Comparative study of open abdomen treatment: ABThera™ vs. abdominal dressing™

C. Olona · A. Caro · E. Duque · F. Moreno · J. Vadillo · J. C. Rueda · V. Vicente

Digestive and General Surgery Department, University Hospital Joan XXIII Tarragona, 4th Dr. Mallafre Guasch St. 3th floor, 43007 Tarragona, Spain
e-mail: drcarlesolona@gmail.com

Abstract
Introduction Negative pressure therapy (NPT) is a widely recognised procedure for the temporary closure of open abdominal wounds. In this study, we compare two NPT products, the V.A.C.® abdominal dressing (AD) system and the new ABThera™ (ABT) system, in terms of the primary closure rates achieved, types of closure, and the associated morbidity.

Methods We employed a retrospective comparative study of open-abdomen patients treated with NPT using either AD or ABT. The indications for treatment were damage control surgery, abdominal compartment syndrome, or severe abdominal sepsis.

Results The group of patients treated with ABT showed a higher percentage of primary closures (41 vs. 11 %) and required fewer days of NPT (17 vs. 26 days) than the AD group. Differences were statistically significant. In addition, only 4 % of patients in the ABT group exhibited enteroatmospheric fistulae, compared to 17 % in the AD group.

Conclusions Compared to the AD system, ABT can achieve faster primary closure after open abdomen treatment with only minor complications.

Keywords Negative pressure therapy · Open abdomen · Abdominal closure

Introduction

The open abdomen (OA) technique is a practice that has spread rapidly over the last 20 years and can now be indicated with greater accuracy. Current indications are based on three principal settings: treatment of abdominal compartment syndrome, damage control surgery for polytrauma with abdominal injury, and treatment of abdominal sepsis [1].

Open abdomen procedures are challenging for surgeons, and many different techniques are described for abdominal closure. These procedures must achieve several goals, including haemostasis, reduction of abdominal pressure, reduction of visceral oedema, protection of abdominal contents, minimisation of respiratory pressure, maintenance of tissue perfusion, and prevention of fascial retraction to allow successful midline closure. Negative pressure systems have been found to be one of the most successful options for achieving these goals [2] and reducing the associated morbidity [3].

Our department has performed NPT using the V.A.C.® abdominal dressing system (KCI, San Antonio, USA) since 2006 [4] and the new ABThera™ system (KCI, San Antonio, USA) since 2011. Both techniques utilise polyurethane foam and continuous suction to manage the OA. The new ABThera system has a different inner layer design consisting of a polyurethane film-covered central foam structure with six arms that can provide more uniform levels of negative pressure throughout the abdomen, particularly at the level of the paracolic gutters and Douglas’ space, and that evacuate more fluid than the V.A.C.® system during in-vitro testing [5].
Objectives

The main aim of this study was to analyse the time to closure of the abdominal wall with the use of each system. The secondary aims were to examine the type of closure achieved and the complications and fistulae observed.

Materials and methods

A retrospective comparative study of patients treated with open abdomen NPT between January 2006 and January 2013 was conducted at the general and digestive surgery unit of a University Hospital Joan XXIII of Tarragona.

The decision to proceed with an open abdomen was taken at the discretion of the surgeon, according to the presence of coagulopathy, hypothermia, and acidosis in patients with abdominal haemorrhage, intestinal ischemia, severe peritonitis, hemodynamic instability, or abdominal compartment syndrome.

The devices used to apply NPT in this study were the V.A.C.® abdominal dressing (AD) system and ABThera™ (ABT) system, both developed by KCI, San Antonio, USA. The abdominal dressing system (Fig. 1) consists of a first micro-perforated silicone inner layer with an internal sponge, designed to be placed in direct contact with the viscera. A macroporous foam dressing is placed in contact with the abdominal wall and subcutaneous tissue and covered with an occlusive adhesive sheet attached to the tubing that connects to the vacuum unit. The new ABThera™ system comprises the same elements, but with an inner layer that covers the entire abdominal viscera and an inner sponge with a radial form that extends to the edges of the sheet to facilitate the extraction of peritoneal fluids and more uniform application of negative pressure (Fig. 2).

The devices were applied as described in previous studies [6]. The abdominal cavity was washed with saline solution and the perforated non-adhesive sheet applied beneath the anterior abdominal wall, covering the entire abdominal viscera. Next, one or two pieces of polyurethane foam dressing were applied, depending on the thickness of the abdominal wall, and adjusted to the open wound edges. The dressing was sealed with the adhesive sheets and an opening of 2–3 cm was made for the TRACpad, which is connected to the pump that applies negative pressure to the wound. An initial pressure of 125 mmHg was applied.

If an intestinal resection is carried out, the anastomosis is protected among the intestinal loops, away from the polyurethane film, in order to prevent the appearance of enterocutaneous fistulas. If intestinal fistulae occur while using NPT, they can be excluded by applying a V.A.C.® WhiteFoam dressing [6] or by using baby bottle nipples and soft drainage tubes to isolate the fistula [3]. Additionally, the intensity and continuity of the negative pressure applied to the wound is reduced (−50 mmHg intermittently).
Dressings were changed every 48–72 h in the operating room and afterwards in the ICU once the patient’s condition improved.

Closure was performed once the causes of the instability had been corrected. Where possible, primary closure was performed 7–10 days after surgery. In those cases where extended NPT was required, closure was performed by Chevrel’s technique [7] or by two-sided component separation if the muscle margins were widely separated. Both techniques employed a light polypropylene prosthesis in the onlay position. If the therapy was too prolonged and led to a frozen abdomen, a secondary closure was carried out in which definitive closure was deferred for 9–12 months and the abdomen was closed with a ventral hernia repair.

To facilitate the analysis, diagnoses were classified into four principal categories: peritonitis, mesenteric ischemia, abdominal compartment syndrome, and visceral trauma. We analysed the characteristics of the patients in each treatment group, the treatment duration, the number of changes, the type of definitive closure performed, the complications observed, and the associated mortality.

Categorical variables were described as absolute (N) and relative frequencies (%), and quantitative variables as mean and standard deviation. Percentage differences between ABT and AD were calculated using the two-proportion z-test. Age and days of treatment were compared between groups using the one-sample t-test. Statistical significance was set at \( p < 0.05 \). The statistical analysis was carried out using the SPSS 17.0 software.

Results

Between 2006 and 2012, a total of 73 patients with open abdomens were treated with NPT. Abdominal dressing (AD) was used until 2010, and then ABThera has been used from 2011 to the present. Of these, 27 (37 %) were treated with ABT and 46 (63 %) with AD (Fig. 3), with no differences in age or sex between the two groups (Table 1).

The diagnoses leading to treatment with NPT were 38 cases of severe peritonitis, 10 cases of mesenteric ischemia, 14 cases of ACS, and five cases of polytrauma with abdominal injury, with no differences between groups (Table 1). The group treated with AD also contained three patients with acute pancreatitis and three patients undergoing post-operative care for abdominal aortic aneurysm; these were excluded from the analysis in order to maintain the uniformity of the groups.

Intestinal resection and anastomosis were studied to determine if there is any relationship between intestinal resection and fistula formation. Intestinal resection was carried out in 41 patients (56 %), 22 in the AD group and 19 in the ABT group, with intestinal anastomosis in 23 cases (13 in the AD group and 10 in the ABT group), and ostomy in 18 cases (nine in each group), with no differences between groups.

The average time to abdominal closure was 26 days in the AD group and 17 days in the ABT group, and differences were statistically significant (Table 2); the mean
A non-suture closure method that prevents mechanical damage to the abdominal tissue, leaving surfaces intact for more effective closure. It also stabilises the abdominal wall, improves patients’ respiratory function, allows for quantification and drainage of fluids, and reduces contamination by creating an interface between the abdominal cavity and the exterior. The negative pressure applied to the foam dressing transmits mechanical forces uniformly to the wound edges and prevents fascial retraction [13].

In this study, we compared AD—the first method for the treatment of open abdomen with NPT, applied in our hospital from 2006 to 2010—to the new ABThera™ system, designed by the same firm and currently applied in our centre. The main difference between the two systems is that ABThera™ uses a radial sponge configuration covered by the protective sheet applied to the visceras. This allows for better evacuation of peritoneal fluid and stabilises wound contraction, as described in a recent experimental study [14].

These outcomes were confirmed in our study by the observation of a significant increase in primary closures (reaching 40 %) and a reduction in treatment time. However, we believe that the improvement is due not only to the greater control of the wound that the new devices provides, but also to the experience that we have acquired in the treatment of open abdomen patients. We would stress, like many other authors, that it is particularly important to close the abdominal wall in the first 7–10 days of treatment [15]. By avoiding unnecessary delay, we prevent the emergence of complications in the wound, the intestine, and the patient’s general condition, and improve patient recovery, as has been observed by Ioannis et al [16]. In our unit, primary fascial closure is only considered in those cases where the procedure can be performed without placing tension on the wound edges and without increasing intra-abdominal pressure. When these conditions cannot be met, abdominal wall reconstruction using component separation or the Chevrel technique is preferred along with permanent light-weight onlay polypropylene mesh repair [6]. The definitive closure will have a better chance of success if the patient and the abdominal wall are in optimal condition. The NPT applied by the ABT system can reduce oedema and inflammation of the abdominal wall, and its contents may make it possible to carry out all the standard surgical options. In cases where fascial closure was not possible, vacuum-assisted NPT was used to achieve delayed closure in 48 % of patients in the AD group and 22 % of patients in the ABT group, allowing a hernia to be created for subsequent ventral hernia repair and definitive closure nine months of more after completion of NPT. The longer a patient waits, the further the fascia separates, and the more the bowel agglutinates to the abdominal wall (thus preventing re-approximation of the fascia), and

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**Table 2** Days to closure and techniques for abdominal wall closure

<table>
<thead>
<tr>
<th></th>
<th>ABD dressing (n = 40)</th>
<th>ABThera (n = 27)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days to abdominal closure mean (range)</td>
<td>26 (6–92)</td>
<td>17.3 (2–80)</td>
<td>0.026*</td>
</tr>
<tr>
<td>Abdominal wall closure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary fascial closure</td>
<td>5 (12.5 %)</td>
<td>11 (40.7 %)</td>
<td>0.007*</td>
</tr>
<tr>
<td>Chevrel onlay technique</td>
<td>16 (40 %)</td>
<td>2 (7.4 %)</td>
<td>0.005*</td>
</tr>
<tr>
<td>Component separation technique</td>
<td>0 (0 %)</td>
<td>8 (29.6 %)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Secondary closure</td>
<td>19 (47.5 %)</td>
<td>6 (22.2 %)</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Asterisks indicate statistically significant values

number of dressing changes was eight in the AD group and five in the ABT group.

Primary fascial closure of the abdominal wall was performed in five (11 %) patients treated with AD and 11 (41 %) patients treated with ABT, whereas secondary closure was performed in 19 (48 %) of the AD group and six (22 %) of the ABT group. These differences were also statistically significant (Table 2).

No complications related to NPT or minor complications classified as Clavien grade I–II [8] were observed in 17 of the patients treated with AD (42 %) and 22 patients of the patients treated with ABT (81 %). Fistulae, classified as Clavien grade III, were observed in eight patients (20 %) in the AD group and only one patient (4 %) in the ABT group. Differences were not statistically significant. Multi-organ failure, classified as Clavien grade IV, occurred in two patients in the ABT group and ten in the AD group, although this was related to the general conditions of the patient and not directly to the application of NPT.

No deaths occurred as a direct result of NPT, but during follow-up, 15 patients (33 %) in the AD group and four patients (15 %) in the ABT group died due to the worsening of the underlying condition.

**Discussion**

Open abdomen technique is a practice that has spread rapidly over the last 20 years, leading to a reduction in the initial mortality rate [9] in damage control surgery for polytrauma and ACS. In recent years, particularly in Europe, the technique has also been applied in the treatment of severe abdominal sepsis in the context of damage control surgery [10]. There are various techniques for the temporary closure of the open abdomen, including the Bogota bag, the sandwich technique, and zipper systems, among others. Systematic reviews have identified the Wittmann patch and NPT as the techniques that achieve the highest fascial closure rates [11] and lowest mortality [12]. NPT is...
therefore, the less chance there is of carrying out a component separation. Consequently, there was greater use of the Chevrel onlay technique. Other techniques used for progressive fascial closure have been published, including a combination of NPT with a temporary mesh, tightened every few days until the fascial defect is under control, when the mesh is removed and the fascia is closed primarily [17]. Another recently described technique is progressive closure using a dynamic fascial suture [18].

One of the most common complications of open abdomen, and perhaps that of greatest concern to surgeons, is the appearance of enteroatmospheric fistulae, as they add to the difficulty of the procedure and lengthen treatment time [19]. One of the key improvements obtained with ABT is the reduction in the appearance of enteroatmospheric fistulae, which were observed in only one patient (4 %) compared with 20 % in the AD group. This is particularly notable given that 19 patients underwent some form of intestinal resection and 10 underwent intestinal anastomosis during NPT, and the patient who presented with a fistula in the ABT group did not have intestinal anastomosis. The almost complete absence of fistulae in the ABThera™ group could be associated with the improved distribution of negative pressure by the dressing and that fact that it is not applied directly to exposed bowel loops, as is shown by Bjarnason [20] in the analysis of the pressure distributions applied by ABThera™ on the open abdomen. The risk of enterocutaneous fistulae has been associated with the friction and dryness of the intestine, and comorbidities in the patient such as mesenteric ischemia, infections and MOF; however, in cases requiring intestinal anastomosis, the anastomotic line was kept as far as possible from the plastic sheet of the dressing to prevent the NPT from encouraging the appearance of these fistulae.

The limitations of this study include its retrospective non-randomised design and the different use of either technique by year of study. This difference in the application time of each treatment may influence the results because we have been gaining experience and knowledge of the biodynamics of the abdominal wall. Although the complexity and severity of the cases considered would make it difficult to include patients in a randomised trial, the groups were comparable in terms of patient type, diagnosis, and surgery type. We have excluded from the analysis those patients with pancreatitis and aortic aneurysm in the AD group who were not included in ABT group. An additional limitation is the small number of patients included in the study, which, as in similar publications, is due to the fact that the treatment in question is only required in severe cases with highly specific characteristics such as abdominal sepsis, ACS, or indications for damage control surgery.

By achieving higher primary closure rates, NPT with ABThera™ reduces the need for abdominal wall reconstruction and may improve patient recovery and reduce overall costs.

Acknowledgments We are grateful to the all members of the General and Digestive Surgery Department for their collaboration, to the Statistical Service of the IISPV for the statistical analysis, and to the language service of the Rovira i Virgili University for translating our original text. This study has not received any form of funding and the authors of this article do not have any commercial interest.

Conflict of interest C.O. declares no conflict of interest. A.C. declares no conflict of interest. E.D. declares no conflict of interest. F.M. declares no conflict of interest. J.C. R. declares no conflict of interest. J.V. declares no conflict of interest. V.V. declares no conflict of interest.

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