Laparostomy with topical negative pressure for treating severe peritonitis
Preliminary experience with 16 cases and review of the literature

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Ciro De Martino, Paolo Caiazzo, Michele Albano, Francesco Calbi, Mauro Pastore, Pio Rocco Tramutoli

Emergency Surgery Unit, "San Carlo" Regional Hospital Potenza, Italy

Laparostomy with topical negative pressure in the treatment of severe peritonitis: preliminary experience with 16 cases and review of the literature.

INTRODUCTION: *The aim of this study was to assess the authors' initial experience with laparostomy and intraperitoneal topical negative pressure (TNP) in patients with severe peritonitis. The authors also reviewed the recent literature on the effectiveness and safety of abdominal TNP.*
PATIENTS AND METHODS: *Sixteen patients (10 male, 6 female, mean age 55 years), suffering from severe peritonitis, underwent emergency laparotomy and laparostomy with TNP. Abdominal sepsis originated from the small intestine (n = 7), large intestine (n = 6), biliary tract (n = 2), and pancreas (n = 1). In 2 patients abdominal wall mesh infection and soft tissue gangrene were observed.*
RESULTS: *The mortality rate was 31.2%. The main complications probably related to TNP were enteric fistulae (25%), bleeding (25%), abdominal abscesses (12.5%), bowel ischemia (6.2%). Delayed primary closure was performed in 8 patients (57.1%) whereas in 6 cases a parietal graft was necessary, and one patient underwent an autologus skin graft.*
CONCLUSIONS: *Laparostomy with intraperitoneal TNP is a safe and effective method for managing patients with severe peritonitis. Morbidity can be reduced through individualized application of the laparostomy dressing and pressure gradient. The abdominal wall should be managed in such a way as to make possible delayed primary closure.*

KEY WORDS: Laparostomy, Peritonitis, Topical negative pressure.

Introduction

The principles of surgical treatment of peritonitis have remained the same for decades. The key points of this treatment are elimination of the septic focus, removal of necrotic tissue, and drainage of the collections of pus [1]. In spite of the progress made in antimicrobial therapy and intensive care, the mortality and morbidity rates in patients with severe peritonitis remain high [2].
In many cases improved results are linked to the possibility of one or more revisions of the surgical site (second look surgery). This can be achieved with the open abdomen technique [3]. Although the concept of a second look after damage control surgery to manage abdominal trauma is widely accepted, the use of second look surgery in patients with severe abdominal peritonitis is still controversial [4].
Various surgical techniques have been developed to facilitated second look surgery. A method based on vacuum assisted closure (V.A.C.®) which involves the application of topical negative pressure (TNP) to the abdominal cavity has recently been developed [4,5]. The technique has been shown to have many advantages, but doubts have been voiced regarding its safety [6-8]. The authors of the present study report the preliminary experience of their

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Correspondence to: Dr. Ciro De Martino, MD, Via F. Wenner 18, 84080 Pellezzano (SA), Italy (e-mail: ciro.de@tiscali.it)

emergency surgery unit with laparostomy combined with TNP in the management of patients with severe peritonitis.

Materials and methods

At the Emergency Surgery Unit of the San Carlo Regional Hospital in Potenza, Italy, in the period from June 2010 to November 2011, 16 patients, 10 males and 6 females, with an average age of 55 years (range: 21-78 years), underwent emergency laparotomy and laparostomy formation for severe peritonitis. The patients were suffering from acute abdomen secondary to disease of the small intestine (n = 7), the colon (n = 6), the biliary tract (n = 2) and the pancreas (n = 1). Two of these patients had gangrene of the abdominal wall due to infection of prosthetic mesh. The severity of peritonitis was assessed using the Mannheim Peritonitis Index (MPI) (9) (Table I). Patient characteristics, cause of peritonitis and basic underlying pathology are listed in Table II. The decision whether fashion a laparostomy was made based on the patient's general medical condition, patient anatomy and surgical considerations.

TABLE I - *Mannheim peritonitis index score assigned to each risk factor*

Risk factors	Points
Age > 50 years	5
Female sex	5
Organ failure*	7
Malignancy	4
Duration of peritonitis: > 24 hours before surgery	4
Origin not in the colon	4
Extension of peritonitis: generalized peritonitis	6
Peritoneal fluid:	
clear	0
purulent	6
fecal	12

*Definition of organ failure: Kidney: creatinine > 177 mmol/L, urea > 167 mmol/L, oliguria < 20 ml/h; Lung: pO_2 < 50 mmHg, pCO_2 > 50 mmHg; hypodynamic or hyperdynamic shock; paralytic ileus for > 24 hours or complete mechanical ileus.

Surgical Technique

After the peritoneal toilet was completed, the abdominal viscera were protected with a fenestrated synthetic film, on which a polyurethane sponge, matching the size of the laparostomy, was placed, contacting the edges of the abdominal wall. The margins of the dressing were sometimes further stabilized with non absorbable sutures. Then, to hermetically seal the abdominal cavity, a film was applied that covered the dressing and adhered to the skin (Fig. 1). A small hole was made in this film and a suction device was applied to generate TNP (Renasys™, Smith&Nephew). The device was set to generate intermittent TNP at a subatmospheric pressure of 50-80 mmHg, depending on the amount of abdominal secretions (greater pressure) and bleeding (lesser pressure). After the procedure, the patients were taken to the Intensive Care Unit and put on mechanical ventilation. Laparostomy revere performed in the operating room at intervals of 48-72 hours. Additional revisions were performed, sometimes at the bedside, in cases of excessive secretions, bleeding, or loss of the airtight seal around the dressing.

TABLE II - *Patients' characteristics*

Number	Age	Sex	Origin of peritonitis	Underlying pathology	MPI*
1	68	M	Enterotomy dehiscence	Colon cancer	27
2	78	F	Perforation of ascending colon	Colon cancer	35
3	52	F	Hepatojejunal dehiscence, lesion of portal branch	Cholecysto-choledochal fistula	21
4	74	F	Colostomy dehiscence	Acute diverticulitis	16
5	76	M	Perforation and dehiscence of colostomy	Colon cancer	34
6	71	M	Perforation of transverse colon, dehiscence of biliary tract suture	Acute gangrenous cholecystitis	34
7	70	M	Perforation of sigmoid colon	Colon cancer	31
8	31	F	Pancreatic necrosis,abdominal compartment syndrome	Acute severe pancreatitis	28
9	52	M	Abdominal wall gangrene, gangrenous cholecystitis	Infection of abdominal wall prosthesis	26
10	78	F	Enterotomy dehiscence	Intestinal obstruction due to adhesions	35
11	34	M	Dehiscence of duodenal sutures	Duodenal perforation	27
12	60	M	Abdominal wall gangrene	Infection of abdominal wall prosthesis	25
13	21	F	Gangrenous appendicitis	Acute appendicitis during pregnancy	28
14	30	M	Intestinal infarction	Severe arteriopathy, chronic renal insufficiency	23
15	40	M	Perforation of cecum	Closed abdominal trauma	29
16	46	M	Diastatic perforation of colon	Peritoneal carcinosis from gastric cancer	33

*Mannheim peritonitis index

Fig. 1: Creation of laparostomy with topical negative pressure.

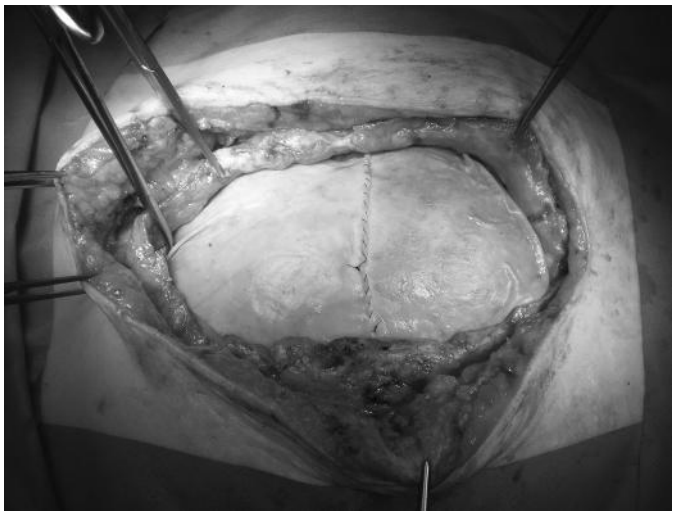

Fig. 2: Abdominal wall closure with biological prosthesis.

Fig. 3: "Planned laparocele" with autologous skin graft.

In 14 patients, there was satisfactory cleaning of the abdominal cavity, and the abdominal wall was closed. Direct sutures were used in 8 patients, a biological prosthesis in 5 (Fig. 2), an absorbable synthetic prosthesis in one and, in the remaining patient, after 80 days of open abdomen treatment, an autologous skin graft was used to cover the preperitoneal space because it was impossible to approximate the wound edges (Fig. 3). The patients were then transfered to the Emergency Surgery Ward, underwent rehabilitation, and finally discharged home. They had follow-up visits at regular intervals, initially once a week, then less frequently, depending on their clinical condition.

Results

The average MPI was 28.2, with a minimum MPI of 16 (patient 4, with colostomy dehiscence), and a maximum MPI of 35 (patient 10, with dehiscence of an enterotomy executed during surgery for intestinal occlusion).

The average duration of laparostomy was 23.4 days, with a minimum of 3 days (patient 8 with acute hemorrhagic necrotizing pancreatitis complicated by abdominal compartment syndrome who died on postoperative day 3), and a maximum of 80 days (patient 9). The latter underwent surgery for gangrene of the abdominal wall caused by an infection of a synthetic prosthesis (treatment for incisional hernia) and an enteric fistula. After removal of the infected prosthesis and repair of the fistula, the patient developed septic shock due to gangrenous cholecystitis. The prolonged duration of the laparostomy was a result of subcritical mesenteric ischemia and recurrent enteric fistulae. By day 80 all fistulae of the small bow-

TABLE III - *Laparostomy management and results*

N.	Duration (days)	Number of inspections	Method of abdominal wall closure	Complications*	Results
1	30	13	Direct sutures	Right subphrenic abscess	Healing
2	40	23	Direct sutures	Intestinal hemorrhage, enteric fistula	**Death**
3	11	6	Absorbable synthetic prosthesis		Healing
4	20	9	Direct sutures		Healing
5	30	13	Biological prosthesis / Direct sutures		Healing
6	5	3	Biological prosthesis		**Death**
7	15	6	Direct sutures		Healing
8	3	1	–		**Death**
9	80	35	Skin graft	Enteric fistula, intestinal ischemia	Incisional hernia, enterocutaneous fistula
10	20	8	Biological prosthesis	Enteric fistula	Periprosthetic seroma
11	9	4	Biological prosthesis	Hemorrhage	Periprosthetic seroma
12	20	11	Biological prosthesis	Hemorrhage	Periprosthetic seroma
13	4	2	Direct sutures		Healing
14	18	9	–		**Death**
15	60	28	Direct sutures	Hemorrhage, left subphrenic abscess	Incisional hernia
16	10	4	Direct sutures	Enteric fistula	**Death**

* Only surgical complications potentially associated with the laparostomy are reported

el had been closed although there was still a mature colonic fistula. The laparostomy was closed using an autologous skin graft.

Overall mortality was 31.5% (5/16 patients). Two patients died before abdominal closure: patient 8 and patient 14, a young male with insulin-dependent diabetes mellitus, diffuse arteriopathy and chronic renal insufficiency, who died of intestinal and hepatic infarction on postoperative day 18. Three patients died after laparostomy closure: patient 2 who died of massive gastric hemorrhage, patient 6 who died of sepsis resulting from gangrenous cholecystitis and colonic fistulization, and patient 16, who had peritoneal carcinosis arising from gastric cancer and had undergone surgery for intestinal perforation. The patients who died had an average MPI of 36.2, which was slightly higher than the average MPI of the survivors (27.2). This difference was not statistically significant (p=0.25).

During open abdomen treatment, 2 patients (12.5%) developed a subphrenic abscess. Four patients (25%) developed hemorrhage: in one case (patient 2) bleeding from ileotransverse anastomosis, and in the other 3 cases bleeding from the abdominal wall. Four patients (25%) developed enterocutaneous fistulae (patients 2, 9, 10, and 16). In one patient (patient 9) enteric hypoperfusion persisted even after normalization of hemodynamic parameters, suspension of the infusion of vasoactive amines, and the presence of normal splanchnic vessel anatomy.

At follow-up 6 patients (37.5%) were completely healed. Two patients (12.5%) were found to have developed a laparocele. In patient 9 the laparocele had been "planned": instead of fascial suturing or application of a

TABLE IV - *Summary of patient characteristics and results*

Number of patients	16	
M:F	10:6	
Average age	55	21-78
Origin of peritonitis		
- Small intestine	7	43.7%
- Colon	6	37.5%
- Biliary tract	2	12.5%
- Pancreas	1	6.2%
- Abdominal wall	2	12.5%
Malignancy	5	31.2%
Mannheim Peritonitis Index	28.2	16-35
Duration (days)	23.4	3-80
Revisions	10.9	1-35
Closure	14	
- Direct suture	8	57.1%
- Biological prosthesis	5	35.7%
- Synthetic absorbable prosthesis	1	7.1%
- Skin graft	1	7.1%
Complications		
- Enteric fistula	4	25%
- Hemorrhage	4	25%
- Abdominal abscess	2	12.5%
- Intestinal ischemia	1	6.2%
Results		
- Complete healing	6	37.5%
- Periprosthetic seroma	3	18.7%
- Incisional hernia	2	12.5%
- Enteric fistula	1	6.2%
- Death	5	31.5%

prosthesis an autologous skin graft was placed in direct contact with the preperitoneal tissue which was loose and thickened as a result of TNP.
Patient 15 developed a laparocele as a consequence of dehiscence of the fascial sutures and healing of the abdominal wall by second intention. One patient (6.2%), patient 9, currently has an enterocutaneous fistula which developed during open abdomen treatment. Three patients (18.7%), all with a biological abdominal wall prosthesis, have a periprosthetic seroma draining through a small dehiscence of the laparotomy wound, and complicated by recurrent infection. These patients (100% of the patients in our series who currently have a biological abdominal wall prosthesis), still require medication ad regular intervals. Our results are shown in Table III and Table IV.

Discussion

The problems highlighted by our preliminary experience, correspond to those currently discussed in the literature on the open abdomen technique. Of special interest are the relationship between TNP and intestinal perfusion, the incidence and management of enterocutaneous fistulae, delayed closure techniques, long-term complications of open abdomen and how they influence quality of life.

Intestinal Perfusion

Since almost all studies have found that treatment with TNP increases patient's risk of developing enteric fistulae, some authors began to wonder about the effects of TNP on intestinal perfusion. It is well known that, in contrast to the subcutaneous tissue and muscle of the abdominal wall which when exposed to negative pressure becomes better perfused and richer in granulation tissue, the intestinal loops lying near the surface and therefore exposed to a greater pressure gradient, are often pale in color and dotted with petechiae. Lindstedt and colleagues analyzed the effects of TNP on the trophic status of the intestine in an experimental study on 12 pigs that underwent laparostomy [10]. The study showed that there was a direct relationship between negative pressure values and signs of intestinal ischemia (petechiae), and that it was possible to reduce ischemic damage by placing a divider (for instance a plastic disc) between the intestinal loops and the suction system.
A later study conducted by the same authors demonstrated, by means of laser-doppler measurements, that there was a reduction of arterial flow in the intestines of pigs that underwent TNP and that this reduction was proportional to the pressure gradient of the TNP system [11].
In our series we observed only one case of subcritical prolonged intestinal ischemia, indicated by pallor of the intestinal loops, reduced vascular markings, and recurrent enteric fistulae (patient 9). Initially this condition was attributed to septic shock and the inevitable use of vasopressors. However, normalization of hemodynamic parameters was not immediately followed by improvement in intestinal perfusion. The signs of subcritical ischemia disappeared only after approximately 20 days of hemodynamic stability and the resection of a small segment of the ileum because of fistula formation.

Enterocutaneous Fistulae

The formation of enterocutaneous fistulae is one of the most frequent abdominal complications in patients with a laparostomy, second only to the formation of intraperitoneal infected fluid collections. The incidence of these fistulae ranges from 5 to 19%, depending on the initial diagnosis and the indications for open abdomen treatment [12]. Management of enterocutaneous fistulae is made difficult by the lack of sufficiently vascularized tissue around the exposed intestine, which, in most cases, prevents spontaneous healing. The continual draining of intestinal contents onto the skin, combined with chronic exposure of the viscera to air, contribute to an increase catabolic activity, protein loss, and the formation of infected fluid collections, inevitably resulting in an increased mortality rate.
Several strategies aimed at promoting healing of enterocutaneous fistulae in patients treated with TNP have been described. Girard and colleagues reported some cases of definitive closure of enteric fistulae using fibrin glue and an acellular skin matrix [13]. TNP is associated with an increased rate of fistula closure only when the intestinal loop affected is isolated so as to divert the intestinal contents away from the rest of the laparostomy wound [14]. On the other hand, surgical exteriorization of the fistula is often made difficult by the retraction of the mesentery caused by the diffuse edema of the soft tissues and the intestine itself. Some authors have described a floating stoma created by suturing a collecting device made of synthetic material directly to the affected intestinal loop. Intubation of the fistula is effective in reducing contamination of the abdominal cavity, but is almost always associated with more output and less possibility of spontaneous healing. Another option is resection of the segment containing the fistula. With this method, the more better the condition of the patient and the control of intraperitoneal infection, the better the results.
Stawicki and colleagues propose a three-stage approach to enterocutaneous fistula, drawing on the philosophy of damage control surgery: stage 1: correction of hemodynamic and metabolic inbalance, and drainage of infected foci; stage 2: investigation of the anatomical characteristics of the fistula; stage 3: definitive treatment (15). Often the indications for definitive treatment of these

fistulae are the same as those for treatment of enteric fistulae in patients with a "closed" abdomen: conservative treatment in "distal", low output fistulae and surgical revision consisting of intestinal resection in cases of "proximal", high output fistulae.
In our series 4 patients developed enteric fistulae and in 2 cases (patients 9 and 10) the fistulae healed after stabilization of hemodynamic and metabolic parameters followed by resection of the affected segments of intestine. In the remaining 2 cases our treatment of the fistulae was unsuccessful: in one patient (patient 2) intubation of the fistula was attempted, but there was a progressive increase in fistula output. The patient died of acute anemia caused by gastric hemorrhage. In the other patient (patient 16) the presence of peritoneal carcinosis arising from gastric cancer contributed to persistence of the fistula. The patient died of advanced malignancy complicated by sepsis.

Delayed Closure of the Abdominal Wall

In the early phases of management of the open abdomen, the surgeons' attention is, understandably, focused on resolving the abdominal sepsis, and the anatomical and pathophysiological modifications of the abdominal wall are of secondary importance. However, studies conducted at various centers that have used the open abdomen technique for years have shown that the longer a patient has a laparostomy the greater the retraction and loss of elasticity of the fascial margins. As a result of this phenomenon and the increase in viscero-parietal adhesions, direct closure of the abdominal wall becomes impossible [16-19]. Therefore, techniques aimed at reducing lateral retraction of the fascial edges during open abdomen treatment arouse great interest as do techniques which permit satisfactory delayed reconstruction of the abdominal wall even in patients whose general clinical condition is severely compromised.
Van Hensbrock and coll. [16] conducted an extensive study on 57 case series about open abdomen treatment, related to a total of 3169 patients, comparing the various methods for creating a laparostomy: TNP, vacuum-pack, Wittmann patch (two sheets of synthetic material attached to opposing fascial edges), progressive tension sutures, skin approximation, synthetic or biological prostheses, zipper closure. The study showed that the highest percentage of primary closure of the abdominal wall was obtained using TNP (60%), the Wittmann patch (90%), and progressive tension sutures (85%).
It is, however, important to note that, all techniques aimed preventing lateral retraction of the fascial edges, with the exception of TNP, cause an increase in intra-abdominal pressure (IAP). This can certainly be tolerated by most patients with intraperitoneal sepsis, but careful monitoring of the IAP is needed in order to prevent abdominal compartment syndrome.
Whatever the technique(s) used during open abdomen treatment [17-19], the number of patients requiring complex reconstruction of the abdominal wall remains high (52-64%). The problems related to such reconstruction can be explained by the fact that the indications for the use of synthetic prostheses, which, more than any other option, would guarantee good mechanical stability, are controversial in cases of prior abdominal sepsis. Biomechanical engineering provides surgeons with various solutions, from completely absorbable prostheses, to biological prostheses, to hybrid prostheses (dual-mesh). The absence of guidelines for the use of these materials, and the limited number of studies in the literature, are indications that it is currently not possible to determine the ideal treatment for all patients and that it is advisable to have experience using them all so as to tailor abdominal wall reconstruction to the condition of each patient (degree of sepsis, presence/absence of enteric fistula(e), age, respiratory function, biomechanics of the abdominal wall).

Long-Term Disability

Open abdomen treatment often involves with a long stay in the Intensive Care Unit, a large number of days on mecchanical ventilation, and a long period of physical inactivity. All these factors are associated with an increase in respiratory complications (atelectasis, pulmonitis), and cardiovascular complications (deep venous thrombosis, pulmonary embolism). Moreover, changes in the mechanical properties of the abdominal wall (due to suture dehiscence, planned incisional hernia, incisional hernia with loss of domain) can progressively worsen, further prolong the patient's hospital stay, and limit the possibilities of delayed abdominal wall reconstruction.
Fischer and coll., in a study reviewing 10-years of experience, observed that when an incisional hernia post-laparostomy is complicated by an enteric fistula the complexity of the case increases considerably, and there may be malabsorption, weakness, and the need for continual, advanced medications [20].
Other studies, conducted on small series, link the degree of long-term disability to several factors: incisional hernia size, presence of skin and subcutaneous tissue at the site of the defect, and the presence of enterocutaneous fistula [21,22]. Cheatham and coll. reported that 55 to 78% of patients returned to work after abdominal wall reconstruction [23]. However, other studies, conducted on patients with large incisional hernias, showed that patients' ability to perform daily activities, productivity, and quality of life were significantly and permanently compromised [24].

Conclusions

Our data, although limited by the small sample size and the short follow-up, lead to the conclusion that the use of TNP with laparostomy for the management of severe

peritonitis provides satisfactory results when compared to techniques that have already been validated, in terms of a reduction in the mortality rate, and in early and late complications.

In our opinion, the complications observed which could be associated with TNP (hemorrhage, intestinal hypoperfusion, enteric fistula formation) only partially invalidate the benefits of TNP. Awareness of these complications should induce surgeons to use individualized treatment, modifying the pressure gradient and the technique of laparostomy formation based on the patient's general medical condition, patient anatomic and surgical considerations, by using, for instance, a lower pressure gradient in patients with hemorrhage or signs of intestinal hypoperfusion, and approximation of fascia layers with sutures in patients with prolonged open abdomen and a low IAP.

Moreover, the abdominal wall, considered no longer a simple "coating", but instead an "organ" with its particular physiology and pathophysiology, should, starting with the first laparostomy revisions, be managed in such a way as to favor direct suturing of the wound and, if this is not feasible, facilitate the most suitable reconstruction of the abdominal wall.

Riassunto

INTRODUZIONE: Lo scopo dello studio è riportare l'esperienza preliminare degli autori circa l'utilizzo della laparostomia con pressione topica negativa (TNP) intraperitoneale nei pazienti affetti da peritonite severa. Gli autori riportano una revisione della recente letteratura circa l'efficacia e la sicurezza della TNP applicata all'addome aperto.

PAZIENTI E METODI: Sedici pazienti (10 maschi, 6 femmine, età media 55 anni), affetti da peritonite severa, sono stati sottoposti a laparotomia d'urgenza e a confezionamento di laparostomia con TNP. La sepsi addominale era originata dall'intestino tenue (7 pazienti), dal colon (6), dal distretto biliare (2), dal pancreas (1) ed in 2 pazienti è stata riscontrata una infezione di protesi addominale, complicata da gangrena dei tessuti molli.

RISULTATI: La mortalità è stata del 31.2%. Le principali complicanze attribuibili verosimilmente alla TNP sono state le fistole enteriche (25%), il sanguinamento (25%), gli ascessi addominali (12.5%), l'ischemia intestinale (6.2%). La sutura fasciale diretta è stata eseguita in 8 pazienti (57.1%) mentre in 6 casi è stata necessaria l'applicazione di una protesi parietale, ed un paziente è stato sottoposto ad innesto di cute autologa.

CONCLUSIONI: La laparostomia con TNP intraperitoneale è un sistema valido ed efficace nella gestione dei pazienti con peritonite severa con possibilità di cura. Il tasso di morbilità può diminuire attraverso un uso personalizzato dell'allestimento della laparostomia e del gradiente pressorio applicato. Infine, quando possibile, la parete addominale dovrebbe essere gestita, fin dalle prime revisioni, in modo tale da consentire alla fine della procedura una chiusura fasciale diretta.

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