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Comparison of open abdomens in non-trauma and trauma patients: A retrospective study

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ABSTRACT

Introduction: *Open abdomen (OA) spans an entire spectrum of traumatic and non-traumatic indications. We hypothesize that uniformly managed OA patients have favorable outcomes regardless of the initial traumatic or non-traumatic etiology.*

Methods: *This is a retrospective review of OA patients from 2001 to 2006. A comparison was carried out between NTP and trauma OA patients, examining patient demographics, physiologic parameters, resource utilization, and outcome measures.*

Results: *There were 60 OA patients [35 non-trauma (NTP), 25 trauma (TP)]. NTP were significantly older than TP (60.9 vs 38.3 years). The initial mean pH, SAPS II score, predicted and observed 28-day mortality were similar for both groups. The initial base deficit was 5.53 in NTP and 10.4 in TP (P = 0.0191). Lactic acid levels were 3.54 in NTP and 5.57 in TP (P = 0.0326). Time to abdominal closure was 18.2 days for TP and 20.7 days for NTP. NTP had longer mean ICU stays (11.6 vs 8.5 days, P = 0.0438). NTP had more abscesses (20.0% vs 8.00%), fistulae (17.1% vs 8.00%), and enteric leaks (11.4% vs 4.00%) than TP. The average number of procedures per patient was 5.81 for NTP and 6.24 for TP (mean 4.34 days between procedures for NTP and 2.38 days for TP).*

Conclusions: *TP and NTP undergoing OA showed many similarities. Outcomes for OA patients were similar regardless of the initial diagnosis. A trend was observed toward more postoperative complications in the NTP and greater initial physiologic derangement in TP. NTP had longer mean ICU stays. The mortality for both groups was half of that predicted by SAPS II score, likely due to the physiologic benefits of OA.*

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INTRODUCTION

The concept of open abdomen (OA) has evolved markedly since its inception.[1-3] It now spans an entire spectrum of traumatic and non-traumatic indications.[4-7] Open abdomen is a temporizing measure, and is closely related to the damage control (DC) approach, which initially provided trauma surgeons with the ability to break the lethal triad of acidosis, coagulopathy, and hypothermia in critically injured patients. The three components of the lethal triad synergistically lead to a myriad of physiologic derangements and eventually, death.[3, 4]

The DC/OA approach serves as a bridge to restoring the patient to a more normal physiologic state, with subsequent delayed abdominal closure.[3, 5] The DC/OA approach can be applied to critically ill non-trauma surgical patients (NTP) with abdominal sepsis, intra-abdominal and retroperitoneal hemorrhage, severe pancreatitis, and other conditions that produce intra-abdominal hypertension and abdominal compartment syndrome (ACS).[4-5, 8]

The purpose of this study is to compare the utilization and results of DC/OA for TP and NTP at a level I community-based trauma center. We hypothesize that although the indications and the underlying conditions may differ, the physiology and outcomes of patients undergoing DC/OA are similar. We further postulate that a uniform approach to managing these patients helps attain good outcomes. Although both technical and physiologic aspects of open abdominal management are discussed, the authors will focus on the physiologic aspect of damage control surgery.

METHODS AND MATERIALS

All patients with open abdomens (OA) at our institution from September 2001 to January 2006 were included. Recorded data included demographics (age and gender), primary diagnoses at the time of the initial damage control laparotomy, surgical techniques and types of closure, complications, and 28-day mortality. Many of the definitions used in this study follow the previously published standards and recommendations, according to the World Society of the Abdominal Compartment Syndrome (WSACS), and can be accessed online at ***http://www.wsacs.org/***. [9]

Complications recorded included enterocutaneous fistula, abscess, enteric leak, decubitus ulceration, clostridium difficile colitis, pneumonia (as abstracted from medical record), and deep venous thrombosis (DVT). Physiologic parameters included initial pH, base deficit, lactic acid and albumin level. Coagulopathy was represented by international normalized ratio (INR) measurements. Outcome measures included 28-day complications and mortality. Predicted mortality for the study group was calculated using the Simplified Acute Physiology Score (SAPS II) recorded at the time of the index emergency (DC) exploratory laparotomy.[10] A distinction was also made with regards to the index emergency (DC) surgery being the 'initial' versus 'subsequent' laparotomy. SAPS II was utilized due to its applicability to both traumatic and non-traumatic etiologies.

Resource utilization measurements included hospital length of stay (LOS) starting at the point of initiation of the DC/OA approach to patient death or discharge, intensive care unit (ICU) LOS, time to abdominal closure, type of nutritional supplementation utilized (parenteral and/or enteral), requirement for tracheostomy, abdominal procedures per patient until

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abdominal closure, average number of days between procedures (between the initial operation and abdominal closure), as well as the number of procedures per patient per LOS (the number of days in hospital divided by the number of procedures per patient). Patients who did not survive beyond the initial 24 hour period were ***excluded*** from analysis of the following variables: time to abdominal closure, mean and median length of stay (LOS), mean intensive care unit (ICU) LOS, procedures per patient, average days between procedures, procedures per patient per LOS, requirement for tracheostomy, type of nutritional support, and all of the above listed non-mortality complications.

All patients were managed by a team of 5 critical care-trained emergency-trauma surgeons, according to a modification of previously published treatment algorithm for open abdomen patients (**Figure 1**).[4] Initially, all patients had a vacuum assisted fascial closure (VAFC) applied. Two VAFC techniques employed (based on surgeon preference) included: (a) polyethylene covered surgical towel with suction drains layered above the towel and covered with an impervious adhesive drape or (b) a commercially prepared sponge device (V.A.C., KCI International, San Antonio, Texas). Utilization of vicryl mesh was based on the presence or absence of omental coverage over the underlying bowel. If ample omentum was present and no bowel was exposed, then vicryl mesh was not used. However, if partial coverage of exposed bowel was needed, then vicryl mesh was utilized.

All patients underwent re-exploration within 6-48 hours depending on clinical stability and indications for the initial laparotomy. When possible, a tension-free primary fascial closure was performed at that time. Abdominal closure performed within 24 hours of the initial surgery was termed early delayed primary closure (DPC). If patients continued to manifest clinical characteristics that obviated abdominal closure (e.g. continued bleeding, bowel or retroperitoneal edema, gross contamination) then VAFC was continued. Primary fascial closure utilizing VAFC more than 24 hours after the initial laparotomy was termed DPC with VAFC.

Patients with prolonged VAFC (greater than 7 days) were re-evaluated after definitive operative and physiologic restoration was complete. When possible, DPC with VAFC was performed at that time. If the patient had lost abdominal domain, one of two management options was considered. Patients with gross contamination at any time during the resuscitation were managed as planned ventral hernias (PVH). These patients had a split thickness skin graft (STSG) placed over the OA wound when a healthy, clean granulation bed formed (**Figure 2B, I-V,** page 7). An abdominal wall reconstructive procedure would be performed on these patients at a later time.

Patients without gross contamination had a velcro Wittmann Patch (WP) sewn to their fascia. The patch consists of two large sheets of velcro-type material, which are attached to the visible fascial edges with permanent sutures. The bottom (deep) sheet overlying the bowel has a smooth surface that faces abdominal contents and a rough external surface that attaches to the rough adhesive surface of the top sheet. The top (superficial) sheet is never allowed to come in direct contact with the bowel as this could potentially generate an enteric fistula. Consequently, the bottom sheet is left wide enough that it completely underlies the top sheet. The patch is then advanced daily (typically, 1 to 2 cm at a time) until fascial edges are closed primarily (**Figure 2A, I-IV,** page 7). Both the top and the bottom sheet of the WP are trimmed to an appropriate width during each advancement procedure, maintaining complete coverage of the abdominal contents with the smooth surface of the bottom sheet. After patch advancement, the patient is observed for signs of intra-abdominal hypertension (high peak airway pressures, oliguria, decreased cardiac output).

Patients who failed WP fascial closure were treated as PVH. These patients underwent either split thickness skin graft (STSG) coverage over granulated bowel and/or omental surfaces, or skin flap closure (SFC) over a bioprosthetic fascial repair (Alloderm™, LifeCell Corp, Branchburg, NJ, USA or Permacol™, Tissue Science Laboratories, Covington, GA, USA) and STSG coverage of the resulting lateral abdominal skin relaxing incision (**Figure 2C, I-V,** page 7).[11] In some instances, the WP allowed significant reduction of the fascial defect, thus reducing the size of the ventral hernia and the amount of bioprosthetic material used for closure. Although rectus muscle release procedures were not utilized in this study, they remain a very good and viable option for abdominal wall reconstruction following open abdomen.

Analytical methods included descriptive statistics, chi-square and Student's t-test statistics. Statistical significance was set at alpha = 0.05. In addition, an updated open abdomen management algorithm was created to reflect the addition of SFC and rectus muscle release procedures to the previously published algorithm.[4]

RESULTS

A total of 60 patients underwent open abdomen (OA) from 2001 to 2006. Thirty-five of those were non-trauma patients (NTP) and 25 were trauma patients (TP). Non-trauma patients were significantly older than TP (60.9 vs 38.3 years). There were 17 men and 18 women in the NTP group, and 17 men and 8 women in the TP group (**Table 1**).

Looking at whether the DC/OA approach was initiated during the 'initial' or 'subsequent' operation, significantly higher proportion of NTP required DC/OA management during 'subsequent' operation (14/35) than did TP (2/25, P = 0.0073). The most common diagnoses on initial presentation among NTP were perforated viscus (13/35) and abdominal compartment syndrome following major abdominal operation (6/35). Among TP, the most common diagnoses were severe splenic (8/25) and liver injury (5/25) alone or in combination (**Table 2**).

Trauma patients demonstrated more severe acute physiologic derangement than NTP (**Table 1**), as demonstrated by greater initial base deficit (10.4 vs 5.53, P = 0.0191) and higher initial lactic acid levels (5.57 vs 3.54, P = 0.0326). There were no significant differences in initial pH and SAPS II scores. Albumin levels were lower in TP than NTP (1.84 vs 2.37, P = 0.0382). The international normalized ratio (INR) was elevated regardless of

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the initial presentation, with a mean value of 1.72 ± 1.08 and no statistically significant difference between TP and NTP.

The predicted mortality, as determined by SAPS II scores, was 39.8% for NTP and 49.0% for TP (P = 0.1626). The observed 28-day mortality was 17.1% for NTP and 32.0% for TP (P = 0.2232) when all patients in both groups are considered. When patients who died within 24 hours of admission were excluded, the mortality was 9.38% for NTP and 22.7% for TP (P = 0.2855). This reflects a trend toward greater mortality in TP as compared to NTP (**Table 1**). When stratified by SAPS II score, NTP with scores ≥20 had significantly higher mortality than those with scores <20 (6/20 or 30% vs 0/15 or 0%, P = 0.0311). This difference was not observed in TP. Considering both groups (TP and NTP), patients with initial lactate level ≥4 mmol/L had significantly higher mortality (12/34 or 35.3%) than those with initial lactate levels <4 mmol/L (2/26 or 7.70%, P = 0.0147).

In terms of nutritional support, patients in both groups received enteral nutrition or a combination of parenteral and enteral nutrition. A minority of patients in each group received parenteral nutrition only (18.8% in NTP and 9.10% in TP group), many of whom either did not survive long enough to transition to enteral nutrition or were maintained on long-term parenteral nutrition secondary to presence of a fistula.

Non-trauma patients were more likely to have postoperative complications, as demonstrated by more abscesses (21.9% vs 9.09%), fistulae (18.8% vs 9.09%), and enteric leaks (12.5% vs 4.54%). Pneumonia complicated clinical course in 21.9% of NTP and 18.1% of TP. Deep venous thrombosis (DVT) was very common in both NTP (25.0%) and TP (40.9%) groups, despite an aggressive DVT prophylaxis protocol at our institution. Decubitus ulcers complicated the hospital course of 3/32 NTP (9.38%), one of which required a myocutaneous skin flap closure. Overall, both TP and NTP showed a significant predisposition for complications, with at least one of the listed complications in 68.8% of NTP and 54.5% of TP (**Figure 3**).

Twenty-three percent of patients died prior to definitive abdominal closure, with 6 of those patients (10%) dying within the first 24 hours. For patients who survived beyond the first 24 hours, additional 8 patients (14.8%) died prior to definitive abdominal closure. Delayed primary closure (DPC) was attempted whenever possible (22.2%). For patients in whom DPC was not possible, a combination of Wittmann patch (WP)-aided closure (12.9%), split thickness skin grafting (STSG) (37.0%), or skin flap closure (SFC) with bioprosthetic material (12.9%) were utilized. Abdominal closure methods are summarized in **Table 3** (page 8). The mean time to definitive abdominal closure was 20.7 days for NTP and 18.2 days for TP. Although our overall patient sample size was small, we found that patients with skin flap closure utilizing bioprosthetic fascial replacement had their OA closed more than 5 days earlier than the remaining patients (14.7 ± 6.70 vs 20.9 ± 18.3 days, P = 0.3880).

With respect to resource consumption (**Table 1**), there was no statistical difference in hospital length of stay (LOS) between TP and NTP (44.4 days for NTP vs 31.7 days for TP, P = 0.1917). However, the mean intensive care unit (ICU) LOS was significantly greater in the NTP group than in the TP group (11.6 ± 6.11 vs 8.50 ± 3.97, P = 0.0438). In addition, 50% of NTP and over 45% of TP required tracheostomy during their hospitalization. The average number of procedures per patient was 5.81 ± 5.03 for NTP and 6.24 ± 5.08 for TP (P = 0.7873), with an average of 4.34 days between procedures for NTP and 2.38 days between procedures for TP (P = 0.0479). Examination of the number of procedures per patient per LOS in TP and NTP showed a trend toward a greater 'density' of operations in TP, with smaller time intervals between procedures and shorter LOS following definitive abdominal closure.

Table 1. Comparison of demographic, physiologic, and outcome parameters, in non-trauma patients (NTP) and trauma patients (TP).

Category	NTP	TP	p –value
Basic demographics			
Number of patients	35	25	--
Mean age	60.9 ± 15.9	38.3 ± 15.0	0.0001 *
Gender	17M/18F	17M/8F	0.1758 †
Physiologic parameters at the time of index open abdominal case			
	(n = 35)	*(n = 25)*	
Initial pH	7.27 ± 0.20	7.18 ± 0.16	0.0891 †
Initial base deficit	5.53 ± 7.00	10.4 ± 7.34	0.0191 *
Initial lactic acid	3.54 ± 3.36	5.57 ± 2.85	0.0326 *
Initial SAPS	20.6 ± 7.45	24.1 ± 9.82	0.1395 †
Initial albumin	2.37 ± 0.96	1.84 ± 0.51	0.0382 *
Outcome parameters			
Predicted mortality	39.8%	49.0%	0.1626 †
Observed mortality (28-day)			
All patients	6/35 (17.1%)	8/25 (32.0%)	0.2232 †
Pts alive ≥24 hours	3/32 (9.38%) [a]	5/22 (22.7%) [a]	0.2855 †
SAPS <20	0/15 (0%)	2/10 (20.0%)	
SAPS ≥20	6/20 (30.0%)	6/15 (40.0%)	
Time to abdominal closure [a]	20.7 ± 19.0 days (***n=29***)	18.2 ± 13.7 days (***n=17***)	0.6623 †
% with ≥1 complication	22 (68.8%) (***n=32***)	12 (54.5%) (***n=32***)	0.3913 †
Nutritional supplementation [a]			
	(n = 32)	(n = 22)	
Parenteral nutrition only	6 (18.8%)	3 (9.10%)	0.7230 †
Enteral nutrition only	11 (34.4%)	12 (45.5%)	0.1695 †
Combination of both	15 (46.9%)	7 (18.2%)	0.3984 †
Resource utilization [a]			
	(n = 32)	*(n = 22)*	
Mean length of stay (LOS)	44.4 ± 31.0 days	31.7 ± 40.1 days	0.1917 †
Median hospital LOS	43.5 days	20.5 days	
Mean intensive care LOS	11.6 ± 6.11	8.50 ± 3.97	0.0438 *
Procedures per patient	5.81 ± 5.03	6.24 ± 5.08	0.7873 †
Avg days between surgeries	4.34 ± 3.31	2.38 ± 1.64	0.0479 *
Procedures/patient/LOS	12.9 ± 10.4	7.52 ± 4.54	0.0755 †
Required tracheostomy	16/32 (50.0%)	10/22 (45.5%)	0.7874 †

[a] Analysis excludes patients who died within 24 hours of admission

* Denotes statistical significance

† Denotes no statistical significance

DISCUSSION

The open abdominal (OA) technique evolved from the classic trauma damage control (DC) approach as surgeons became more comfortable managing patients requiring delayed abdominal closures. At the heart of the initial management of patients with DC/OA is the prevention of the abdominal compartment syndrome (ACS), which was first noted by Sperling and

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Wagensteen in 1935, and has been recognized by Gross who developed the so-called *Chimney Technique* for gastroschisis.[12,13] The DC/OA approach halts the ACS and the progression of cardio-respiratory and renal dysfunction.[4,14-16] The ACS can affect both trauma patients (TP) and non-trauma patients (NTP), and constitutes an independent risk factor for multiple organ failure.[17-24] Utilization of open abdominal techniques in the setting of intra-abdominal hypertension and ACS has also been described by vascular surgeons back in 1984.[25] Less often, the 'pure' OA approach may be called upon when loss of abdominal domain or other technical or disease factors make abdominal closure impossible, even in the absence of the classic DC indications.

The purpose of this study was to compare the utilization and outcomes of the DC/OA approach in NTP and TP at our institution. We also attempt to define the unifying characteristics of the DC/OA approach in both NTP and TP. The authors believe that although this study's findings are not unexpected, the emergency surgery specialist could potentially benefit from better delineation of the differences between TP and NTP in the setting of open abdomen and damage control.

The classic triggers for initiation of DC in TP include pH less than 7.30, temperature less than 35°C, and coagulopathy (presence of non-mechanical bleeding).[3] In addition to critically ill trauma patients, general surgery patients with abdominal sepsis, intra-abdominal or retroperitoneal hemorrhage, or severe pancreatitis may also meet the criteria for initiating the DC/OA approach, based on the above physiologic parameters or the presence of documented ACS.[3,4] In this series, both the TP and NTP groups showed significant acidosis, with mean pH of 7.26 in NTP and mean pH of 7.17 in TP at the time of the initial operation. Although not directly examined in this study, hypothermia was common, and its presence reflected in SAPS II score calculations. Patients in this study also demonstrated coagulopathy, with INR of approximately 1.7 regardless of the initial diagnosis, and no significant difference between TP and NTP.

The classic trauma DC/OA paradigm consists of a three-phase approach, beginning with an abbreviated laparotomy to control hemorrhage and contamination, followed by resuscitation in an intensive care unit (ICU) setting, and a number of subsequent laparotomies to provide definitive repair of injuries and to further temporize physiologic deficits.[4,7] A definitive abdominal closure then follows, either in an early or a delayed fashion (**Figure 1**).[4,11]

The resuscitation phase serves to optimize hemodynamics, reverse coagulopathy, achieve resuscitation end points, and re-warm the patient. In those patients who survive the resuscitation phase, the second laparotomy provides the opportunity to perform anatomic restoration(s) and a chance to assess the feasibility of definitive abdominal wall closure. In our series, approximately 5% of patients were able to undergo primary fascial closure at this point. If such delayed primary closure (DPC) is not feasible, the third phase of damage control begins, and continues until successful abdominal closure is achieved. This was the pathway for approximately 70% of patients in this study. Of note, approximately 24% of patients in this series (17.6% NTP and 33.3% TP) died prior to definitive abdominal closure. In a large study of DC/OA patients, Miller *et al*, demonstrated a similar percentage (20%) of patients who did not survive to definitive wound closure.[26]

The NTP group contained more patients, had a greater mean age and was more evenly distributed between men and women than the TP group. This is not surprising, as male predominance among trauma patients is well documented in the literature.[6,27] The mean age of the TP group is in good agreement with other DC/OA studies in trauma population.[26]

In this study, there were no significant differences in SAPS II scores between the NTP and TP groups at the time of initiation of the DC/OA approach. However, we observed significantly greater initial base deficit and lactic acid levels in the TP group. This may be due to the fact that base deficit and lactic acid levels can reflect very acute physiologic changes more accurately than SAPS II, and is consistent with previous reports of severe base deficits in trauma patients undergoing damage control.[27] At the same time, we noted a significantly lower initial albumin level in the TP group, which most likely is a reflection of fluid resuscitation rather than underlying hypoalbuminemia. In this series, initial serum lactate level greater than 4 mmol/L was associated with significant mortality (35.3%). Previous studies demonstrate that lactate levels above 8 mmol/L positively correlate with in-hospital mortality and mortality within 24 hours of admission following abdominal traumatic injury requiring damage control.[28]

Despite no statistically significant differences in mortality between the NTP and TP in this study, we noted a trend toward higher overall mortality in TP. Not surprisingly, patients with SAPS $\geq$20 had higher mortality than those with SAPS <20. Our observed overall mortality of TP (33.3%) was somewhat higher than that in other series, which may be because some of these series excluded patients who did not survive the initial 24 hour period following injury.[4,6-7,26-27,29] It has been noted that mortality varies depending on the etiology of OA, with pancreatitis associated with the highest observed mortality (43%), followed by gastrointestinal sepsis (36%), and trauma (13-27%).[6,7,27] Our experience corroborates the previously observed high mortality in patients with OA due to severe pancreatitis.

Table 2. Presenting diagnoses directly leading to utilization of open abdomen (OA) in this study. More than one diagnosis per patient may be present.

Diagnosis	**# of patients (%)**
Non-trauma patients (n=35)	
Perforated viscus	13 (37.1%)
Postoperative abdominal compartment syndrome	6 (17.1%)
Necrotizing/severe pancreatitis	5 (14.2%)
Bowel ischemia	4 (11.4%)
Massive retroperitoneal hemorrhage	3 (8.57%)
Toxic megacolon	2 (5.71%)
Gastric volvulus with gastric necrosis	1 (2.86%)
Ruptured abdominal aortic aneurysm	1 (2.86%)
Trauma patients (n=25)	
Severe splenic injury	8 (32.0%)
Severe blunt injury to the liver	5 (20.0%)
Massive retroperitoneal/pelvic hematoma	4 (16.0%)
Small bowel or colonic perforation	3 (12.0%)
Penetrating injury to the liver	2 (8.00%)
Inferior vena cava injury	2 (8.00%)
Penetrating pancreatic and duodenal injuries	1 (4.00%)

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Similar to our OA experience, Finlay noted a reduction in observed patient mortality based on predicted mortality rates between 49.6% and 64.5%.[5] The lower observed 28-day mortality in our study (17.1% for NTP and 32.0% for TP), as compared to the predicted mortality (39.8% for NTP and 49.0% for TP), may be due to several factors. Although the data in this study is not sufficient to demonstrate clear mortality advantage, one can speculate that perhaps the greatest contributing factor is the utilization of the DC/OA approach, and its physiologic benefits in the face of the ACS.[4,20] Another factor likely responsible for the improved outcomes is the uniform approach to critically ill TP and NTP by a specialized team of trauma and surgical critical care practitioners. Thirdly, goal-directed resuscitation and modern end-organ supportive measures may play a significant role in this setting.

In terms of resource utilization, we noted that NTP demonstrated a trend toward greater hospital length of stay (LOS). Furthermore, NTP had significantly longer ICU length of stay than TP (an approximate 3 day difference). NTP underwent relatively fewer operative interventions per patient per LOS (number of days in hospital divided by the number of procedures per patient, where a larger number indicates greater interval between procedures and/or a greater length of stay following the definitive abdominal closure). In fact, NTP did have a significantly greater average number of days between subsequent procedures. At the same time, the TP group had a greater number of procedures per patient. Nearly half of all patients in this study required a tracheostomy, with no significant difference between the TP and NTP groups. Others report a number of operations per patient that is similar to that in our study, with anywhere between 2.5 and 5.2 operations per patient, depending on the type of closure utilized.[26]

Although not measured in this study, the significant requirement for continued medical and surgical services among DC/OA patients continues well after hospital discharge. In fact, in one study 14% of DC/OA patients required at least one readmission to hospital, with diagnoses including small bowel obstruction, ventral hernia, intra-abdominal abscess, and wound infection.[26] Moreover, mean hospital charges resulting from hospitalization for DC/OA vary from $130,000 to over $300,000 and depend on the type and timing of abdominal closure.[26]

In this series, complications were common in both groups of patients. In fact, over 68% of NTP had at least one complication, as compared to approximately 54% of TP. While DVT was more frequent in the TP group, all of the other complications studied tended to be more frequent in the NTP group (enterocutaneous fistula, abscess, enteric leak, decubitus ulceration, pneumonia, clostridium difficile colitis). This is despite the higher mean albumin level in NTP, as well as significantly greater base deficit and lactic acid level in TP at the time of the initial DC/OA operation. Multiple factors could be responsible for this phenomenon, including differences in patient age, differences in type and quantity of resuscitative fluids given, amount of physiologic reserve, preoperative level of functioning, presence of chronic health conditions, and presence of malignancy. In other studies, the most common DC/OA complications included enterocutaneous fistulae (8.6%-16.9%) and abscess formation (7%-17.1%).[6,7] Also, while others report enterocutaneous fistula rates similar to ours, the incidence of abscesses among NTP in our series (20%) is higher than previously reported.[6-7,26] Miller *et al*, demonstrated that early definitive closure of the DC/OA is associated with significantly lower fistula formation rate (3%) when compared to temporizing abdominal coverage (30%).[26] In addition, they noted that complication rate increased from 25% to 40% when abdominal packs were left in place for more than four days.[26] The authors of this study also observed a higher overall rate of enteric leaks (8.3%) than reported by others (2.9%).[6] The high rate of DVT in this study corroborates previous observations that the risk of DVT increases significantly with increasing magnitude of physiologic derangement and injury severity.[30]

Tsuei *et al*, investigated the management and outcome of the DC/OA approach in patients with gastrointestinal sepsis, pancreatitis, and trauma, demonstrating that DC/OA management could be effectively applied across the different patient populations.[7] Similar to Tsuei, we also noted that types of closure and mortality appear to be related to the underlying etiology.[7] Although not statistically significant, we did observe a trend toward higher initial mortality in TP. We also noted different patterns of abdominal closure techniques used between TP and NTP, including more common use of the WP closure in TP, more frequent utilization of vicryl mesh ± STSG technique in NTP, and tendency to use skin flap closure in NTP. Our findings are similar to those of Tsuei *et al*, in that patients with gastrointestinal sepsis were more likely to require STSG ± vicryl mesh closure while trauma patients were more likely to have primary or assisted fascial closure.[7] In this series, the average time to abdominal closure was similar for TP and NTP (18 vs 21 days, respectively).

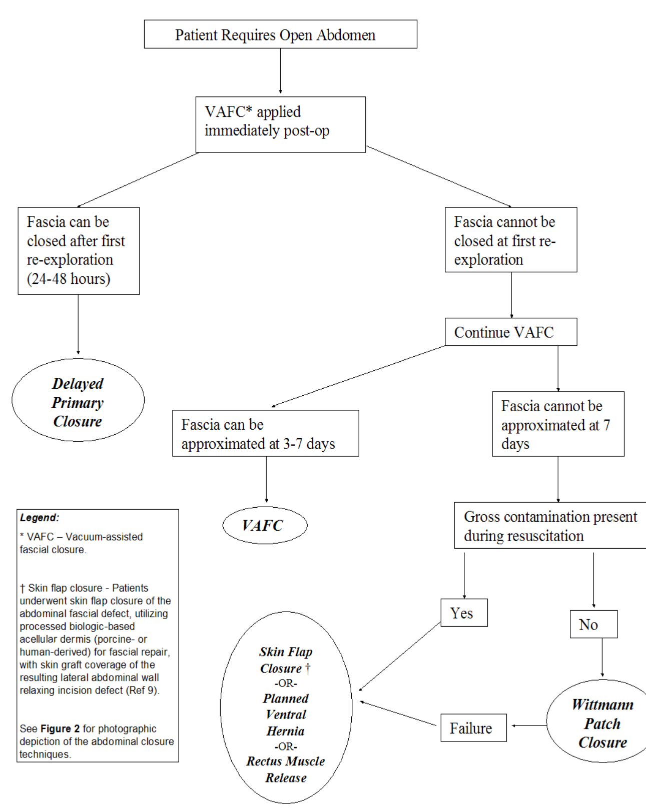

Figure 1. Proposed algorithm for management of open abdomens.

Submitted 09/2006 – Accepted 05/2007 – Published 09/2007

The overall distribution of TP and NTP in this study is consistent with other previously published reports.[5,7] While our series included five patients (8.3%) with severe pancreatitis as the etiology of the abdominal compartment syndrome, such low number of patients precludes any meaningful comparisons utilizing pancreatitis patients as a distinct subgroup. Including our series, severe pancreatitis was the least frequent of diagnoses leading to DC/OA, with approximately 6%-31% incidence in major published series.[5,7] Others reported that patients with OA due to pancreatitis had more operations per patient and were more likely to have no formal abdominal closure and highest mortality.[7]

Throughout our experience with DC/OA, we noted several techniques useful in expediting abdominal closure and in reducing the size of the resultant fascial defect. In one scenario, the Wittmann patch can be utilized to minimize the size of the fascial defect, and thus to reduce the amount of bioprosthetic material utilized prior to definitive closure of the defect and coverage with a skin flap, even if primary fascial closure itself is not feasible. In another scenario, gradual closure of the inferior and superior abdominal fasciae and skin, allow for significant reduction of the fascial and skin defects and facilitate delayed primary closure or allow significant reduction in the use of bioprosthetic material and subsequent reduction in skin flap mobilization requirement.

Of interest, although not statistically significant, we found that among patients who survived to have their abdomens closed, those with skin flap closure utilizing bioprosthetic fascial replacement had their OA closed over 5 days earlier than patients undergoing other types of abdominal closure (14.7 vs 20.9 days). As our experience with the skin flap closure grows, we expect this difference to become more significant, especially in terms of resource consumption. Other avenues of bioprosthetic material application in DC/OA patients include the possibility of alternative coverage of enteric fistulae.

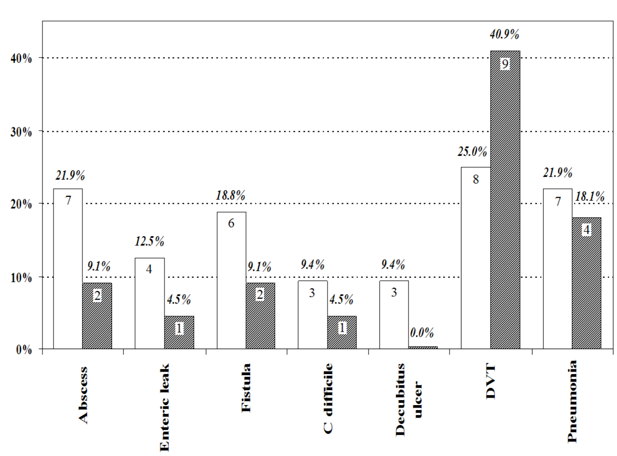

Figure 3. Complications observed in non-trauma patients (non-shaded bars) and trauma patients (shaded bars) in this study. The complications are listed on the x-axis and the percentage of patients with each complication is reflected on the y-axis. The numbers inside each bar indicate the actual number of patients within each group.

This study demonstrates the physiologic similarity between the critically ill TP and NTP with DC/OA, and supports the theory that outcomes for DC/OA patients can be better than predicted across a broad spectrum of traumatic and non-traumatic diagnoses. We speculate that this may be due to a uniform approach to these patients utilizing a dedicated team of trauma, emergency and critical care surgeons.[31]

Limitations of this study include its retrospective nature and lack of detail regarding patient resuscitation techniques (volumes, resuscitation solutions used, blood transfusions, etc). The relatively small patient sample size limits the statistical power of observations in this study. The authors also recognize the shortcomings of utilizing the SAPS II score in the setting of this study, especially when applied to trauma patient population.

The authors of this study did not perform rectus muscle release procedures, which constitute a viable option for closing OA defects. However, rectus muscle release procedure was included as an option in our proposed algorithm for abdominal closure (**Figure 1**). While outcome-based study comparing the different abdominal wall reconstructive techniques would significantly add to the current manuscript, such information is not available. Also, we recognize that the lack of long-term wound complication information (incisional hernias, mesh infections, etc.) represents a significant limitation of this study. Finally, it is difficult to assess how the gradual change and modifications in abdominal closure modalities over the study period affected patient outcomes.

CONCLUSIONS

Trauma patients and non-trauma patients undergoing DC/OA approach were similar in overall outcomes. A trend was observed toward more postoperative complications in the NTP and greater magnitude of initial physiologic derangement in TP. The actual mortality for both groups was half of that predicted by SAPS II score, at least in part due to the beneficial physiologic effects of the DC/OA approach. Both TP and NTP groups demonstrated higher mortality with initial SAPS ≥20 and lactic acid level ≥4 mmol/L. Even though the hospital length of stay was not statistically different between the two groups, a trend toward longer LOS was noted in NTP. In addition, NTP had significantly longer ICU LOS. While the two groups differed in terms of types of abdominal closure utilized and the average number of days between subsequent procedures, they were similar in terms of the number of procedures per patient and tracheostomy requirement.

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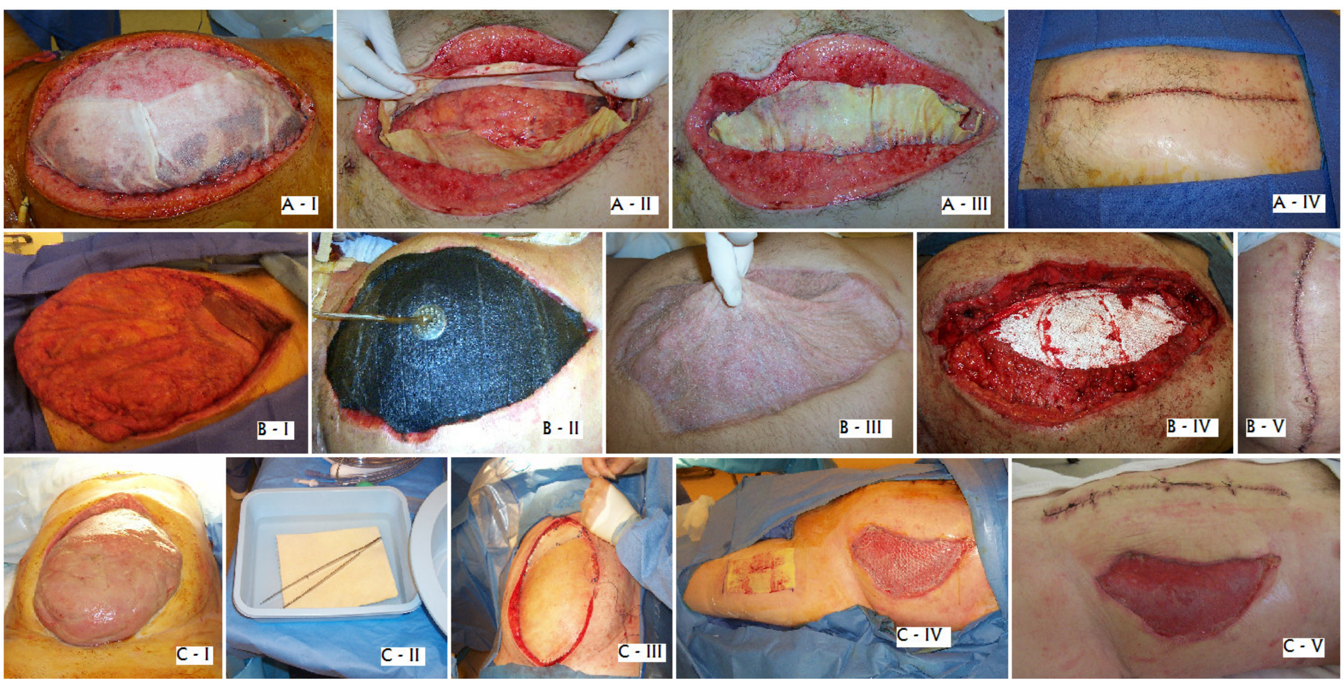

Figure 2. Images depicting three different methods of abdominal closure in the setting of damage control/open abdomen. (A, I-IV) Wittmann patch closure, with initially wide open abdominal defect (A-I) gradually narrowed to a much smaller size (A-II and A-III), followed by definitive fascial closure (A-IV); (B, I-V) Split thickness skin graft (STSG) closure with planned ventral hernia, beginning with application of VAC therapy over the wound (B-I and B-II), followed by skin grafting and maturation of the skin graft ('pinch sign', B-III), with synthetic mesh closure of the resulting planned ventral hernia (B-IV) and definitive skin closure (B-V); (C, I-V) Skin flap closure utilizing bioprosthetic material and lateral releasing skin flap, where exposed bowel and omentum (C-I) are covered with bioprosthetic material (C-II and C-III), followed by creation of a relaxing lateral incision, which subsequently is covered with STSG from ipsilateral thigh donor site (C-IV). Final result of the skin flap closure approach (C-V).

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Table 3. Comparison of abdominal closure methods between non-trauma patients (NTP) and trauma patients (TP). Bold type numbers indicate the absolute number of patients who underwent a given type of procedure. Numbers in parentheses indicate the percentage of patients in each category out of the total number of patients. Numbers in square brackets indicate the percentage of patients in each category after patients who died within the first 24 hours were excluded.

Closure method	NTP	TP	Total
Not able to be closed			
A. Died within the initial 24 hours	3 (8.57%) [N/A]	3 (12.0%) [N/A]	6 (10.0%) [N/A]
B. Died after the initial 24 hours	3 (8.57%) [9.38%]	5 (20.0%) [22.7%]	8 (13.3%) [14.8%]
Combined **A + B**	**6 (17.1%)[N/A]**	**8 (32.0%) [N/A]**	**14 (23.3%) [N/A]**
Delayed primary closure			
A. Closure within 24 hours	1 (2.86%) [3.13%]	2 (8.00%) [9.09%]	3 (5.00%) [5.56%]
B. Vacuum-assisted fascial closure ‡	7 (20.0%) [21.9%]	2 (8.00%) [9.09%]	9 (15.0%) [16.7%]
Combined **A + B**	**8 (22.9%) [25.0%]**	**4 (16.0%) [18.2%]**	**12 (20.0%) [22.2%]**
Wittmann patch (WP) closure	**2 (5.71%) [6.25%]**	**5 (20.0%) [22.7%]**	**7 (11.7%) [12.9%]**
Skin flap closure †			
A. Initially planned	4 (11.4%) [12.5%]	--	4 (6.67%) [7.41%]
B. Following WP failure	1 (2.86%) [3.13%]	--	1 (1.67%) [1.85%]
C. Following WP-facilitated reduction of fascial defect	1 (2.86%) [3.13%]	1 (4.00%) [4.55%]	2 (3.33%) [3.70%]
Combined **A + B + C**	**6 (17.1%) [18.8%]**	**1 (4.00%) [4.55%]**	**7 (11.7%) [12.9%]**
*STSG ± Vicryl mesh **			
A. Following Wittmann patch failure	2 (5.71%) [6.25%]	2 (8.00%) [9.09%]	4 (6.67%) [7.41%]
B. Initially planned STSG (PVH) [a]	11 (31.4%) [34.4%]	5 (20.0%) [22.7%]	16 (26.7%) [29.6%]
Combined **A + B**	**13 (37.1%) [40.6%]**	**7 (28.0%)[31.8%]**	**20 (33.3%) [37.0%]**
Total number of patients	**35 [32]**	**25 [22]**	**60 [54]**

* Vicryl mesh was utilized when insufficient omental coverage of the underlying bowel was present. This was followed by split thickness skin grafting (STSG) over the vicryl mesh following adequate tissue granulation.

† Patients underwent skin flap closure of the abdominal fascial defect, utilizing processed biologic-based acellular dermis (porcine- or human-derived) for fascial reconstruction, with STSG coverage of the resulting lateral abdominal wall relaxing incision defect.[9]

[a] PVH = Planned ventral hernia

‡ Vacuum-assisted fascial closure is defined as fascial closure performed more than 24 hours after the initial operation.

