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Prophylactic negative pressure wound dressings reduces wound complications following emergency laparotomies: A systematic review and meta-analysis

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ABSTRACT

Background: Wound complications are a common cause of postoperative morbidity and incur significant healthcare costs. Recent studies have shown that negative pressure wound dressings reduce wound complication rates, particularly surgical site infections, after elective laparotomies. The clinical utility of prophylactic negative pressure wound dressings for closed emergency laparotomy incisions remains controversial. This meta-analysis investigated the rates of wound complications after emergency laparotomy when a negative pressure wound dressing was applied.

Methods: A systematic review and meta-analysis were performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. PubMed, Embase, Cochrane Registry, Web of Science, and Clinialtrials.gov databases were searched from January 1, 2005, to April 1, 2022. All studies comparing negative pressure wound dressings to standard dressings on closed emergency laparotomy incisions were included.

Results: A total of 1,199 (negative pressure wound dressings: 566, standard dressing: 633) patients from 7 (prospective: 4, retrospective: 3) studies were identified. Overall, the surgical site infection (superficial/deep) rate was 13.6% (77/566) vs 25.1% (159/633) in the negative pressure wound dressing versus standard dressing groups, respectively (odds ratio 0.43, 95% confidence interval 0.30–0.62). Wound breakdown (skin/fascial dehiscence) was significantly lower in the negative pressure wound dressing (7.7%) group compared to the standard dressing (16.9%) group (odds ratio 0.36, 95% confidence interval 0.19–0.72). The incidence of overall wound complications was significantly lower in the negative pressure wound dressing (15.9%) group compared to the standard dressing (30.4%) group (odds ratio 0.41, 95% confidence interval 0.28–0.59). No significant differences were found in hospital length-of-stay and readmission rates.

Conclusion: Prophylactic negative pressure wound dressings for closed emergency laparotomy incisions were associated with a significant reduction in surgical site infections, wound breakdown, and overall wound complications, thus supporting its clinical use.

Amar Lakhani and Wael Jamel are joint first authors.

Author contributions: AL: data collection, analysis, interpretation, manuscript drafting and final approval. JW: data collection, analysis, interpretation, manuscript drafting and final approval. GER: study design, data interpretation, manuscript drafting and final approval. CSC: study design, data analysis, interpretation, manuscript drafting and final approval. SS: study design, data interpretation, study supervision, manuscript drafting and final approval. DSL: study conceptualization, design, data interpretation, study supervision, manuscript drafting and final approval.

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Introduction

Surgical site infections (SSI) are common and incur significant healthcare costs.[1,2] Emergency surgery increases the risk of SSI by 500%.[3] Wound complications include SSI (both deep and superficial), wound dehiscence, and hematoma and seroma formation.[4] Despite the use of prophylactic antibiotics,[5] wound lavage,[6] and novel strategies to reduce SSI—such as innovative closure techniques and tissue repair stimulants—the rate of SSI has remained high in emergency general surgery.[7] Recently, evidence has emerged suggesting that negative pressure wound dressings (NPWD) applied prophylactically on closed incisions may significantly reduce the risk of SSI after emergency and elective general surgery.[8] Whilst high-level evidence supports the use of NPWD in the elective general surgical setting,[8] there is a lack of consensus to support its use in the emergency general surgery setting.[9]

Although randomized controlled trials (RCTs) report conflicting evidence for the efficacy of prophylactic NPWD in reducing SSIs after elective general surgery,[10,11] recent meta-analyses of these studies have shown that NPWD successfully reduces the risk of SSI in this cohort.[12,13] In general, NPWD applies 70 to 125 mmHg of negative pressure to a closed wound. These devices are purported to act by removing the excess fluid and affecting the inflammatory milieu within the subcutaneous space.[14] This is hypothesized to promote wound healing and reduce the risk of wound complications by facilitating the formation of healthy granulation tissue, promoting angiogenesis and fibroblast infiltration, whilst removing any wound contaminants.[14]

Emerging literature suggests that prophylactic use of NPWD after emergency laparotomies may also reduce SSI.[4,15-17] This finding, however, is not consistently seen across all studies.[18-20] This discrepancy may be partly explained by studies being underpowered and heterogenous in their patient population, particularly with respect to the extent of wound contamination, underlying pathology, and operative approach. Currently, several RCTs are investigating the utility of prophylactic NPWD for closed emergency laparotomy wounds.[21,22] Moreover, all systematic reviews and meta-analyses on this topic have so far reported on outcomes after elective laparotomies or contain a mixture of elective and emergency cases. No meta-analysis has specifically focused on the emergency-only cohort.

The aim of this study is to systematically review and meta-analyze the presently available data addressing the efficacy of NPWD in reducing rates of SSI and other wound complications amongst patients undergoing emergency laparotomy.

Methods

Study identification

A systematic review and meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines was performed.[23] A comprehensive search was conducted of PubMed, Web of Science, Cochrane Central Registry of Controlled Trials, Embase, and Clinicaltrials.gov to identify eligible studies published between January 1, 2005, and April 1, 2022. The search commenced from 2005 since this was the first recorded use of prophylactic NPWD. The search terms included the following: 'negative pressure wound therapy,' 'negative pressure wound dressing,' 'npwt,' 'npwd,' 'npd,' 'npt,' 'pico,' 'prevena,' 'laparotomy,' 'abdominal wound,' and 'abdominal incision.' Publications titles, abstracts, and full-text articles were screened independently by 2 authors (AL and WJ) using the Endnote version 8 (Clarivate) software, and duplicate reports were removed. Reference lists of included articles were also inspected to identify any additional studies. Any discrepancies were resolved by consultation with senior authors (SS and DSL). Duplicate studies were erased, and titles as well as abstracts were screened to identify the included studies (Fig 1).

Eligibility criteria

Eligible studies included those published in all languages that compared the use of NPWD to standard dressings on closed emergency laparotomy incisions. Eligible studies must have reported the rate of SSI. Exclusion criteria included the following: noncomparative studies, elective laparotomies, nonlaparotomy wounds, and absence of SSI as an endpoint. For studies that included a mix of elective and emergency laparotomies, they were included in the final meta-analysis if the emergency cohort and their associated outcomes could be extracted from their overall dataset. Human Research Ethics Committee approval was not required.

Outcomes

The primary outcome of this meta-analysis was the rate of SSI. Secondary outcomes included wound breakdown (superficial and fascial dehiscence), wound collection (hematoma and seroma), all wound complications, length-of-stay, 30-day reoperation rate, Clavien-Dindo complication, frequency of dressing changes, admission to high dependency or intensive care unit, wound-related hospital readmission, and 30-day mortality.

Data extraction

Data were extracted independently by 2 authors (AL and WJ) from selected studies using a data-entry spreadsheet created *a priori*. Both authors cross-checked their data with the primary source and then verified again by a third author (CC) before committing to meta-analysis. Any discrepancies were resolved by senior authors (SS and DL). Extracted data points included author, country, year published, study design, number of patients in control and treatment arms, intervention, follow-up duration, as well as primary and secondary endpoints.

Statistical analysis

Statistical analysis was performed using Review Manager software (version 5.4. The Cochrane Collaboration). The random effects model was used to calculate pooled odds ratios (OR) for primary and secondary outcomes. Study heterogeneity was assessed using I^2, and >50% was considered significant heterogeneity.

Assessment of bias

Included studies were assessed for bias by 2 authors (AL and WJ) using the Methodological Index for NOn-Randomized Studies (MINORS) score.[24] The MINORS tool allocates scores across a variety of categories to assess study quality. The highest possible score is 24. Studies included in this meta-analysis achieved scores between 17 and 22 (Supplementary Table S1).

Results

Of the 8,314 abstracts and titled screened, 8,230 reports were excluded based on these studies bearing no relevance to the use of NPWD in patients undergoing emergency laparotomy. Of the remaining 34 reports, 27 were not included in the final meta-analysis. The reasons for this are detailed in Figure 1. In total, 7

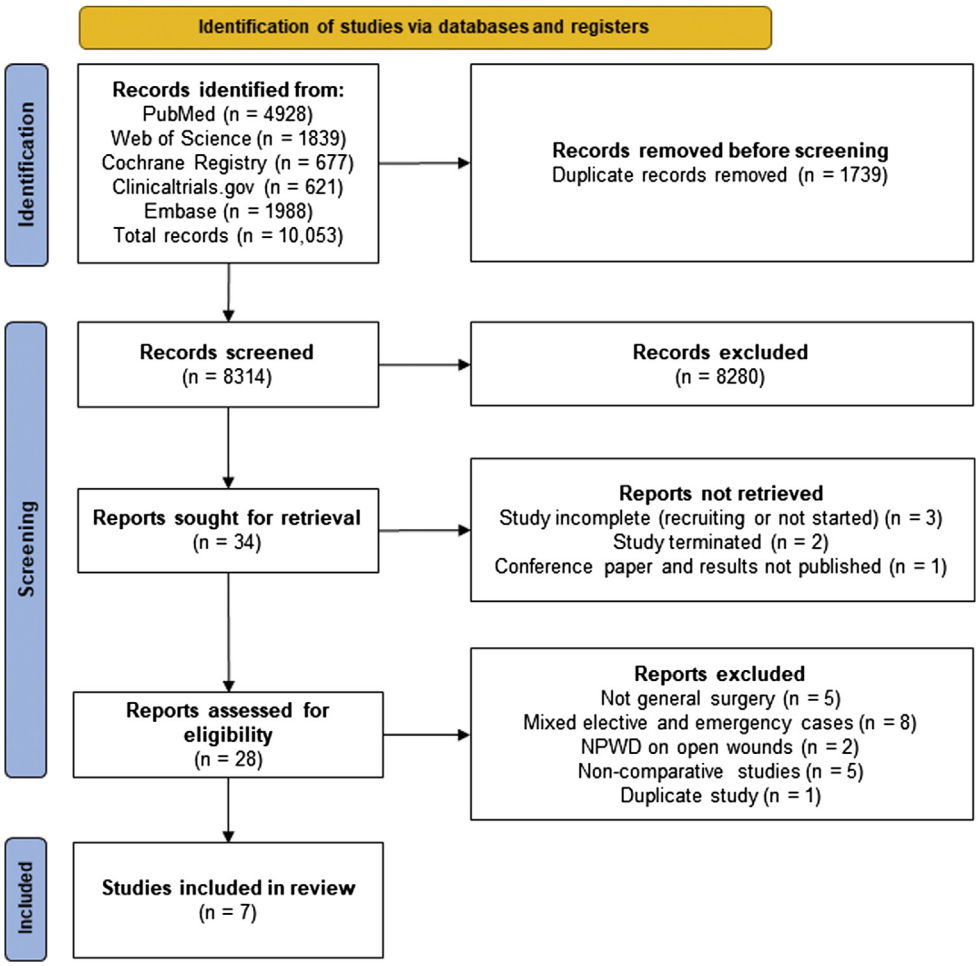

Fig 1. Prisma flowchart.

studies met the inclusion criteria for the systematic review and meta-analysis (Table I). Eligible studies included 2 RCTs,[19,20] 2 prospective cohorts,[15,18] 2 retrospective cohorts,[4] and 1 retrospective case-control study.[25] In total, 1,199 patients were included—566 patients received NPWD, and the remaining 633 received standard dressing only. The patient characteristics of each study are detailed in Table II.

NPWD reduced rates of SSI in closed emergency laparotomy incisions

All included studies reported on their rates of SSI and were included in the meta-analysis. NPWD use was associated with a significantly lower incidence of SSI (OR 0.43, 95% CI 0.30−0.62, $P < .001$). Study heterogeneity for this category was 11% (Fig 2). We performed further subgroup meta-analyses separating the 2 RCTs from the 5 cohort studies (Supplementary Figs S1 and S2). These analyses are consistent with the overall finding that NPWD significantly reduces the risk of SSI after emergency laparotomy.

NPWD reduced rates of wound breakdown in closed emergency laparotomy incisions

Three studies reported on wound breakdown and were meta-analyzed.[4,19] NPWD use was associated with a significantly lower incidence of wound breakdown, including both superficial and

Table I
Summary of studies

Authors	Region	Year	Study design	Sample size NPWD: control	NPWD device (pressure x intervention period)	Control	Follow-up period
Schurtz et al[25]	United States	2017	Retrospective case control	48:48	Prevena (125 mmhg × 4–8 d)	Standard dressing	30 d
Garg et al[19]	India	2020	Randomized control trial	25:25	VAC (70 mmhg × 3 d)	Standard dressing	30 d
Andrade et al[18]	United States	2020	Prospective cohort	87:52	VAC	Standard dressing	30 d
Liu et al[4]	Australia	2020	Retrospective cohort	70:157	Prevena (125 mmhg × 5–7 d)	Standard dressing	30 d
Di Re et al[20]	Australia	2021	Randomized control trial	26*:35*	Prevena (125 mmhg × 5–7 d)	Standard dressing	30 d
Chung et al[15]	United Kingdom	2021	Prospective cohort	237:237	VAC (70 mmhg × 7 d)	Standard dressing	30 d
Kabir et al[17]	United States	2022	Retrospective cohort	73:79	Prevena (125 mmhg × 5 d)	Standard dressing	30 d

NPWD, negative pressure wound therapy.
* Emergency surgery patients only.

Table II
Patient characteristics

Studies	Schurtz et al[25]		Liu et al[4]		Andrade et al[18]		Garg et al[19]		Chung et al[15]		Di Re et al[20]		Kabir et al[17]	
	NPWD	Control	NPWD	Control	NPWD	Control	NPWD	Control	NPWD	Control	NPWD	Control	NPWD	Control
Patients, n	48	48	70	157	87	52	25	25	237	237	26	35	73	79
Age, mean (SD), y	61.4 (20.8)	61.9 (15.1)	61.3 (16.7)	63.2 (17.1)	58.1 (16.4)	57.7 (15.4)	46.76 (12.2)	41.96 (8.3)	57*	60*	70 (22–92)†	66 (28–92)†	–	–
Gender, n (%), male	20 (41.7)	26 (51.4)	37 (52.9)	79 (50.3)	39 (44.8)	23 (44.2)	12 (48.0)	16 (64.0)	125 (52.7)	106 (44.7)	30 (49.2)	36 (57.14)	60 (82.0)	66 (84.0)
Diabetes, n (%), yes	5 (10.4)	16 (33.3)	14 (20)	25 (15.9)	25 (28.7)	9 (17.3)	–	–	–	–	16 (26.2)	17 (27.0)	3 (4.0)	2 (2.5)
Body mass index, mean (SD), kg/m^2	28 (7.3)	28.9 (6.4)	–	–	30.6 (10.0)	26.6 (7.1)	–	–	–	–	27 (16–60.9)†	26.5 (16.2–43.8)†	–	–
Smoking, n (%), yes	28 (58.3)‡	37 (77.0)‡	21 (30)	33 (21)	19 (22.6)	13 (26.5)	–	–	40 (16.9)	40 (16.9)	15 (24.6)	5 (8.1)	–	–
Immunosuppression, n (%)	17 (35.4)	18 (37.5)	9 (12.9)	11 (7.0)	12 (13.8)	5 (10.2)	–	–	–	–	7 (11.5)	9 (14.3)	–	–
Wound class, n (%)														
Clean	11 (22.9)	14 (29.2)	2 (2.9)	32 (20.4)	11 (12.6)	21 (40.4)	–	–	–	–	7 (11.5)	6 (9.5)	–	–
Clean-contaminated	19 (39.6)	20 (41.7)	15 (21.4)	37 (23.6)	15 (17.2)	6 (11.5)	–	–	–	–	12 (19.7)	10 (15.9)	–	–
Contaminated	18 (37.5)	14 (29.2)	36 (51.4)	68 (43.3)	22 (25.3)	11 (21.2)	–	–	–	–	42 (68.9)	46 (73.0)	–	–
Dirty	0 (0.0)	0 (0.0)	17 (24.3)	20 (12.7)	39 (44.8)	14 (26.9)	–	–	–	–	0 (0.0)	1 (1.6)	–	–

–, data not available; *NPWD*, negative pressure wound dressing; *SD*, standard deviation.
* No standard deviation recorded.
† Data reported as (range).
‡ Includes current and ex-smokers.

fascial dehiscence (OR 0.36, 95% CI 0.19–0.72, P = .003). Study heterogeneity for this category was 0% (Fig 3).

NPWD reduced rates of all wound complications in closed emergency laparotomy incisions

We also meta-analyzed outcomes of all wound complications reported across all included studies. NPWD use was associated with a reduction in all wound complications (OR 0.41, 95% CI 0.28–0.59, P < .001) (Fig 4). We performed further subgroup meta-analyses separating the 2 RCTs from the 5 cohort studies (Supplementary Figs S3 and S4). These analyses are consistent with the overall finding that NPWD significantly reduces the risk of all wound complications after emergency laparotomy.

NPWD did not affect rates of wound collection in closed emergency laparotomy incisions

Two studies were meta-analyzed to assess the efficacy of NPWD in reducing wound collection.[4,19] NPWD did not significantly reduce the rate of wound collections (Supplementary Fig S5).

NPWD did not reduce hospital length of stay or other clinical outcomes

We also investigated whether NPWD use was associated with a significant improvement in other clinical outcomes, such as hospital length-of-stay and 30-day readmission. We found no significant reduction in these clinical outcomes in association with NPWD (Supplementary Figs S6 and S7).

Discussion

SSI contributes to significant morbidity in patients and is costly for healthcare providers. Whilst consensus has been established for the use of prophylactic NPWD in the elective general surgical setting,[12,13] no consensus has been reached in the emergency setting.[9] Emergency surgery carries greater risk of postoperative wound infection due to higher likelihood of both wound contamination and impaired physiological condition.[4,20] Therefore, the scope for NPWD to reduce rates of SSI amongst patients undergoing emergency surgery is significant. This is the first systematic review and meta-analysis comparing the rate of SSI in patients undergoing emergency laparotomies when treated with NPWD versus standard dressing on closed wounds. This study showed that NPWD greatly reduced the rate of SSI for patients undergoing emergency laparotomy. NPWD use was also associated with a significant reduction in all wound complications, including wound breakdown.

Boland et al meta-analyzed the results of 931 patients in 5 randomized control trials examining the use of NPWD dressings in patients undergoing both elective and emergency procedures.[8] They reported that NPWD use was associated with a reduction in the overall rate of SSI (OR 0.71). Whilst RCT-level evidence has examined the role of NPWD in the elective setting, the same level and extent of evidence was not available to us for meta-analysis in the emergency-only setting. Therefore, our meta-analysis included a range of comparative studies, ranging from retrospective cohort studies to RCTs, and is not a meta-analysis of RCTs alone. Additionally, both included RCTs were considerably underpowered to detect a significant difference in the rate of SSI.[19,20] Despite this, 6 of the 7 studies reported that NPWD reduced the risk of SSI by more than half compared to standard dressing (6 out of 7 studies reported an OR ≤0.4) and favored the use of NPWD. Studies by Liu et al and Andrade et al were actually biased toward greater wound contamination relative to the other studies, where approximately

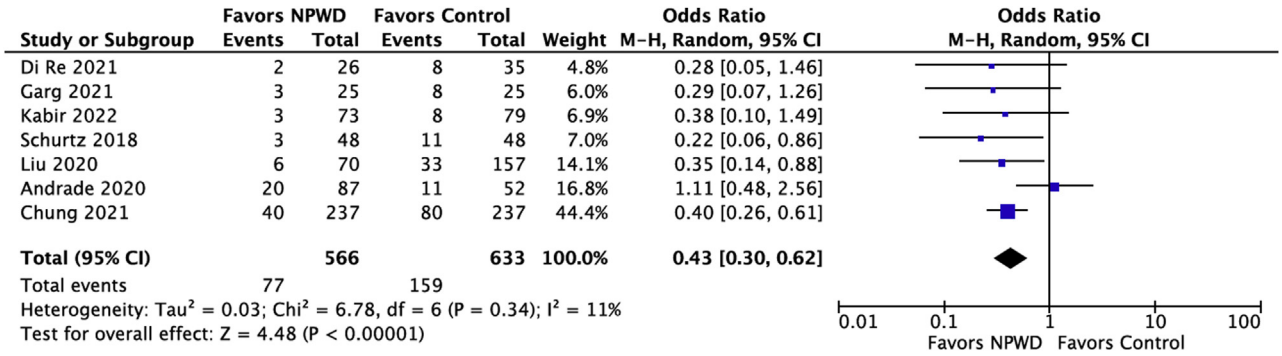

Fig 2. Forest plot meta-analysis for surgical site infections (superficial and deep) comparing negative pressure wound therapy to standard therapy. *NPWD*, negative pressure wound therapy.

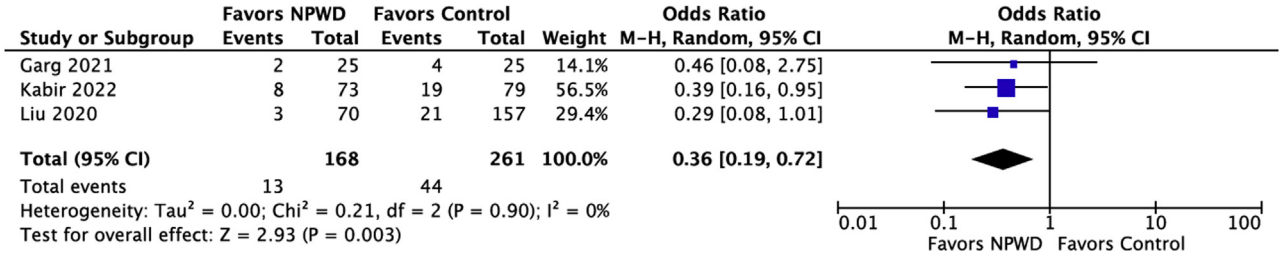

Fig 3. Forest plot meta-analysis for wound breakdown comparing negative pressure wound therapy to standard therapy. *NPWD*, negative pressure wound therapy.

one-fourth of patients in both studies had dirty (Center for Disease Control class 4) wounds.[4,18] Despite this adverse factor, Liu et al reported an OR of 0.35 in favor of the use of NPWD even when compared to propensity score-matched controls.[4]

Whilst NPWD did significantly reduce the rate of SSI in this meta-analysis, their use was not associated with a reduction in length-of-stay or 30-day readmission. This is perhaps not surprising, given that in this cohort of acutely unwell patients who have undergone an emergency laparotomy, it is likely that other factors beyond those of wound complications determine each patient's length of stay and need for readmission. In this context, whether NPWD leads to a reduction in overall health care cost per emergency laparotomy admission requires further investigation.

Not all emergency laparotomies carry the same risk of SSI. Studies have highlighted that SSI risk is greatest for patients undergoing emergency laparotomy for colonic pathologies.[12,26,27] Only 2 of the included studies analyzed procedural type according to anatomical site.[15,20] Due to the heterogeneity in this parameter, we could not meta-analyze the rate of SSI according to the organ system operated on at laparotomy. However, on a study-by-study analysis, Chung et al reported a significant increase in the frequency of SSI (OR 2.38) for colorectal-type emergency procedures.[15] Di Ri et al also reported a higher rate of SSI (OR 3.07) for patients undergoing similar procedures.[20] Given that colorectal pathologies frequently require emergency laparotomies and carry an inherently high SSI risk, prophylactic NPWD may be of particular benefit in this subgroup of patients.[12,15,20,26,27]

We attempted to collect and compare outcomes data for reoperation rate, Clavien-Dindo complication grading, frequency of dressing changes, intensive care admission, perioperative mortality, and the extent of wound contamination in NPWD versus control groups. We also attempted to undertake subgroup analyses with respect to procedural type, intrabdominal pathology, patient age, sex, diabetes, body mass index, smoking, and immunosuppression status for SSI. However, due to limited and heterogenous reporting of these outcomes in our included studies, we could not meaningfully proceed with a meta-analysis. We acknowledge that this is a limitation in our study. In conclusion, emergency laparotomies are associated with high rates of wound complications leading to increased patient morbidity and healthcare cost. Until now, the

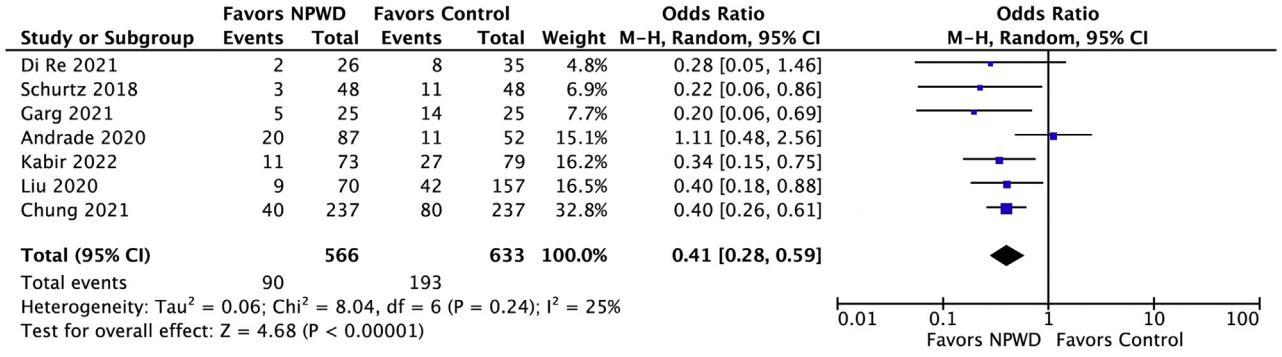

Fig 4. Forest plot meta-analysis for all wound complications comparing negative pressure wound therapy to standard therapy. *NPWD*, negative pressure wound therapy.

utility of prophylactic NPWD in patients undergoing emergency laparotomy has been controversial. Our meta-analysis demonstrates that NPWD has clinical utility by reducing the risk of postoperative SSI and wound breakdowns. Our findings justify and support the ongoing randomized trials in this area.[21,22]

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Conflict of interest/Disclosure

The authors have no related conflicts of interest to declare.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.surg.2022.05.020.

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