CASE STUDY

Challenges of Complex Open Abdominal Wound Management in Trauma: A Novel Use of Chitosan and Hyaluronic Acid as a 3-Dimensional Scaffold to Overcome Resilient Open Abdomen Infections

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KEYWORDS:

Open abdomen technique;
Chitosan;
Hyaluronic acid;
Negative pressure wound
therapy

Abstract Case presentation of a novel method for the management of complex open abdomen technique. This Mmethod includes the combination of chitosan, hyaluronic acid and negative pressure wound therapy. Patient was initially managed with traditional operating room wash-outs and packing. Implementation of novel method achieved closure in 17 days with split-thickness-skin-graft.
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Background

The open abdomen is a relatively new and increasingly common strategy for the management of abdominal emergencies in both trauma and general surgery. The open abdomen can reduce mortality associated with conditions such as abdominal compartment syndrome, bowel perforation and internal organ laceration. However, the resulting open abdomen is a complex clinical problem.^{1,2} Advanced techniques and improved technologies are now readily available, allowing management of the open abdomen as well as the progressive reduction of the resulting abdominal and underlying fascial defect. Recent studies indicate both an improved survival rate and increased likelihood to successfully close a large proportion of patients, treated with open abdomen technique (OAT). Moreover, these patients can now be closed within the initial hospitalization.³ These techniques and technologies

include the appropriate use of negative pressure therapy (NPWT)⁴ and synthetic or biologic repair materials.⁵ It is essential that general and trauma surgeons understand the core principles underlying the need for and management of the open abdomen.

As described by the Open Abdomen Advisory Panel,⁶ the open abdomen technique (OAT)^{7–9} is widely utilized in life-threatening trauma, intra-abdominal sepsis and abdominal compartment syndrome. The OAT poses a variety of critical care challenges, inclusive of surgical, metabolic and nutritional complications; as well as infections both local and systemic.⁶ Negative pressure wound therapy (NPWT)¹⁰ has become increasingly common for the management of the open abdomen. NPWT does not completely overcome the challenges posed by mesh degradation, inevitable epiboly at the peri-wound, or complex wound gutters.³ This case demonstrates a novel approach to complex open abdomen wound management utilizing NPWT in combination with 2 unique dressings, chitosan and hyaluronic acid. Hyaluronic acid (HA), is unique among glycosaminoglycans in that it is nonsulfated, forms

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in the plasma membrane, instead of the Golgi apparatus, and can be very large, with its molecular weight often reaching the millions. in a stabilized form; it provides a 3D-biopolymer scaffold, that promotes endothelial cell migration¹¹; thus supporting neo-vascularization, a foundation of granulation tissue and extracellular matrix revitalization. Chitosan (CS) is a marine polysaccharide that in and of itself has hemostatic, anti-microbial and anti-inflammatory properties.¹² Harkins et al, further demonstrated that CS is a biocompatible material which does not inhibit the cellular function of fibroblasts, necessary for the formation of granulation tissue; and that CS significantly inhibited the production of TNF- α and IL-6 by pro-inflammatory macrophage, decreasing the overall inflammatory environment locally.¹² A CS fiber dressing, impregnated with silver (Ag+I) is anti-microbial and retains the core CS properties of vertical wicking, hemostasis, and is anti-inflammatory via cellular pathways.¹³⁻¹⁵ Here we present the novel use of chitosan-silver (CSS) and HA as compatible substrates with NPWT. The unique combination of CSS and HA resulted both in cellular proliferation, neo-vascularization and reduction of infection; providing the basis for terminal re-epithelialization sufficient to support terminal closure by split-thickness-skin-graft (STSG).

Case Presentation

MM is a 45-year-old man who sustained multiple knife stab wounds to his abdomen. He was immediately transferred to a Level I Trauma Center. After initial assessment, the patient underwent emergent exploratory laparotomy and was found to have multiple penetrating organ injuries. Damage control surgery was performed. The patient was left in discontinuity, open abdomen with NPWT to manage exudate and provide barrier mechanism. The patient was then transferred in critical condition to the trauma intensive critical care unit (TICU). MM underwent aggressive resuscitation with multiple abdominal washouts, and ultimately placement of a Polyglactin 910 mesh to approximate the fascia; with NPWT was placed in the OR theater to manage drainage, abdominal pressure and facilitate granulation. NPWT set at continuous pressure at 100 mm Hg. Unfortunately, within 7 days, the inevitable occurred; necrosis of the overlying mesh with combined areas of tissue necrosis and mesh degradation. Large wound gutters began forming at the peri-wound interface, particularly in the inferior quadrants. Biofilm/bioburden formation consistent with multibacterial colonization were confirmed with laboratory analysis. NPWT was discontinued and wet-to-wet gauze dressings instituted. Further degradation and thickening of the peri-wound margins continued with the formation of yellow-green biofilm over the Polyglactin 910 mesh (Fig. 1).

MM's open abdominal wound with bacterial colonization and mesh degradation posed a difficult dilemma for the

Figure 1 Open Abdomen 4/14/2015. NPWT discontinued wet-to dry dressings initiated. Vicryl mesh apparent with juncture of mesh visualized at midline horizontally.

medical team. MM was not acutely septic from his wounds; providing an opportunity to avert utilization of traditional surgical pathway; (i.e.) repeated abdominal washout in the operating room (OR) theater with explantation of mesh. This treatment approach could have been potentially catastrophic for this patient. Instead, a decision was made to opt for a broad-spectrum-antimicrobial treatment (CSS) in combination with a molecular biologic substrate (HA) that would facilitate angiogenesis, fibroblast migration, and deposition of ECM components.^{16,17} The utilization of CSS to mitigate bioburden and the use of HA in combination with NPWT (at a lower setting 50 mm Hg–75 mm Hg) was selected to manage abdominal pressures and wound exudate.

Prior to the application of the Chitosan/HA/NPWT combination, the wound surface area was 750 cm² (Figs. 1 and 2). The abdominal wound was initially managed using surgical washouts and NPWT placement in the OR. Fig. 3 shows the appearance of the CSS dressing prior to cleansing and replacement with NPWT change. The CSS appears as yellowish squares along the peri-wound margin which trapped the exudate. With improved granulation, noted on 5/2/2015, the CSS was replaced after the wound was cleansed gently with a non-cytotoxic cleanser. On 5/14/2015 CSS and HA were applied to appropriate areas of the open abdomen under NPWT secondary to improved granulation and decreasing wound size and gutters. Fig. 4 illustrates the both the CSS and HA dressing (clear and shiny). Note that different dressings under the NPWT are used in areas determined to be appropriate for the properties of that specific dressing. CSS was used for its antimicrobial effect and HA for the neo-angiogenic effect.

Figure 2 Open abdomen note increasing gutters in bilateral lower quadrants and thickening of fascia and peri-wound margins with increased necrotic tissue and decreased healthy granulation. NPWT in place from 4/15/2015 to 4/25/2015 at 75 mm Hg–125 mm Hg. NPWT discontinued on 4/25/2015.

After approximately 17 days of combination therapy (NPWT plus HA and CSS), MM was closed after 17 days using a split-thickness-skin-graft over a good granulation base with no additional complications and no readmission.

Method

The chitosan Ag+1 (CSS) dressing which as described above is anti-microbial, wicks vertically, is hemostatic and

by charge association traps bacteria and fungi. CSS is positively charged both by nature of the CS fiber and silver Ag+1. Most bacteria and fungi are negatively charged on the cellular surface. CSS does not disrupt the effect of NPWT and was found to collocate the wound exudate associated with bioburden. [Fig. 3](#) illustrates the appearance of CSS after 48 h under NPWT; the CSS maintains its shape and appears as the yellowish-looking squares/rectangles lining the peri-wound. CSS was placed under NPWT for approximately 14 days, until 5/14/2015. On 5/14/

Figure 3 Reapplication of NPWT after chitosan in place for 48 h under NPWT at 75 mm Hg. NPWT with chitosan placed on 4/30/2015. Beginning 5/2/2015 chitosan replaced with each NPWT change.

Figure 4 Open abdomen. Note Clear HA in the upper right quadrant, chitosan just inferior to HA and chitosan along upper right quadrant. All are prior to gentle cleansing and reapplication of NPWT. Increased granulation present throughout wound bed, decreased exudate and odor.

2015, with improved granulation present and a noted decrease in wound exudate; both HA and CSS were placed under NPWT in areas appropriate for either the CSS or HA. The HA was perforated to allow for exudate to be removed by the NPWT, the thin silicone membrane is left intact. In [Fig. 4](#), at NPWT take-down, the HA is seen at the superior-left quadrant as clear and shiny. The HA gradually integrates into the surrounding tissue. Once the HA is integrated the superficial silicone layer is removed. An additional layer of HA is placed in areas of increased wound depth as required.

In all instances, NPWT was placed over a primary non-adherent layer, protecting areas that demonstrated healthy granulating tissue, followed by KCI white foam. NPWT setting was 50–75 mm Hg. On 5/19/2015, as illustrated in the photo in [Fig. 5](#); an improved granulation base evidenced by: 1) granulation to surface, 2) decreased presence of bio-burden and 3) integration of Polyglactin 910 mesh was observed at NPWT change. Less than 48 h later, MM was taken to the OR for placement of an STSG as a vehicle for final closure.

Discussion

With the advent of advanced fiber technology and biologics that are compatible with NPWT; the trauma

surgeon and multi-disciplinary team now has additional options for closure in the OAT in a more-timely fashion. This is a single case study that demonstrates these principles and the combination requires additional study.

Figure 5 Open abdomen after NPWT with HA and chitosan for 19 days (NPWT from 5/5/2015 to 5/19/2015) NPWT pressure at 50–75 mm Hg. No chitosan in field. HA has been fully incorporated. Allevyn thin is surrounding peri-wound to protect from maceration. STSG performed on 05/20/2015.

References

1. Johnston M, Safcsak K, Cheatham ML, Smith CP: Management of the open abdomen in obese trauma patients. *Am Surg.* 2015;81(11):1134–1137.
2. Open Abdomen Advisory P, Campbell A, Chang M, et al: Management of the open abdomen: from initial operation to definitive closure. *Am Surg.* 2009;75(11 suppl):S1–S22.
3. Boele van Hensbroek P, Wind J, Dijkgraaf MG, Busch OR, Goslings JC: Temporary closure of the open abdomen: a systematic review on delayed primary fascial closure in patients with an open abdomen. *World J Surg.* 2009;33(2):199–207.
4. Perathoner A, Margreiter R, Kafka-Ritsch R: Surgical treatment of the open abdomen in patients with abdominal sepsis using the vacuum assisted closure system. *World J Surg.* 2009;33(6):1332–1333. author reply 1334.
5. Sharrock AE, Barker T, Yuen HM, Rickard R, Tai N: Management and closure of the open abdomen after damage control laparotomy for trauma. A systematic review and meta-analysis. *Injury.* 2015;47(2):296–306.
6. Burlew CC, Moore EE, Cuschieri J, et al: Sew it up! A Western Trauma Association multi-institutional study of enteric injury management in the postinjury open abdomen. *J Trauma.* 2011;70(2):273–277.
7. Diaz JJ Jr., Cullinane DC, Dutton WD, et al: The management of the open abdomen in trauma and emergency general surgery: part I-damage control. *J Trauma.* 2010;68(6):1425–1438.
8. Diaz JJ Jr., Cullinane DC, Khwaja KA, et al: Eastern Association for the Surgery of Trauma: management of the open abdomen, part III-review of abdominal wall reconstruction. *J Trauma Acute Care Surg.* 2013;75(3):376–386.
9. Diaz JJ Jr., Dutton WD, Ott MM, et al: Eastern Association for the Surgery of Trauma: a review of the management of the open abdomen—part 2 “Management of the open abdomen”. *J Trauma.* 2011;71(2):502–512.
10. Piazza RC, Armstrong SD, Vanderkolk W, Eriksson EA, Ringler SL: A modified “fistula-VAC” technique: management of multiple enterocutaneous fistulas in the open abdomen. *Plast Reconstr Surg.* 2009;124(6):453e–455e.
11. Arnold PB, Green CW, Foresman PA, Rodeheaver GT: Evaluation of resorbable barriers for preventing surgical adhesions. *Fertil Steril.* 2000;73(1):157–161.
12. Harkins AL, Duri S, Kloth LC, Tran CD: Chitosan-cellulose composite for wound dressing material. Part 2. Antimicrobial activity, blood absorption ability, and biocompatibility. *J Biomed Mater Res B Appl Biomater.* 2014;102(6):1199–1206.
13. Archana D, Singh BK, Dutta J, Dutta PK: Chitosan-PVP-nano silver oxide wound dressing: in vitro and in vivo evaluation. *Int J Biol Macromol.* 2015;73:49–57.
14. Asthana S, Goyal P, Dhar R, et al: Evaluation extracellular matrix-chitosan composite films for wound healing application. *J Mater Sci Mater Med.* 2015;26(8):220.
15. Aubert-Viard F, Martin A, Chai F, et al: Chitosan finishing nonwoven textiles loaded with silver and iodide for antibacterial wound dressing applications. *Biomed Mater.* 2015;10(1):015023.
16. Jayanth ST, Pulimood A, Abraham D, Rajaram A, Paul MJ, Nair A: A randomized controlled experimental study comparing chitosan coated polypropylene mesh and Proceed mesh for abdominal wall defect closure. *Ann Med Surg (Lond).* 2015;4(4):388–394.
17. Chen WY, Abatangelo G: Functions of hyaluronan in wound repair. *Wound Repair Regen.* 1999;7(2):79–89.