JOURNAL OF THE
ANUS, RECTUM AND COLON
dx.doi.org/10.23922/jarc.2019-043
http://journal-arc.jp

Original Research Article

Efficacy of Negative Pressure Wound Therapy Followed by Delayed Primary Closure for Abdominal Wounds in Patients with Lower Gastrointestinal Perforations: Multicenter Prospective Study

Hirofumi Ota[1)2)], Katsuki Danno[1)3)], Katsuya Ohta[1)4)], Tae Matsumura[1)5)], Takamichi Komori[1)6)], Shu Okamura[1)7)], Miho Okano[1)8)], Atsuhiro Ogawa[1)9)], Hiroshi Tamagawa[1)10)], Mamoru Uemura[1)11)], Chu Matsuda[1)11)], Tsunekazu Mizushima[1)11)], Hirofumi Yamamoto[1)11)], Riichiro Nezu[1)12)], Yuichiro Doki[1)11)] and Hidetoshi Eguchi[1)11)]

1) The Multi-Center Clinical Study Group of Osaka, Colorectal Cancer Treatment Group (MCSGO)
2) Department of Digestive Surgery, Ikeda City Hospital, Ikeda, Japan
3) Department of Surgery, Minoh City Hospital, Minoh, Japan
4) Department of Gastroenterological Surgery, Higashiosaka City Medical Center, Higashiosaka, Japan
5) Department of Surgery, Osaka Rosai Hospital, Sakai, Japan
6) Department of Surgery, Osaka General Medical Center, Osaka, Japan
7) Department of Surgery, Suita Municipal Hospital, Suita, Japan
8) Department of Surgery, Kaizuka City Hospital, Kaizuka, Japan
9) Department of Surgery, Tane General Hospital, Osaka, Japan
10) Department of Surgery, Otemae Hospital, Osaka, Japan
11) Department of Gastroenterological Surgery, Osaka University Graduate School of Medicine, Suita, Japan
12) Department of Surgery, Nishinomiya Municipal Central Hospital, Nishinomiya, Japan

Abstract

Objectives: The efficacy of negative pressure wound therapy (NPWT) and its application to severely contaminated wounds sustained during surgery remain to be established. Here, we evaluated the efficacy of utilizing NPWT until delayed primary closure (DPC) by assessing the infection rates in patients with lower gastrointestinal perforations.

Methods: This prospective multicenter cohort study included 56 patients that underwent abdominal surgery for lower gastrointestinal perforations in eight institutions, from February 2016 to May 2017. All patients received NPWT after surgery before attempting DPC. The extent of peritonitis was categorized according to Hinchey's classification. Patients in stages II-IV were included.

Results: Five patients had surgical site infections (SSIs) during NPWT and did not receive a DPC (9%). Of the 51 patients that received DPCs, 44 had no infection (91%) and 7 developed SSIs after the DPC (13.7%). For stages II, III, and IV, the SSI rates were 0%, 22.6%, and 35.7%, respectively; the median (range) times to wound healing were 15 (10-36), 19 (11-99), and 19 (10-53) days, respectively. There were no significant differences between the stages.

Conclusions: NPWT followed by DPC resulted in low infection rates in each peritonitis stage. This approach appears promising as an alternative to traditional DPC alone for treating lower gastrointestinal perforations.

Corresponding author: Hirofumi Ota, hirootajp@yahoo.co.jp
Received: December 24, 2019, Accepted: March 24, 2020
Copyright Ⓒ 2020 The Japan Society of Coloproctology

Keywords
delayed primary closure, emergency surgery, lower gastrointestinal perforation, negative pressure wound therapy, peritonitis

J Anus Rectum Colon 2020; 4(3): 114-121

Introduction

Acute peritonitis caused by severe diverticulitis, fecal impaction, obstruction due to cancer, appendicitis, and so forth is a considerable source of postoperative complications[1], and it is associated with a high frequency of surgical site infections (SSIs). The bowel contains a large number of bacteria that contribute to high infection rates. Thus, the reported SSI rates following surgery for lower bowel perforations ranged from 32%[2] to 63%[3]. SSIs require frequent wound irrigation and dressing changes, leading to a significant reduction in patient satisfaction due to prolonged hospital stays, problems with wound scar appearance, and the high risk of incisional hernias[4]. SSIs are also detrimental to both patients and hospital management due to the prolonged hospital stays and increased medical costs[5]. Therefore, it is essential to establish preventive measures.

A large body of research on closure measures for contaminated wounds in patients with peritonitis has been published. Some comparative studies of primary skin closures and alternative procedures, such as secondary closures or delayed primary closures (DPCs), have been conducted worldwide. The primary skin closure is defined as a closure of the abdominal fascia and skin at the end of surgery. In DPC, only the fascia is closed, with the skin left open at the end of surgery. Then, the wound is treated conservatively, with irrigation and drainage, and intravenous antibiotics might be given, depending on the patient's condition. In some cases, basic fibroblast growth factor analog therapy[6] or high pressure oxygen therapy[7] is added to facilitate granulation. Some studies have reported[8-12] that DPCs resulted in a lower incidence of SSIs and shorter hospital stays compared with primary closures. In contrast, other reports[13,14] revealed no significant difference in SSI rates between DPCs and primary closures. In addition, DPCs require additional time and cost due to extended care before the complete wound closure is performed; thus, hospital stay might be extended.

Negative pressure wound therapy (NPWT) was recently reported as an effective treatment for open wounds in a wide range of surgeries. NPWT creates suction, which drains the wound of exudate (i.e., fluid, cells, and cellular waste that escape from blood vessels and seep into interstitial tissues). During the NPWT procedure, a piece of foam is placed over the wound and a drainage tube over the foam. A large piece of transparent tape is placed over the whole area, including the healthy tissue, to secure the foam. The tube is connected to a vacuum source, and fluid and debris are drawn from the wound, through the foam, into the tube, and finally, into a disposable canister. Thus, the entire wound area is subjected to negative pressure, which is thought to help increase blood flow to the wound surface, facilitate the growth of granulated tissue, and, thus, enhance wound healing. On the other hand, applying NPWT on the exposed bowel is contraindicated, as it is likely to develop perforation.

NPWT is commonly applied after an SSI associated with digestive surgery. Several studies have evaluated the efficacy of NPWT as a preventive measure for SSIs[15,16]. NPWT is expected to reduce the frequency of dressing changes and the medical cost, in addition to alleviating pain and mental stress in patients. However, further study is required to evaluate the efficacy of NPWT applied to dirty (contaminated) wounds.

In this multicenter study, we evaluated the efficacy of utilizing NPWT before attempting a DPC. We assessed the rate of infection in patients at a very high risk of SSIs, with panperitonitis associated with a bowel perforation.

Methods

Study design and treatment

This prospective multicenter cohort study included patients that underwent abdominal surgery in eight institutions for a lower gastrointestinal perforation, from February 2016 to May 2017. All surgeries were performed with an open procedure, except three laparoscopic surgeries for patients with a perforation of the sigmoid cancer, rectal cancer, or small intestine of malignant lymphoma, which led to panperitonitis. All patients received NPWT. The extent of peritonitis was determined by the surgeon at the time of surgery, and it was categorized according to Hinchey's classification, which was originally devised to describe the severity of diverticulitis[17]. The details are as follows. Stage I: A pericolic abscess confined by the mesentery of the colon. Stage II: A pelvic abscess resulting from local perforation of a

pericolic abscess. Stage III: Generalized peritonitis resulting from the rupture of either a pericolic or pelvic abscess into the general peritoneal cavity. Stage IV: Fecal peritonitis resulting from the free perforation. We believe that Hinchey's classification is the most appropriate for evaluating the SSI rate in severe peritonitis. Although our study included three perforated sites of the lower bowel and various etiologies, including diverticulitis, we used the same classification system for all patients. For the sake of expediency, in this study, Hinchey's stages are called "peritonitis stages." We targeted patients with stages II-IV peritonitis for NPWT and excluded those with localized abdominal abscesses classified as stage I peritonitis.

For the NPWT procedure, the peritoneum, muscle, and fascia were closed in one layer with absorbable sutures. The skin and subcutaneous tissue incisions remained open. Open subcutaneous tissues were packed with gauze soaked in normal saline. When possible, the day after surgery, we placed a black GranuFoam dressing (VAC therapy, Kinetic Concepts Inc. [KCI], San Antonio, TX) over the wound. When a surgery was performed on a Friday, the dressing was placed on the following Monday. The NPWT continued for 5-7 days. Dressings were changed every 48 to 72 h, not fewer than three times per week. Negative pressure was set at 75 to 125 mmHg, at the discretion of the surgeon, with continuous suction. When detectable wound granulation had formed and the wound appeared clean, it was closed with a vertical mattress suture under local anesthesia.

After the wound was closed, the occurrence of SSI was assessed every day, except weekends, by members of a wound rounds team, which included a nurse expert in infection. An SSI was defined according to the standardized criteria outlined by the Centers for Disease Control and Prevention (CDC)[18,19]. An incisional SSI was defined as an infection that occurred at the incision site within 30 days of surgery. It was characterized by at least one of the following features: purulent drainage from the incision; isolation of an organism from a culture of fluid from the incision; incisional pain, tenderness, localized swelling, redness, or heat, upon opening the incision; or a diagnosis by the surgeon or attending physician. Superficial incisional SSIs involved only the skin or subcutaneous tissue at the incision site. Deep incisional SSIs involved the deep soft tissues (e.g., fascial and muscle layers) at the incision site.

All patients received perioperative intravenous antibiotics that included anaerobic coverage until they achieved normal values for body temperature, white blood cell count, and markers of gastrointestinal function. Patients were excluded when they exhibited naked blood vessels in the wound, a fistula in the abdominal cavity, an uncontrolled organ-space SSI, or any contraindications to the VAC therapy device. Moreover, we excluded patients that were judged unsuitable for this therapy by an attending physician.

All procedures involving human participants were performed in accordance with the ethical standards of the institutional or national research committee and with the 1964 Helsinki Declaration and its later amendments, or comparable ethical standards. This study was approved by the institutional review board of each participating hospital. Informed consent was obtained prior to every registered surgery.

Demographics

We collected the following data for all patients: age, sex, body mass index (BMI), bacteria cultured from ascites fluid, time to epithelialization (i.e., time to achieve complete wound healing), NPWT device application time, length of postoperative hospital stay, and the presence of an SSI. We also recorded underlying medical conditions that could contribute to infectious complications, including diabetes mellitus, obesity, malnutrition, steroid use, and the presence of a stoma. Epithelialization was defined as the presence of epithelium covering the wound, the absence of wound exudate, and no need for gauze or wound dressings. Treatment-related adverse events (AEs) were evaluated according to the Common Terminology Criteria for Adverse Events, version 4.0.

Statistics

We conducted descriptive data analyses. Categorical variables are expressed as frequencies and percentages and continuous variables as the median (range). We evaluated the significance of between-group differences with the Mann-Whitney U test and the Bonferroni correction; with the chi-squared test; or with the Kruskal-Wallis test, as appropriate. All statistical analyses were conducted using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA). A p-value < 0.05 was considered significant.

Results

Among 60 patients that underwent surgery for peritonitis secondary to a lower gastrointestinal perforation, only one was ineligible for the study due to a stage I classification. In addition, three patients underwent re-operations due to anastomotic leakage or repeated perforations. These three patients were excluded from analysis because re-operated wounds could not be evaluated (Figure 1). Thus, the study included 56 patients that received NPWT following surgery before attempting a DPC. The demographics of these patients are presented in Table 1 and the perforation etiologies in Table 2.

Bacterial cultures from the ascites fluid were positive in 43 of 48 examined patients (89.6%). The most common organisms cultured were *Enterococcus* spp., *Escherichia coli*, *Klebsiella* spp., *Streptococcus* spp., and *Bacteroides* spp.

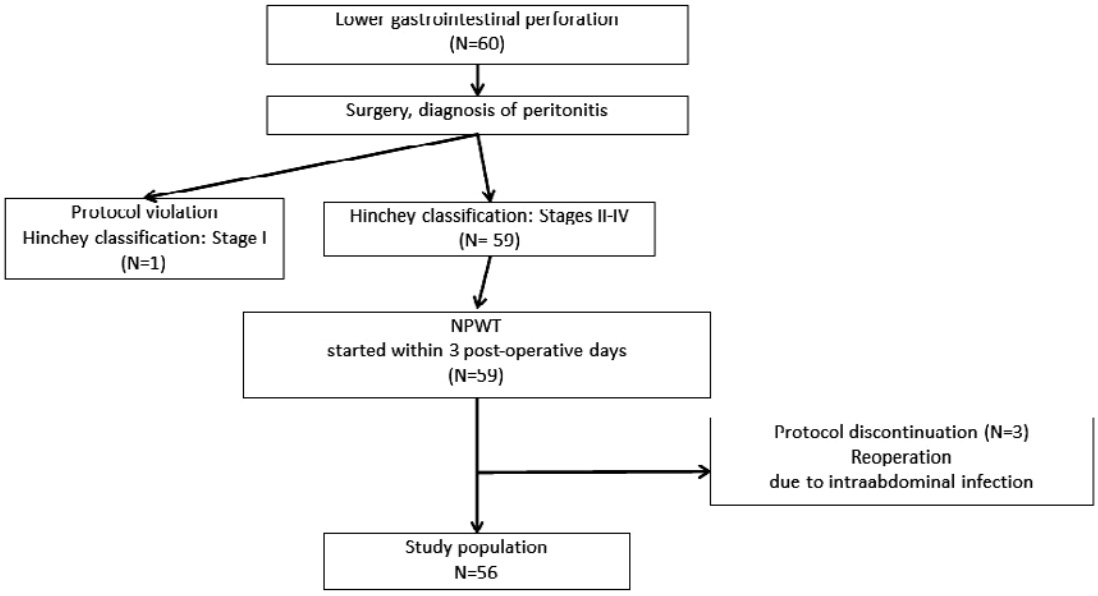

Figure 1. Flow chart of patient selection. NPWT, negative pressure wound therapy.

Table 1. Baseline Clinical Characteristics (n = 56).

Median age (range), years	68 (31-94)
Gender	
Male	30 (53.6)
Female	26 (46.4)
Perforated site	
Large bowel	36 (64.3)
Small bowel	6 (10.7)
Appendix	14 (25.0)
Risk factor	
Smoking	13 (23.2)
Transfusion	7 (12.5)
Diabetes mellitus	7 (12.5)
Steroid use	4 (7.1)
Overweight (body mass index > 25 kg/m^2)	11 (19.6)
Stoma creation	24 (42.9)
Operation time > 180 min	13 (23.2)
Stage	
I	0 (0)
II	11 (19.6)
III	31 (55.4)
IV	14 (25)

Data are expressed as n (%) unless otherwise noted.

Table 2. Etiology of Perforation (n = 56).

Perforated organ	Etiology	n
Large bowel	Obstruction due to cancer	10
	Cancer treatment-associated cause	
	Anastomotic leakage	5
	Endoscopic submucosal dissection	1
	Chemotherapy (Nivolumab)	1
	Cytomegalovirus infection	1
	Diverticulitis	8
	Fecal impaction	8
	Volvulus	1
	Idiopathic	1
Small intestine	Strangulation	4
	Fish bone	1
	Malignant lymphoma	1
Appendix	Appendicitis	14

The detection rates for each peritonitis stage are presented in Table 3. Among the 56 patients included in the study, 5 had SSIs during the NPWT and did not receive DPCs (9%). Fifty-one patients underwent DPCs (91%). Of these, 44 exhibited no signs of infection and 7 (13.7%) developed SSIs. Patients classified as stage II had no SSIs after the NPWT and DPC. Patients classified as stage IV had an SSI rate of 25%, but no significant difference was observed between stages II, III, and IV (p = 0.218; Table 4). An analysis of patients with perforations only in the large bowel (i.e., excluding the small intestine and appendix) revealed that 88.9% moved on to a DPC and 12.5% developed wound infections (Table 5). The median postoperative hospital stay tended to be influenced by the peritonitis classification; however, only stage IV was associated with significantly extended hospital stays (stage II vs. IV, p = 0008; stage III vs. IV, p = 0.036). The median (range) times to wound healing for stages II, III, and IV were 15 (10-36), 19 (10-99), and 20 (14-94) days, respectively, but these times were not significantly different (II vs. III, p = 0.201; III vs. IV, p = 0.598; II vs. IV, p = 0.569). Thus, by implementing NPWT + DPC, wound healing was achieved within a median of 20

Table 3. Detection Rate of Bacteria According to Peritonitis Classification.

Stage	II (n = 11)	III (n = 31)	IV (n = 14)	Total (n = 56)
Ascites fluid examined	9	28	11	48
Bacteria detected	8	24	11	43
Detection rate of bacteria	88.9%	85.7%	100%	89.6%

Data are expressed as number of samples unless otherwise indicated.

Table 4. Outcomes of NPWT Followed by DPC According to Peritonitis Classification (n = 56).

Stage	II (n = 11)	III (n = 31)	IV (n = 14)	Total (n = 56)	*p*-value
Perforated organ					
Large bowel	8 (72.3)	15 (48.4)	13 (92.9)	36 (64.3)	-
Small bowel	0	5 (16.1)	1 (7.1)	6 (10.7)	-
Appendix	3 (27.7)	11 (35.5)	0	14 (25)	-
Median NPWT duration, days (range)	5 (3-17)	5 (3-17)	6 (3-14)	5 (3-17)	0.365
DPC implementation after NPWT	11 (100.0)	28 (90.3)	12 (85.7)	51 (91.0)	0.451
Wound infection after NPWT+DPC	0	4 (14.3)	3 (25)	7 (13.7)	0.218
All SSIs after surgery	0	7 (22.6)	5 (35.7)	12 (21.4)	0.094

Data are expressed as n (%) unless otherwise indicated.

Table 5. Outcomes of NPWT Followed by DPC for Perforated Large Bowel According to Peritonitis Classification (n = 36).

Stage	II	III	IV	Total	*p*-value
Perforated organ					
Large bowel	8 (22.2)	15 (41.7)	13 (36.1)	36 (100)	-
Median NPWT duration, days (range)	6 (5-8)	5 (3-17)	5 (3-14)	5 (3-17)	0.738
DPC implementation after NPWT	8 (100.0)	13 (86.7)	11 (84.6)	32 (88.9)	0.518
Wound infection after NPWT+DPC	0	1 (7.7)	3 (27.3)	4 (12.5)	0.164
All SSIs after surgery	0	3 (20.0)	5 (38.5)	8 (22.2)	0.116

Data are expressed as n (%) unless otherwise indicated.

days, regardless of the extent or severity of peritonitis.

The incidence of treatment-related AEs was evaluated from the time of NPWT initiation (Table 6). Fascial dehiscence was observed in one case. Four patients experienced pain that did not require analgesics. However, four patients developed SSIs, of which two were deep-layer infections.

Patients with BMIs > 25 kg/m^2 had the highest incidence of SSIs (36.4%). Patients with other risk factors, including smoking, transfusion, stoma creation, and steroid use, represented 25% or more of the SSI incidence (Table 7).

Discussion

Among patients that undergo emergency surgery due to peritonitis, the reported SSI risk is >50%[3]. Thus, some surgeons have attempted to employ DPC procedures to prevent SSIs. However, Cohn et al.[9] reported that 46% of peritonitis surgeries were associated with SSIs, despite leaving the subcutaneous layer open, and the remaining 54% moved on to the DPC procedure. Among the patients that underwent DPCs, 21% developed later SSIs. In comparison, in the present study, 91% of the patients that underwent surgery for severe peritonitis due to lower gastrointestinal perforations moved on to DPCs following NPWT. Among the patients that underwent DPCs, only 13.7% developed later SSIs. Even if cases of perforations of small intestine and appendix are excluded, 88.9% moved on to a DPC and 12.5% developed wound infections. These findings suggested that NPWT might contribute to fewer SSIs and the successful implementation of DPC in patients with severe peritonitis.

To the best of our knowledge, this study was the first prospective study on the NPWT procedure followed by DPC that focused on lower gastrointestinal peritonitis. We found that patients classified as stage II had no SSIs after NPWT followed by DPC. This was surprising, because the stage II bacterial detection rate was 88.9%, which is highly risky for

Table 6. Adverse Events Related to Negative Pressure Wound Therapy (NPWT) (n = 56).

Event	CTCAE Version 4.0	
	Grade 1, 2	≥Grade 3
Pain	4 (7.1)	0
Surgical site infection (SSI) during NPWT		
Superficial	2 (3.6)	0
Deep	2 (3.6)	0
Fascial dehiscence	0	1 (1.8)
Total	8 (14.3)	1 (1.8)

Data are given as n (%).

Table 7. Incidence of SSI According to Risk Factors.

Risk factor	n	SSIs*, n	SSI rate (%)
BMI > 25 kg /m^2	11	4	36.4
Smoking	13	4	30.8
Transfusion	7	2	28.6
Stoma creation	24	6	25.0
Steroid use	4	1	25.0
Operation time > 180 min	13	2	15.4
Diabetes mellitus	7	1	14.3

SSI, surgical site infection; BMI, body mass index.

a primary closure procedure. The absence of SSIs in this group might be explained by either low amounts of bacteria in the peritoneum or the fact that the patients were in relatively better general condition than those with stages III and IV peritonitis. The frequency of all SSIs following surgery tended to be higher among stage IV patients (35.7%) than among stage II (0%) and III patients (14.3%; p = 0.094). Moreover, stage IV patients had prolonged hospital stays. However, the median time to wound healing was not extended in stage IV compared with other stages. These results suggested that NPWT followed by DPC eventually reduced the severity of the wound infection in stage IV, which facilitated wound healing. Therefore, the extended length of hospital stay in the stage IV group was likely due to poor systemic conditions rather than delayed wound healing.

We found that NPWT was associated with only a few AEs. Four patients developed superficial or deep SSIs during NPWT and had to discontinue NPWT. These SSIs might have been unavoidable if patients had manifested severe sepsis, which can inhibit wound healing. Four patients experienced pain when the starting NPWT was set at 125 mmHg. Of these patients, three experienced pain relief with oral analgesics, and one experienced pain relief by reducing the negative pressure to 40 mmHg.

How does the degree of magnitude of negative pressure affect wound healing? A randomized controlled study was conducted by Chen et al.[20] applying NPWT in a total of 251 cases with serious limb lacerations due to dog bites. When NPWT was performed, low negative pressure (−75 mmHg) had the same positive effects as high pressure (−125 mmHg). However, more robust evidence will be required to conclude the efficacy according to the magnitude of negative pressure.

This study did not address whether a wound-edge protector should be used in the protocol to lower the prevalence of SSIs in very severe peritonitis surgeries. Even so, in 54 out of 56 cases, wound-edge protectors were used. No SSIs were detected in two patients without wound-edge protectors. Three cases of laparoscopic procedure were included, which did not develop SSIs after NPWT followed by DPC. Possibly, a smaller incision might have an advantage in the peritonitis surgery. We should have assessed the method of opening the abdomen like median or pararectal incision, or muscle-splitting incision. But no data were obtained concerning it.

Watanabe et al.[2] demonstrated in a multivariate analysis that the risk factors for SSI in emergency colorectal surgery were obesity and severe incisional contamination. In our study, patients with high BMIs had a high incidence (36.4%) of incisional SSIs. A stoma was created in 24 patients, of which 25% developed SSIs. However, no relevant risk factors involving high BMI, stoma creation, smoking, transfusion, long operation time, steroid use, or diabetes mellitus were found in a statistical analysis (data not shown).

Only a few studies have investigated lower gastrointestinal perforations, and none of those studies applied the NPWT procedure followed by DPC. Other studies investigated the effect of NPWT alone on dirty wounds[10-12]. However, those analyses might have included some patients with only slightly dirty wounds, because they had not clearly defined the extent of contamination necessary to qualify as a dirty wound. However, an important point in our study, which distinguished it from other similar studies, was that we analyzed SSI rates according to the peritonitis classification, which reflected the extent of intra-abdominal contamination. As expected, the rate of SSIs varied according to the extent of peritonitis. The failure to classify different degrees of contamination might be the main reason for the heterogeneity of analyses among previous SSI-related studies. In turn, due to the heterogeneity in the results of previous studies, it is difficult to draw any conclusions. On the other hand, our results revealed that, in patients with lower gastrointestinal perforations, NPWT followed by DPC was an effective post-surgical treatment, particularly for severely dirty wounds.

However, it remains unknown whether DPC is effective for dirty wounds. A meta-analysis conducted by Bhangu et al.[8] could not demonstrate definitive evidence of the efficacy of DPC due to poor methodological design in the published studies, with clinical and statistical heterogeneity and

a high risk of bias. SSIs often occur when primary closure is performed in emergency surgery. According to a previous report[1], as many as 82.4% of patients with pan-peritonitis that undergo emergency colorectal surgery develop SSIs following primary closures. Those authors insisted that, when a colon perforation occurs with generalized contamination, the surgeon should consider either a DPC or leaving the incision open to heal by secondary intention, because, in addition to the wound contamination, the general condition of the patient might be important. Similarly, our results suggested that primary closure was not necessarily appropriate in patients with severe peritonitis; thus, we recommend the implementation of a strategy that includes a DPC.

Several recent reports investigated the efficacy of closed NPWT. Closed NPWT was defined as the application of NPWT to roughly closed laparotomy incisions. Two large-volume randomized controlled trials[21,22] were implemented to test closed NPWT in patients that underwent elective abdominal surgery. However, both studies found no significant difference between closed NPWT and primary closure; therefore, they could not recommend closed NPWT as a therapeutic intervention to reduce infectious complications in elective surgery for colorectal, gastrointestinal, pancreatic, or perineal surface malignancies. Frazee et al.[23] conducted a randomized controlled trial to test the efficacy of closed NPWT vs. open NPWT for dirty wounds. They revealed that the SSI rates were not significantly different between these procedures (8.0% vs. 4.1%, $p = 1.0$). On the other hand, Bonds et al.[15] conducted a retrospective study of closed NPWT vs. primary closure after open colorectal surgery. They found that only 25% of all patients had contaminated wounds. Their SSI rates were 12.5% vs. 29.3%, respectively, which favored a closed NPWT over primary closure alone. However, the application of closed NPWT for pan-peritonitis (i.e., wounds that are considerably more contaminated) might be challenging.

A limitation of the present study is that we did not analyze whether NPWT provided added benefit to a DPC in preventing SSIs. Undoubtedly, bacterial contamination of the incision during surgery is a major risk factor in the development of an SSI. In the present study, 89.6% of ascites fluid samples had positive bacterial cultures. The benefits of NPWT were most likely attributable to the constant drainage of contaminated wound effluent, which can interfere with incision healing. Duttaroy et al.[12] demonstrated that, for dirty abdominal incisions, a DPC alone significantly reduced the rate of SSIs compared with a primary closure (2.7% vs. 42.5%, $p < 0.0000375$). Consequently, we speculate that NPWT applied right after surgery might contribute to a decrease in the risk of developing an SSI following a DPC. However, it has not been proven whether NPWT itself plays an additional role in the DPC procedure. To elucidate whether NPWT provided added benefit to a DPC in preventing SSIs, it would be necessary to conduct a randomized controlled trial on patients treated with DPCs, with or without NPWT, for dirty surgical wounds due to lower gastrointestinal perforations.

Conclusion

NPWT followed by a DPC resulted in a low SSI rate in each peritonitis stage. Thus, this approach appears promising as an alternative to a traditional DPC alone for treating a lower gastrointestinal perforation.

Conflicts of Interest

There are no conflicts of interest.

Author Contributions

Dr. Ota mainly wrote a draft of the manuscript. Dr. Danno designed an original protocol of the present study. Dr. Uemura, Dr. Matsuda, Dr. Mizushima, and Dr. Yamamoto revised the study protocol appropriately. Dr. Ohta, Dr. Matsumura, Dr. Komori, Dr. Okamura, Dr. Okano, Dr. Ogawa, Dr. Tamagawa, and Dr. Nezu enrolled patients which met inclusion criteria for the present study and closely revised the draft of the manuscript. Profs. Doki and Eguchi revised the draft as well, supervising the current research.

Approval by Institutional Review Board (IRB)

Ikeda City Hospital; 3270, Higashiosaka City Medical Center; 02-0328-A, Osaka Rosai Hospital; 27-88, Osaka General Medical Center; 27-2026, Kaizuka City Hospital; 133 Otemae Hospital; 2015-025, Tane General Hospital; no designated number on an IRB approval, Nishinomiya Municipal Central Hospital; 353

References

1. Matsuda C, Adachi Y. Evidence for laparoscopic peritoneal lavage for purulent diverticulitis. Ann Gastroenterol Surg. 2017 Sep; 1(3): 238.
2. Watanabe M, Suzuki H, Nomura S, et al. Risk factors for surgical site infection in emergency colorectal surgery: a retrospective analysis. Surgical Infect. 2014 Jun; 15(3): 256-61.
3. Danno K, Matsuda C, Miyazaki S, et al. Efficacy of negative-pressure wound therapy for preventing surgical site infections after surgery for peritonitis attributable to lower-gastrointestinal perforation: A single-institution experience. Surgical Infect. 2018 Oct; 19 (7): 711-6.
4. Viljkovi R, Protic M, Gluhovic A, et al. Prospective clinical trial of factors predicting the early development of hernia after midline laparotomy. J Am Coll Surg. 2010 Feb; 210(2): 210-9.
5. Badia JM, Casey AL, Petrosillo N, et al. Impact of surgical site infection on healthcare costs and patient outcomes: a systematic review in six European countries. J Hosp Infect. 2017 May; 96(1): 1-15.
6. Nishino Y, Ebisawa K, Yamada Y, et al. Human deciduous teeth

dental pulp cells with basic fibroblast growth factor enhance wound healing of skin defect. J Craniofac Surg. 2011 Mar; 22(2): 438-42.

7. Lambrinos A, Chan B, Wells D, et al. Hyperbaric oxygen therapy for the treatment of diabetic foot ulcers: A health technology assessment. Ont Health Technol Assess Ser. 2017 May; 17(5): 1-142.

8. Bhangu A, Singh P, Lundy J, et al. Systemic review and meta-analysis of randomized clinical trials comparing primary vs delayed primary skin closure in contaminated and dirty abdominal incisions. JAMA Surg. 2013 Aug; 148(8): 779-86.

9. Cohn SM, Giannotti G, Ong AW, et al. Prospective randomized trial of two wound management strategies for dirty abdominal wounds. Ann Surg. 2001 Mar; 233(3): 409-13.

10. Chiang RA, Chen SL, Tsai YC. Delayed primary closure versus primary closure for wound management in perforated appendicitis: a prospective randomized controlled trial. J Chin Med Assoc. 2012 Apr; 75(4): 156-9.

11. Khan KI, Mahmood S, Akmal M, et al. Comparison of rate of surgical wound infection, length of hospital stay and patient convenience in complicated appendicitis between primary closure and delayed primary closure. J Pak Med Assoc. 2012 Jun; 62(6): 596-8.

12. Duttaroy DD, Jitendra J, Duttaroy B, et al. Management strategy for dirty abdominal incisions: primary or delayed primary closure? A randomized trial. Surg Infect. 2009 Apr; 10(2): 129-36.

13. Lahat G, Tulchinsky H, Goldman G, et al. Wound infection after ileostomy closure: a prospective randomized study comparing primary vs. delayed primary closure techniques. Tech Coloproctol. 2005 Dec; 9(3): 206-8.

14. Siribumrungwong B, Noorit P, Wilasrusmee C, et al. A systematic review and meta-analysis of randomised controlled trials of delayed primary wound closure in contaminated abdominal wounds. World J Emerg Surg 2014 Sep; 9(1): 49.

15. Bonds AM, Novick TK, Dietert JB, et al. Incisional negative pressure wound therapy significantly reduces surgical site infection in open colorectal surgery. Dis Colon Rectum. 2013 Dec; 56(12): 1403-8.

16. Vargo D. Negative pressure wound therapy in the prevention of wound infection in high risk abdominal wound closures. Am J Surg. 2012 Dec; 204(6): 1021-3.

17. Hinchey EJ, Schaal PG, Richards GK. Treatment of perforated diverticular disease of the colon. Adv Surg. 1978; 12: 85-109.

18. Horan TC, Gaynes RP, Martone WJ, et al. CDC definitions of nosocomial surgical site infections, 1992: A modification of CDC definitions of surgical wound infections. Am J Infect Control. 1992 Oct; 20(5): 271-4.

19. Mangram AJ, Horan TC, Pearson ML, et al. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Am J Infect Control. 1999 Apr; 27(2): 97-132.

20. Chen R, Huang L, Zheng J, et al. Negative pressure wound therapy for serious dog bites of extremities: A prospective randomized trial. Am J Emerg Med. 2016 Jun; 34(6): 1006-10.

21. Shen P, Blackham AU, Lewis S, et al. Phase II randomized trial of negative-pressure wound therapy to decrease surgical site infection in patients undergoing laparotomy for gastrointestinal, pancreatic, and peritoneal surface malignancies. Am Coll Surg. 2017 Apr; 224 (4): 726-37.

22. Murphy PB, Knowles S, Chadi SA, et al. Negative pressure wound therapy use to decrease surgical nosocomial events in colorectal resections (NEPTUNE): A randomized controlled trial. Ann Surg. 2019 Jul; 270(1): 38-42.

23. Frazee R, Manning A, Abernathy S, et al. Open vs closed negative pressure wound therapy for contaminated and dirty surgical wounds: A prospective randomized comparison. J Am Coll Surg. 2018 Apr; 226(4): 507-12.

Journal of the Anus, Rectum and Colon is an Open Access journal distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view the details of this license, please visit (https://creativecommons.org/licenses/by-nc-nd/4.0/).