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ORIGINAL ARTICLE

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Open abdomen closure methods for severe abdominal sepsis: a retrospective cohort study

Gaetano Poillucci[1] · Mauro Podda[2] · Giulia Russo[3] · Sergio Gaetano Perri[4] · Domenico Ipri[4] · Gabriele Manetti[4] · Maria Giulia Lolli[4] · Renato De Angelis[4]

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Abstract

Purpose The open abdomen (OA) procedure as part of damage control surgery represents a significant surgical advance in severe intra-abdominal infections. Major techniques used for OA are negative pressure wound therapy (NPWT) and non-NPWT. The aim of this retrospective study is to evaluate the effects of different abdominal closure methods and their outcomes in patients presenting with abdominal sepsis treated with OA.

Materials and methods We retrospectively analyzed clinical outcomes of patients affected by severe intra-abdominal sepsis treated with OA. Demographic features, mortality prediction score, abdominal closure methods, length of hospital stay, complications and mortality rates of patients were determined and compared.

Results This study included 106 patients, of whom 77 underwent OA with NPWT and 29 with non-NPWT. OA duration was longer in NPWT patients ($p=0.007$). In-hospital mortality rates in NPWT and in non-NPWT patients were 40.3% and 51.7%, respectively ($p=0.126$), with an overall 30-day mortality rate of 18.2% and 51.7%, respectively ($p=0.0002$). After emergency colorectal surgery, patients who underwent OA with NPWT had a lower rate of colostomy ($p=0.025$).

Conclusions NPWT is the best temporary abdominal closure technique to decrease mortality and colostomy rates in patients managed with OA for severe intra-abdominal infections.

Keywords Open abdomen · Abdominal sepsis · Bogota-Bag · Negative pressure wound therapy · Emergency surgery

Abbreviations

ACS	Abdominal compartment syndrome
APACHE	Acute Physiologic Assessment and Chronic Health Evaluation
CIAOW	Complicated Intra-Abdominal Infections Worldwide Observational
DCS	Damage control surgery
DFC	Definitive fascial closure
EAF	Entero-atmospheric fistula
IAH	Intra-abdominal hypertension
IAI	Intra-abdominal infections
IAP	Intra-abdominal pressure
ICU	Intensive care unit
MPI	Mannheim Peritonitis Index
NPWT	Negative pressure wound therapy
OA	Open abdomen
SIRS	Systemic inflammatory response syndrome
SOFA	Sequential Organ Failure Assessment
TAC	Temporary abdominal closure
WBC	White blood cell
WSACS	World Society of the Abdominal Compartment Syndrome
WSES	World Society of Emergency Surgery

✉ Gaetano Poillucci
gaetano.poillucci@gmail.com

1 Department of General and Specialized Surgery “Paride Stefanini”, Policlinico Universitario Umberto I, Viale del Policlinico, 155, 00161 Rome, Italy

2 Department of General, Emergency and Minimally Invasive Surgery, Policlinico Universitario “D. Casula”, University of Cagliari, Monserrato, Italy

3 Department of General Surgery, San Camillo De Lellis Hospital, Rieti, Italy

4 Department of General Surgery, San Giovanni Addolorata Hospital, Rome, Italy

Introduction

Intra-abdominal infection (IAI) is the second source of severe sepsis and the second cause of death from infections in intensive care unit (ICU) patients [1, 2]. If not correctly treated, IAIs develop into peritonitis, severe sepsis and septic shock [3, 4].

Current treatment of severe sepsis involves prompt source control, early appropriate antimicrobial therapy, and adequate resuscitation [5]. Damage control surgery (DCS) represents a valid therapeutic alternative in critically ill patients with severe IAI. These conditions may lead to severe physiologic derangements and multiorgan failure, unless this self-perpetuating vicious cycle is interrupted by abdominal decompression [6].

In the study by Shapiro et al. for DCS the rate of complications and mortality is high. Morbidity includes wound infection (5–100%), intra-abdominal abscess (0–83%), dehiscence (9–25%), bile leak (8–33%), entero-atmospheric fistula (EAF; 2–25%), and abdominal compartment syndrome (ACS; 2–25%). Multisystem organ failure is described in 20–33% of patients, contributing significantly to the mortality rate of 12–67% [7].

The open abdomen (OA) approach can be considered important in managing intra-abdominal catastrophes and an effective technique in preventing or treating deranged physiology caused by severe intra-abdominal sepsis or septic shock, especially in those situations in which disease progression to septic shock leaves no room for a definitive surgical procedure [8, 9].

The OA strategy consists of intentionally leaving the abdominal fascia edges of the rectus abdominus muscles unapproximated in all cases in which the abdomen cannot be closed owing to the presence of visceral edema or the inability to completely control the underlying source of IAI, thus leading to the necessity of further re-explorations in a planned re-look laparotomy strategy.

Within this context, temporary abdominal closure (TAC) refers to the method for providing protection to the abdominal viscera during the time the fascia remains open [5].

A realistic figure would probably be 3–5% of laparotomies performed for severe IAIs with intra-abdominal hypertension (IAH) [10].

The aim of this retrospective study was to compare intra-hospital morbidity, mortality, and definitive fascial closure (DFC) rates in severe abdominal sepsis patients who underwent OA with temporary negative pressure wound therapy (NPWT) versus the Bogota-Bag closure technique to relate the experience of our center with data existing in the literature. Secondly, we quantified the impact of NPWT use on surgeons' decisions to perform a primary colonic anastomosis or an end colostomy for patients with sepsis of hindgut origin.

Patients and methods

From August 2010 to August 2018, 106 patients with OA were treated at the Department of Surgery of the San Giovanni Addolorata Hospital in Rome (Italy). Informed consent was obtained from all individual patients when possible. This study was performed in accordance with the ethical principles of the 1975 Declaration of Helsinki.

Inclusion criteria

Patients with preoperative evidence of severe sepsis or septic shock with a suspected or known abdominal source of infection requiring urgent or emergent laparotomy for source control were included in the study. Sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection. Organ dysfunction can be identified as an acute change in total Sequential Organ Failure Assessment Score (SOFA) $\geq$ 2 points consequent to the infection. A SOFA score $\geq$ 2 reflects an overall mortality risk of approximately 10% in a general hospital population with suspected infection. Septic shock is a subset of sepsis in which underlying circulatory and cellular/metabolic abnormalities are profound enough to substantially increase mortality. Patients with septic shock can be identified with a clinical construct of sepsis with persisting hypotension requiring vasopressors to maintain mean arterial pressure $\geq$ 65 mmHg and having a serum lactate level > 2 mmol/L (18 mg/dL) despite adequate volume resuscitation. With these criteria, hospital mortality is in excess of 40% [11].

Exclusion criteria

Patients less than 18 years of age, sepsis secondary to trauma, laparotomies for non-septic indications, and abdominal sepsis managed without laparotomy were excluded.

Measures of disease severity

Disease severity was measured using the Mannheim Peritonitis Index (MPI) score and the APACHE-II score on admission. This system is a widely utilized tool for stratifying disease severity and predicting patient mortality in ICU [12].

Surgical technique

Patients with severe sepsis or septic shock due to IAI requiring laparotomy were divided into two groups depending on TAC methods:

- With negative pressure wound therapy (NPWT—ABThera™ OA NPT; KCI USA Inc.): following source control procedure, the fascia was left open with a negative pressure dressing. The decision for ABThera™ application during the initial operation was made at the surgeon's discretion. With the vacuum system, a protective and fluid-permeable membrane was laid over the abdominal organs. Then, a spongy material allowing fluid absorption was placed over the membrane and finally the abdomen was covered with a drape for closure. An opening of about 3 cm^2 was left on the drape, and through this opening 75–125 mmHg negative pressure was administered continually or at intervals. Patients returned to the operating room for reassessment of the peritoneal cavity within 48–72 h. This process was repeated and terminated until the abdomen was suitable for DFC, following macroscopic resolution of peritonitis and clinical assessment.
- With non-NPWT: this group comprised patients who underwent Bogota-Bag positioning after OA. Necrotic tissues were removed, perforations were repaired, the abdomen was washed and aspirated, and drains were placed in the abdominal cavity. Patients returned to the operating room within 48–72 h of the first operation.

Definition of outcomes

Primary outcomes

- Overall post-intervention in-hospital mortality rate, including 30-day mortality rate;
- DFC rate.

Secondary outcomes

- Overall post-intervention complications: the number and rate of EAF, postoperative bleeding, anastomotic leak and planned ventral hernia;
- Length of primary hospital stay;
- OA duration.

Statistical analysis

Patients were divided into two groups depending on the temporary abdominal closure techniques: NPWT and non-NPWT. Preoperative variables related to patient (gender, age, comorbidities) and disease (contamination source, CT findings, APACHE II score, MPI score) were evaluated. All categorical variables were expressed both as a number and percentage, while continuous variables were expressed as mean and standard deviations. The continuous variable data were analyzed using Mann–Whitney *U* test, while categorical variables were compared using Fisher's exact test. The level of statistical significance was established at $p < 0.05$ (two-tailed model for unpaired data). Statistical analyses were performed using MedCalc statistical software version 15.2.

Results

During the 8-year observation period, 106 patients with severe IAIs were managed with OA. The general characteristics of patients enrolled in the study are shown in Table 1. We managed OA using ABThera™in 77 patients (72.6%) and Bogota-Bag in 29 patients (27.4%).

There was no statistically significant difference between the two groups in terms of gender, mean APACHE-II score, mean MPI score, and primary etiology of abdominal sepsis, as reported in Tables 2 and 3.

In the NPWT group, mean age was 64.7 ± 13.2 years, while in the non-NPWT group it was 70 ± 15.3 years ($p = 0.039$). In the NPWT group, the in-hospital mortality rate was 40.3% (27 patients) compared to 51.7% (15 patient) in the non-NPWT group ($p = 0.126$). The 30-day mortality rate was significantly lower in the NPWT group (18.2%) compared to the non-NPWT group (51.7%) ($p = 0.0002$).

The mortality rate was indexed against the predicted by calculating an observed/predicted mortality ratio. This yielded ratios of 0.63 for the NPWT group and 0.85 for the other, thus indicating an actual mortality rate below that predicted by the APACHE-II score. Hospitalization periods in the two groups were 20.8 ± 21.9 days and 13.2 ± 10.2 days, respectively ($p = 0.019$), and the duration of OA was significantly shorter in the non-NPWT group (14.2 ± 18.7 vs 4.4 ± 6.2, $p < 0.00001$).

The complication rate in NPWT group was 7.8% (6 patients), and 17.2% (5 patients) in the non-NPWT group ($p = 0.154$) as shown in Table 3.

Table 1 General characteristics of patients enrolled in the study

N. of patients enrolled in the study	106
Age: mean ± SD	69.1 ± 14.1
Gender: *N.* (%)	
Male	56 (52.8%)
Female	50 (47.2%)
APACHE-II score: mean ± SD	27.3 ± 5.9
Mannheim Peritonitis Index score: Mean ± SD	22.3 ± 5.8
Duration of OA: mean ± SD	11.5 ± 16.9
In-hospital mortality: *N.* (%)	42 (39.6%)
30 Day-mortality: *N.* (%)	26 (24.5%)
Complications: *N.* (%)	11 (10.4%)
Hospitalization time: days ± SD	18.5 ± 19.4

Table 2 Abdominal sepsis sources

Contamination source	Overall: *N*. %	NPWT group ($n=77$)	Non-NPWT group ($n=29$)	*p* value
Large bowel	34 (32%)	25 (32.5%)	9 (31.1%)	0.99
Large bowel perforation	27/34 (79.4%)	20 (25.9%)	7 (24.2%)	
Large bowel obstruction	7/34 (20.6%)	5 (6.5%)	2 (6.8%)	
Small bowel	26 (24.5%)	17 (22.1%)	9 (31.0%)	0.4476
Postoperative fluid collection	20 (18.9%)	14 (18.2%)	6 (20.7%)	0.7846
Pancreas	15 (14.2%)	11 (14.2%)	4 (13.7%)	0.99
Gallbladder	5 (4.7%)	4 (5.2%)	1 (3.4%)	0.99
Stomach	4 (3.8%)	4 (5.2%)	–	0.573
Cecal appendix	2 (1.9%)	2 (2.6%)	–	0.99

Table 3 Demographic data and outcomes of the two groups

	NPWT group ($n=77$)	Non-NPWT group ($n=29$)	*p* value
Gender (M:F)	45:32	11:18	0.080
Age (years ± SD)	64.7 ± 13.2	70 ± 15.3	**0.039**
APACHE-II score (mean ± SD)	27.5 ± 6.1	26.8 ± 5.4	0.503
Mannheim Peritonitis Index score (mean ± SD)	22.0 ± 5.6	22.9 ± 6.3	0.646
Duration OA (days ± SD)	14.2 ± 18.7	4.4 ± 6.2	**< 0.00001**
30-day mortality: *N*. (%)	11 (18.2%)	15 (51.7%)	**0.0002**
In-hospital mortality: *N*. (%)	27 (40.3%)	15 (51.7%)	0.126
Observed/predicted mortality ratio	0.63	0.85	
Abdominal closure: *N*. (%)			
Definitive fascial closure (DFC)	40/77 (51.9%)	10/29 (34.5%)	0.129
Planned ventral hernia	37/77 (48.1%)	19/29 (65.5%)	
Complications: *N*. (%)	6 (7.8%)	5 (17.2%)	0.154
Entero-atmospheric fistula (EAF)	3/6 (3.9%)	3/5 (10.2%)	0.884
Postoperative bleeding	2/6 (2.6%)	1/5 (3.5%)	
Anastomotic leak	1/6 (1.3%)	1/5 (3.5%)	
Hospitalization time (days ± SD)	20.8 ± 21.9	13.2 ± 10.2	**0.019**

Highlighted in bold the *p* values indicate that statistically significant

The objective of DFC in NPWT and in non-NPWT groups was achieved in 51.9% and 34.5% of the patients, respectively ($p=0.129$), while 48.1% of patients in the NPWT group and 65.5% in the non-NPWT group underwent planned ventral hernia.

During the study period, 34 patients underwent DCS for IAI secondary to large bowel perforation or obstruction. The overall characteristic of these patients are summarized in Table 4. NPWT for OA was performed in 25 of these patients (73.5%). In the NPWT group, intestinal continuity was restored in 17 cases (68%), while in the non-NPWT group only two primary colonic anastomoses (22.2%) were performed. In the NPWT group, the in-hospital mortality rate was 28% (7 patients) compared to 33.3% (3 patients) in the other group ($p=1.000$). In this subgroup of patients, the 30-day mortality rate was significantly lower in the NPWT group (4%) compared to the non-NPWT group (33.3%) ($p=0.048$).

In both groups, a reoperation was needed for an anastomotic leak in one case (5.6% vs 33.3%, $p=0.271$). In all patients with anastomotic leak, the anastomosis was taken down and an end colostomy was performed. The rate of end colostomies performed was statistically lower in the NPWT group (8 colostomies, 32%) than in the other (7 colostomies, 77.8%) ($p=0.025$).

Table 4 General characteristics of the patients who underwent emergency colorectal resection

	NPWT group ($n=25$)	Non-NPWT group ($n=9$)	p value
Gender (M:F)	14:11	2:7	0.125
Age (years ± SD)	62.7 ± 14.3	67.3 ± 15	0.105
APACHE-II score (mean ± SD)	26.6 ± 4.8	28.8 ± 4.2	0.334
Mannheim Peritonitis Index score (mean ± SD)	23.4 ± 4.6	24.7 ± 5.5	0.562
Duration of OA (days ± SD)	8.8 ± 16.7	7.2 ± 9.9	0.052
End colostomy: *N*. (%)	8 (32%)	7 (77.8%)	**0.025**
In-hospital mortality: *N*. (%)	7 (28%)	3 (33.3%)	0.99
30-day mortality: *N*. (%)	1 (4%)	3 (33.3%)	**0.048**
Anastomotic leak: *N*. (%)	1/18 (5.6%)	1/3 (33.3%)	0.271
Hospitalization time (days ± SD)	8.6 ± 9.4	8.9 ± 10.1	0.634

Highlighted in bold the *p* values indicate that statistically significant

Discussion

The OA is increasingly used after DCS for patients with severe abdominal sepsis. The mortality rate in septic patients can reach 36.5%, as recently reported in the CIAOW study [13].

The mortality rates in our groups are lower than those predicted. These results are encouraging, but mortality is still high due to the severity of preoperative status. This is the reason why surgical treatment must be rapid and aggressive so as to control the source of infection and inhibit the systemic inflammatory response. Within this context, urgent laparotomy is the treatment of choice, and in septic patients it can be considered a form of DCS.

Today, there are three techniques available to manage laparotomy in critically ill patients with severe abdominal sepsis [14, 15]: relaparotomy on demand, planned relaparotomy every 36–48 h, and OA.

Furthermore, data from trauma patients showed that the time to re-exploration reduces the DFC rate by 1.1% for each hour after the first 24 h following the primary operation, and the first re-exploration performed after 48 h is related to an increased rate of complications [16]. In the recent systematic review by Cristaudo et al., enteral nutrition, organ dysfunction, local and systematic infection, number of re-explorations, Injury Severity Score (ISS) and the development of aN EAF appeared most often related to delayed DFC [17].

OA is a good option in managing septic abdomen. It is an intentional laparostomy based on three steps [5]: recognition and control of the source of infection, stabilization of the patient in the ICU, planned second look and management of the OA.

Several strategies for maintaining the OA have been reported: Bogota-Bag, Barker's vacuum packing technique, NPWT, and interpositional mesh placement. They result in different DFC rates and EAF risks.

In our study, NPWT has shown to be a more feasible and efficient technique for managing OA compared to the Bogota-Bag. Previous studies have demonstrated that NPWT in severe peritonitis patients provides the best results in terms of DFC and mortality rates [18, 19] and should be considered the preferred technique for TAC [6].

The advantages of NPWT over non-NPWT lie in increasing blood flow at the wound site by decreasing interstitial pressure and reducing the severity of inflammation and infection by removing the exudate.

Moreover, NPWT increases angiogenesis and granulation by stimulating cell reproduction and proliferation, thereby positively contributing to wound healing. NPWT also actively drains toxin-and bacteria-rich intraperitoneal fluid.

Atema et al., in a recent review of OA in non-trauma patients, found a 30% postoperative mortality rate [20].

In the present study, 30-day mortality was significantly lower in the NPWT group compared to the other. Complications were also less frequent in the NPWT group, although the difference did not reach statistical significance. OA duration and length of hospitalization were however shorter in the non-NPWT group.

There are few studies focused on complications of OA managed with NPWT, and their results are difficult to interpret because no subgroup analyses based on indications for OA are reported.

Postoperative bleeding is one of the most common complications following OA. Its incidence in the literature is 24% [21–23] when considering trauma and septic patients together. In our study, the incidence of hemorrhage was similar in the two groups. It is worth nothing that for patients at risk of hemorrhage due to underlying comorbidity, we started with a negative pressure of -75 mmHg instead of − 125 mmHg.

Recurrent ACS is another reported complication. Although recurrent ACS is a rare complication, interval measures of bladder pressure every 4–6 h, as the expression of IAP is deemed necessary to detect and treat recurrent ACS [24]. Elevated IAP commonly causes marked deficits in both regional and global perfusion that may result in significant organ failure.

The combination of IAH and the physiological effects of severe sepsis and septic shock may result in high morbidity and mortality rates [5]. In our study, there were no episodes of recurrent ACS after the first laparotomy.

Patients undergoing OA strategy are at risk of developing EAF, "frozen abdomen", and secondary intra-abdominal abscesses [13, 25].

The incidence of EAF in septic patients is highly variable (5–54%) [26, 27]. The development of EAF is the most serious local complication in patients with OA and it depends on OA duration, presence of synthetic meshes, residual infection, and number of surgical re-explorations [5, 28]. Large bowel resections and strong administration of intravenous fluids (> 5–10 L) in the early postoperative period (< 48 h) appear to influence the development of intra-abdominal complications such as EAF and abscesses [17]. EAF is associated with high mortality and morbidity (up to 42%) [29].

Key components in the management of EAF include adequate delivery of nutrition, electrolyte/fluid deficit correction and adequate broader spectrum antimicrobial therapy. The most common strategies for EAF management include control and diversion of fistula output (even by using NPWT applied over the surrounding tissue to allow granulation), skin grafting over the granulation tissue around the fistula to apply a colostomy bag, and the definitive surgical treatment of the fistula when the patient has fully recovered and is in a good nutritional state (usually after 6–12 months).

In the present study, the EAF rate was similar in the NPWT and non-NPWT groups, and our results are in line with those reported by Bruhin et al. [30].

Success in closing the abdominal wall depends on OA duration and the TAC used to manage OA [31]. Miller et al. reported that the complication rate following OA increased dramatically when the DFC was not performed within 7 days of the primary operation [32].

According to literature, when using NPWT there is better chance of abdominal wall healing with primary fascial closure because negative pressure contrasts abdominal muscle diastasis. On the contrary, the Bogota-Bag does not provide sufficient traction to the wound edges and allows the fascial edges to retract laterally, resulting in difficult DFC under significant tension, especially if closure is delayed.

An additional advantage of the OA strategy in abdominal sepsis is to delay the bowel anastomosis [33] in hemodynamically unstable patients. In patients with severe secondary peritonitis, significant hemodynamic instability and compromised tissue perfusion, primary anastomosis is at high risk of anastomotic leakage. Ordonez et al. concluded that in patients managed with staged laparotomies, deferred primary anastomosis can be performed safely as long as adequate control of the septic foci and restoration of deranged physiology is achieved prior to reconstruction [34].

Our results are in line with those reported by Kafka-Ritsch et al., with a high rate of intestinal reconstruction and a low in-hospital mortality rate reported for OA patients managed with NPWT for generalized peritonitis caused by colonic obstruction or perforation [35].

Possible limitations of this study are related to its retrospective, non-randomized, single-center design, which carries a high risk of selection bias. This means that the level of evidence behind the results of this study is not high. However, this has the merit of being focused on the use of OA in a large cohort of patients with severe IAIs, thus providing useful information in a field of research monopolized by trauma reports thus far.

Conclusions

OA treatment can be considered a form of DCS in patients with severe IAIs. In these patients, attempts at abdominal closure should be made as soon as the patient can physiologically tolerate it.

NPWT for temporary abdominal wall closure decreases the 30-day mortality rates, and positively contributes to the DFC by reducing the planned ventral hernia rate. Conversely, NPWT increases OA duration and hospitalization time compared to non-NPWT strategies. Although with few data available, NPWT seems to reduce the incidence of ostomy in patients with IAI by colonic obstruction or perforation.

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Compliance with ethical standards

Conflict of interest Gaetano Poillucci, Mauro Podda, Giulia Russo, Sergio Gaetano Perri, Domenico Ipri, Gabriele Manetti, Maria Giulia Lolli, and Renato De Angelis have no conflict of interest to declare.

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