randomised data by Nordmeyer et al[3] (2016) in spinal trauma fixation patients suggested significant reductions in postoperative seroma volume [0 mL vs 1.9 mL on day 5 ($P = 0.0007$); and 0.5 mL vs 1.6 mL on day 10 ($P < 0.024$)], dressing material requirement (total number of compresses: 11 ± 3 vs 35 ± 15; $P = 0.0376$); and dressing/wound-care time (31 ± 10 vs 13.8 ± 6 minutes; $P = 0.0005$), thereby validating the practical efficacy of the procedure. The first RCT by Perez-Acevedo et al[16] in pediatric patients demonstrated a 5-fold reduction in surgical wound complications (7.7% 38.5%, $P = 0.009$) after scoliosis correction surgeries, with $12.93 savings for every $1 spent on NPWT. In another recent retrospective review by Woldesenbet et al,[2] NPWT was demonstrated to be particularly effective in patients with multiple comorbidities ($P < 0.01$), emphasising the role of tailored use in high-risk populations. In the most up-to-date systematic review and meta-analysis by Rathore et al,[47] a 55% reduction in SSI risk (OR 0.45, 95% CI 0.29-0.72; $P < 0.001$) and near-significant reduction in dehiscence rates (OR 0.53, 95% CI 0.26-1.06; $P = 0.07$), thereby supporting its prophylactic adoption in posterior spinal surgeries.

Current Evidence and Gaps in the Literature

The evidence regarding prophylactic NPWT specific to spine surgery is largely heterogeneous and fragmented.[1,3,6,15,16,31,33,35,36,40,42,45-47,49] The initial studies were limited by small sample sizes, non-randomised study designs and inclusion of mixed populations (trauma, revision, and trauma surgeries), thereby limiting the generalizability of the results. In addition, variations in the NPWT systems PREVENA, PICO, or VAC), negative pressure settings (−75 to −125 mmHg), and durations of application have made direct comparisons challenging. While some studies have demonstrated marked reductions in wound dehiscence

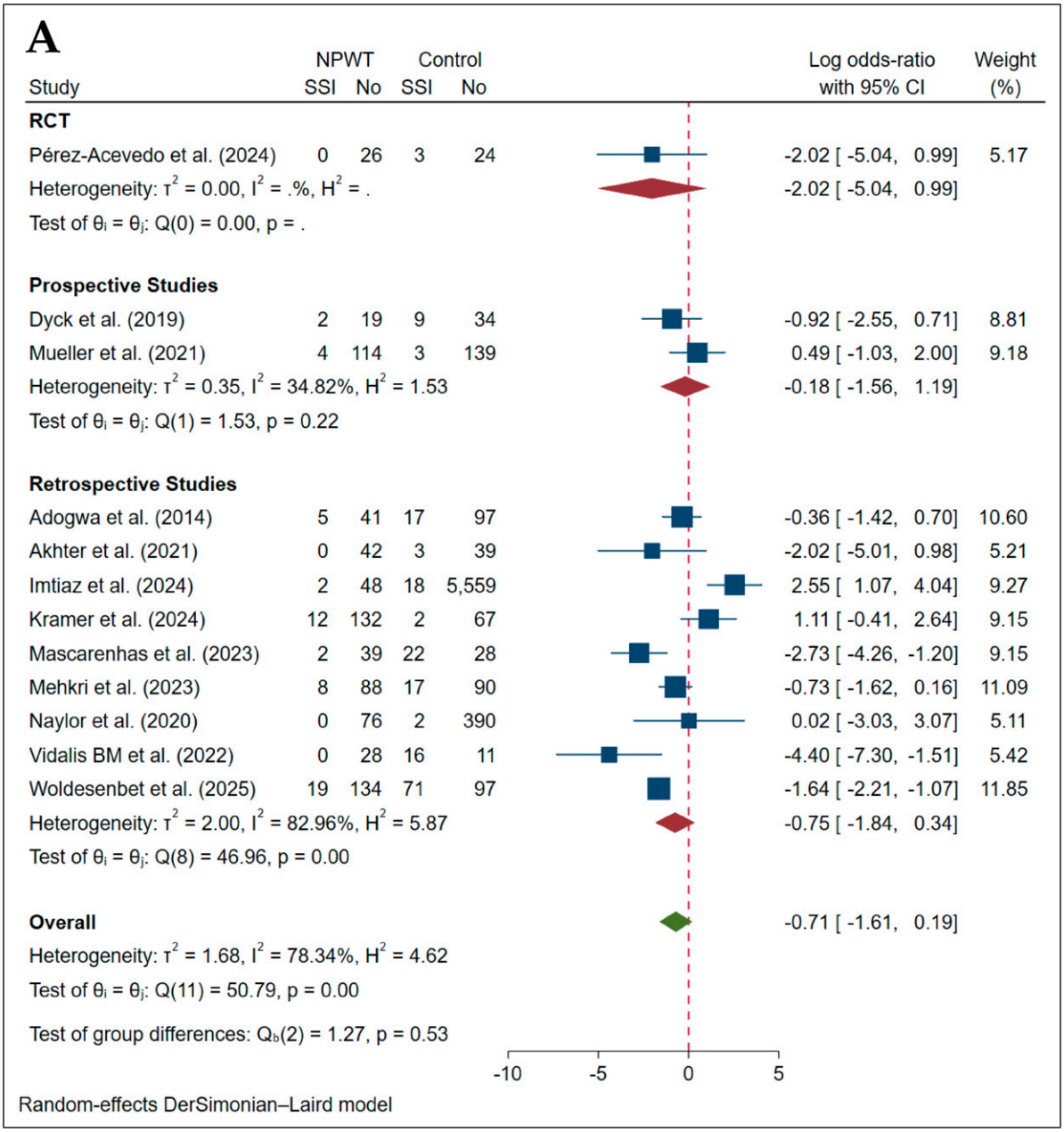


Figure 4. Subgroup analysis of SSI outcome based on (A), Study design of the included studies, and (B), pressure utilized in the NPWT systems in the included studiess

and SSI, particularly in high-risk or spinal deformity surgeries[6,19]; other studies failed to demonstrate a statistically significant difference in comparison with the standard wound dressings.[31,34,35] These inconsistencies fuelled the ongoing debate on whether the NPWT must be routinely employed as an adjunct or only reserved for select high-risk scenarios.

Another critical gap regarding prophylactic NPWT pertains to its economic and practical feasibility. Although incisional NPWT devices entail higher initial expenditure than conventional dressings, early data suggest that they may reduce the overall expenditure by preventing costly wound-related complications, reoperations, and extended hospital stays.[15,16] However, only a few studies have quantified the cost-effectiveness of NPWT in the context of spine surgeries. The findings on this subject are broadly inconsistent due to variations in the healthcare systems and individual study designs, and paucity of standardised guidelines within the spine community.[50,51] Some of the earlier analyses also combined the therapeutic (infection management) and prophylactic (infection prevention) use of NPWT, thereby confounding the pooled estimates.

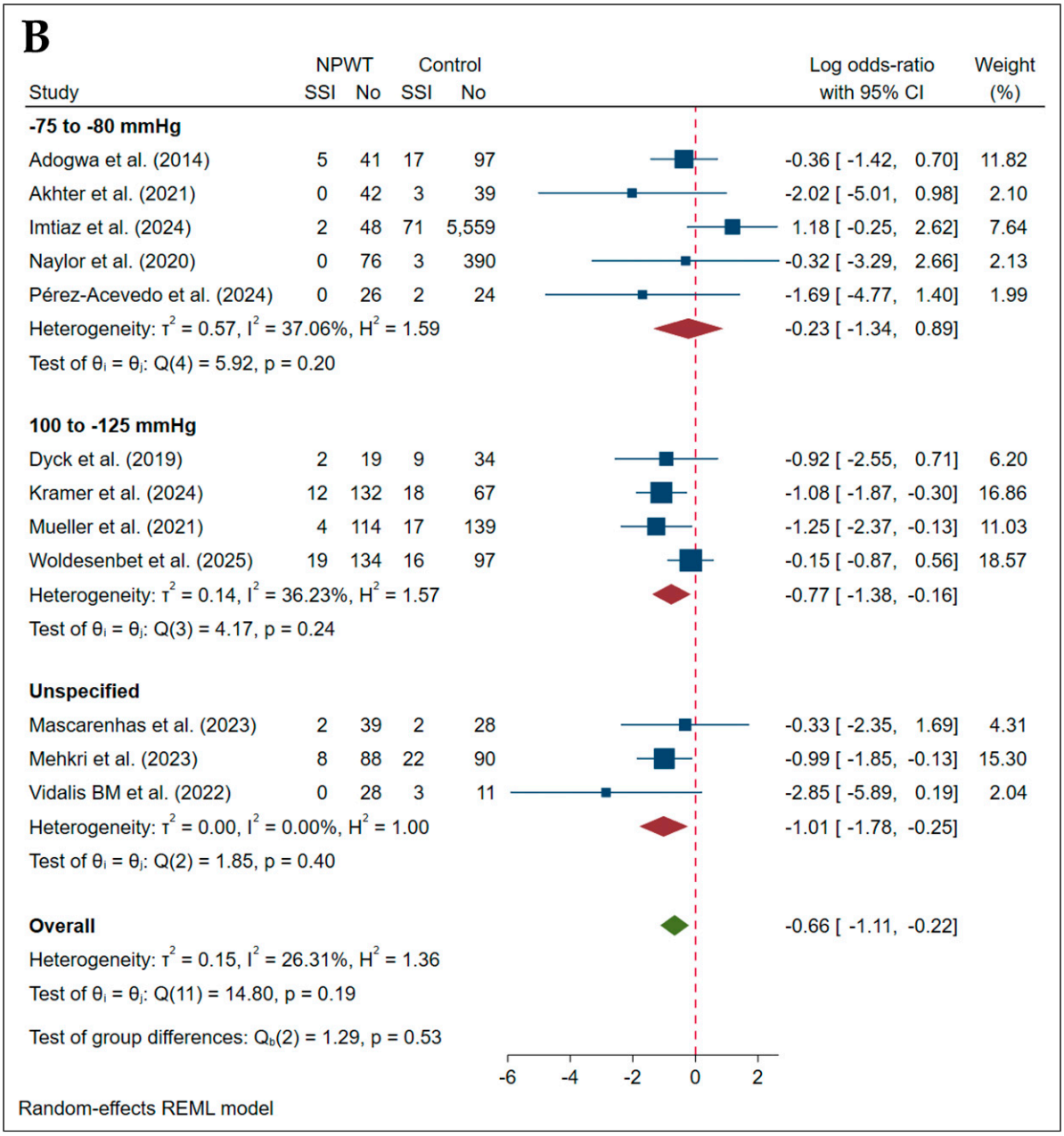


Figure 4. Continued.

The current review was designed to incorporate high-quality RCTs and prospective cohort studies (including studies on both adult and pediatric populations) and provide novel insights into the applicability of NPWT across age groups and surgical indications.

Differences from Prior Spine-specific Studies

The pooled OR (0.42) observed in our study was significantly lower than that for prior spine-specific analyses (where the OR ranged between 0.50 and 0.65). This could be attributed to the recent studies with standardised NPWT protocols (PREVENA or PICO systems) and earlier postoperative application, which may have amplified the overall efficacy. In addition, the present study stratified the results based on pressure settings (−75mmHg to −125mmHg), demonstrating a consistent advantage across subgroups, thereby addressing prior ambiguity regarding optimal suction settings as shown in Table 5.

Clinical Implications of Our Study

The findings of our review have significant implications for perioperative wound management in patients undergoing spine surgery. Routine prophylactic NPWT may not be

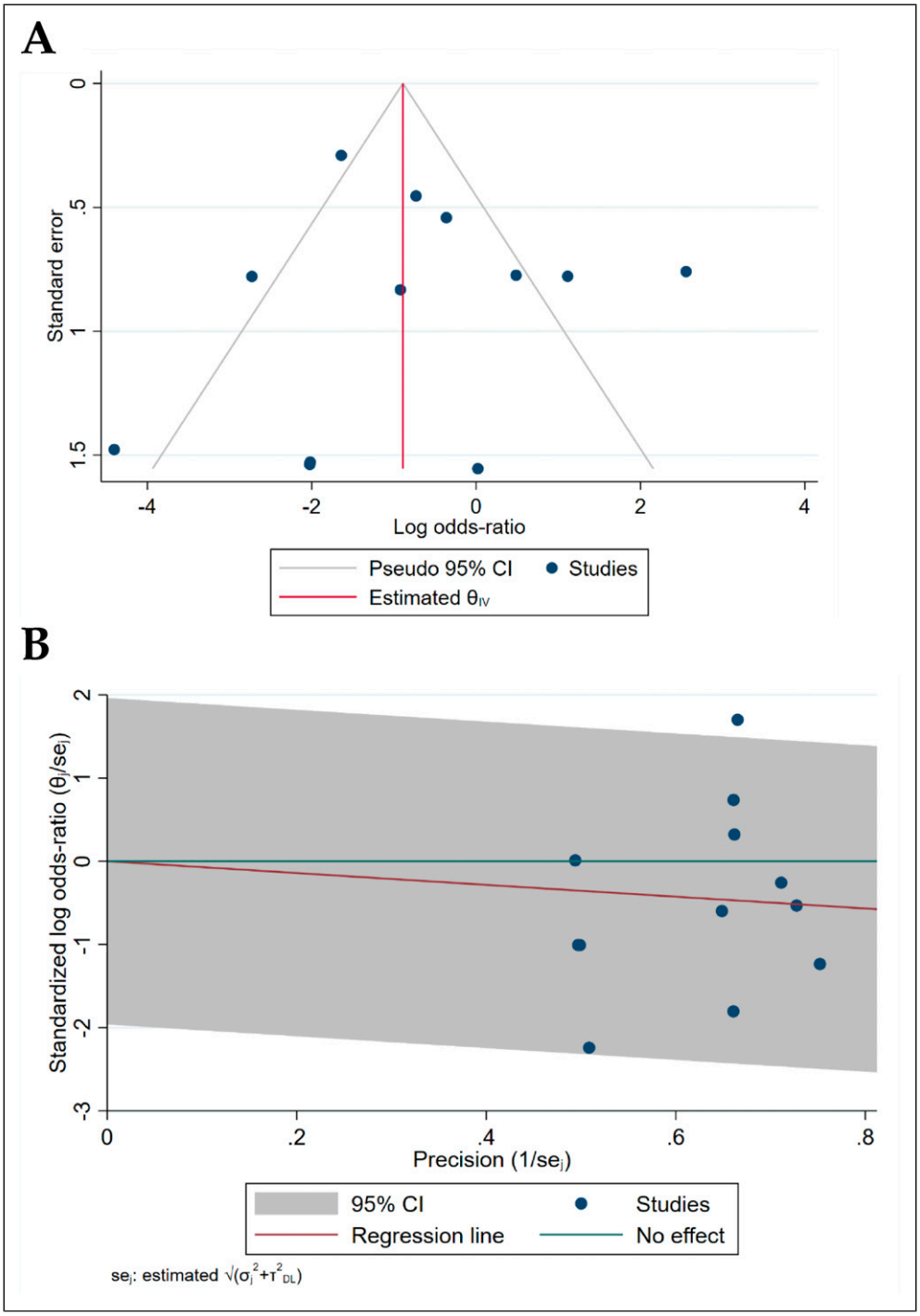


Figure 5. (A) Funnel plot, and (B), Galbraith plot of SSI outcomes in the included studies

necessary for all patients; however, its use is justified in high-risk subgroups such as those undergoing deformity correction, multilevel fusions, revision surgery, prolonged procedures, or in individuals with diabetes and elevated body mass index (BMI >30), where maximal cost-effectiveness can be achieved. Our analysis also indicates comparable efficacy between −80 and −125 mmHg settings, suggesting that lower-pressure systems (such as PICO) may deliver similar benefits while improving patient comfort and reducing device-related issues like skin irritation or leakage alarms. However, these subgroup analyses are exploratory, underpowered, and likely influenced by confounding factors such as device type, application duration, and surgical indication. Thus, the inference of pressure-independent efficacy should be considered

Table 4. Rationale for Prophylactic NPWT in Post-spinal Surgery Wounds

Micro-deformation and mechanical tension offloading	• NPWT exerts uniform sub-atmospheric pressure across the incision line → minimising the lateral tension and micromotion between the wound edges • his mechanical offloading limits the shear stress on newly-developed capillaries → promotes early epithelialization and mitigates wound dehiscence
Improved perfusion and lymphatic drainage	• NPWT enhances local perfusion by up to 40% by mitigating hypoxia and reducing interstitial edema
Exudate control and reduction of infective burden	• By delivering continuous suction, NPWT removes serous fluid and hematoma → reduces bacterial proliferation and local inflammation • The closed system provides an impermeable barrier to exogenous contamination, critical in spinal wounds with extensive dead spaces
Enhanced granulation and modulation of cytokine activity	• NPWT upregulates VEGF, FGF-2 and IL-8 expression → promotes angiogenesis and fibroblast proliferation • Resultant granulation tissue functions as a biological scaffold and supports greater restoration of wound strength and closure
Reduction in nursing interventions	• NPWT dressings maintain a stable microenvironment for 5-7 days (unlike conventional dressings which require regular changes) → thereby decreases dressing-related trauma, nursing time → improves patient comfort and early mobilization

NPWT = Negative Pressure Wound Therapy; VEGF = Vascular Endothelial Growth Factor; FGF-2 = Fibroblast Growth Factor-2; IL-8 = Interleukin-8.

hypothesis-generating rather than definitive. Furthermore, NPWT can be integrated into Enhanced Recovery After Surgery (ERAS) pathways as part of multimodal strategies to mitigate perioperative complications. From an economic perspective, cost analyses demonstrate substantial savings primarily through avoided SSI-related reoperations and shortened hospital stays. Although NPWT systems entail higher upfront expenditure compared to standard dressings, modelling shows breakeven thresholds with as little as a 4-5% reduction in SSI incidence. The observed 58% relative reduction far exceeds this threshold, thereby confirming the financial viability of NPWT in most institutional contexts.

Interpretation of Secondary Outcomes

Reoperations and Readmissions

Although the pooled estimates did not achieve statistical significance, both reoperations and readmissions trended lower in the NPWT group. Given the small absolute event numbers and multifactorial aetiology of these endpoints, the lack of statistical difference is possibly attributable to limited power rather than the absence of effect. Importantly, nearly all readmissions in standard dressing groups were precipitated by wound infections, suggesting that indirect benefits of NPWT may still manifest through downstream resource utilisation.

Table 5. Value Addition of the Current Review Compared to the Earlier Review in the Literature on Prophylactic NPWT

Dimension	Earlier reviews	Current review (2025)
Scope of inclusion	Limited to fusion procedures (Chen et al, Lambrechts et al) or retracted datasets (Liu et al.)	Includes 13 studies spanning fusion, deformity, trauma, and pediatric cases, providing the broadest dataset to date
Study designs	Mostly retrospective	Incorporates 2 RCTs, 2 prospective cohorts, 9 retrospective → higher strength of evidence
Analytical model	Fixed-effects; limited heterogeneity handling	Random-effects with DerSimonian–Laird τ^2 + knapp–Hartung correction, improving small-sample accuracy
Outcomes assessed	Focused primarily on SSI	Expands to wound complications, reoperation, LOS, readmissions, cost-effectiveness
Subgroup analyses	Absent	By NPWT pressure (−75 vs −125 mmHg), design, indication (trauma/deformity/paediatric)
Publication bias	Rarely examined quantitatively	Funnel plot + Egger's test (P = 0.34) demonstrate minimal bias
Clinical translation	General statements	Provides NNT (8), cost savings ($163k–$270k/100 patients), and practice algorithm for high-risk cohorts
Novel contribution	Evidence that NPWT reduces SSI	Demonstrates consistent SSI and wound-complication reduction across indications, validates economic and clinical benefit, and defines optimal pressure and duration

NPWT = Negative Pressure Wound Therapy; RCT = Randomized Controlled Trial; SSI = Surgical Site Infection; LOS = Length of Stay.

LOS

On a similar note, although the mean reductions in LOS approached one day, this difference was not statistically significant. However, in high-cost health care systems, even modest reductions translate to substantial economic savings, especially when coupled with mitigated infection-associated readmissions. The importance of future RCTs on this subject, incorporating cost-utility analyses, LOS, reoperations and patient-reported recovery metrics cannot be understated.

NPWT lowered the odds of wound-related complications by nearly half. However, reductions in reoperation, readmission, and LOS did not reach statistical significance, and therefore the evidence for these secondary outcomes remains inconclusive. These findings suggest possible benefit but should be interpreted cautiously until validated by larger prospective studies.

Limitations of the Review

Several limitations warrant cautious interpretation of our findings. The majority of included studies were retrospective, which may introduce selection and reporting bias despite efforts to control for confounders. The surgical populations were heterogeneous, ranging from single-level fusions to extensive deformity corrections; while this enhances external validity, it limits precision in estimating indication-specific outcomes. Variability in NPWT devices and protocols, including differences in dressing types (PICO vs PREVENA vs VAC), suction pressures, and duration of application, could also contribute to residual heterogeneity. Cost-effectiveness analyses were restricted to two studies with variable frameworks, underscoring the need for unified economic evaluations across healthcare systems to validate financial claims. Furthermore, most studies reported only early postoperative outcomes (<30 days), leaving the long-term impact of NPWT on delayed wound complications, pseudomeningocele formation, or scar cosmesis incompletely evaluated. Although NPWT was consistently associated with reduced SSI across included studies, the certainty of evidence remains limited. The majority of studies were retrospective, introducing risk of selection bias and confounding. Furthermore, substantial heterogeneity in surgical indications and NPWT protocols reduces confidence in the generalizability of pooled estimates. Taken together, the certainty of evidence can be considered low to moderate, and these findings should be interpreted as supportive associations rather than definitive proof of efficacy.

Future studies on this subject must focus upon conducting large-scale, multi-centred, RCTs stratified by surgical indications (such as deformity vs trauma vs degenerative), and standardising NPWT protocols (duration, pressure and timing). Further, evaluating cost-effectiveness based on unified economic models, integrating patient-reported outcome measures (PROM), and exploring the role of incisional NPWT with instillation therapy or hybrid antimicrobial interfaces in high-risk or contaminated cases also remains a priority.

Conclusions

This systematic review and meta-analysis indicate that prophylactic NPWT is associated with lower SSI and wound complication rates in spine surgery. However, the certainty of evidence is limited by the predominance of retrospective designs, heterogeneity in surgical indications and NPWT protocols, and selective application in higher-risk cohorts. Secondary outcomes such as reoperation, readmission, and LOS remain inconclusive, and cost-effectiveness findings are preliminary. For clinicians, NPWT may be most justified in high-risk patients—such as those undergoing multilevel fusion, deformity correction, oncology or trauma stabilisation, or those with obesity and diabetes—while its role in routine degenerative surgery remains uncertain. Future multicentric RCTs with standardised protocols and economic analyses are essential to define their broader applicability.

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Author Contributions

Dr SMuthu and Dr VKV contributed to the conceptualization and design of the research goals and aims. Dr SMuthu developed the methodology and statistical framework. Dr SM, DVKP carried out the data collection. Data validation and ensuring the accuracy of results were undertaken by Dr SMuthu and Dr VKV. Dr SMuthu secured the necessary resources for the study, and Dr BP curated and organized the study data. Writing the original draft of the manuscript was managed by Dr SMuthu, with Dr VKV providing critical revisions and editing. Visualization and creation of figures were executed by Dr SMuthu. Supervision and coordination of the project were led by Dr SMuthu. Dr KS, Dr SRRM, Dr ST and Dr SKRC helped in the revision of the manuscript. All the authors approved the final version of the manuscript.

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Data Availability Statement

Data generated in the study will be made available upon reasonable request to the authors.

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