Perioperative Factors Associated With Respiratory Complications Following Open Abdomen Management

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BACKGROUND: Postoperative respiratory complications are often severe and associated with a high risk of mortality in patients who undergo open abdomen (OA) management following emergency damage-control surgery. The causes of postoperative respiratory complications remain unknown. Therefore, we evaluated postoperative factors associated with respiratory complications in nontrauma patients who had undergone OA management using propensity score matching, with a focus on OA-related risk factors. METHODS: This retrospective analysis included subjects who underwent OA management during a 4-y study period. Age, body mass index, and smoking history were selected as covariates. After propensity score matching, we compared postoperative factors (ie, first operative time, duration of OA, initial 3-d fluid balance, length of ICU stay, and in-hospital mortality) in 2 groups of subjects: those who had post-OA respiratory complications (PORCs) and those who did not. RESULTS: 60 subjects (33 men and 27 women) were identified; 38.3% of these subjects had PORCs. After propensity score matching, 18 subjects were matched. The 3-d fluid balance was significantly higher in subjects with PORCs than in those without PORCs (3,513 mL vs 1,087 mL; $P = .03$). CONCLUSIONS: To our knowledge, this is the first study to examine factors associated with respiratory complications following OA in nontrauma subjects. After adjusting for known co-factors associated with postoperative respiratory complications, the 3-d fluid balance was identified as a significant risk factor for PORCs in subjects who had undergone OA. Clinicians should pay attention to the incidence of PORCs in OA subjects with a positive fluid balance after emergency abdominal surgery. *Key words: open abdomen; open abdominal management; postoperative open-abdomen respiratory complication; emergency surgery; respiratory failure; fluid balance.* [Respir Care 2020;65 (11):1663–1667. © 2020 Daedalus Enterprises]

Introduction

Following emergency damage-control surgery, delayed closure of the abdomen may prevent intra-abdominal hypertension and attendant consequences. This technique is known as staged closure and management with an open abdomen (OA). It has become a standard salvage procedure worldwide for intra-abdominal emergency surgery, both in trauma cases and in nontrauma cases.[1,2] Therefore, intensivists should acquire proficiency in this type of management in the perioperative period. This technique is reported to reduce the mortality risk in critically ill patients; however, it is associated with a high morbidity rate (38–73%).[2,3] In nontrauma OA patients, postoperative complications can include surgical site infection, respiratory failure, acute renal failure, and enteroatmospheric fistula.[4,5] Seternes et al[6] reported in their analysis of OA subjects (> 90% nontrauma) that the most common cause of death was respiratory failure (86.4%). Khan et al[7] reported that 21% of nontrauma OA subjects who had undergone early closure experienced respiratory failure. The incidence of enteroatmospheric fistula, which is considered an OA-specific

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complication, was lower, with one report suggesting a rate of 5.7–17.2% in nontrauma subjects who had undergone OA.[8]

Respiratory complications are among the major OA-related adverse outcomes. The precise mechanism is not known. Despite this relatively high rate of respiratory complications in nontrauma patients, there is very limited research that focuses on this topic. There have been reports about postoperative respiratory complications after conventional abdominal surgery. Serejo et al[9] revealed that old age and high body mass index were independently associated with postoperative respiratory complications after emergency abdominal surgery. Other reports have suggested that risk factors associated with the incidence of postoperative respiratory complications are older age, higher body mass index, smoking history, and comorbidities, including COPD and congestive heart failure.[10-13]

Therefore, the aim of this study was to evaluate and detect the unknown factors associated with post-OA respiratory complications (PORCs) in nontrauma subjects who had undergone OA.

QUICK LOOK

Current knowledge

An increasing number of patients are managed with open abdomen (OA) following emergency damage-control surgery. Postoperative respiratory complications in these patients are often severe. Underlying reasons for these complications are unknown, and perioperative factors have not been previously analyzed.

What this paper contributes to our knowledge

We adjusted for known factors associated with postoperative respiratory complications. As a result, 3-d fluid balance was identified as a significant risk factor in the perioperative period. Clinicians should pay attention to the incidence of postoperative respiratory complications in OA patients with a positive fluid balance after emergency abdominal surgery.

Methods

After institutional review board approval was obtained (Sakai City Medical Center, No. 108), patients who had undergone OA at our hospital between August 2015 and August 2019 were enrolled in this study. Informed consent was obtained via an opt-out process on the web site. Exclusion criteria included age < 20 y (patients < 20 y were considered minors), duration of OA < 24 h, death before primary closure, existence of pneumonia before OA, and patients with COPD or congestive heart failure. Medical records were reviewed retrospectively for demographic data and clinical variables, including laboratory findings, operative factors, and PORCs.

The duration of OA was defined as the period from the day of the first operation to the day of fascia closure. All subjects were managed by the acute care surgery team according to our protocol, which has been reported previously.[4] Subjects with OA were extubated after fascial closure. Intravenous fluid resuscitation, targeting dynamic parameters (eg, stroke volume variance, respiratory variation in inferior vena cava diameter), was performed judiciously to prevent the development of acute compartment syndrome and intra-abdominal hypoperfusion.

According to the review by Thompson and Lisco,[13] PORC was confirmed when one of the following occurred: respiratory failure (including a condition requiring tracheotomy), pneumonia, mechanical ventilation > 48 h after primary fascia closure, acute respiratory distress syndrome, or pneumothorax. Postoperative factors included first operative time, duration of OA, initial 3-d fluid balance (from the first operative day), length of ICU stay, and in-hospital mortality. Continuous variables were presented as medians and interquartile ranges, and categorical variables were presented as percentages.

SPSS 24.0 (IBM, Armonk, New York) was used for statistical analysis. One-to-one matching was performed without replacement using a caliper width of 0.2 standard deviations of the logit of the estimated propensity score.[14] Age, body mass index, and smoking history were selected as covariates because they were identified in previous research as independent risk factors for postoperative respiratory complications after laparotomy.[11] After propensity score matching, 2 groups were handled as unpaired independent groups. The Mann-Whitney U test was used to compare continuous data of the 2 groups, whereas categorical data were analyzed using a chi-square or Fisher exact test, as appropriate. A value of $P < .05$ was regarded as statistically significant.

Results

In total, 60 nontrauma subjects who had undergone emergency surgery and were managed with OA at our institution were included (Fig. 1). Subject backgrounds in both groups were closely balanced by the propensity score matching, which resulted in 18 matched pairs (Table 1). In the entire population, 23 subjects (38.3%) experienced PORCs.

There were no significant differences in age, body mass index, or smoking history between the two groups. After propensity score matching, the 3-d fluid balance was significantly higher in the PORC-positive group (3,513 mL vs 1,087 mL; $P = .03$) (Table 2). The PORC-positive group

also stayed significantly more days in the ICU (10.5 d vs 5 d, $P < .001$) (Table 2). Moreover, duration of OA, first operative time, and first operative hemorrhage did not differ significantly between the 2 groups after propensity score matching (Table 2). In-hospital mortality after propensity score matching was 16.7% in the PORC-positive group and 0% in the PORC-negative group, but this difference was not significant.

Discussion

To our knowledge, this is the first article to investigate OA-related factors associated with PORCs after adjusting for co-factors including age, body mass index, and smoking.[10-13] Our results highlight that the 3-d fluid balance is an important risk factor for PORCs in nontrauma patients.

The OA technique has been constantly adapted, and its use has been expanded to include the management of critical nontrauma patients with the development of commercial negative-pressure wound therapy systems. However, assessments for the complications of OA are still insufficient. Generally, emergency abdominal surgery is associated with a high incidence of complications.[15] In a nationwide database study on critically ill abdominal surgical subjects, postoperative respiratory complications were found to occur at a high rate, with 15.3% of critical subjects undergoing emergency abdominal surgery being dependent on the ventilator for > 48 h.[16] In our study, the percentage of subjects on the ventilator for > 48 h after primary closure was 37.5%. Among nontrauma subjects, recent studies have reported that 20–27% of OA subjects experience postoperative respiratory failure.[4,7,17] These data suggest that the OA condition may be associated with the risk of PORCs.

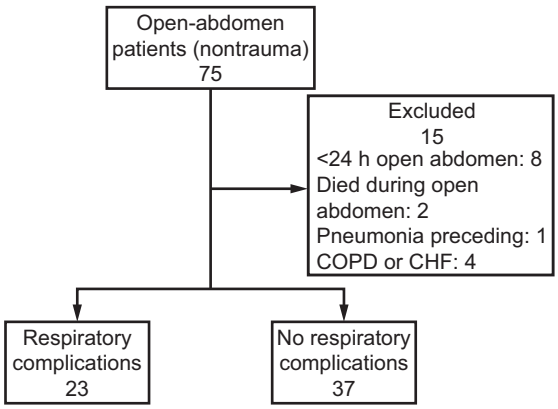

Fig. 1. Flow chart. CHF = congestive heart failure.

Although PORC is a major OA-related complication, the responsible mechanisms are not well understood. Ventilator-associated pneumonia, atelectasis due to high intra-abdominal pressure, and pleural effusion may all contribute to respiratory failure in OA patients. The causes of unplanned intubation and respiratory failure are complex, with multiple adverse effects on the respiratory system.[18] In our study, positive fluid balance was suspected to be a contributory factor to PORCs.

Several studies have reported that a positive fluid balance was associated with an poorer prognosis in specific populations of ICU subjects after high-risk abdominal surgery.[19,20] It has been suggested that a positive fluid balance worsens pulmonary interstitial edema.[21] Furthermore, high intra-abdominal pressure might be a partial clinical expression of the interstitial tissue and organ edema. It elevates diaphragm, leading to atelectasis. Diaphragmatic dysfunction and extravascular lung fluid are associated with impaired

Table 1. Characteristics of 60 Nontrauma Subjects With or Without PORCs Before and After Propensity Score Matching

	Before Propensity Score Matching		After Propensity Score Matching		*P*
	PORC-Positive	PORC-Negative	PORC-Positive	PORC-Negative	
Subjects, *n*	23	37	18	18	
Male	12 (52.2)	21 (56.8)	10 (55.6)	12 (66.7)	.73
Age, y	77 (68–82)	70 (62–76)	73 (65–81)	74 (67–77)	.92
Body mass index, kg/m^2	23.1 (20.6–23.9)	22 (20.6–24.6)	23.1 (21.3–23.5)	22.7 (21.8–25.4)	.83
Smoking history	11 (47.8)	19 (51.4)	10 (55.6)	9 (50)	> .99
Laboratory findings					
Hemoglobin, g/dL	12 (10.6–13.5)	13.1 (10.8–14.7)	12.1 (9.4–13.7)	13.1 (11.3–15.3)	.30
Platelets, $10^4/\mu$L	18.2 (11.8–23.7)	23.5 (15.8–32.7)	19.4 (10.7–30)	24.3 (17.8–28.6)	.16
Albumin, g/dL	2.7 (2.2–3.1)	3.3 (2.5–3.6)	2.5 (2–3)	3.3 (3–3.7)	< .001
C-reactive protein, mg/dL	4.85 (1.43–17.61)	6.51 (1.19–15.32)	8.09 (1.96–18.3)	4.67 (0.56–14.64)	.14
pH	7.35 (7.26–7.4)	7.42 (7.37–7.46)	7.36 (7.3–7.4)	7.42 (7.37–7.46)	.046
Lactate, mmol/L	3.2 (1.7–6.7)	2.85 (1.58–4.12)	3.1 (1.88–5.92)	3.15 (1.52–5.57)	.66

Data are presented as median (interquartile range) or *n* (%).
PORC = post open-abdomen respiratory complication

Table 2. Comparison of OA-Related Factors in Subjects With or Without PORCs After Propensity Score Matching

	PORC-Positive	PORC-Negative	*P*
First operative time, min	66 (51–73)	73 (52–97)	.40
First operative hemorrhage, mg	100 (0–337)	45 (5–676)	.51
Duration of OA, d	2.5 (2–4.75)	2 (1.25–3)	.07
3-d fluid balance, mL	3,513 (2,995–4,303)	1,087 (338–2,051)	.03
Length of ICU stay, d	10.5 (7.25–16.75)	5 (4–7)	<.001
In-hospital mortality	3 (16.7)	0 (0)	.23

Data are presented as median (interquartile range) or *n* (%). PORC-Positive: $n = 18$ subjects; PORC-Negative: $n = 18$ subjects.
OA = open abdomen
PORC = post open-abdomen respiratory complication

pulmonary function. Edema itself might lead to a poorer prognosis through multiple organ failure due to capillary leak related to inflammation and hypoalbuminemia.

In cases where a negative-pressure wound therapy system is used, ascites is drained from the abdominal cavity. This promotes loss of extracellular fluid and albumin and therefore additional fluid administration is required. As a result, fluid overload provokes further hypoalbuminemia and makes fascial closure difficult because of bowel edema and reduced abdominal wall pliability.[3,20]

Some reports indicate a significant association between a longer duration of mechanical ventilation and failure of extubation.[21-23] In addition, repeated sedation to facilitate further observation of the abdominal cavity may lead to excessive sedation. Furthermore, the greater the number of ventilator days, the greater the risk of ventilator-associated pneumonia.[24] In the additional analysis after propensity score matching, the ventilator days were significantly higher in the PORC-positive group (8.5 d vs 4 d, $P < .001$). Because this study design was retrospective, we could not prove causation between PORC and prolonged ventilator days or fluid volume. Based on actual clinical experience, we believe that fluid volume also tended to cause difficulties for fascial closure due to high intra-abdominal pressure. This might extend the duration of OA, which is associated with prolonged intubation and ventilation that may cause PORC. This can also prolong ICU stay. Thus, fluid volume might cause PORC directly or indirectly. Therefore, in OA, clinicians should pay attention not only to the abdomen but also to the respiratory system.

Our study population was small, so further multi-center studies with greater numbers of subjects are needed to confirm our findings. This study was also limited by its dependence on retrospective data. In addition, we excluded a significant portion of our patients because of propensity score matching. Given the inherent limitations of our medical records, we were unable to assess the specific causes of PORCs without a chest computed tomography scan.

Conclusions

After adjusting for already known factors associated with PORCs, 3-d fluid balance was identified as a new significant risk factor for PORCs in subjects who had undergone OA. Therefore, OA strategy must include careful monitoring of fluid balance to minimize the incidence of PORCs, which may improve mortality and morbidity of critically ill patients.

REFERENCES

1. Demetriades D, Salim A. Management of the open abdomen. Surg Clin North Am 2014;94(1):131-153.
2. Coccolini F, Montori G, Ceresoli M, Catena F, Ivatury R, Sugrue M, et al. IROA: International Register of Open Abdomen, preliminary results. World J Emerg Surg 2017;12(1):10.
3. Goussous N, Kim BD, Jenkins DH, Zielinski MD. Factors affecting primary fascial closure of the open abdomen in the nontrauma patient. Surgery 2012;152(4):777-783.
4. Inukai K, Usui A, Yamada M, Amano K, Mukai N, Tsunetoshi Y, et al. Open abdominal management for perforative peritonitis with septic shock: a retrospective analysis on usefulness of a standardized treatment protocol. Eur J Trauma Emerg Surg 2019 [Epub ahead of print] doi: 10.1007/s00068-019-01132-2.
5. Arhinful E, Jenkins D, Schiller HJ, Cullinane DC, Smoot DL, Zielinski MD. Outcomes of damage control laparotomy with open abdomen management in the octogenarian population. J Trauma 2011;70 (3):616-621.
6. Seternes A, Rekstad LC, Mo S, Klepstad P, Halvorsen DL, Dahl T, et al. Open abdomen treated with negative pressure wound therapy: indications, management and survival. World J Surg 2017;41(1):152-161.
7. Khan A, Hsee L, Mathur S, Civil I. Damage-control laparotomy in nontrauma patients: review of indications and outcomes. J Trauma Acute Care Surg 2013;75(3):365-368.
8. Teixeira PG, Inaba K, Dubose J, Salim A, Brown C, Rhee P, et al. Enterocutaneous fistula complicating trauma laparotomy: a major resource burden. Am Surg 2009;75(1):30-32.
9. Serejo LG, da Silva-Júnior FP, Bastos JP, de Bruin GS, Mota RM, de Bruin PF. Risk factors for pulmonary complications after emergency abdominal surgery. Respir Med 2007;101(4):808-813.
10. Ramachandran SK, Nafiu OO, Ghaferi A, Tremper KK, Shanks A, Kheterpal S. Independent predictors and outcomes of unanticipated early postoperative tracheal intubation after nonemergent, noncardiac surgery. Anesthesiology 2011;115(1):44-53.
11. Sachdev G, Napolitano LM. Postoperative pulmonary complications: pneumonia and acute respiratory failure. Surg Clin North Am 2012;92 (2):321-344.
12. Fernandez-Bustamante A, Frendl G, Sprung J, Kor DJ, Subramaniam B, Martinez Ruiz R, et al. Postoperative pulmonary complications, early mortality, and hospital stay following noncardiothoracic surgery: a multicenter study by the Perioperative Research Network Investigators. JAMA Surg 2017;152(2):157-166.
13. Thompson SL, Lisco SJ. Postoperative respiratory failure. Int Anesthesiol Clin 2018;56(1):147-164.
14. Austin PC. Some methods of propensity-score matching had superior performance to others: results of an empirical investigation and Monte Carlo simulations. Biom J 2009;51(1):171-184.
15. Tolstrup MB, Watt SK, Gögenur I. Morbidity and mortality rates after emergency abdominal surgery: an analysis of 4346 patients scheduled for emergency laparotomy or laparoscopy. Langenbecks Arch Surg 2017;402(4):615-623.

16. Saze Z, Miyata H, Konno H, Gotoh M, Anazawa T, Tomotaki A, et al. Risk models of operative morbidities in 16,930 critically ill surgical patients based on a Japanese nationwide database. Medicine (Baltimore) 2015;94(30):e1224.
17. Bruns BR, Ahmad SA, O'meara L, Tesoriero R, Lauerman M, Klyushnenkova E, et al. Nontrauma open abdomens: a prospective observational study. J Trauma Acute Care Surg 2016;80 (4):631-636.
18. Brueckmann B, Villa-Uribe JL, Bateman BT, Grosse-Sundrup M, Hess DR, Schlett CL, et al. Development and validation of a score for prediction of postoperative respiratory complications. Anesthesiology 2013;118(6):1276-1285.
19. Nisanevich V, Felsenstein I, Almogy G, Weissman C, Einav S, Matot I. Effect of intraoperative fluid management on outcome after intraabdominal surgery. Anesthesiology 2005;103(1):25-32.
20. Huang Q, Zhao R, Yue C, Wang W, Zhao Y, Ren J, et al. Fluid volume overload negatively influences delayed primary facial closure in open abdomen management. J Surg Res 2014;187(1):122-127.
21. Thille AW, Harrois A, Schortgen FD, Brun-Buisson C, Brochard L. Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med 2011;39(12):2612-2618.
22. Brown CV, Daigle JB, Foulkrod KH, Brouillette B, Clark A, Czysz C, et al. Risk factors associated with early reintubation in trauma patients: a prospective observational study. J Trauma 2011;71(1):37-41.
23. Seymour CW, Martinez A, Christie JD, Fuchs BD. The outcome of extubation failure in a community hospital intensive care unit: a cohort study. Crit Care 2004;8(5):R322-R327.
24. Cook DJ, Walter SD, Cook RJ, Griffith LE, Guyatt GH, Leasa D, et al. Incidence of and risk factors for ventilator-associated pneumonia in critically ill patients. Ann Intern Med 1998;129(6):433-440.