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Use of Negative Pressure Wound Therapy for Abdominal Wounds: A Review of Recent Literature

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Abstract
Introduction: Negative Pressure Wound Therapy (NPWT) is used extensively in the acute and chronic wound care arena of health care. It has become a standard of care for many types of wounds from non-healing diabetic foot ulcers and burns to traumatic and surgical wounds. Recently attention has been paid to using this system for the treatment of catastrophic abdominal wounds.

Purpose: This literature review will examine the question of the effectiveness of Negative Pressure Wound Therapy in the treatment of open abdomen as a consequence of trauma or surgery. This is an important consideration as the use of damage control laparotomy continues to gain popularity among trauma surgeons more and more patients will be treated with this technique. A clear understanding of the current literature can lead to the formation of concise and practical guidelines which can be used in the application of this technique for the benefit of patients.

Methods: The literature considered for this study met certain requirements. They should have been English language studies published in the last 10 years. They had to study an aspect of application of Negative Pressure Wound Therapy to an abdominal wound whether as a result of trauma or surgery. Consensus statements and other summery articles were excluded from this review. This literature was obtained through an exhaustive search of Medline, PUBMED, MD Consult, and Up-to-date Online. Although efforts were made to find literature published in the last 2 years articles from 1998 to the present were considered for review. To reduce the potential introduction of bias a concerted effort was made to find studies and observations by entities not affiliated with KCI, Inc.

Results: There is agreement among these authors that Negative Pressure Wound Therapy is effective in the treatment of open abdominal wounds in the setting of both surgery and trauma. There was a noted an increased formation of granulation in the wounds as well as possible improvement in control and quantification of wound fluid output. NPWT is a useful adjunct in the setting abdominal compartment syndrome as a means of control of intra-abdominal pressures. Decreases were noted in morbidity rates and complications due to the open abdomen. NPWT is effective in the treatment and prevention of the postoperative complications of enterocutaneous fistulae, abdominal wound dehiscence, and ventral hernia.

Conclusion: Taken as a whole the literature presented above shows compelling reasons include Negative Pressure Wound Therapy in the armamentarium of treatments used for the resolution of open abdominal wounds and their potential consequences, most notably enterocutaneous fistulae and abdominal wound dehiscence, in the settings of trauma, massive resuscitation, prior abdominal surgeries, and infection

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Keywords
Wound Vac, Assisted, Closure, Compartment, Laparotomy, Fascia

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Use of Negative Pressure Wound Therapy for Abdominal Wounds: A Review of Recent Literature

By:
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A Clinical Research Project Submitted to the Faculty of the
School of Physician Assistant Studies
Pacific University
Hillsboro, OR

For the Masters of Science Degree August 16, 2008

Faculty Advisor: Mark Pedemonte MD
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STATEMENT OF ACCEPTANCE:

This project is hereby accepted as a requirement for completion of the degree of:
Masters of Science in Physician Assistant Studies at Pacific University School of Physician Assistant Studies on this day the sixteenth of August, 2008.

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Biography

Evan Excell was born in southern Utah and grew up in a wide variety of locations throughout the southwest including Grand Canyon National Park, Death Valley National Park, and Dinosaur, Colorado. He certified as an Emergency Medical Technician in 1997 and passed the Registry for Respiratory Therapy in 2001. He completed his Bachelor of Science degree in Respiratory Therapy at Weber State University, Ogden, UT in 2003. The completion of Pacific University’s Physician Assistant program is the culmination of a 10 year old goal. Evan married his lovely wife, Jan Alicia, in 2004 and their precocious son Sean was born in 2005. Following graduation they plan to return to the desert southwest to start the next phase of their lives.

Abstract

Introduction: Negative Pressure Wound Therapy (NPWT) is used extensively in the acute and chronic wound care arena of health care. It has become a standard of care for many types of wounds from non-healing diabetic foot ulcers and burns to traumatic and surgical wounds. Recently attention has been paid to using this system for the treatment of catastrophic abdominal wounds.

Purpose: This literature review will examine the question of the effectiveness of Negative Pressure Wound Therapy in the treatment of open abdomen as a consequence of trauma or surgery. This is an important consideration as the use of damage control laparotomy continues to gain popularity among trauma surgeons more and more patients will be treated with this technique. A clear understanding of the current literature can lead to the formation of concise and practical guidelines which can be used in the application of this technique for the benefit of patients.

Methods: The literature considered for this study met certain requirements. They should have been English language studies published in the last 10 years. They had to study an aspect of application of Negative Pressure Wound Therapy to an abdominal wound whether as a result of trauma or surgery. Consensus statements and other summery articles were excluded from this review. This literature was obtained through an exhaustive search of Medline, PUBMED, MD Consult, and Up-to-date Online. Although efforts were made to find literature published in the last 2 years articles from 1998 to the present were considered for review. To reduce the potential introduction of bias a concerted effort was made to find studies and observations by entities not affiliated with KCI, Inc.

Results: There is agreement among these authors that Negative Pressure Wound Therapy is effective in the treatment of open abdominal wounds in the setting of both surgery and trauma. There was a noted an increased formation of granulation in the wounds as well as possible improvement in control and quantification of wound fluid output. NPWT is a useful adjunct in the setting abdominal compartment syndrome as a means of control of intra-abdominal pressures. Decreases were noted in morbidity rates and complications due to the open abdomen.
NPWT is effective in the treatment and prevention of the post-operative complications of enterocutaneous fistulae, abdominal wound dehiscence, and ventral hernia.

**Conclusion:** Taken as a whole the literature presented above shows compelling reasons include Negative Pressure Wound Therapy in the armamentarium of treatments used for the resolution of open abdominal wounds and their potential consequences, most notably enterocutaneous fistulae and abdominal wound dehiscence, in the settings of trauma, massive resuscitation, prior abdominal surgeries, and infection

**Keywords:** Negative, Pressure, Wound, Therapy, Wound Vac, Open, Abdomen, Vacuum, Assisted, Closure, Compartment, Syndrome, Healing, Laparotomy, Fascia

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To *My Loving Wife Jan Alicia*: Your Love, Support, and Dedication to me and my success make this accomplishment as much yours as mine. A simple “Thank-you” is too pale a sentiment.

To *my son*: “Life is a highway…”

To *my parents*: You’re always there for us through thick and thin. This is for you.

To *my Grandmother Geraldine Excell*: Your advice and support mean so much to us. Thanks for being there.
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List of Abbreviations

ECF.................................................................Enterocutaneous Fistula(e)
GFS..........................................................GranuFoam Silver
ICU............................................................Intensive Care Unit
ISS.........................................................Injury Severity Score
KCI..........................................................Kinetic Concepts, Inc.
NPWT.....................................................Negative Pressure Wound Therapy
mmHG......................................................Millimeters of Mercury
PU.........................................................Polyurethane
PVA.........................................................Polyvinyl Alcohol
PVH.........................................................Planned Ventral Hernia
SAPS II....................................................Simplified Acute Physiology Score II
STSG..........................................................Split Thickness Skin Graft
Use of Negative Pressure Wound Therapy for Abdominal Wounds:  
A Review of Recent Literature

INTRODUCTION

Negative Pressure Wound Therapy (NPWT) is used extensively in the acute and chronic 
wound care arena of health care. It has become a standard of care for many types of wounds 
from non-healing diabetic foot ulcers and burns to traumatic and surgical wounds. Recent 
attention has been paid to using this system for the treatment of catastrophic abdominal wounds. 
It is the purpose of this literature review to gain perspective on the use of NPWT for the 
treatment of abdominal wounds and their complications using the evidence published on this 
topic.

BACKGROUND

The idea of placing a vacuum over a wound to improve wound healing has been in 
practice since 1993 when Dr. Fleischmann and his cohorts in Germany published their data on 15 
patients with open fractures\(^1\). These patients were treated with suction applied to a foam 
dressing. An increase in tissue granulation was noted as well as no apparent infection of the 
wound beds. Fast-forward to 1997 Dr. Morykwas and his colleagues presented their experiential 
data using the first (and only) commercially available device: the Wound Vac. This device, 
conceived at Wake Forest University Medical School, is manufactured and distributed by Kinetic 
Concepts Incorporated (KCI, Inc) located in San Antonio, TX USA\(^2\).

NPWT application to a patient is straightforward and can be broken into three main 
components. The first component consists of a type of sponge that is custom cut by a bedside 
practitioner to fit the wound. Three types of foam are available to fit different wound 
circumstances. Polyurethane (PU) foam is black in color and is hydrophobic and reticulated
which allows even distribution of pressure across the wound bed. This is beneficial for ulcers, flaps, and deep, acute wounds but can be used universally without ill-effect if the other types of foam are not available\(^2\). Polyvinyl Alcohol (PVA) foam is the second type. It is white in color, hydrophilic, and with higher tensile strength than PU foam. These properties make it useful for tunneling and shallow undermining wounds but it can also be put to use superficially\(^2\). The third type of foam is GranuFoam Silver (GFS) which is a relatively recent addition to the line up that is of particular use with wounds of high bacterial burden\(^2\). No matter which type of foam is chosen it is cut to the shape of the wound and so that it will fit inside without overlapping the wound edges so as not to become a barrier to approximation.

The second part of NPWT application is the creation of an airtight seal over the wound thus facilitating the application of vacuum to the wound bed. In comparison to the other portions of this therapy this may be the most difficult to achieve as anatomy and the conformations of the wound itself may get in the way of applying the adhesive occlusive dressing necessary to create the seal. This layer of dressing needs to completely cover the foam and the wound itself. The achievement of a seal can be facilitated by ensuring that the skin edges are clean and dry as well as by the application of an adhesive (if desired). The Wound Vac is capable of detecting a leak in the system and it has an alarm system to alert the practitioner. Dressing changes are effected every second or third day\(^2\). This has the added benefit of freeing the patient and caregivers from frequent, time-consuming procedures. Presuming that there are no other acute problems, the careful patient can be discharged to home only having to be seen in the wound clinic on a periodic basis. Several studies have noted the decrease in cost due to decreased patient contact hours and decreased hospital admission rates.
Vacuum application to the wound bed and dressing is the third portion of NPWT therapy. Vacuum tubing is attached directly to the commercially available Wound Vac dressing and this is attached at the other end to the Vac machine itself. In earlier models and experimentation wall suction in the hospital was used to provide vacuum. During the early stages of NPWT use the resident physicians as Brigham and Women’s Hospital in Boston were able to create an entire NPWT system from common materials found in the utility room on the medical floor.

Undoubtedly, the advent of the Wound Vac, which is portable and rechargeable, has been a great boon to patients who otherwise would be limited to their hospital beds. This has certainly improved adherence to therapy and early studies showed the benefit of maintaining suction to the wound between dressing changes. The system is also capable of adjusting the amount of pressure applied to the wound. Morykwas, et al were able show that best wound healing is achieved at 125 mmHg. They were also able to show that pressures in excess of 400 mmHg were detrimental to blood flow. From this information guidelines have been extrapolated and published by the manufacturer. These guidelines have also suggested that, for patient comfort, continuous suction need only be applied for the first 48 hours and then the device should be switched to intermittent suction mode. Lower pressures with upward titration can be instituted for pain reduction as well.

In general the main treatment end-points for NPWT are approximation of the wound edges so that it can be closed primarily or eventual closure of the wound by secondary intention. The usual end-point for the open abdomen is the same. For example, following damage-control laparotomy NPWT is used as an adjunct in the management of the open abdomen. It is used as a dressing to allow decreased pressure in the abdominal cavity in the setting of abdominal compartment syndrome. In both of these circumstances has been credited with
setting the stage for eventual closure of the wound as the application of negative pressure has been credited with an increase tissue granulation\(^6,^2,^5\), decreased bacterial burden in the wound\(^2\), and the vacuum itself tends to pull the wound edges closer together\(^2\). Dressings can be changed, as mentioned above, every 2 to 3 days in the intensive care unit (ICU), in the operating room (OR), or in the clinic on an out-patient basis\(^2\). As the swelling subsides the wound is either closed or it is assessed for skin grafting which would necessitate a decreased wound depth and increased tissue granulation. It has also been postulated that the use of Wound Vac decreases the frequency and severity of potentially devastating and deforming consequences of the open abdomen including ventral hernia and enterocutaneous fistulae\(^8,^9,^5,^2\). With other types of wounds as well as the open abdomen the commonly held conception that there is a decreased bacterial load in a wound treated with NPWT is a consideration\(^6,^10,^11\). Therefore open abdomen is treated with NPWT due to effectiveness of therapy, reduction in complications, and reduction in infections.

**PURPOSE OF STUDY**

This literature review will examine the question of the effectiveness of Negative Pressure Wound Therapy in the treatment of open abdomen as a consequence of trauma or surgery. This is an important consideration as the use of damage control laparotomy continues to gain popularity among trauma surgeons more and more patients will be treated with this technique. A clear understanding of the current literature can lead to the formation of concise and practical guidelines which can be used in the application of this technique for the benefit of patients.

**METHODS**
The literature considered for this study met certain requirements. They were English language studies published in the last 10 years. They had to study an aspect of application of Negative Pressure Wound Therapy to an abdominal wound whether as a result of trauma or surgery. Consensus statements and other summery articles were excluded from this review.

This literature was obtained through an exhaustive search of Medline, PUBMED, MD Consult, Up-to-date Online and visual search of study references. Although efforts were made to find literature published in the last 2 years, articles from 1998 to the present were considered for review. To reduce the potential introduction of bias a concerted effort was made to find studies and observations by entities not affiliated with KCI, Inc.

Keywords: Negative, Pressure, Wound, Therapy, Wound Vac, Open, Abdomen, Vacuum, Assisted, Closure.

**LITERATURE REVIEW RESULTS**

Submission 1: *Management of Abdominal Wound Dehiscence Using Vacuum Assisted Closure in Patients with Compromised Healing* published by the American Journal of Surgery. Heller et al studied the effects of using NPWT on open abdomen following post-operative dehiscence. This situation is often treated with delayed closure and NPWT was used as a dressing for the wound in the meantime.

Methods: The KCI Wound Vac system was used for 21 patients who experienced post-operative wound dehiscence following laparotomy that could not be immediately closed. Retrospective data including demographics, frequency of dressing changes, surgical procedures, and outcome were collected for each patient. Laparotomy was originally performed for a variety of reasons including cancer (11), trauma (4), ventral hernia repair (3), cesarean section (2), and
aortic aneurysm repair (1). Nine of the patients had actual bowel exposure. Each of the patients was initially treated with saline gauze dressings for a period of time before being referred for to the plastic surgery service for more definitive treatment. One of the patients had been treated for almost 6 weeks with saline gauze dressings. Patients in whom initial closure of the abdomen was possible were not referred to the service and therefore were not studied. The Wound Vac system was used along with wound debridement of necrotic tissue. Pressure was maintained continuously on -75 mmHg for the patients with frank bowel exposure and -125 mmHg for the patients without. Dressings were changed every two days. Patients were discharged from the hospital with home care if their condition was sufficiently stable. Vac therapy was kept in place until the wound was able to be closed by surgery or if it closed by secondary intention.

Results: NPWT was considered appropriated for all patients reviewed by this study. Vac therapy was applied as the initial therapy for 16 of the patients. The other 5 were taken to the OR initially for debridement prior to Vac placement. Four members of the first group were eventually taken back to the OR for debridement on a later occasion. The average time using Vac therapy for the entire group was 5 weeks which ranged from 2 to 21 weeks. Those followed as outpatients (n = 7) had a slightly longer average of 9 weeks. A decrease in bowel wall edema and a decrease in observed wound volume were noted by the practitioners. Less pain was reported by the patients with the Vac dressing changes in comparison to their experience with the saline gauze dressing changes.

Three of the patients were assessed initially with “imminent fascia dehiscence” but following placement of the Wound Vac each of them showed vast improvement. Their fascia was preserved in each case.
In the group assessed with simple dehiscence, fascial closure was achieved in 9 of the 13 patients.

Complete skin coverage for both groups was eventually completed by skin flap (n = 6), skin grafting (n = 9), or by secondary intention (n = 6). The treatment course for two of the patients was complicated by development of enterocutaneous fistula (ECF). One of which was resolved by surgery and the other by “conservative management”. One of the patients had a partial loss of skin grafting. In the 6 month follow up period none of the patients experienced re-opening of their wound and none of them required assessment for wound healing difficulties.

Conclusions: NPWT has certain advantages over the use of saline dressings for the treatment of abdominal dehiscence. These include a decrease in edema and wound volume, increased vascularization and granulation of the wound, and control and monitoring of the wound fluid output. Removal of this excess fluid may promote healing due to improved vascular and lymphatic drainage as well as increased nutrient and oxygen delivery. It is worth noting the decreased number of dressing changes required for the Wound Vac system: every 2-3 days as opposed to 1-3 times per day for saline gauze dressings. Less pain during dressing changes was reported by the patients in this submission as well.

Although NPWT has been applied to open abdominal wounds in the trauma setting, the patients in this submission were different in that they were seen as prior treatment failure which probably led to the tendency toward longer periods of time on NPWT therapy.

NPWT should be used as part of treatment algorithms for post-operative wound dehiscence and patients with wound compromise due to provision of stable healing in these types of wounds.
Commentary: Although this is a small study it is adequate to show benefits of using NPWT. Eventual closure of all of the wounds described as well as the use of the system by out-patients shows that this therapy can be successfully applied in a variety of situations. Certainly this could have been done in a more controlled manner with a group of patients receiving only saline gauze dressings for comparison. Further considerations offered by the authors were the possible inclusion of data on cost, nutrition, and patient pain. There were no conflicts of interest reported by the authors.

Submission 2: Vacuum-Assisted Facial Closure for Patients with Abdominal Trauma published in the Journal of Trauma in 2004. Dr Stone, et al described their use of NPWT as a method of assisting in the treatment of 48 open abdominal wounds following trauma over a 3 year period. Although primary initial closure is not always possible with these patients, use of NPWT as a temporizing measure can be used as an interim step.

Methods: From January, 2000 to January, 2003 forty-eight laparotomy patients were identified who had temporary wound closure with the Wound Vac device. Data from this retrospective chart review included patient demographics, mechanism of injury, reasons for leaving the abdomen open, number of attempts to close, day of final closure, type of injury, net fluid balance, injury severity score (ISS), and serum lactic acid levels obtained in both the emergency department (ED) and ICU post-operatively. Statistical tests included Fisher’s exact test, the General Linear Mondel, t tests, and Spearman correlations. All statistics were calculated using SAS for Windows.

Results: The vacuum-assisted facial closure was used to treat 48 patients who had a mean ISS of 25. Blunt injury was the cause for 87.5% and the remaining 12.5% were the results of
penetrating trauma. Leaving the abdomen open was indicated due to damage control or planned re-exploration in 17 patients. Decompression due to abdominal compartment syndrome was performed in 10 cases. The remaining 21 were left open due to “impending” abdominal compartment syndrome. Twenty-six patients had primary closure of their wound performed within 7 days of injury. Two more were completed after 8 days.

Sixteen of the total 48 died of their injuries although half of those deaths occurred within 24 hours of admission. High serum lactate levels were observed in these cases although these levels were not found to be predictive of the ability to eventually close the patients’ abdominal wound. High lactate levels were correlated, however, with mortality.

Complications included five abdominal abscesses and two enterocutaneous fistulae which occurred after split thickness skin graft (STSG) placement.

Conclusions: In all, 32 of the patients who survived their injuries to be discharged from the hospital had delayed abdominal closure using the Wound Vac device. Advantages to using the Vac device included containment and protection of the abdominal contents, prevention of fluid loss, prevention of wound contamination, and ease of dressing changes. Decreased damage to the fascia from repeated attempts at suturing, and continuous tension on the edges of the fascia made it easier to re-approximate the edges at a later time. This allowed them to avoid acute, possibly lethal circumstances such as abdominal compartment syndrome.

The Vac dressing was deemed effective even for the patients (n = 2) that the longest times to closure. This efficacy was attributed to decreased fascial trauma and increased fascial mobility even after long delays. The authors further credited NPWT with contributing to decreased edema and fluid in the wound which resulted in decreased tension on the wound eventually leading to facilitated re-approximation. This was supported by the data collected
which showed higher successful closures rates in patients with net negative fluid balance. This technique is useful to decrease the morbidity associated with the open abdomen.

Commentary: This is a compelling study that offers some interesting perspectives on the use of NPWT. For instance it has been postulated that the Vac device reduces edema and this data shows an improved rate of abdominal wound closure with decreased fluid on the wound. Trauma patients who undergo damage control surgery or decompression due to abdominal compartment syndrome have a high rate of morbidity specifically as it relates to their abdominal wounds and their eventual repair. These surgeons were able to use this technique to stave off some of the associated complications by allowing the wounds to be closed rapidly with decreased incidence of complications. The authors believed that the small sample size was a limitation in their ability to show correlations with lower lactate levels and prediction of successful abdominal closure. They were also limited by the retrospective nature of the study and the absence of a control group which prevented more solid statements regarding the effectiveness of the Vac device.

Submission 3: *A Proposed Algorithm for Managing the Open Abdomen* was published in the journal American Surgeon in 2005. Dr Cipolla, et al described the use of NPWT as a part of delayed abdominal closure algorithm for the traumatic or surgical abdominal wounds due to damage control surgery or abdominal compartment syndrome decompression. Their experience and success in applying these techniques assisted in the creation of this algorithm which they intend for the consistent application of the techniques described.

Methods: A retrospective chart review from the level 1 trauma center was performed from September, 2001 to June, 2004. Patients who required transfer or who died within 24 hours
of admission were excluded from the study. Data collected included: demographics, primary diagnosis, surgical techniques, types of closure, complications associated with the open abdomen, and 28-day mortality. Predicted mortality was calculated by employment of the Simplified Acute Physiology Score (SAPS II). For this group the SAPS II score was 31 which predicted a mortality rate of 73%. All patients had NPWT applied post-operatively via a polyethylene sheet covering a surgical towel or by the KCI Wound Vac device. Choice of the technique was left up to the surgeon. All patients were re-explored within 48 hours of their first surgery depending upon clinical stability. Primary closure of the abdomen was done at that time if deemed safe. Otherwise, NPWT was continued in all patients with open abdominal wounds until time of closure. When possible, closure was attempted within 7 days. Patients unable to be closed at that time because of demonstrated clinical instability were treated with a Velcro Wittmann Patch or were treated as a planned ventral hernia (PVH) depending on surgeon preference.

Results: Twenty patients were managed with these techniques. Two died within 24 hours and one required transfer to a different hospital. The remaining patients were managed using NPWT as part of their post-operative regimen. Of the 17, nine of them required damage control surgery, two of the patients had abdominal compartment syndrome decompression, one had a ruptured abdominal aortic aneurysm, and 5 had peritonitis requiring emergency surgery and massive fluid resuscitation. Twenty eight day mortality rate was 5.9%.

Two of the patients in the PVH group who were originally treated with a Wittmann Patch had to be re-treated with NPWT due to wound maceration obviating definitive closure. Two of the patients developed enterocutaneous fistulae, one of which closed on its own and the other
was lost to follow up. Fascial closure was achieved in 6 of the patients and the others went on to be treated as planned ventral hernia repairs.

Conclusions: Delayed abdominal closure is a largely successful technique for trauma and critical care patients that require abdominal surgery. In this algorithm all patients were initially treated with NPWT if they could not be closed primarily. The authors credit this technique with the control of abdominal pressure and prevention of abdominal compartment syndrome. This has shown a reduction in organ failure and improvement of clinical stability thus eliminating abdominal compartment syndrome as a risk factor for post-operative organ failure.

Of particular note in this submission is that the reported mortality rate was much lower than originally predicted by the SAPS II scores to which the authors credit the decreased incidence of abdominal compartment syndrome and its ensuing sequelae. A larger sample size in a prospective study might be able to elucidate this further. Although fistulae and ventral hernia still appear as consequences of open abdomen, the use of NPWT is still acknowledged as one of several techniques with which surgeons should be familiar.

Commentary: The authors of this submission note that NPWT is a successful method of assisting in fascial closure both in their study and elsewhere. They also opine that the technique should be used as part of an overall strategy for management of the open abdomen and not as a sole method of practice. They further add that there are other methods may make more practical sense under certain conditions, such as the Wittmann Patch, even though 2 of their patients had the patch removed in favor of definitive treatment with NPWT. This study again shows the difficulty of gathering large amounts of data on this subject. This study might have benefited from larger sample size and long-term, detailed follow up. The authors also might have compared mortality, morbidity, complication, and infection rates with patients treated with other
modalities that they use concurrently with NPWT. However, these results are consistent with other studies.

Submission 4: *Vacuum-assisted Wound Closure Provides Early Fascial Reapproximation in Trauma Patients with Open Abdomens* was published in the American Journal of Surgery in 2001. Due to the increased use of damage control surgery and decompression for abdominal compartment syndrome the number of patients managed for open abdomen had increased dramatically. The traditional treatment, placement of absorbable mesh, often has a large ventral hernia as a consequence. To avoid the higher cost in terms of pain, rehabilitation, and further surgeries, the use of NPWT in the form of the KCI Wound Vac device was implemented to facilitate early closure of the abdominal wound and therefore lessen the impact of this dramatic surgical event on the future of these patients.

Methods: A retrospective chart review of the patients entered into the trauma registry at Memorial Hermann Hospital in Houston, TX identified 14 patients that qualified for this study. Eight of the patients underwent resuscitation protocols and had open abdominal wounds for which NPWT was used for fascial re-approximation. Six more patients were identified that underwent damage control surgery or decompression laparotomy who also had their open abdominal wound treated with NPWT. The trauma registry provided demographic information for this study as well as information regarding Injury Severity Score, etiology of the open abdomen, and number of days until wound closure. Morbidity and mortality rates specifically related to use of NPWT were collected. The standard initial surgical approach was to use towel clips or Bogota bag closure. Then, following a second laparotomy 24-48 hours later, NPWT was initiated if the wound could not then be closed. This placement was done in the OR under sterile
conditions. Pressure was then set on the device at -175 mmHg. Sutures were used to approximate the fascia as much as possible. This procedure was repeated in the OR every 24-48 hours until the fascia could be closed completely without significant tension on the wound edges.

Results: The average age of the patients in this study was 40.1 years. Ten of the patients were female. The most common mechanism of injury was blunt trauma (n = 12 or 86%). Of the eight that underwent resuscitation protocol, 3 had damage control laparotomy and 5 had decompression for abdominal compartment syndrome. The average ISS was 24.4 and each of them required massive volumes of both blood and crystalloid fluid. Of the remaining 6 patients in the study, 1 had damage control laparotomy and the others underwent decompression for abdominal compartment syndrome although their resuscitation requirements were much less than the previous group. Complete fascial closure was not possible in only 1 patient who, after 6 NPWT dressing changes, was thought to have too poor a quality of fascial borders for definitive closure. Absorbable mesh was placed in that case. There were two minor wound infections treated with local wound care. No major infections and no ECF reported.

Conclusions: Early primary closure of the fascia in open abdominal wounds following damage control or decompression of abdominal compartment syndrome is of benefit to avoid long term surgical complications especially those associated with ventral hernia. The high continuous pressures used were credited with the removal of fluid in the wound and reduction of edema. Serial dressing changes allowed for the wound to be continually assessed for fascial closure and this submission demonstrated a 90% early closure rate. Vigilant monitoring for potential complications including wound infection, bleeding, and bowel perforation was implemented but sequelae were limited to minor wound infections that resolved following fascial closure. Bowel perforation, although potentially disastrous, was not experienced in these cases.
Wound dehiscence was considered more of a patient factor than that of a potential problem with the type of dressing used in wound care. Long-term follow up is yet to be studied in detail in these severely injured patients.

Commentary: This study shows the utility of using NPWT for the closure of massive abdominal wounds. These authors demonstrated a high success rate in the presence of a very difficult patient population. They point out that long-term follow up would be of benefit in further study. Also, comparison to patients of the same type who used a different wound closure technique with associated wound closure, infection, morbidity, and mortality rates would have been of interest.

Submission 5: *Prospective Evaluation of Vacuum-assisted Fascial Closure after Open Abdomen: Planned Ventral Hernia Rate is Substantially Reduced* was published by the Annals of Surgery in 2004. Due to the increase in use of damage control surgery and decompression for abdominal compartment syndrome it has become necessary to create a protocol for initiating techniques for maintaining and treating open abdominal wounds that would allow for re-approximation of the fascia and protection of the abdominal contents.

Methods: Patients were included in this study if they required management of their open abdominal wounds by protocol. Patients in this submission required damage control laparotomy or decompression due to actual or potential abdominal compartment syndrome. Data was collected over a 19 month period from November, 2001 to May, 2003 at Wake Forest University Baptist Medical Center. The results of the use of this protocol were compared to the results from patients studied using vacuum closure techniques prior to the institution of the protocol. A standard Vac pack dressing using a surgical towel was placed after the first operation and then, at
the second operation, the Wound Vac sponge was placed instead of a towel. The sponge was only necessary if the wound could not be closed at the time of the second operation. Suture was placed to stabilize the sponge and vacuum was applied to the dressing. The effect of the vacuum on the dressing caused the viscera to be pushed into the abdominal compartment and the edges of the wound were pulled medially. Thus, traction was maintained on the wound edges by suction alone as the sutures were not under tension.

Dressings were changed every 3-5 days and could be accomplished in the ICU depending on the assessment of the clinicians involved. As the edema resolved the wound edges were able to be closed as the fascia was undamaged by repeated use of sutures required by previous techniques.

Studied end-points included: fascial closure rate, time to closure, abdominal complications (fistulae, abscess, and dehiscence), and the post operative development of ventral hernia. Statistical analysis was accomplished using Statview 5.0 and variables were compared using $X^2$, Fisher exact test, or Student $t$ test as appropriate. $P$ values less than or equal to 0.05 were considered significant.

Results: During the study period 53 patients required management with an open abdominal wound: 87% from blunt trauma and 13% from penetrating injury. Damage control surgery accounted for 45 of the patients and 8 underwent decompression for abdominal compartment syndrome. Forty-five or 78% of these patients survived until definitive abdominal closure. The mean age of the group was 36 and had an average ISS of 34. Vacuum dressings were used in all patients. Two patients progressed to planned ventral hernia. One of whom developed an ECF and the other required rectus flap repair due to another injury. Thirty-eight (88%) of the 43 patients that underwent closure under the protocol were successful. This was
much higher than the pre-protocol group’s 69% closure rate. Average time to abdominal closure was 9.6 days ranging from 1 to 21 days. Dressings were changed an average of 3.4 times. It is worth noting that late closure (past 9 days) was accomplished in 21 patients. Follow up on the closed patients was an average of 185 days ranging from 14 to 708 days. Over that time there were no abscesses and 2 patients experienced dehiscence. Both of whom had successful repairs.

Conclusions: Prior to the use of NPWT patients with open abdominal wounds experienced adhesions and retraction of the abdominal fascia that required a planned ventral hernia. This procedure, which entailed surgical repair at a later date, meant that the patient was essentially trapped into many months of time and resource consuming medical procedures. These are now essentially avoided by the placement of NPWT at the outset of care. Results of this study compared with the experience of using NPWT without protocol showed an improvement with the initiation of a standard of care approach. The reported rate of infection was essentially nil.

Commentary: This study shows a very good abdominal wound closure rate and is consistent with other data that have been presented. It has the benefit of comparison data with previous patients for whom the NPWT technique was applied. It implies that the use of NPWT with protocol improves the outcomes even further. Comparison with non-vacuum techniques at the same center including data on time to closure, infection rates, and cost would have added a further dimension to this submission.

It is of note that this study took place at Wake Forest University where the original Wound Vac concept was developed. Despite this fact, no conflicts of interest were reported by the authors.
Submission 6: *Vacuum-Assisted Closure for Defects of the Abdominal Wall* was published by the Journal of Plastic and Reconstructive Surgery in 2008. Reconstruction of the abdominal wall following trauma or surgery is a major concern. Difficulties with the integrity of the abdomen as well as the cleanliness of the wound surface all become factors in long-term success of primary closures, skin grafting, flap and mesh placement. These factors are influenced by the use of NPWT. Of particular interest were associated complication rates and time to reconstruction when NPWT was used prior to reconstruction.

Methods: Charts for 100 patients who underwent abdominal wall reconstruction following the use of NPWT were reviewed retrospectively. The data collected included the cause of the wound, the reconstruction technique, complications, and the number of days on NPWT. Serum albumin measurements were recorded as well if they were available. Patients aged from infancy to 78 years, 48 males and 52 females, were included in this study. 63 of the patients’ wounds were considered partial-thickness and 37 were considered full-thickness.

The partial thickness wounds were caused by prior surgeries, infection, trauma, or a combination of the above. The full-thickness wounds were caused by prior surgery, trauma, infection, or a combination of those factors. Eleven of those wounds were the result of abdominal compartment syndrome.

The equipment used to apply NPWT was the commercially available abdominal kit from KCI. Wound size varied considerably from 30 cm$^2$ to 700 cm$^2$. The partial thickness wounds were smaller in size in the range of 30 to 80 cm$^2$ and the full thickness wounds were larger ranging from 300 to 700 cm$^2$.

Results: The patients with partial-thickness wounds had an average vacuum-assisted closure time of 13 days. This is up to 30-50% shorter a time than the authors’ previous
experience without NPWT. This is of particular value to patients who require STSG as faster granulation time means shorter time to graft placement. Only 3 patients required NPWT for longer than 14 days. The longest was 96 days as this patient refused further surgical intervention and was allowed to heal by secondary intention augmented by NPWT alone. All patients with partial-thickness wounds were treated as out-patients and patient compliance was only an issue with the 3 patients that had therapy for the longest periods of time. The size of the partial-thickness wounds did not seem to effect closure time as all wounds closed in 11-14 days no matter their size. The only major complication in this group was wound infection and only one of the five reported occurred while the patient was still using NPWT. Albumin was not collected for all of these patients, only those with larger wounds. The average was 2.8 g/dl.

Of the 37 patients with full-thickness wounds 15 of them were able to have primary closure with this therapy. Twenty-eight of the patients had repair of their ventral hernias augmented with NPWT and none of them had recurrence of their hernia in a 2 year follow up. Complications included 1 intra-abdominal abscess, 1 abdominal wall abscess, 1 dehiscence, 1 STSG failure, and 3 deaths. None of the patients studied developed enterocutaneous fistulae within the 2 year follow up. Two of the patients died before repair and one afterward. The deaths of these patients were not noted to be in conjunction with their use of NPWT. Albumin data was not collected universally for this group either. The average was 2.2g/dl.

Conclusions: NPWT has been shown to decrease the wound closure time no matter the size of the wound. Simplified surgical reconstruction of these wounds and lower complication rates are benefits noted by the authors of this submission. Infection rates were low, only about 7% overall following treatment even though 71% of the partial-thickness group and 51% of the full-thickness group were considered contaminated prior to NPWT placement. Albumin,
measured as a marker of nutritional status, was not universally collected and therefore no correlations to wound healing can be made.

Commentary: This is by far the largest study so far that has shown benefit from NPWT in the treatment of open abdominal wounds. Although its results are consistent with other studies some of the conclusions were based on the authors’ “prior experience” with other, unspecified wound care modalities most notably in conjunction with time to closure rates. The authors further contend that NPWT has a minimizing effect on wound complications. The reported infection rate of 7% following NPWT therapy despite a fairly large contamination rate prior to treatment is sited as a benefit of the therapy itself. That could mean NPWT is effective at lowering bacterial burden. This submission has the benefit of 2 year, long-term follow up and a fairly sizable patient population although it is hampered by its retrospective nature and lack of a control group. Another potential issue involving this work is its association with KCI and Wake Forest University where the Wound Vac Device was conceived as this introduces the possibility of bias.

Submission 7: Management of Enterocutaneous Fistulas Using Negative Pressure Dressings was published in 2006 in the Annals of Plastic Surgery. Enterocutaneous Fistula (ECF), an abnormal communication between the intestine and the skin, is a known complication of patients with open abdominal wounds especially following trauma and abdominal surgery. ECF are a challenge to manage and are associated with long-term morbidity and disability. Output of an ECF is damaging to skin and wound surfaces that may still exist in an open abdominal wound. Although many of these patients are medically stable even to the point of management as out-patients, there is the possibility of major complications and infection.
Surgical options exist but, even so, ECF sometimes fail to close. The use of NPWT for ECF has been instituted for patients whose ECF is deemed inappropriate for surgical repair or failures of the same.

Methods: Since 1999, 15 patients at the authors’ institution have been deemed inappropriate for surgical management of their ECF or they had failure with such repair. Of the 15 patients (9 males, 6 females), all had ECF that were clinically confirmed by CT scan, fistulography, or contrast swallow study. Data collected on these patients included: age, serum albumin, co-morbidities, ECF output (characterized as low, medium, or high), cause of ECF, location of ECF (small bowel or colon), visible intestinal mucosa, and exposure to radiation therapy. The mean age of the patients was 50 years, 2 patients had pre-existing abdominal cancers, 2 were status post lung transplant, 2 had Crohns disease, 1 had been exposed to radiation therapy, 4 patients had exposed bowel, 9 had low output ECF and 6 were characterized as high-output. Indications for the initial surgeries included: abdominal cancer, inflammatory bowel disease, cystocele, ischemic bowel, ventral hernia, perforated bowel, bowel obstruction, and colovesicular fistula. Eleven of these patients had small bowel ECF. Three were isolated to the colon and 1 involved both colon and small bowel. NPWT was applied to each patient and dressing changes were done every 3 days. The primary outcome measured was closure of the ECF and a multivariate analysis was performed using the above clinical data collected from the patients.

Results: Eleven (73.3%) of the patients achieved closure of their ECF. The four that did not close had visible intestinal mucosa. Mean time to closure in the 11 successful patients was 14 days. ECF output was noted to decrease over time with NPWT placement. No visible intestinal mucosa ($P = 0.0007$) and age ($P = 0.0271$) were statistically associated with higher rates of
closure. Albumin, co-morbidities, ECF output, and ECF location had no significant statistical impact on closure rates. Interestingly, the patient with the history of radiation exposure achieved ECF closure. At a mean follow up time of three months there were no fatalities and none of the 11 patients had recurrence of their ECF.

Conclusions: This study shows a consistent correlation between visible intestinal mucosa and non-closure the ECF with NPWT. The authors point out that this should not be considered a failure of NPWT as it is then used as a bridge to help the patients to improve their medical status in order to undergo more definitive care. With NPWT in place, ECF output is directed away from wound surfaces and skin. This has the effect of allowing healing of the abdominal wound to more easily take place. In patients with no visible intestinal mucosa, NPWT is able to close the ECF successfully.

Commentary: This study shows a dramatic use for NPWT in a known complication of open abdominal wounds. They have shown results consistent with other case reports and reviews. The small sample size is indicative of the difficulty in recruitment of patients for a study of this type as not all are refractory to surgical treatment. The authors note that the small sample size may be contributory to statistical artifact in certain categories most notably younger age as a risk factor for non-closure. Although the data is compelling, the retrospective nature of this study and lack of control contribute to decreased validity.

Submission 8: The “Fistula Vac”, a Technique for Management of Enterocutaneous Fistulae Arising within the Open Abdomen: Report of 5 Cases was published in 2006 in the Journal of Trauma. Dr. Goverman, et al reported their experience using NPWT in the treatment of ECF developing in patients who have undergone damage control surgery. The vacuum in this
case was used in a novel fashion, not to close the fistula, but to maintain the area around the fistula allowing the ECF to heal on its own. Their experience was related as 5 case reports.

Methods: The wounds were first cleansed and then the standard Wound Vac dressing was modified to fit around the ECF opening allowing for suction to be applied only to the area around the ECF. This, in effect, isolated the opening of the fistula. An Ostomy appliance and foley bag were attached to the open ECF allowing it to drain. This was done as a pre-cursor to STSG. Prior to the graft placement the dressing was changed every three days. Following the STSG the Vac dressing was left in place for 5 days. Patient historical data for this study can be found in Table II.

Results: All 5 of the patients had diversion of ECF output using this system. Healthy granulation tissue was noted in all cases within a week of application. Two of the patients died as a result of sepsis that was considered to be not related to their abdominal wounds. The remaining 3 patients underwent STSG with 95% success rates. After 5 more days on NPWT the device was removed and a standard Ostomy was placed for each patient. They were all subsequently discharged to home. Between 6-10 months later each patient was then taken to the OR for elective surgery to remove the STSG, resection of the fistula, and repair of their abdominal hernia.

Conclusions: For these 5 patients the use of this novel form of NPWT allowed them to effectively divert enteric material away from their open abdominal wound. The surrounding wound bed itself benefited from the negative pressure environment without contamination from the fistula.

Commentary: This is an interesting approach to the application of NPWT and it has far reaching implications in this setting of increased popularity and success of damage control.
surgery in the avoidance of abdominal compartment syndrome. Certainly this technique could benefit from more formal prospective, controlled study.

RESULTS

There is consensus among these submissions that Negative Pressure Wound Therapy is effective in the treatment of open abdominal wounds in the setting of both surgery and trauma. There was a noted increased formation of granulation in the wounds as well as possible improvement in control and quantification of wound fluid output. NPWT is a useful adjunct in the setting abdominal compartment syndrome as a means of control in the setting of increased intra-abdominal pressures. Decreases were noted in morbidity rates and complications due to the open abdomen and their ensuing consequences including enterocutaneous fistulae, abdominal wound dehiscence, and ventral hernia. This finding occurred in spite of co-morbid conditions.

CONCLUSIONS

Taken as a whole, the literature submitted above shows compelling reasons to include Negative Pressure Wound Therapy in the treatment armamentarium used in the resolution of open abdominal wounds. Also, potential consequences of open abdominal wounds, most notably enterocutaneous fistulae and abdominal wound dehiscence, occur less frequently with NPWT. These findings were noted even in the setting of massive fluid resuscitation, prior abdominal surgeries, and infection.

Time to closure of the abdominal wound is used as a marker of effectiveness of NPWT in many of these studies. (Cipolla et al, Stone et al, Garner et al, and DeFranzo et al) These authors were all able to show that the times to closure were not excessive when NPWT was in use.
Among the submissions that reported time to closure, rates averaged 16.4 days in 200 patients. This included the study by Heller et al in which all of the 21 patients had previously failed saline gauze treatment. These patients were referred to Heller’s plastic surgery group due to the chronic nature and complexity of their wounds. Miller et al and Garner et al had very similar closure rates (9.5 and 9.9 days respectively) in patients with traumatic injuries. This lends even more credence to their use of NPWT in the setting of damage control laparotomy and abdominal compartment syndrome which are discussed in greater detail below.

All authors had experience using other techniques, such as saline gauze, which they felt were more time and labor intensive. Shorter duration of therapy has a positive impact on the lives of patients as they will spend less time dealing with a chronic medical condition. That is an important consideration with all of the associated difficulties involved with an abdominal wound including cost, potential for infection, and exacerbation of other medical problems. Shorter duration of therapy has a positive impact on an already strained medical system as well. Shortages of personnel and allocation of health care dollars are of major concern currently. Associated disruptions in care can be minimized by simply decreasing the time for which the patient needs wound care.

Morbid consequences to the patient who has to undergo massive abdominal surgery can be devastating. However, NPWT has the potential to decrease the impact of these problems or, in some cases, to obviate them completely. These submissions have shown a surprising and encouragingly small rate of enterocutaneous fistulae. As previously mentioned, ECF can cause major problems for a patient including skin damage, infection (including septic shock), and social isolation. As seen in these studies use of early NPWT may decrease the occurrence of ECF in this patient population. If an ECF does occur, the submissions by Gunn et al and
Goverman et al indicate that NPWT has shown efficacy in the resolution of ECF effects when they occur. The other submissions show the relatively low occurrence of ECF formation of 11.7% when NPWT is utilized. The actual ECF closure rate was 68.4% overall even with one patient lost to follow up.

Ventral hernia is another problem faced by patients in this population. Placement of absorbable mesh in patients with open abdominal wounds often leads to massive and unsightly hernias\(^{52}\). The patient is then subjected to major and difficult repairs over long periods of time. These repairs are, more often than not, less than successful from an aesthetic standpoint. These submissions suggest that early use of NPWT allows for an excellent opportunity for early closure of the fascia due to evacuation of local edema thus providing the basis for a more acceptable and more presentable outcome.

Infection rates and their complications were not universally reported among these submissions. The four that did report infection (or abscess) rates variance of 0 to 19% with an average infection rate of 7.8%\(^{16, 15, 13, 20}\). The smaller studies actually showed the higher percentage of infection probably due to their smaller populations. The infection rates with larger study groups may prove much lower than it appears here. Defranzo et al had the largest patient population of these submissions and demonstrated only a 7% infection rate.

The low rate of infection and abscess formation has been attributed to the use of NPWT due to evacuation of edema and serous wound drainage. Animal models that have shown decreased bacterial burden in wounds covered by NPWT\(^3\). This has not been completely borne out in human studies however. Bacterial colonization of these wounds has not been shown to have a deleterious effect on outcomes according to some authors\(^{10}\).
Failure of previous therapy is also an indication for use of NPWT. Wounds that have dehisced or have failure of more conventional therapy, as demonstrated by Gunn et al, have been shown to benefit in that they have closed following institution of this therapy.

NPWT has also shown to be an effective tool in the treatment of abdominal compartment syndrome\textsuperscript{5}. Major fluid resuscitation and fluid shifts can cause increased pressure in the abdominal compartment much like cerebral edema can cause increased intracranial pressure. This pressure increase causes damage to the internal organs in much the same fashion by reduction of blood supply and the application of mechanical forces. In addition, release of inflammatory cascade factors and cytokines in this situation lead to further damage to organs and vasculature. Decompression laparotomy is the treatment that has shown major success in this setting\textsuperscript{12, 13, 20}. Blood flow to organs remains optimal if the pressure on the organs remains physiologically normal or less than 25 mmHg\textsuperscript{5}. Leaving the abdomen open allows the fluid to dissipate without creating an increased intra-abdominal pressure. NPWT is an effective temporizing measure that can allow fluid shifts without pressure increase. Re-exploration of the abdominal compartment can be accomplished with relative ease if necessary\textsuperscript{13, 20}. As the edema subsides there is lower incidence of domain loss in the abdomen (a major contributor to ventral herniation), less adhesion formation, and less damage to the fascia all of which facilitate early, successful, and aesthetic closure of the abdomen.

There are certainly aspects of NPWT that warrant further investigation. First and foremost, as mentioned above, the decreased time to closure. Thus far comparisons to earlier therapy have been experiential rather than experimental\textsuperscript{16}. Retrospective analysis could be made to compare past patients and older techniques with NPWT\textsuperscript{12}. This area of study could also benefit from a prospective, randomized study which would lend more power to the argument that
NPWT reduces time to closure of wounds. Inclusion of patient demographics and other characteristics such as wound size, depth, and location as well as time to final closure of the wound would allow for more meaningful comparisons across different studies. It was difficult to compare the patient populations in these submissions due in part to missing some of this vital information. Chronic wounds are a huge cost in terms of patient suffering and healthcare expense. Any reduction in either of these factors would be welcome.

Second: study of NPWT in the setting of trauma and abdominal compartment syndrome should continue. Damage control surgery continues to show it effectiveness in actual practice. The use of NPWT to augment and improve that success should be documented in the form of prospective studies. This has the potential to improve the morbidity and mortality rates in the general population. In addition, military applications of NPWT under battlefield conditions have been largely unexplored until recently\(^2\). Comparisons to civilian experience may elucidate more efficient and more practical applications of these techniques which could lead to more standardization of care\(^5\).

Third: study of NPWT in the setting of enterocutaneous fistulae should be ongoing. This consequence of open abdominal surgery can be unforgiving in its effects on patients, their recovery, and their well-being. NPWT has great potential in this area. Long term follow up of patients with and without fistulae as well as prospective study of NPWT as therapy would be a great boon to healthcare in this setting.

Fourth: the study of infection rates as it relates to NPWT and abdominal wounds would be intriguing. Studies have been done that suggest that NPWT leads to a decrease in the bacterial burden of chronic wounds but this was not specific to the abdomen\(^11,10\).
Lastly, KCI has done an exceptional job of collecting information, studies, and guidelines on the use of Negative Pressure Wound Therapy. Independent studies would add a great deal of legitimacy to the body of work already presented on this subject.
TABLES

Table I: Calculation of Injury Severity Score (ISS)

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Injury Severity Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Head/neck</td>
<td>▪ Sum of the squared AIS scores of the three most severely injured body regions</td>
</tr>
<tr>
<td>B. Face</td>
<td>▪ A score of 6 in any region is automatically assigned an injury severity score (ISS) of 75</td>
</tr>
<tr>
<td>C. Chest</td>
<td>▪ &gt;20% blood loss generally raises the score by 1 in the most severely injured region</td>
</tr>
<tr>
<td>D. Abdomen/pelvic contents</td>
<td>▪ Example: A patient with a grade 4 splenic laceration, closed femur fracture, and hand laceration: $D^2 + E^2 + F^2 = 4^2 + 3^2 + 1^2 = 26$</td>
</tr>
</tbody>
</table>

Reproduced from reference.21
Table II: Patient Historical Data for Submission 8

Case Reports

Patient 1  The first application of the fistula-VAC involved a patient who previously underwent exploration for radiation induced small bowel obstruction complicated by abdominal compartment syndrome requiring decompressive laparotomy. Two enteric fistulae developed within the open abdominal wound and were treated with the fistula-VAC.

Patient 2  The second patient was transferred to our institution after a laparoscopic transvaginal hysterectomy complicated by postoperative sepsis necessitating several re-explorations. At the time of transfer, the abdomen had been left open and a large enteric fistula had developed in the upper portion of the wound.

Patient 3  This patient had a history of infected pancreatic necrosis complicated by abdominal compartment syndrome and multiorgan dysfunction syndrome. He underwent multiple pancreatic necrosectomies and abdominal washouts and developed an enteric fistula draining into his open abdominal wound.

Patient 4  The fourth patient had a history of evisceration after laparotomy for peritonitis following PEG placement. She was left with an open abdomen containing one prominent bowel loop within the wound that eventually broke down forming an enteric fistula.

Patient 5  The final patient developed severe sepsis after gastric bypass necessitating relaparotomy and small Intestinal resection for necrosis. His abdomen was left open and an enteric fistula developed.

Reproduced from reference.18
### Table III: Average Time to Closure

<table>
<thead>
<tr>
<th>Study</th>
<th># of Patients</th>
<th>Average Time to Wound Closure (in days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defranzo et al</td>
<td>97</td>
<td>15.5</td>
</tr>
<tr>
<td>Miller et al</td>
<td>43</td>
<td>9.5</td>
</tr>
<tr>
<td>Garner et al</td>
<td>13</td>
<td>9.9</td>
</tr>
<tr>
<td>Heller et al</td>
<td>21</td>
<td>43</td>
</tr>
<tr>
<td>Stone et al</td>
<td>26</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>200</strong></td>
<td><strong>16.4</strong></td>
</tr>
</tbody>
</table>

### Table IV: Wound Infection Rate

<table>
<thead>
<tr>
<th>Study</th>
<th># of Patients</th>
<th># of Wound Infections (abscesses)</th>
<th>% Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defranzo et al</td>
<td>97</td>
<td>7</td>
<td>7%</td>
</tr>
<tr>
<td>Miller et al</td>
<td>43</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Garner et al</td>
<td>13</td>
<td>2</td>
<td>15%</td>
</tr>
<tr>
<td>Stone et al</td>
<td>26</td>
<td>5</td>
<td>19%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>179</strong></td>
<td><strong>14</strong></td>
<td><strong>7.80%</strong></td>
</tr>
</tbody>
</table>
Table V: Enterocutaneous Fistula with Closure Rates Using NPWT

<table>
<thead>
<tr>
<th>Study</th>
<th># of Patients</th>
<th>Reported ECFs</th>
<th>% ECF</th>
<th># of Closures Using NPWT</th>
<th>% Closed Using NPWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defranzo et al</td>
<td>97</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Garner et al</td>
<td>13</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Heller et al</td>
<td>21</td>
<td>2</td>
<td>9%</td>
<td>1</td>
<td>50%</td>
</tr>
<tr>
<td>Cipolla et al</td>
<td>17</td>
<td>2</td>
<td>11%</td>
<td>1*</td>
<td>50%*</td>
</tr>
<tr>
<td>Gunn et al</td>
<td>15</td>
<td>15</td>
<td>100%</td>
<td>11</td>
<td>73%</td>
</tr>
<tr>
<td>Totals</td>
<td>163</td>
<td>19</td>
<td>11.7%</td>
<td>13</td>
<td>68.4%</td>
</tr>
</tbody>
</table>

* 1 patient with ECF was lost to follow up.
Figures

Figure I: NPWT Applied Following Laparotomy

(A) An open abdomen following a trauma laparotomy. (B) The sponge is placed after a nonstick protective layer is placed over the viscera. (C) The wound contracts when suction is applied. (D) With successive dressing changes, the wound edges are gradually brought together. This wound was closed 9 days after initial injury. (From Gordon ES, editor. A Collection of Images and illustrations. Winston-Salem, NC: Department of Plastic Surgery, Wake Forest University School of Medicine; 2002. p. 121–5)

Reproduced from reference.²
Figure II: Algorithm Created by Miller et al

Open Abdomen
  ↓
Vacuum Pack*
  ↓
Re-operation
  ↓
Able to Close Abdomen?
  ↓
Yes
  ↓
Close Fascia
  ↓
VAFC
  ↓
Re-operation
  ↓
Able to Close Abdomen?
  ↓
No
  ↓
VAFC (attempt partial closure)
  ↓
Repeat Every 3-5 Days Until**

Algorithm for VAFC applied to patients requiring open abdomen. *Standard vacuum pack dressing as described by Barker et al3 using surgical towel. Sponge is usually placed at second look when edema has improved. **Or until repeated dressing changes interfere with patient recovery.

Reproduced from reference.13
Clinical algorithm for management of patients who require delayed abdominal closure (DAC).

Reproduced from reference.\textsuperscript{12}
Figure IV: “Fistula VAC” Dressing

Tailored VAC sponge applied with polyurethane drape and -75 mm Hg continuous pressure. The ostomy bag is adherent to the VAC drape collecting the enteric contents. [Fistula vac]

Reproduced from reference.¹⁸
Bibliography


