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Negative Pressure Wound Therapy with Delayed Closure Versus Primary Closure in Perforation Peritonitis: A Randomized Controlled Trial

Dr Shuvangi Singh[1], Dr Sonia Moses[2], Dr Sachin Verma[3], Dr Aditi Gawli[4]

[1]Post Graduate Resident, Department of General Surgery, M.G.M Medical College Indore (M.P.)
[2]Professor, Department of General Surgery, M.G.M Medical College Indore (M.P.)
[3]Associate Professor, Department of General Surgery, M.G.M Medical College Indore (M.P.)
[4]Post Graduate Resident, Department of General Surgery, M.G.M Medical College Indore (M.P.)

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Corresponding Author:

Dr Shuvangi Singh
Post Graduate Resident, Department of General Surgery, M.G.M Medical College Indore (M.P.)

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ABSTRACT

Background: Perforation peritonitis is a serious surgical emergency due to heavy intra-abdominal contamination and a high incidence of postoperative surgical site infections (SSIs). Conventional primary closure of such contaminated laparotomy wounds often entraps bacteria, resulting in wound disruption.
Objectives: To compare clinical efficacy of NPWT with delayed wound closure and primary wound closure on SSI rates and healing in patients undergoing surgery for perforation peritonitis.
Material and Methods: A prospective randomized controlled trial was performed on 60 patients (30 in each arm) who developed perforation peritonitis and presented for emergency laparotomy. After source control, the NPWT cohort were managed with continuous sub-atmospheric pressure (-125 mmHg) for three days followed by standard dressings, and the control cohort underwent immediate primary closure. Primary end points were SSI incidence, epithelialization time, and infection relative risk.
Results: The baseline demographic and operative parameters were similar between groups. NPWT group had a significantly lower rate of surgical site infection (SSI) than conventional primary closure group (13.3% vs 43.3%, p = 0.010). In addition, NPWT effectively obstructed superficial SSIs and promoted rapid epithelialization (p = 0.019). The relative risk of developing an SSI in the NPWT cohort was 0.308 (95% CI: 0.113–0.836, p = 0.022) indicating a decrease of 69% in the probability to experience an infection.
Conclusion: NPWT with delayed closure was found to be a very effective, safe alternative of Primary Closure in Perforation peritonitis. It greatly reduces SSI risk and improves tissue healing without increasing the rate of other wound complications.

Keywords: *Perforation Peritonitis, Negative Pressure Wound Therapy, Surgical Site Infection, Emergency Laparotomy, Delayed Primary Closure.*

INTRODUCTION

Perforation peritonitis has, unfortunately, remained a major and common surgical emergency most often due to hollow viscus perforation leading to massive gastrointestinal spillage in the peritoneal cavity. Despite modern advances in critical care and effective antimicrobial therapy, this condition is associated with significant morbidity that is particularly influenced by postoperative wound complications.[1] Emergency laparotomy incisions in these circumstances are inherently categorized as contaminated or dirty, placing the surgical site at risk for high bacterial inoculums and severe systemic inflammatory responses. As a result, surgical site infections (SSIs) occur in 30% to 60% of these patients and cause delayed healing, fascial dehiscence, and prolonged hospital stays.[2]

The conventional standard of care entails closure of the wound primarily after the laparotomy; however, sealing a contaminated surgical field inevitably locks in place necrotic debris and bacterial organisms within a hypoxic environment that actively favours ongoing microbial growth and purulent exudate generation.[3] In order to overcome these negative

physiological conditions, Negative Pressure Wound Therapy (NPWT) or vacuum-assisted closure, has evolved as a dynamic wound modulation therapy. NPWT continuously evacuated infected exudates by control of sub-atmospheric pressure, decreased interstitial oedema, and mechanically stimulated local microcirculation to form robust granulation tissue.[4] Although the use of prophylactic NPWT has demonstrated benefits in clean-contaminated surgeries, its effects on perforation peritonitis highly septic environment have not been specifically assayed. This study is a randomized controlled trial designed to determine whether NPWT followed by delayed closure provides improved wound healing and reduced relative risk for SSI compared to conventional primary closure in a tertiary care setting.

MATERIALS AND METHODS

Study Design and Setting:

This prospective randomized controlled trial was carried out over a period of one year at the Department of Surgery, M.G.M. Medical College and M.Y. Hospital, Indore, a high-volume tertiary care teaching institution. The study followed the institutional ethical guidelines and was approved formally.

Study Population:

Sample size calculation was based upon the expected differences in event proportions between the two study arms, using the following formula for comparing two independent proportions: $n= (Z_\alpha+Z_\beta)^2 (P_1Q_1 + P_2Q_2)/(P_1-P_2)^2$, where $Q_1=100-P_1$ and $Q_2=100-P_2$, at a 90% statistical power ($Z_\beta = 1.28$) at a 95% confidence level ($Z_\alpha = 1.96$), projecting outcomes to be 13.7% (P_1) in the NPWT cohort and 50.0% (P_2) in the conventional cohort, where $Q_1=100-P_1$ and $Q_2=100-P_2$. Based on this statistical calculation, a minimum of 29.34 subjects per arm were necessary and thus 30 patients for each cohort were deemed adequate resulting in an overall sample size of 60 subjects.

Thus, the trial randomized 60 adult patients (>18 years old) admitted for emergency abdominal surgery with closed laparotomy wounds. Exclusion criteria included allergies to NPWT dressing materials, history of abdominal surgeries at any site, pre-existing surgical site infection and refusal for informed consent. Eligible patients were prospectively randomized into two equal cohorts of 30 patients each: Group A (NPWT + delayed wound closure) and Group B (Conventional primary wound closure).

Surgical Procedure and Intervention:

All participants had a standard exploratory laparotomy. After adequate intra-abdominal source control and peritoneal lavage, the fascial layer (rectus sheath) was approximated.

● **NPWT Protocol (Group A):** Subcutaneous tissue and skin left open. After placing a protective layer over the surrounding skin, the entire infiltration site was covered with gauze impregnated with chlorhexidine, located directly over the fascial incision. Microporous polyurethane sponge-loaded customized suction evacuation drain was placed into the wound cavity. An occlusive adhesive drape was placed over the entire assembly in a hermetic manner. Negative pressure at -125 mmHg was continuously applied. The NPWT device was removed on the 3rd postoperative day and conventional dry dressings were used to manage the wound until delayed closure was feasible. (Figure 1 and 2)

● **Control Group (Group B):** The surgical wound was primarily closed and dressed with povidone-iodine ointment and dry sterile gauze, which was changed daily according to the standard ward protocols.

Operational Definitions and Follow-up

- **Surgical Site Infection (SSI):** Defined according to the standardized surveillance criteria of the Centre for Disease Control and Prevention as an infection at the surgical incision occurring within 30 days of surgery; further categorized as superficial (involving skin/subcutaneous tissue) or deep (involving fascial/muscle layer) infections.[5]
- **Delayed Primary Closure:** A technique in which all contaminated skin and subcutaneous tissues are left open after laparotomy for continuous drainage and reduced inflammatory load, followed by surgical approximation when healthy granulation tissue has developed.[6]

Patients were closely followed up on postoperative day 14, 21, and 30 endpoints such as presence of surgical site infection (SSI), epithelialization time, wound dehiscence seroma formation and cosmetic scores. Data were entered in Microsoft Excel and statistically analysed through JAMOVI statistical software. Continuous data were presented as mean ± standard deviation or median with interquartile range. Categorical variables were reported as frequencies and percentages. Chi-square test or Fisher's exact test were used to compare the two study groups for categorical variables. P values less than 0.05 were considered statistically significant.

Figure 1: Wound after application of Negative Pressure Dressing

Figure 2: Showing wound immediately after removing the NPWT dressing at post-operative day 3

RESULTS

The baseline socio-demographic and clinical characteristics of the 60 study participants are illustrated in Table 1. There were no statistically significant variations in mean age, gender demographic, or systemic comorbidities between the Negative Pressure Wound Therapy (NPWT) and traditional primary closure cohorts. Moreover, perforation aetiology and intraoperative peritoneal contamination degree showed a similar distribution within both groups; thus preventing pre-existing physiological and anatomical factors from confounding the post-operative healing outcomes.

Table 2 describes the preoperative laboratory parameters and the mean times of surgical procedures. Despite comparable haemoglobin concentrations, serum albumin levels and total operative times between the two study arms, more patients in the NPWT cohort had significantly higher baseline white blood cell (WBC) counts ($p = 0.048$). This increased leucocytosis suggests a significantly greater baseline systemic inflammatory and infectious load in the intervention group before source control was achieved surgically.

The incidence and anatomic depth of SSIs in surgeries performed by individual groups are summarized in Table 3 and Figure 3. NPWT resulted in a significant reduction in overall SSI rates (13.3% v 43.3% for the conventional primary closure group) ($p = 0.010$). Essentially, the NPWT protocol virtually eliminated superficial incisional infections and modulated

deep fascial infection spread, signifying an enormous significance in preventing tissue injury at the incision microenvironment level.

The relative risk (RR) analysis for the development of postoperative wound infections is shown in Table 4 and in Figure 4. Statistical analysis yielded an RR of 0.308 (95% CI: 0.113–0.836); p = 0.022. The strong evidence while using this quantitative measure is that sub-atmospheric pressure therapy followed by delayed fascial approximation achieved a remarkable 69% relative reduction in infection risk compared to immediate primary wound closure.

Table 5 illustrates differences in the postoperative healing dynamics, showcasing the time needed for full epithelialization between treatment cohorts. Our study shows that patients treated under the NPWT protocol exhibited a significant increase in epithelialization scores compared to those managed by traditional methods (p = 0.019), indicating that NPWT is more effective and result-getting than conventional management. In light of these data, the perpetuation of a stable wound bed may suggest that controlled negative pressure directly promotes stabilization of any exuding factors that deter cellular proliferation necessary for optimal epidermal repair.

Table 1: Baseline Socio-demographic and Clinical Characteristics

Parameter	NPWT Cohort (n = 30)	Conventional Cohort (n = 30)	p-value
Age (years), Mean ± SD	52.87 ± 15.43	46.30 ± 18.36	0.139
Sex, n (%)			
Male	17 (58.6%)	12 (41.4%)	0.196
Female	13 (41.9%)	18 (58.1%)	
Primary Diagnosis, n (%)			
Peptic Perforation	8 (47.1%)	9 (52.9%)	0.985
Ileal Perforation	9 (50.0%)	9 (50.0%)	
Appendicular Perforation	7 (50.0%)	7 (50.0%)	
Others	6 (54.5%)	5 (45.5%)	
Comorbidities Present, n (%)	18 (58.1%)	13 (41.9%)	0.196
Contamination Grade, n (%)			
Mild	5 (33.3%)	10 (66.7%)	0.286
Moderate	12 (60.0%)	8 (40.0%)	
Severe	13 (52.0%)	12 (48.0%)	

Table 2: Preoperative Laboratory Parameters and Operative Duration

Parameter	NPWT Cohort (Mean ± SD)	Conventional Cohort (Mean ± SD)	p-value
Hemoglobin (g/dL)	11.44 ± 1.67	11.72 ± 1.52	0.506
Albumin (g/dL)	3.66 ± 0.42	3.81 ± 0.41	0.179
WBC Count (cells/mm³)	11,991.47 ± 2,664.67	10,611.17 ± 2,627.19	0.048
Operative Time (min)	118.23 ± 25.16	113.03 ± 25.67	0.431

Table 3: Incidence and Typology of Surgical Site Infection (SSI)

SSI Classification	NPWT Cohort (n = 30)	Conventional Cohort (n = 30)	p-value
Overall SSI Incidence, n (%)	4 (13.3%)	13 (43.3%)	**0.010**
SSI Typology			
No Infection	26 (86.7%)	17 (56.7%)	**0.013**
Superficial SSI	0 (0.0%)	6 (20.0%)	
Deep SSI	4 (13.3%)	7 (23.3%)	

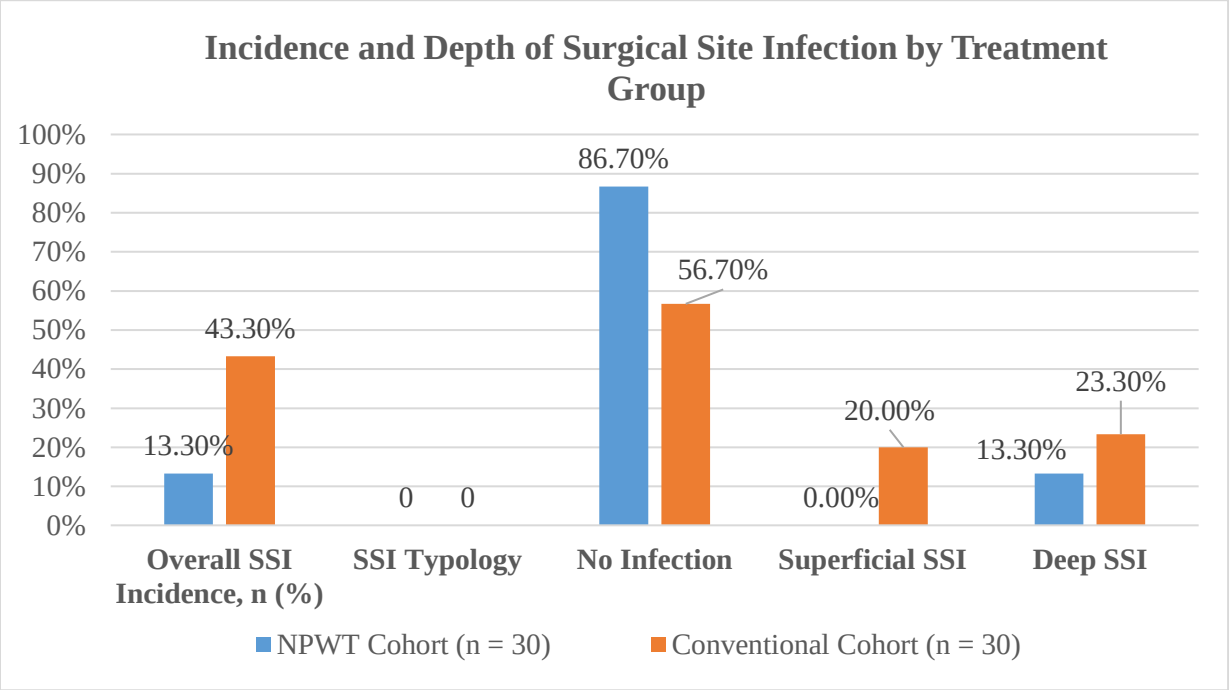

Figure 3: Incidence and Depth of Surgical Site Infection by Treatment Group

Table 4: Relative Risk Analysis for Surgical Site Infection

Measure	Value
Risk in NPWT Cohort	0.133 (13.3%)
Risk in Conventional Cohort	0.433 (43.3%)
Relative Risk (RR)	0.308
95% Confidence Interval	0.113 – 0.836
p-value	0.022

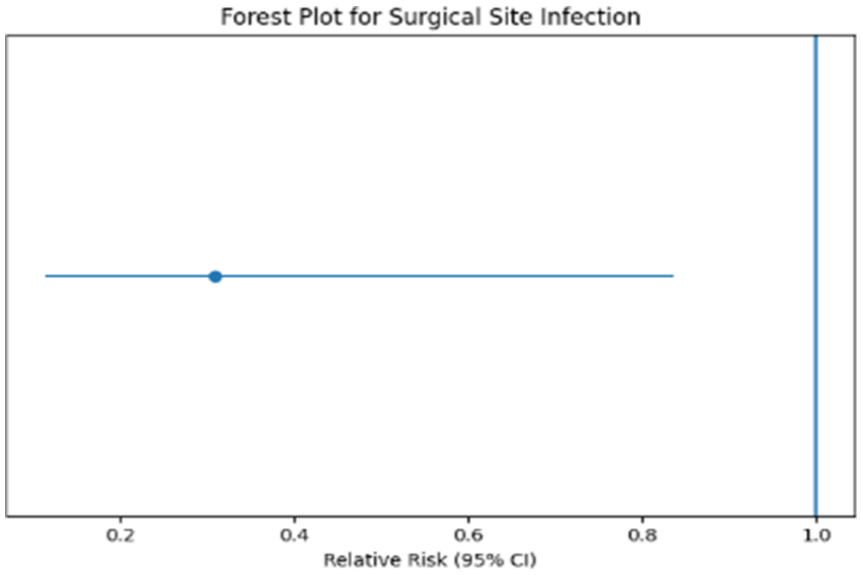

Figure 4: Forest Plot of Relative Risk for Surgical Site Infection

Table 5: Time to Complete Epithelialization

Group	Mean ± SD (Days/Score)	p-value
NPWT Cohort	0.93 ± 0.254	0.019
Conventional Cohort	0.70 ± 0.466	

DISCUSSION

The aim of this randomized controlled trial to investigate the clinical effectiveness of NPWT with delayed closure compared with standard practice (primary closure) in patients undergoing laparotomy for contaminated intervals. The results of the present study convincingly showed that NPWT significantly modifies the hostile wound microenvironment and promotes better postoperative outcomes. This decrease in SSI rate in NPWT group (13.3%) was pronounced compared to the conventional primary closure arm (43.3%).

This major decrement substantially correlates with recent high-impact surgical literature. Shen et al. (2017) studied high-risk laparotomies and showed that prophylactic negative pressure led to a statistically significant 31.0% reduction to only 16.9% SSI rates.[7] Similarly, O'Leary et al. (2017) showed significant protection in abdominal surgery, with a decrease in SSI from 16% to only 4% when closed-incision NPWT was applied.[8] NPWT reduces local bioburden because it continuously evacuates trapped fluid and neutralizes the hypoxic environment. Frazee et al. (2018) confirmed this mechanism, showing that closed NPWT in dirty surgical wounds achieves more rapid definitive closure and lower complication rates.[9]

In addition, the RR from our relative risk analysis was 0.308 corresponding to a staggering 69% relative risk reduction in terms of development of wound infection. This represents a level of protection similar to that reported by Danno et al. (2018) who reported a 76.2% relative risk reduction in severe peritonitis models.[10] Liu et al. (2021) found that prophylactic negative-pressure dressings significantly reduce the risk of developing surgical site infection and any healthcare burden associated with emergency laparotomies.[11] Singh et al. (2023) uncovered a similar pattern regarding emergency gastrointestinal perforations and noted that NPWT decreased SSI rates to 10.0%, while conventional standard care had a failure rate of 30.0%.[12] It was not until the international study by the SUNRRISE Trial Study Group (2025) definitively confirmed these cumulative findings through large multicentred high-powered trials that substantial absolute risk reductions with negative pressure therapeutics became clearly visible.[13] In addition to prevention of infection, we found that the NPWT arm resulted in a complete resolution of superficial SSIs and that there was a significantly accelerated rate of complete epithelialization ($p = 0.019$). The transition from state of chronic inflammation to proliferation is thus bridged by mechanical stabilization of the wound edges and promotion of robust angiogenesis due to sub-atmospheric pressure. Importantly, this accelerated healing was paralleled even in the presence of significant baseline leucocytosis within the NPWT cohort ($p = 0.048$), demonstrating that maximal systemic inflammatory response can still be overcome by means of an external intervention.

CONCLUSION

NPWT with delayed primary closure is a very effective, safe and biologically superior alternative in perforation peritonitis compared to immediate primary closure. It significantly decreases both the incidence and severity of surgical site infections, actively promotes epithelialization, and markedly lowers relative risk of infection without increasing seroma or dehiscence rates; thus supporting its adoption in emergency surgical protocols.

Recommendations

Surgical units treating high-risk, contaminated laparotomies in a healthcare setting concern NPWT and delay closure protocols as a routine modality to reduce the burden of severe wound morbidity and unify management on infection control.

Strengths and Limitations

The rigorous randomized controlled underpinning affords significant internal validity, but the somewhat limited cohort (n=60 people) from a single tertiary institution may limit wider epidemiological extrapolation.

Relevance of the Study

Provides vital, actionable clinical evidence for customizing wound survivability optimization in mega-lethal emergency general surgery presentations.

Authors' Contribution

Conceptualization, data collection, statistical analysis and manuscript preparation were conducted by all authors equally.

Ethical Consideration

Institutional Ethics Committee approval; written informed consent was strictly obtained from all participants before enrolment.

Financial Support and Sponsorship

Nil.

Conflicts of Interest

None.

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