When managing enteric fistulae the immediate focus is on infection control, nutrition, and fluid and electrolyte management with a secondary focus on effluent control and wound management. Enteroatmospheric fistulae are difficult to control due to the lack of a defined tract and absence of surrounding skin. Additionally, the open granulating “frozen” abdominal viscera often precludes resection or exteriorization of the involved segment. If spontaneous closure of the fistula does not occur, surgical correction is often delayed for at least 3 months, during which management of the fistula stoma becomes technically challenging.

Management difficulties arise from moisture within the wound bed and the absence of surrounding dermis rendering an ostomy appliance ineffective. Contamination by fistula effluent increases wound bacterial burden and inhibits granulation tissue formation and subsequent healing. Bowel effluent may quickly lead to skin excoriation or cellulitis, delayed wound healing, bacteremia, or sepsis if the fistula is not isolated. The ideal dressing for an enteroatmospheric fistula would allow for collection of fistula effluent, protect surrounding tissues, promote granulation, and reduce the overall number of dressing changes.

**Abstract:** Background. The following describes successful isolation of enteroatmospheric fistulae within a negative pressure wound therapy system (V.A.C.®, KCI, San Antonio, TX). Methods. An impermeable tubular structure was placed around the fistula with a dressing applied to the surrounding wound base, dressed with an impermeable drape and negative pressure, and then an ostomy appliance was placed over the isolated fistula stoma. Cost analysis compared traditional dressings to the NPWT isolation method. Results. All patients underwent fistula isolation with complete diversion of enteric contents. Typical dressing changes occurred 3 times per week. Four patients were discharged from the hospital prior to surgical repair. Conclusion. Successful isolation of enteroatmospheric fistulae using a NPWT system has the potential to lower healthcare system costs by allowing for earlier hospital discharge.
Table 1. Case profiles.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Injury</th>
<th>Comorbidities</th>
<th>VAC use prior to fistula?</th>
<th>Fistula volume</th>
<th>No. of fistula openings</th>
<th>Nutrition following isolation</th>
<th>Duration of fistula isolation</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>Dehiscence after radical cystectomy with ilial conduit. Fistula due to retention suture injury to bowel.</td>
<td>Bladder cancer; COPD; obesity; HTN; GERD</td>
<td>No</td>
<td>&gt; 500 mL/day</td>
<td>1</td>
<td>TPN</td>
<td>6 wks</td>
<td>Successful fistula resection</td>
</tr>
<tr>
<td>77</td>
<td>Internal iliac to SMA bypass; bowel injury. Fistula from anastomosis.</td>
<td>SMA stenosis; vasculopath; COPD; HTN; CAD</td>
<td>No</td>
<td>&gt; 500 mL/day</td>
<td>1</td>
<td>TPN</td>
<td>21 days</td>
<td>Death secondary to graft infection</td>
</tr>
<tr>
<td>35</td>
<td>Bowel resection, ileostomy, wound dehiscence. Fistula from anastomosis.</td>
<td>Crohn’s disease; asthma</td>
<td>No</td>
<td>&gt; 500 mL/day</td>
<td>1</td>
<td>Full liquids</td>
<td>4 mts</td>
<td>Successful fistula resection</td>
</tr>
<tr>
<td>65</td>
<td>Gunshot wound to abdomen, multiple bowel injuries, colon and small bowel resection. Fistula from anastomosis.</td>
<td>Schizophrenia; diabetes; CHF; A-fib; obesity</td>
<td>No</td>
<td>&gt; 500 mL/day</td>
<td>2</td>
<td>TPN</td>
<td>5 mts</td>
<td>Successful fistula resection</td>
</tr>
<tr>
<td>66</td>
<td>Infected mesh eroded into bowel causing initial fistula. After mesh removal, developed further fistulae.</td>
<td>Obesity; ventral hernia</td>
<td>No</td>
<td>&lt; 500 mL/day</td>
<td>2</td>
<td>All oral</td>
<td>6 wks</td>
<td>Discharged to local nursing home, then home with successful isolation; transitioned to wound manager prior to successful surgical revision months later.</td>
</tr>
<tr>
<td>55</td>
<td>Fistula noted after elective hernia repair.</td>
<td>Obesity; ventral hernia</td>
<td>Yes</td>
<td>&lt; 500 mL/day</td>
<td>1</td>
<td>All oral</td>
<td>8 wks</td>
<td>Discharged home with VAC isolation; transitioned to wound manager at 8 wks. Surgical revision successful months later.</td>
</tr>
<tr>
<td>25</td>
<td>Resection after failed pancreas transplant, residual abscess with injury during drainage. Subsequent small bowel resection with wound dehiscence.</td>
<td>Diabetes</td>
<td>Yes</td>
<td>&gt; 500 mL/day</td>
<td>1</td>
<td>TPN and clear liquids</td>
<td>4 wks</td>
<td>Discharged to nursing home; transitioned to wound manager prior to successful surgical repair months later.</td>
</tr>
<tr>
<td>28</td>
<td>Facial debridement after infection following multi-system penetrating trauma.</td>
<td>None</td>
<td>Yes</td>
<td>&gt; 500 mL/day</td>
<td>7 (isolated the 2 highest output)</td>
<td>TPN and oral nutrition shakes</td>
<td>8 wks</td>
<td>TPN-related liver dysfunction led to surgical repair at 8 wks; repair was successful.</td>
</tr>
</tbody>
</table>
While KCI (San Antonio, TX) has marketed their NPWT system for several patient populations, its use for fistula isolation has not been widely published. Goverman et al described the “fistula V.A.C.” in which a Xeroform® dressing (Covidien, Mansfield, MA) is applied to the wound bed, leaving a hole for the enteric opening with a tailored foam, drape, and continuous negative pressure with a foam dressing and an ostomy appliance to cover the stoma. It has been the authors’ experience that without an impermeable barrier between the fistula and the NPWT system, effluent is drawn into the foam, tubing, and often the canister, leading to occlusion of the NPWT system, contamination of the wound bed, or disabling the NPWT system. The additional time and effort required to troubleshoot such issues can also lead to discontinuance of the system.

Successful wound bed management that pre-covers the superficial wound bed with numerous Eakin® cohesive seals (TG Eakin Ltd., Londonderry, UK) has been reported. While it is the authors’ experience that the Eakin product adheres better than many other products, it has led to cobblestone appearance on the wound bed rather than an ideal granular bed. Additionally, the authors have not found this method to be successful for deeper, larger wounds. The authors’ experience of cannulating the proximal stoma opening with an inverted nasal trumpet, Mallencot tube, or similar catheter with attachment to a collection bag or suction system has been inconsistently successful with the majority of success for those immobilized patients.

Following inconsistent success of previously described techniques as well as other fistula isolation methods, the authors have found most consistent success through the creation of a “ring”/“silo” within a NPWT system. This case series describes several patients with differing underlying diagnoses, who developed enteroatmospheric fistulae that presented wound management challenges. Isolation of the fistulae was successfully achieved in two separate academic institutions by utilizing an air and fluid impermeable “ring”/“silo” within an NPWT system. The purpose of this case series is to describe this unique isolation method, as well as to illustrate the potential cost effectiveness of isolating enteroatmospheric fistulae within an NPWT system.

**Wound Management Procedure**

The successful isolation technique utilized at the two institutions had the same underlying premise: an air and liquid impermeable “ring”/“silo” within a NPWT dressing. Wounds were first cleansed with saline solution and the wound bed, excluding the fistula, was dressed based upon granulation thickness. Petroleum gauze was applied to prevent additional fistula formation. Once the ring/silo was placed over the fistula mouth, both methods were dressed similarly by applying the V.A.C.® Granufoam (KCI, San Antonio, TX), and in some instances V.A.C.® Whitefoam (KCI) with Granufoam overlay, to the pre-dressed wound base, placing the V.A.C.® drape (KCI) across the wound bed and over the top lip of the “ring” or to the sidewalls of the “silo” isolation device. The
V.A.C.® T.R.A.C.™ pad (KCI) was then placed onto the foam away from the isolation device with continuous negative pressure set at 100 mmHg. Once negative pressure was initiated, simultaneous manual pressure was applied downward onto the isolation device. Any inner or outer isolation device leaks were sealed off with stoma paste until the leak was no longer audible. An ostomy appliance or alternative collection device was then applied on top/around the isolation device for effluent collection. The use of a tubular shaped impermeable barrier around the fistula opening successfully allows for independence between the negative pressure of the dressing and ostomy appliance, thereby improving wound healing while simultaneously collecting enteric drainage for quantification.

**Case 1.** A 25-year-old man with type 1 diabetes mellitus status post failed pancreas transplant with subsequent pancreas removal at an outside hospital presented with a large infected wound resulting in enterocutaneous fistula. The high output fistula was successfully managed with NPWT and ring isolation method for greater than 4 weeks, then transitioned to a wound manager (Figure 1). The patient required total parenteral nutrition (TPN) in conjunction with a clear liquid diet. Surgical repair was successful 5 and a half months later.

**Ring Method:** The fistula isolation “ring” was constructed of black V.A.C. foam cut into a circular shape, then completely encompassed with V.A.C. drape to create an impermeable barrier. The use of a tubular shaped impermeable barrier around the fistula opening successfully allows for independence between the negative pressure of the dressing and ostomy appliance, thereby improving wound healing while simultaneously collecting enteric drainage for quantification.

**Case 2.** A 65-year-old man with history of severe bipo-
lar disease sustained a self-inflicted gunshot wound to the abdomen. Emergent laparotomy resulted in colon resection, colostomy, and small bowel resection with Vicryl mesh for fascial closure. Subsequently, he developed two high output enterocutaneous fistulae through the mesh. Nutrition was maintained on TPN and clear liquids. The VAC and silo system successfully isolated the small bowel effluent. After 4 months, multiple skin grafts, and a colostomy takedown, successful surgery with resection of two segments of small bowel containing fistulae was performed.

Silo Method: The "silo" method was constructed from the inside plastic tubing of a tape roll or syringe barrel of a syringe of the appropriate diameter, wrapping petroleum gauze along the side walls, and placement of Duoderm® (ConvaTec, Princeton, NJ) at the base for a bottom cushion. The rest of wound was dressed as desired, with occlusive drape over entire dressing area and stoma paste around outer silo edges. A drainage collection bag was placed surrounding the silo walls (Figure 2).

Methods

Cost analysis was performed by analyzing 2008 affiliated hospital supply cost and daily patient room charge, comparing gauze, daily, and every other day NPWT dressings (Table 2). To obtain cost estimates for both gauze dressing changes and NPWT dressing changes, we made some assumptions based on our experience as well as a case published by Kordasiewicz in 2004. Kordasiewicz’s high output enteroatmospheric fistula patient was initially managed with Kerlix™ dressings (Covidien, Mansfield, MA) every 4 hours. Effluent overflow resulted in the saturation of the bed linens and patient reported intolerable odor. It was assumed that a high output fistula (> 500 mL/24 hours) would most likely require dressing changes every 3 hours totaling 8 times per day to limit effluent overflow. Table 1 further compares costs of daily with every other day NPWT dressing changes. The authors often successfully limit NPWT dressing changes to Monday, Wednesday, and Friday resulting in 12 changes per month. Nursing cost. Hospital RN time was estimated at $40/hour based upon current nursing salary information given potential shift differential and variable experience. A visiting RN averages $125 each 30- to 60-minute visit without additional cost for the act of dressing changes.

Results

Fistulae were successfully isolated in 8 patients for 3–20 weeks. Patients ranged in age from 25–77 years and had 1–7 fistulae. In all but one, fistula output was > 500 cc per day at the time of initial isolation. Both the Whitefoam (KCI) and Granufoam (KCI) were used. Antecedent diagnoses precipitating the fistulae included abdominal gunshot wound, recurrent ventral hernia repairs, stoma takedown, necrotizing soft tissue infec-
tion, and superior mesenteric artery revascularization. All but three patients were able to resume oral nutrition, and for three patients, the only route of alimentation was oral. The patient with superior mesenteric artery revascularization died of a graft infection, while all others underwent successful fistula resection. All of the patients at one hospital were successfully discharged. Discharge at the second institution was not considered despite successful isolation for up to 20 weeks.

Since hospital costs include nursing fees, we itemized materials and charges to better delineate differences between work hours and supplies. Daily supply cost of simple dressings every 3 hours is $95.36 per day versus foam changes, which can reach as high as $230.06. According to Wild et al, however, the higher initial costs involved with the NPWT system result in quicker healing rates, with decreased dressing changes, hospital stay, and care requirements, and potentially a reduction of subsequent illnesses. As stated earlier, a typical time frame for medical management is up to 3 months prior to surgical repair. While the gauze dressings are financially less expensive compared to the NPWT foam, the high daily hospital fees make achieving a successful fistula isolation treatment plan outside of a hospital setting more cost-effective in the long run.

Frequent gauze dressings would typically not allow for hospital discharge prior to surgical repair. While it is possible that alternative dressing methods may be achieved during hospitalization, the likelihood of hospital discharge would be dependent on successful isolation. Hospitalization on a general care floor carries a weekly patient charge of $12,600, compared to 3 times per week home nursing visit of $375, resulting in a savings of $12,225 per week. This is a significant savings through the date of corrective surgery. Since the initial development of this article we have experienced many additional successful hospital discharges with patient management in outpatient wound clinics and sub-acute centers, as well as long-term care centers.

**Discussion and Conclusion**

Treatment of enteroatmospheric fistulae is challenging and often involves several months of treatment. Successful isolation of enteric contents from the wound bed can be achieved through the formation of a “ring”/“silo” within a negative pressure dressing. The benefits of successful isolation have been previously reported to result in accurate documentation of fistulae output, divergence of enteric contents from the wound bed allowing for optimal granulation and preservation of surrounding skin integrity, as well as the possibility of increased patient mobility. Our isolation method has provided prolonged success allowing for hospital discharge prior to surgical correction, providing a significant cost savings.

With the NPWT dressing system and creative use of available materials, we have successfully isolated effluent drainage. Removal of effluent from the exposed healing tissue allowed for the negative pressure wound therapy system to function as it was intended. While we have had many successful isolation cases, some attempts have failed. Typical isolation failures occurred in those wounds within deep crevices or along significant skin fold defects. Due to the complexity of isolation dressings, we have had our greatest success using step-by-step photo documentation for other applicators within and outside of the hospital setting. With isolation success up to 20 weeks, most consuming oral nutrition, as well as the potential for hospital discharge, the authors encourage consideration of the “ring”/“silo” isolation method.

**References**