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Research Article

Negative pressure wound therapy (NPWT) for the treatment of open abdomen

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Abstract. Introduction: Abdominal surgical pathology can contribute to an increased rate of postoperative morbidity, leading to prolonged hospitalization. The most severe complication of open abdomen syndrome (celiostomy) after abdominal surgery is the lateral retraction of the anterior rectus sheath and the oblique muscles aponeuroses, which makes it difficult to close the primary defect, leading to subsequent complications. Negative pressure wound therapy (NPWT) is a relatively new method that facilitates the closing of the anterior wall after open abdomen surgery. In addition to other absorbable or biological mesh-based methods, Bogota bag or Backer's vacuum packing technique, NPWT is seen as a potential bridging method for achieving definitive abdominal closure. The aim of the current study was to present the advantages of NPWT in a retrospective cohort of patients treatment either in the emergency setting of acute abdomen, or in the event of severe postoperative abdominal complications. Patients and Methods: The present study included 15 patients (2018-2020), with ages ranging from 51 to 81 years old. In all patients, total abdominal closure was achieved by using the NPWT Vivanno Hartmann device. The principle behind the rationale of the procedure is similar to other manufacturers' devices and involves the intraperitoneal placement of a microporous silicone material, which is placed in contact with the bowel loops. Results: The in-hospital days ranged between 10 to 124 days, with an average of 65 days. The primary closure rate of the abdomen was achieved in 12 patients. The 90-days post-discharge mortality rate was of 33%. 5 patients died due to septic shock followed by MSOF. Conclusions: The use of NPWT should be tailored, taking into account the primary pathology, as well as the patient's comorbidities. In current clinical practice, NPWT could help reduce hospitalization duration and decrease postoperative morbidity and mortality, with a drastic downfall of in-hospital costs. NPWT remains one of the main therapies that help in bridging the open abdomen towards definitive abdominal closure.

Key Words: Negative pressure, open abdomen, site infection

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Introduction

In an attempt to implement a novel, easy-accessible, adequate and as effective as possible therapy, to be used for the scenarios of complex abdominal pathology (damage control surgery for abdominal trauma, abdominal compartment syndrome (ACS), severe pancreatitis and peritonitis), the technique of the open abdomen (OA) was introduced. This technique involves solving an extremely dynamically complex situation, with one of the most severe further parietal complication being represented by the lateral retraction of the anterior rectus sheath and the oblique muscles aponeuroses. Lateral retraction of the aforementioned muscles decreases the chance of closing the primary defect, with subsequent risk of intestinal fistula or bacterial and fungal colonization. Systemic complications that can be associated to the OA syndrome are represented by respiratory failure associated with pneumonia 30% and acute renal insufficiency 22% (Guidicelli et al 2017). Sepsis is the leading cause of death for these patients. Over time, numerous methods, associated to the management of the OA have been proposed, some put into practice, as to achieve a temporary abdominal closure (TAC) (Alvarez et al 2018). Many technical options have been used, including primary closure of only the skin, inserting absorbable synthetic or biological meshes, Bogota bag or Barker's vacuum packing technique Zaidi and El-Masry (2017). Since 1996, a novel technique, the negative pressure wound therapy (NPWT), has been introduced for the delayed/secondary closure of wounds of the abdominal wall and limbs. In the last decade, this system has also been introduced for the in-hospital management of scenarios requiring some sort of TAC technique (Giudicelli et al 2017; Zaidi and El-Masry 2017). In the case of OA, NPWT implies a system that achieves continuous suction, at a constant negative pressure. The benefits of such constant suction absorbing free fluids and blood out of the abdominal cavity, preventing the formation of adhesions between the viscera, or between viscera and the abdominal wall, becoming a barrier against retrograde deep abdominal colonization of nosocomial micro-organisms, partially contributing do a decrease in fascia or aponeurosis lateral retraction.

Material and methods

The present study included 15 patients, hospitalized between January 2018 and September 2021, out of which 7 were men and

8 women, with ages ranging from 51 to 81 years. All patients enrolled for the study signed the informed consent that their medical data could be used for research purposes. The primary etiology leading to damage control surgery for the septic abdomen were: peritonitis, necrotic/hemorrhagic pancreatitis complicated by compartment syndrome, post-operative eviscerations or anastomotic fistulas. In all patients, TAC, achieved using the NPWT Vivanno Hartmann ® device, was used. The principle of the surgery, similar to other competing devices, involves the intraperitoneal placement of a macroporous silicone material, which is placed in intimate contact with the bowel loops (Figure 1). The protective macroporous barrier must overpass and envelope the visceral bowel content, and exceed the cranial and caudal wound's margins; laterally it must reach up to the right and left laero-colic spaces, thus achieving an efficient drainage of the peritoneal cavity (Figure 2).

In a "sandwich-like-fashion", an elliptic perforated polyurethane foam (micro- or macroporous) is applied on the bowel barrier. Finally, an adhesive hydrofilm dressing is placed above the foam, perforated usually in the midline, thus allowing a subsequent placing of a silicone tube connected to a canister attached to a continuous constant negative pressure suction device (Figure 3). For deep abdominal fluid evacuation, the recommended negative

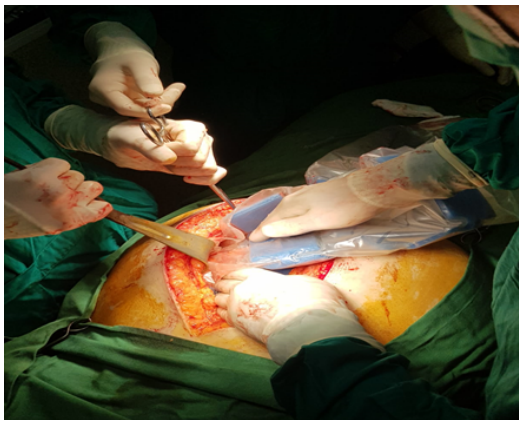

Figure 1 - Placement of the microporous silicone material, in contact with bowel loops

Figure 2 - Fully inserted microporous silicone material

Figure 3 - Negative pressure system fully installed

pressure exerted by it, is of minus 125mmHg (Berrevoet et al 2021). The entire configuration should be changed at every 48-72 hours, or whenever imposed by the output (Berrevoet at al. 2021). For our case series, in order to achieve some sort of partial or definitive abdominal closure, or in order to facilitate a supravisceral granular bed, most patients had 2-4 changes in total, but in some cases, up to 11 changes were used (Table 1).

Results

The median in-hospital stay ranged from 10 to 124 days, with an average of 65 days. The most common cause of OA management, for 6 of the patients, had peritonitis as primary etiology. Out of the 6, 2 patients also presented with concomitant intestinal fistulas (either spontaneous or postoperative). The primary closure rate of the abdomen was achieved in 12 patients. Patient no. 5 presented with upfront clinical and radiological peritonitis caused by a spontaneous perforation of a carcinomatosic nodule residing on the small bowel. For this patient upfront surgical external drainage was undertaken using a Foley catheter placed in the perforation, thus creating an externally directed fistula. Subsequently, the first surgical procedure favored for a same time TAC which was performed with the placement of the NPWT Vivano Hartmann® system. The fistula did not close spontaneously, so that, also to the general and biological status, the patient was lost with a septic condition on the 36th day of hospitalization.

Patient no. 2 was admitted with a Fournier's Gangrene. In the first stage, extensive excisional debridement was undertaken. A perineal NPWT Vivano Hartmann® system was used with a concomitant laparoscopic loop colostomy in the left iliac fossa. The appropriate placement and maintenance of the perineal NPWT system is difficult to achieve due to the anatomical irregularities of the region – inserting the components of the system draws the disadvantages of being located between the anterior urethra and the posterior anus. The wound is easily contaminated, plus its' negative pressure sealing is difficult to sustain (Verbelen et al 2011; Ye et al 2015) . On postoperative

Table 1 - Diagnosis, complications, days of hospitalization, results of the included cohort of patients (Di = discharged)

Patient	Sex	Age	Diagnosis	Number of NPWT exchanges	Postoperative complications	Number of days of hospitalization	Results
1	M	81	General peritonitis. Bladder-rectal fistula.	4	Complicated duodenal (bulbar) ulcers with upper gastrointestinal bleeding. Acute erosive gastritis. Anemia. Right hydronephrosis. Acute renal failure. Urinary infection. Fistula of colo-anal anastomosis. Left internal jugular vein thrombosis.	85	Di
2	M	65	Fournier's Gangrene (peri anorectal, left ischiorectal, central perianal). General peritonitis.	4	Left ischiorectal abscess. Left retroperitoneal abscess. Intestinal fistula. Sacral gr. IV pressure ulcers. Septic shock. Gluteal hematoma. Anemia.	124	Di
3	F	77	General peritonitis. Low rectal tumor.	4	Colorectal anastomotic fistula.	27	Di
4	M	30	General peritonitis. Cecal adenocarcinoma. Multiple liver macro-metastases. Peritoneal carcinomatosis.	4	Enteral fistula. Bowel obstruction. Plastic peritonitis.	49	Di
5	F	52	General peritonitis. Enteral perforation by rupture of the carcinomatosic enteral nodes. Cervical carcinoma. Extended peritoneal carcinomatosis.	9	Ileal abscess. Septic shock with C. Albicans, A. Baumannii, Klebsiella SPP. Beonchopneumonia with ARDS. Hypoproteinemia. Severe encephalopathy.	36	Dead
6	M	76	Postoperative peritonitis with duodenal stump blow-out, after subtotal ¾ gastrectomy for gastric adenocarcinoma, with Roux-en-Y gastro-jejunal-anastomosis.	3	Septic shock	10	Dead
7	M	53	Severe necrotic-hemorrhagic pancreatitis.	2	Abdominal compartment syndrome. Bleeding shock. Septic shock. Multiple organ failure.	105	Dead
8	F	69	Low intestinal obstruction. Occlusive Upper rectal adenocarcinoma.	3	Abdominal compartment syndrome. Septic shock. Toxic megacolon. Generalized fecal peritonitis for rectal stump blow-out.	49	Di
9	F	79	Small bowel obstruction. Multi-saccular abdominal bulky incisional hernia.	2	Abdominal compartment syndrome. Septic shock. Acute renal failure.	27	Di
10	M	55	Postoperative blocked midline evisceration associated with supra aponeurotic abscess.	2	Staphylococcus Aureus infection.	12	Di
11	F	73	Blocked midline infraumbilical evisceration associated with supra aponeurotic parietal phlegmon, pubic, supraumbilical phlegmon.	11	Terminal ileostomy in the right lower fossa, after transverse ischemic necrosis of the colon, occurring after ileo-transverse internal bypass. Spontaneous enteral fistula.	75	Dead
12	F	51	Post-operative midline supra- and infra- umbilical evisceration after hysterectomy with bilateral salphingo-oophoprectomy, with abscessed, fistulated, conical supra-pubic foreign body granuloma.	4	Anemia. Klebsiella Spp. Infection.	14	Di
13	F	76	Supraumbilical evisceration associated with abscessed supra aponeurotic seroma.	1	Staphylococcus Aureus infection.	13	Di
14	M	66	Cephalic pancreatic adenocarcinoma	5	Mechanical jaundice. Cholangitis. Sepsis with Klebsiella and Poteus. Anemia. Sacral pressure ulcers. Gastrointestinal and entero-pancreatic anastomotic fistula. Enteric fistula.	85	Di
15	F	73	Haemoperitoneum after laparoscopic right nephrectomy. Anterior right thigh propeller flap, used right thigh for abdominal wall reconstruction.	2	Damage control surgery with - Retroperitoneal packing. Factor VII and VIII haemophilia. Severe anemia. Thrombocytopenia.	65	Dead

day 3 the patient presented signs of a surgically acute abdomen, which required an abdominal surgical re-exploration, where biliary peritonitis was found at the level of a perforation on the jejunum. This was most probably caused by an ischemic/hypoproteic pre-existent state. Segmental enterectomy, with primary hand-sewn, concomitant to the extension of the NPWT deep in the abdomen,was used (Figure 4, Figure 5). The postoperative status was hampered by the formation of a retroperitoneal abscess, which was treated by ultrasound-guided percutaneous drainage. The NPWT has been changed 11 times. Postoperative follow-up in the ICU was favorable and uneventful, with the delayed-secondary closure of the abdominal wall, facilitated by the NPWT (Figure 6). Traction sutures and continuous directed post-incisional hernia were used, in order to cover the parietal defect.

Figure 4 - Abdominal NPWT in close proximity of a left iliac fossa loop colostomy and external entero-cutaneous fistula

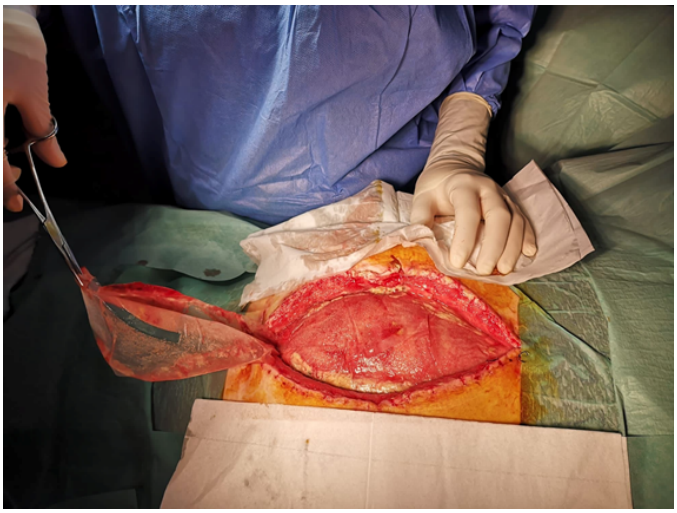

Figure 5 – Granular aspect of the midline laparotomy wound (negative microbiology smears) before starting progressive tension and skin closure

Figure 6 - Closed abdomen after NPWT therapy (6th NPWT exchange, progressive skin sutures performed)

In our case series, the overall 90 days-mortality rate was of 33%. 5 patients died due to septic shock followed by MSOF, either in the same hospitalization interval, or in emergent readmittance.

Discussions

NPWT is a relatively recently introduced method for achieving TAC. Its' advantages are represented by a continuous suction drainage at a negative pressure, which increases the chance of a delayed secondary closure of the abdominal wall and prevents the adhesions of the viscera between themselves, as well as to the abdominal wall (Roberts et al 2012; Seidel et al 2020). Table 2 presents the modern classification of the OA method, described in 2009 (Björck et al 2009).

The decision of when or where to use the aid of NPWT dressing, should be made in stage 1a or latest in stage 1b, before the adhesions between the viscera and the abdominal wall appear (Björck et al 2009).

The advantages of this therapy, which is consistently used in the vast majority of the situation where an OA scenario is expected, are represented by the fact that NPWT: improves granulation, it increases perfusion and neo-angiogenesis, it stimulates the production of VEGF and angioprotein-2 which favor endothelial proliferation and stimulate the development of capillary circulation (Jensen et al 2017). However, there are 2 experimental studies performed on pig-models that show that the NPWT, through its negative-pressure suction, could promote the artificial pulling of the small bowel, thus creating a predisposal state that could lead to bowel ischemia. This would lead to the risk of the development of an entero-atmospheric fistula - a redoubtable complication that is difficult to treat, or to exteriorize (de Martino et al)

The mortality of the patients with primary peritonitis in our study was of 40%, percentage similar to the data from the literature that reports a mortality between 20-40% (Willms et al 2015; Sibaja et al 2017). In our cohort, the two patients, who had enteral fistulas, were lost in the same in-hospital setting, and another one, even though he had intestinal resection, survived. From all the studies it appears that the incidence of bowel fistula, especially after performing an enteral resection with primary anastomosis is an aggravating factor (de Martino et al; Bobkiewicz et al 2017). Many studies prefer an exteriorization of the fistula, irrespective of the strategy chosen (data not commented). However, in most cases this is difficult to achieve due to the infiltration of the mesentery, which is difficult to mobilize, and the thickness of the abdominal wall. In addition, the exteriorization of the fistula in the proximity of NPWT, as well as colostomies can be the source of contamination of the wound. The fistulas in our study were not related to placement of the NPWT. There are studies that show that such devices used for achieving NPWT, in close proximity, or in contact with the bowel loops and negative pressure can lead to the formation of a fistula. That is why it is recommended to cover the intestines with the greater omentum where and whenever possible, or either using a non-adhesive barrier (Richter et al 2013). A comparative study was performed comparing Barker's technique, Bogota bag and NPWT-based dressings techniques; the fistula rate is the lowest in the case of NPWT, even if statistically it is not significant. However, all 3 techniques have

Table 2 - Classification of the open abdominal (OA), modified from Björck (Björck et al. 2009)

Grade	Description
1a	without adherence between bowel and abdominal wall or fixity
1b	contaminated OA without adherence / fixity
2a	clean OA developing adherence / fixity
2b	contaminated OA developing adherence / fixity
3	OA complicated by fistula formation
4 without fistula	frozen OA with adherence/fixed bowel; unable to close surgically, without fistula
4 with fistula	frozen OA with adherence/fixed bowel; unable to close surgically, with fistula

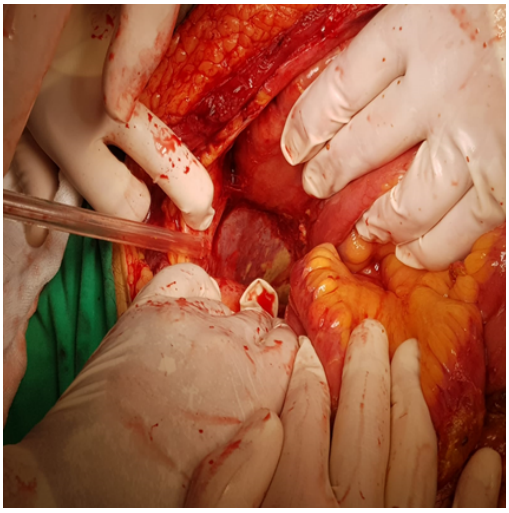

Figure 7 - Pancreatic head with cytosteatonecrosis

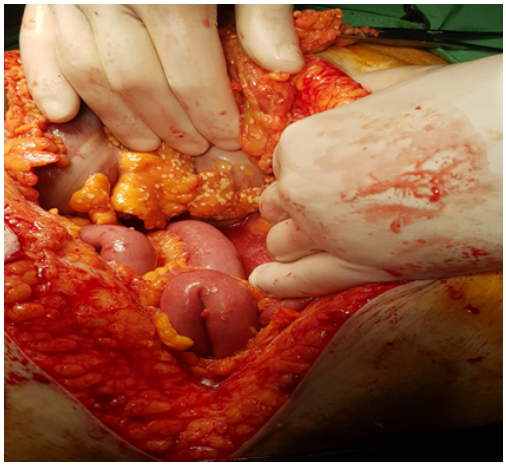

Figure 8 - Cytosteatonecrosis spots in the mesentery and peritoneum

clearly superior results in comparison to the simple placement of a surgical mesh, or plain wound dressings. In any case, everyone agrees that the delayed placement of a surgical synthetic, polypropylene mesh (except for dual/composite meshes), intraperitoneally is prohibitive because it has a high rate of enteric fistulas and important abdominal adhesions, which lead to the impossibility of further exploring the abdomen(Cirocchi et al 2016; Giudicelli et al 2017).

In our current study, 4 patients presented with postoperative free or blocked eviscerations. For all these patients, the TAC was achieved using NPWT. The NPWT dressings change rate was performed between 1 and 11 times. For all 4 patients the primary wall closure was achieved. Patient no. 11 died with general septic complications.

Another indication of performing NPWT, for our cohort of patients, was represented by abdominal compartment syndrome (ACS). Most of the existing studies show that ACS is one of the scenarios where some sort of OA technique is needed in the emergency setting (Willms et al 2017). In our cohort, 3 patients met the criteria of ACS: 1 pacient with severe necrotic-hemorrhagic pancreatitis (Figure 7, Figure 8) and 2 patients with intestinal mechanical ileus. The average number of NPWT changes, varied from 2 to 8. There was a particularity in the case of patient no. 7, where initially 2 NPWT exchanges were undertaken, at 72 hours-interval. At the exchange of the 2nd NPWT, a debridement of pancreatic necrotic tissue was successfully achieved. This triggered an extremely important and difficult to handle hemorrhage residing from the dorsal and magna pancreatis arcades. This required the application of a compressive damage control packing of the retroperitoneum, as per damage control surgery protocols, thus the NPWT was replaced with a Bogota bag management (without facilitating subsequent re-hemorrhage). Although some existing cohort studies report that NPWT could cause hemorrhages, in this scenarios, the hemorrhages was not caused by the continuous negative pressure. The remaining 2 similar cases in our cohort of patients survived, but patient no. 7 died due to septic complications. The anterior abdominal wall closure, in a facilitated-delayed setting, was achieved for these 2 surviving patients.

Patient no. 14 who had a pancreatic head adenocarcinoma, who was subjected to a cephalic pancreaticoduodenectomy (Whipple's) surgical procedure. On postoperative day 6 the patient presented a with a pancreatic leakage with high flow (750 ml/24hrs), requiring NPWT therapy. The closure of the fistula required 5 NPWT exchanges. The closing of the wall could not be delayed-performed and on the granulation tissue, autologous skin graft was applied.

Patient no. 15 presented with an upfront hemoperitoneum, as a complication of a laparoscopic nephrectomy. Initially, retroperitoneal packing was recommended and exchanged after 48h. After administration of recombinant human factor VIII, the bleeding is stopped, thus facilitating the use of an NPWT. No re-hemorrhage episode re-occurred. After 4 NPWT exchanges, an anterolateral thigh flap was used to replace the lateral abdominal wall defect. Unfortunatelly, the patient was lost on postoperative day 65 due to septic shock.

In terms of secondary-facilitated closure rates of the abdominal wall, we have performed this for 80% of our patients (12 representative patients). This is comparable to the data reported by

similar studies (Seternes et al 2017). In all 12 cases, the TAC was achieved and facilitated by use of the NPWT Vivano Hartmann® system. For the remaining two patients, the secondary closure of the abdominal wall was achieved by using Ventrofil barbed wires. One patient with pancreatic head adenocarcinoma required the application of an autologous skin graft.

More recently, in order to increase the secondary-facilitated closure rate sof the abdominal wall, NWPT was associated with Mesh-Mediated Fascial Traction systems, such as ABRA® or ABTHERA ®(Acosta et al 2017). This technique involves the placement between the microporous silicon barrier, applied intraperitoneally and the polyurethane foam of a surgical mesh, which is tensioned at the edge of aponeurosis (Salamone et al 2018). In such settings, after detaching the foam, when exchanging the NPWT configuration, the mesh is split longitudinally through the middle, permitting the change of the silicone barrier. Once it is changed, the mesh excess is marginally excised. Afterwards, it is once again sutured under tension by making a progressive fascial traction of the wall. There are studies with excellent results that give a closure of 100% per wall (Petersson et al 2019; Wang et al 2019). However, several other studies, reported disapproving data, showing that this method carries a risk of mesh infection ranging between 0.6 - 23%, in particular in peritonitis – related patients (Baharestani and Gabriel 2011; de Vries et al 2017). Nono of our cohort's patients benefited from the technique, since our team lacks clinical expertise in this matter.

At 90-days post-discharge, follow-up, 3 of the patients where delayed secondary-facilitated abdominal closer, was achieved, were confirmed with clinical significant incisional hernia. We prefer to treat these patients after at least 6 months after the last surgery, with advanced abdominal wall repair techniques, involving botulinium toxin injection + progressive pneumoperitoneum +/- Transverse abdominis release and concomitant sublay retromuscular large light-weight polypropylene mesh placement (TAR + Rives-Stoppa).

Conclusions

As per existing data, our initial reported selected-cohort experience, using NPWT technique shows the best results in TAC after OA. It is mostly reserved for more complex and serious pathologies of the abdomen, such as peritonitis, necrotic-haemorrhagic pancreatitis, abdominal compartment syndrome and enteral fistula. Existing retrospective studies only take into account a relatively small number of patients, without any potency for stipulating a consensus. There aren't many studies, such as metanalyses or randomized controlled studies, concerning the best management for the OA, and so far no one was able to accurately elaborate therapeutic protocols. Such studies are difficult to realize due to the extremely varied pathology, for which TAC is used for OA. The diversity of patients with different comorbidities, as well as the severe pathologies at the time of surgery also complicates the decision-making process concerning the choice of treatment. Because of this, the use of NPWT must be tailored for each patient in particular, taking into account the primary pathology, as well as the patient's condition. The vast majority of studies agree with the use of NPWT, which leads to a first step in the treatment of the diseases described above. Of course, prospective multicentered studies which have already started implementing NPWT internal protocols, will clarify the benefits of using NWPT therapy.

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