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ORIGINAL SCIENTIFIC REPORT

Trauma Patients with an Open Abdomen Following Damage Control Laparotomy can be Extubated Prior to Abdominal Closure

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Abstract

Background The open abdomen (OA) is commonly utilized as a technique during damage control laparotomy (DCL). We propose that a selected group of these OA patients can be extubated prior to abdominal closure to decrease ventilator days and risk of pneumonia.

Methods A retrospective chart review was performed at a Level I trauma center on all adult trauma patients with an OA following DCL. Patients were stratified into two groups: extubated prior to (PRE) and extubated after (POST) abdominal closure. Successful extubation in the PRE group was measured by the absence of re-intubation. The two groups were compared using the Mann–Whitney U and Fisher's exact tests. Multivariate logistic regression identified independent predictors for successful extubation prior to abdominal closure.

Results Thirty-one patients were in the PRE group, and 59 patients in the POST group. There were no differences between the groups with regard to age, gender, or hours from admission to completion of DCL. The PRE group had a significantly higher incidence of penetrating trauma (77 vs. 53%; $p = 0.02$), a significantly lower number of days from OA to extubation [0.6 (0.2–1.1) vs. 3.4 (2—8) days; $p < 0.001$], and a significant decrease in pneumonia (10 vs. 31%; $p = 0.04$). Two patients in each group required re-intubation [PRE (6%) vs. POST (3%); $p = 0.61$]. In a multivariate binominal logistic regression, penetrating trauma ($p = 0.024$), GCS on admission ($p < 0.0001$), and Injury Severity Score ($p = 0.024$) were identified as independent predictors for successful extubation.

Conclusion Presence of an OA following DCL does not require mechanical ventilation. Extubation of appropriate trauma patients prior to abdominal closure decreases pneumonia and hospital length of stay.

Introduction

The open abdomen (OA) is a common technique following damage control laparotomy (DCL) for a contaminated abdomen or to avoid the development of intra-abdominal hypertension/abdominal compartment syndrome. Typically, especially at low-volume hospitals and in inexperience hands, these patients remain intubated post-operatively until their abdomens are definitely closed, requiring intensive care unit (ICU) admission and management. Data supporting the practice of mandatory intubation for OA patients are limited. Unnecessary intubation places the patient at risk for ventilator-associated pneumonia (VAP) which is reported in 10–20% of patients within 48 h of intubation and affects 8–28% of mechanically ventilated patients [1, 2]. VAP is associated with increased ICU length of stay (LOS), increased cost, morbidity, and mortality [3, 4].

We propose there is a subset of OA patients who can tolerate early extubation prior to closure of their abdomen.

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The consensus definitions and clinical practice guidelines from the Abdominal Compartment Society do not address the timing of extubation in the OA patient [5]. To determine if the OA patient can be extubated prior to abdominal closure resulting in a decreased ventilator days and decreased risk of VAP, we retrospectively reviewed all trauma patients with an OA following DCL at our institution over a 2-year period.

Methods

Institutional review board approval was received to perform a retrospective chart review at a Level I trauma center on all adult trauma patients ($\geq$16 years) from 2014 through 2015 with an OA following DCL. Patients were excluded for admission Glasgow Coma Score (GCS) $\leq$8 with traumatic brain injury, care withdrawn/expired within 72 h of admission, or the OA was not from their primary surgery. The lowest GCS without sedation or paralytics from injury to time of surgery was recorded. Patients were then stratified into two groups: extubated prior to (PRE) and extubated after (POST) abdominal closure. Successful extubation in the PRE group was measured by the absence of re-intubation. Pneumonia was defined as a positive bronchial lavage culture requiring antibiotic treatment [6]. Patients were extubated according to the ventilator weaning guidelines set forth by our institution for extubation readiness. These guidelines include appropriate mental status, adequate oxygenation, appropriate ventilation and work of breathing, hemodynamic stability, and daily spontaneous awakening and breathing trials. All OA were managed with the ABThera™ OA Negative Pressure Dressing (KCI USA, San Antonio, TX, USA) and cared for by the surgical/trauma faculty.

Patient demographics, mechanism of injury, severity of illness scores, OA days, complications (specifically development of pneumonia, re-intubation, and need for tracheostomy), mortality, and economic resource utilization were collected.

Data for patient demographics and outcomes were analyzed using Mann–Whitney U and Fisher's exact tests as appropriate and reported as median with interquartile range (IQR) or percentage. After performing the univariate analysis, all patient demographic characteristics with a p value <0.20 was put in a multivariate binominal logistic regression to identify independent predictors for successful extubation prior to abdominal closure.

To evaluate the validity of our results, we performed a subgroup analysis excluding all patients whose abdomens were closed in less than 48 h (PRE 9, POST 34) to assess the impact it would have on our results. After excluding an additional five patients who developed pneumonia greater than 72 h after extubation (PRE 2, POST 3), 20 patients remained in the PRE group and 22 in the POST group.

Results

During the 2-year study period, 113 adult trauma patients required an OA following DCL. Twenty-three patients were excluded for GCS $\leq$ 8 with traumatic brain injury (10%), expired/care withdrawn within 72 h (5%) or the OA was not from primary surgery (4%). The remaining 90 patients were stratified into the two predefined groups: 31 patients in the PRE group and 59 patients in the POST group.

There was no difference between the groups with regard to age, gender, Abbreviated Injury Score (AIS)-abdomen or mortality. Both groups consisted predominately of men and penetrating trauma (gunshots and knife wounds). However, when the incidence of penetrating trauma was compared between the groups, the PRE group had a significantly higher incidence than the POST group. The POST group had a significantly lower admission GCS, higher Injury Severity Score (ISS) and AIS-chest than the PRE group (Table 1). All patients in both groups underwent initial definitive fascial closure; none of these patients received staged laparotomy or required a split-thickness skin graft to their viscera.

In the multivariate binominal logistic regression, penetrating trauma ($p = 0.043$), admission GCS ($p < 0.001$) and ISS ($p = 0.024$) were identified as significant independent predictors of successful extubation prior to abdominal closure (Table 2).

Table 3 shows there was no difference between the groups in time from admission to the emergency room to completion of DCL with OA or OA days. Patients in the PRE group who remained intubated post-operatively were extubated in a significantly shorter period of time than the

Table 1 Patient demographics

	PRE group	POST group	p value
Patients (n)	31	59	
Age (years)	29 (23–44)	32 (23–49)	0.66
Lowest admission GCS	11 (10–15)	10 (9–10)	<0.001
ISS	14 (9–18)	22 (16–26)	<0.001
AIS-chest	0 (0–2)	2 (0–3)	0.01
AIS-abdomen	3 (3–4)	4 (2–4)	0.59
Penetrating trauma	77%	53%	0.02

Data reported as median with (interquartile range) or percentage

GCS Glasgow Coma Score, *ISS* Injury Severity Score, *AIS* Abbreviated Injury Score

Table 2 Multivariate binominal logistic regression: predictors associated with successful extubation prior to abdominal closure

Predictor	Coefficient	*p* value	Odds ratio	95% confidence interval
Admission GCS	−0.655970	<0.0001	0.52	0.37–0.73
Penetrating trauma	−0.33350	0.043	0.26	0.07–0.96
ISS	0.104170	0.024	1.11	1.01–1.21

GCS Glasgow Coma Score, *ISS* Injury Severity Score

Table 3 Outcome

	PRE group	POST group	*p* value
Patients (*n*)	31	59	
Admission to completion of DCL (hours)	2.6 (2–4)	2.3 (2–4)	0.10
Days from OA to extubation	0.6 (0–1.1)	3.4 (2–8)	<0.001
OA days	2.3 (2–3)	1.8 (2–4)	0.12
Pneumonia	3 (10%)	18 (31%)	0.04
Re-intubation	2 (6%)	2 (3%)	0.61
Tracheostomy	2 (6%)	16 (27%)	0.02
Reopening of abdomen	2 (6%)	3 (5%)	1.0
Mortality	1 (3%)	2 (3%)	1.0

Data reported as median (interquartile range) or total count (percentage)

DCL damage control laparotomy, *OA* open abdomen

POST group. There was no difference in the incidence of re-intubation or reopening of the abdominal wound following closure between the two groups. In the PRE group, two patients required re-intubation before abdominal closure: one for pneumonia and the other for hypoxia. In the POST group, two patients were extubated immediately after abdominal closure but required re-intubation for pneumonia. Both of these patients had an AIS-abdomen and AIS-chest of 3.

Two patients in the PRE group required reopening of the abdomen: one for sepsis and the other for an infected and necrotic wound. Three patients in the POST group required reopening of their abdomens due to complications at the colo-anastomosis site.

The PRE group had a significantly lower rate of pneumonia than the POST group. One patient in the PRE group was extubated while their abdomen was open, but required re-intubation 2 days later for pneumonia. This patient eventually required a tracheostomy. Two PRE patients developed pneumonia 7–9 days after extubation and 5–6 days after abdominal closure. The 18 patients in the POST group who developed pneumonia did so prior to extubation and abdominal closure. The pneumonia-causing pathogens for both groups are listed in Table 4. PRE group patients were significantly less likely to require tracheostomy than POST group patients (6 vs. 27%; $p = 0.023$).

As expected, given the higher pneumonia rate, the POST group's hospital and ICU LOS, and hospital charges were significantly higher (Table 5).

Table 4 Pulmonary bacterial pathogens present in both groups

	PRE group	POST group
	n	*n*
Pathogen (total *n*)	3	18
Acinetobacter baumannii		3
Acinetobacter Iwoffii		1
Candida albicans	1	
Escherichia coli	1	1
Enterobacter aerogenes		1
Enterobacter cloacae		1
Haemophilus influenza		1
Klebsiella pneumonia		2
Pseudomonas aeruginosa		3
Serratia marcescens	1	2
Staphylococcus aureus		3

Table 5 Resource utilization

	PRE group	POST group	*p* value
Patients (*n*)	31	59	
ICU LOS (days)	2.4 (1–4)	6.7 (4–13)	<0.001
Hospital LOS (days)	11.4 (7–20)	20.5 (11–34)	0.007
Hospital charges ($1000)	$231 ($168–362)	$398 ($215–732)	0.001

Data reported as median (interquartile range)

ICU intensive care unit, *LOS* length of stay

The results of the subgroup analysis, after removing patients whose abdomen was open for less than 48 h, confirmed our original study findings. There remained a significantly higher incidence of VAP in the POST group (PRE 5% vs. POST 32%; $p = 0.044$). The one patient in the PRE group who developed pneumonia required re-intubation. All patients in the POST group were still intubated when they developed pneumonia.

Discussion

The use of OA techniques following DCL for traumatic injury or the septic abdomen has become a mainstay of operative management over the past two decades. There are numerous physiological and operational reasons to utilize the OA technique following DCL. Leaving a critically ill patient's abdomen open decreases the incidence of potentially life-threatening intra-abdominal hypertension/abdominal compartment syndrome, improves end-organ perfusion, and improves patient survival [7]. The OA, coupled with negative pressure wound therapy, also allows the evacuation of cytokine-rich pro-inflammatory fluid from the patient's abdomen decreasing the incidence of multisystem organ dysfunction and failure. Since 2010, the surgical/trauma faculty at our institution uses only the ABThera™ OA Negative Pressure Dressing (KCI USA, San Antonio, TX, USA) for management of the OA following DCL. Therefore, other temporary closure techniques were not a factor in this study.

OA patients typically remain intubated post-operatively and are transferred to the ICU until their abdomens are closed several days later when their critical illness and visceral distention has improved. This prolonged period of mechanical ventilation, however, places them at increased risk of VAP. Our review of the literature has identified no recommendations on ventilator management of this patient population. To address this unanswered question, we performed a retrospective study to determine which patients can safely be extubated prior to abdominal closure.

In the multivariate binominal logistic regression, we saw several factors that significantly separated the two groups identifying a subset of patients less severely injured that could be extubated immediately after their initial surgery. These patients were more likely to have penetrating trauma, higher admission GCS, and lower ISS. This is in addition to fulfilling the cardiopulmonary criteria of our mechanical ventilation weaning guidelines. We suspect that patients with a higher admission GCS were more awake and alert and able to maintain their airway as well as participate in more adequate pulmonary toilet. Patients with a lower ISS and AIS-chest were less seriously injured and therefore required less treatment before extubation. Injury to the chest specifically, if increased, would worsen the patient's ability to ventilate and would be an impediment to their extubation, so a lower AIS-chest would logically improve a patient's chance of successful extubation.

Our study showed that a patient with an OA does not necessarily require mechanical ventilation simply because their abdomen is open. Patients with penetrating trauma, higher admission GCS, and lower ISS can be safely extubated in the operating room and, if appropriate, managed on a step-down unit rather than an ICU, potentially optimizing resource utilization. Five patients in the PRE group (all with penetrating wounds to the abdomen) were treated in this manner and tolerated extubation in the operating room without complications. Three of these patients went to the trauma step-down unit and the other two to the ICU. All five patients were left open and returned to the operating room in 24–48 h to re-establish intestinal continuity following further resuscitation. They were re-intubated for surgical abdominal closure, but were extubated immediately post-operation. None of these five patients required reintubation for respiratory insufficiency or difficulty with abdominal wound healing following definitive fascial closure.

The pneumonia rate in our study is significantly lower in the PRE group than the POST group. This suggests how an institution can have an impact on its pneumonia rates by changing the mindset regarding OA management. By extubating patients sooner, we saw a decrease in patient ventilator days and VAP rates. Implementation of this change is simple; patients with an OA should be extubated based on the same parameters as patients without an OA.

We recognize this is a retrospective study having all the associated limitations. Choosing the correct GCS to reflect the patient's true neurological status was difficult due to timing of assessment. Not to overestimate the GCS, we choose the lowest GCS without sedation or paralytics from injury to time of surgery. We excluded patients with traumatic head injuries and GCS ≤ 8 knowing these patients are more likely kept intubated for their head injury and to protect the airway.

Another limitation is the difficulty to avoid selection bias in a non-randomized study. The focus of our study was to prove not all trauma patients with an OA following DCL needs to be intubated and receive mechanical ventilation until definitive closure. Therefore, we chose all patients that met our criteria excluding only those that had associated trauma that would obviously prevent early extubation. We evaluated the remaining patients to identify factors that would lead to early extubation.

We found a significant lower pneumonia rate in the PRE group. Diagnosing pneumonia in a ventilated patient may be easier than a non-ventilated patient. We therefore reviewed the charts of all extubated patients thoroughly for radiographic or clinical signs of pneumonia to ensure no diagnosis was overlooked in the first 72 h of extubation.

While our population may be considered small, the OA is not a common occurrence. At our Level 1 trauma institution, which sees over 5000 trauma patients a year, we average 60–70 patients with an OA following DCL per year. We selected this subset of OA patients because they have the most similarities and are managed by one physician group. We made every effort to limit our exclusion criteria to completely describe this population. During a 2-year time period, minus the exclusion criteria, 90 patients is not a small number for a single-institution study given our rate of OA following DCL. Future multicenter studies achieving higher numbers are needed to confirm our findings.

In conclusion, this is the first report in the literature identifying a select group of adult trauma patients with an OA following DCL who can tolerate early extubation prior to definitive closure of the abdomen. Patients with penetrating trauma who are awake, alert, stable, meet mechanical ventilation weaning guidelines, and have a low overall Injury Severity Score with no to minimal thoracic injuries are appropriate candidates for early extubation. Our results, should at least, cause institutions to re-evaluate how they approach patients with an OA following DCL regarding duration of mechanical ventilation.

Author contributions JAS MD contributed in literature search, study design, data collection, data interpretation, writing, and editing. KS, RN, BSN helped in study design, data collection, data analysis, data interpretation, writing, tables, editing, corrections, and submission. MLC, MD, FACS contributed in study design, data interpretation, writing, and editing. JAI, MD, FACS were involved in study design, data interpretation, and editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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