

Risk factors and prognosis of acute respiratory distress syndrome following abdominal surgery

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Abstract. Risk factors and prognosis of acute respiratory distress syndrome (ARDS) following abdominal surgery were investigated. Five hundred and thirty-two patients who underwent abdominal surgery in Dongyang People's Hospital from February 2006 to May 2016 were enrolled. Among them, 113 patients had ARDS after surgery and 45 patients died. Those patients were included in observation group. The 419 patients who did not develop ARDS were included in control group, and 11 patients died. General data of patients were statistically analyzed, and the factors with statistical significance were subjected to multivariate logistic regression analysis to analyze the risk factors of ARDS. There was a significant difference in age, infection, trauma-to-surgery time, and prognosis between the two groups ($P < 0.05$). Perioperative blood loss, blood transfusion volume, and fluid volume in the observation group were significantly higher than those in the control group ($P < 0.05$). Heart rate, ratio of $\text{PaO}_2/\text{FiO}_2$, ratio of high (low) blood glucose, levels of procalcitonin (PCT) and albumin (ALB) were significantly different between the two groups. Heart rate, PCT, long-term health assessment (APACHE) II scores were higher in observation group than those in control group ($P < 0.05$). Percentage of hyperglycemic patients, $\text{PaO}_2/\text{FiO}_2$, and ALB were lower in observation group than those in control group ($P < 0.05$). Occurrence of ARDS after abdominal surgery was related to age, infection, heart rate, $\text{PaO}_2/\text{FiO}_2$, and PCT levels ($P < 0.05$). Age, infection, heart rate, $\text{PaO}_2/\text{FiO}_2$, ALB and APACHE II scores were related to the prognosis of patients with ARDS after abdominal surgery ($P < 0.05$). Age, infection, heart rate, $\text{PaO}_2/\text{FiO}_2$, PCT levels, blood loss, blood transfusion volume, and infusion volume may be risk factors for ARDS after abdominal surgery. Age, infection, heart rate, $\text{PaO}_2/\text{FiO}_2$, ALB, and APACHE II scores may be related to prognosis of patients with ARDS after abdominal surgery.

Introduction

Acute respiratory distress syndrome (ARDS) is characterized by progressive hypoxemia caused by multiple factors. The main clinical feature of ARDS is progressive hypoxemia. Its early clinical features are increased capillary permeability and coagulation dysfunction (1,2). Traumatic systemic inflammatory response caused by lung injury is considered to be the main cause of ARDS. In spite of the efforts made in the treatment of ARDS, mortality of this disease is still as high as 30–60% (3–5). Increased incidence of abdominal trauma caused by impact injuries, crush injuries, and high-altitude crashes also increase the incidence of ARDS. Excessive infusion is also one of the main causes of ARDS. Therefore, abdominal surgery is a high risk of ARDS, and ARDS is also one of the most serious complications after abdominal injury. ARDS can cause serious disorder in the patient's internal environment, resulting in the patient's whole body sequential organ failure, which greatly increases the patient's mortality rate (6–8). However, risk factors for patients with ARDS after abdominal surgery still have not been well studied. In this study, clinical data of patients with simple abdominal trauma after surgery were retrospectively analyzed and compared between patients with and without ARDS to explore the risk factors for ARDS after abdominal surgery.

Patients and methods

Subjects. A total of 532 patients who underwent abdominal surgery from February 2006 to May 2016 in Dongyang People's Hospital (Dongyang, China) were selected. Among them, 113 patients had ARDS after surgery and 45 patients died. Those patients were included in observation group. The 419 patients who did not develop ARDS were included in control group, and 11 patients in control group died. All patients in observation group met the criteria for ARDS diagnosis (9). All patients were older than 18 years and had simple abdominal trauma. Patients with allergies, pregnant women, and patients who gave up treatment were excluded. This study was approved by the Medical Ethics Committee of Dongyang People's Hospital, and patients or their families signed informed consent.

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ARDS diagnostic criteria. All 113 patients in observation group met the ARDS Berlin definition of 2012. There are

Table I. General data.

Characteristics	Control (n=419)	Observation (n=113)	Statistical value	P-value
Sex [n (%)]			0.013	0.807
Male	316 (75.4)	84 (74.3)		
Female	103 (24.6)	29 (25.7)		
Age	46.5±16.2	55.8±16.9	5.336	<0.001
Infection [n (%)]			50.306	<0.001
Yes	71 (16.9)	56 (49.6)		
No	348 (83.1)	57 (50.4)		
Damage type [n (%)]			0.087	0.742
Open	262 (62.5)	73 (64.6)		
Closed	157 (37.5)	40 (35.4)		
Damaged organ number [n (%)]			0.000	1.000
≤2	291 (69.5)	79 (69.9)		
>2	128 (30.5)	34 (30.1)		
Trauma-to-surgery time [n (%)]			23.411	<0.001
≤12 h	386 (92.1)	85 (75.2)		
>12 h	33 (7.9)	28 (24.8)		
Prognosis [n(%)]			126.830	<0.001
Survive	408 (97.4)	68 (60.2)		
Death	11 (2.6)	45 (39.8)		

high risk factors for direct lung injury or indirect injury. Acute onset, heart failure, and fluid overload do not fully explain respiratory failure, and there is no high hydrostatic pulmonary edema. Hypoxemia: PaO₂/FiO₂ ≤300 mmHg in acute lung injury and PaO₂/FiO₂ ≤200 mmHg in ARDS. Chest imaging changes, chest X-ray or CT scan images show infiltrated shadows in both lungs. Pulmonary arterial wedge pressure ≤18 mmHg or left atrial hypertension was excluded.

Conventional treatment. Patients in control group received conventional treatment including improvement of body's inflammatory response, fluid management, nutritional and metabolic support, respiratory support therapy, and other organ function support.

ARDS treatment plan. Patients in observation group received ARDS treatment program on the basis of routine treatment to control the causes, including drainage, debridement, anti-inflammation treatment with aspirin purchased from Jiaying Nanjian Biological Materials Co., Ltd., (item no: 50-78-2; Jiaying, China) and hypoxemia correction. Under the premise of maintaining adequate cardiac output, early diuresis and regulation of infusion volume were performed. A lower preload of the heart was maintained so that the incarceration pressure of the pulmonary artery does not exceed 1.6 kPa. Nutrition support was performed with the total calories less than 30 kcal/kg.

Observation indicators. General information including sex, age, infection, type of injury, number of damaged organs, trauma-to-operative time, prognosis and body mass index (BMI) were collected. Pretreatment heart rate, PaO₂/FiO₂,

blood glucose, procalcitonin (PCT), albumin (ALB), white blood cell count (WBC), acute disease physiology, long-term health assessment (APACHE) II scores, perioperative bleeding volume, blood transfusion volume and infusion volume were also recorded.

Statistical analysis. SPSS 19.0 (SPSS, Inc., Chicago, IL, USA) was used. Enumeration data were expressed as rate, and compared by using χ^2 test. Measurement data are expressed as mean ± SD and distribution of data was analyzed by Kaplan-Meier method and the log-rank test. Risk factor analysis and prognostic factor analysis were performed by using logistic regression analysis. P<0.05 was considered to indicate a statistically significant difference.

Results

General data. There were 419 patients in control group, including 316 male patients and 103 female patients, with an average age of 46.5±16.2 years. There were 113 patients in observation group, including 84 male patients and 29 female patients, with an average age of 55.8±16.9 years. There was no significant difference in sex proportion, injury type and number of injured organs between the two groups (P>0.05). There was a significant difference in age, infection, trauma-to-surgery time, and prognosis between the two groups (P<0.05) (Table I).

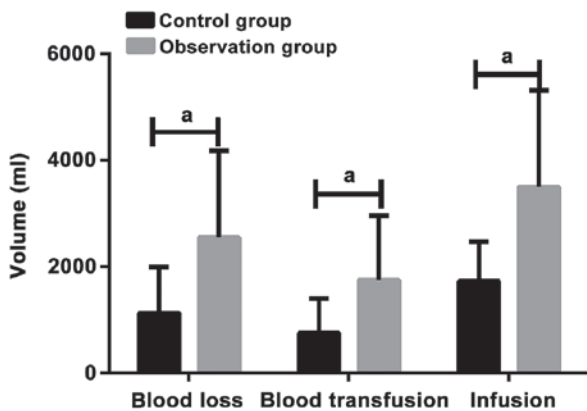
Perioperative conditions analysis. In control group, amount of blood loss was 1125.4±869.5 ml, blood transfusion volume was 756.4±642.1 ml, and infusion volume was 1725.4±744.4 ml. In observation group, blood loss volume was 2548.7±1,622.5 ml,

Table II. Analysis of perioperative conditions (ml).

Conditions	Control (n=419)	Observation (n=113)	Statistical value	P-value
Blood loss	1,125.4±869.5	2,548.7±1,622.5	12.51	<0.001
Blood transfusion volume	756.4±642.1	1,748.6±1,215.9	11.72	<0.001
Infusion volume	1,725.4±7,44.4	3,499.4±1,819.6	15.70	<0.001

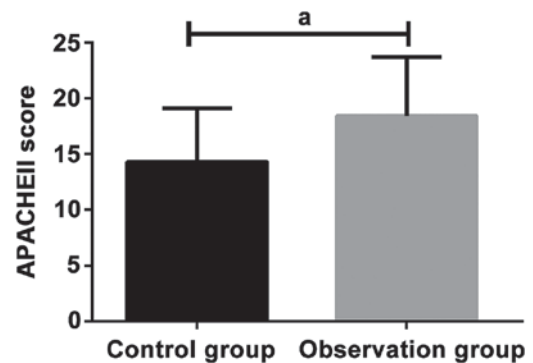
Table III. Analysis of vital signs of two groups of patients.

Vital signs	Control (n=419)	Observation (n=113)	Statistical value	P-value
BMI [n (%)]			0.375	0.521
<25 kg/m ²	177 (42.2)	52 (46.0)		
≥25 kg/m ²	242 (57.8)	61 (54.0)		
Heart rate (times/min)	95.47±10.42	98.41±11.32	2.612	0.009
PaO ₂ /FiO ₂ (mmHg)	136.75±56.45	121.44±49.26	2.626	0.009
Blood glucose [n (%)]			14.475	<0.001
≤150 mg/dl	316 (75.4)	64 (56.6)		
>150 mg/dl	103 (24.6)	49 (43.4)		
PCT (μg/l)	4.2±1.7	4.6±1.5	2.274	0.023
ALB (g/l)	27.2±3.8	25.4±5.7	3.974	<0.001
WBC (x10 ⁹ /l)	11.9±6.8	12.2±7.1	0.412	0.680

Figure 1. Analysis of perioperative conditions. The perioperative blood loss, blood transfusion and fluid transfusion volume in the observation group were significantly higher than those in the control group. ^aP<0.05.

blood transfusion volume was 1748.6±1,215.9 ml, and infusion volume was 3499.4±1819.6 ml. The perioperative blood loss, blood transfusion, and infusion volume in observation group were significantly higher than those in control group (P<0.05) (Table II and Fig. 1).

Analysis of vital signs of two groups of patients. There was no significant difference in BMI and WBC between two groups (P>0.05). There were differences in heart rate, PaO₂/FiO₂, ratio of high (low) glucose, PCT, and ALB between two groups. Heart rate and PCT were higher in observation group than in control group (P<0.05). Percentage of hyperglycemic

Figure 2. APACHE II score results. The APACHE II score in the observation group was higher than that in the control group. ^aP<0.05.

patients, PaO₂/FiO₂, and ALB were lower in observation group than those in control group (P<0.05, Table III).

Comparison of APACHE II score between two groups. APACHE II score in control group was 14.3±4.8, and APACHE II score in observation group was 18.4±5.3. There was a significant difference in APACHE II score between two groups. APACHE II score in observation group was higher than that in the control group (P<0.05) (Fig. 2).

Analysis of risk factors for ARDS after abdominal surgery. Occurrence of ARDS (yes=1, no=0) was set as a dependent variable, and factors with statistical significance were set as independent variables for logistic regression analysis. Results

Table IV. Analysis of risk factors for ARDS after abdominal surgery.

Factors	OR	95% CI	P-value
Age	1.463	1.064-2.013	0.031
Infection	1.389	1.042-1.852	0.036
Trauma-to-surgery time	0.871	0.672-1.130	0.152
Heart rate	0.457	0.261-0.801	0.019
PaO ₂ /FiO ₂	0.192	0.056-0.661	0.024
Blood glucose	1.814	0.925-3.558	0.072
PCT	0.674	0.486-0.930	0.029
ALB	1.143	0.978-1.335	0.047
Blood loss	0.457	0.261-0.801	0.025
Blood transfusion	13.228	1.883-92.936	0.001
Infusion volume	1.483	1.096-1.975	0.016

Table V. Prognostic analysis results.

Factors	OR	95% CI	P-value
Age	1.210	1.020-1.436	0.040
Infection	0.702	0.499-0.986	0.048
Heart rate	1.281	1.031-1.591	0.036
PaO ₂ /FiO ₂	0.529	0.306-0.916	0.035
PCT	0.789	0.625-0.996	0.053
ALB	1.385	0.987-1.683	0.023
APACHE II score	2.380	1.341-4.222	0.011

showed that occurrence of ARDS after abdominal surgery was significantly correlated with age, infection, heart rate, PaO₂/FiO₂, PCT levels, blood loss, blood transfusion volume, and fluid volume ($P < 0.05$), but was not correlated with blood glucose and trauma-to-surgery time ($P > 0.05$) (Table IV).

Prognostic analysis results. Death of ARDS patients after abdominal surgery was set as a dependent variable (yes=1, no=0), and factors associated with ARDS after abdominal surgery and APACHE II score were used as independent variables to carry out logistic regression analysis. Results showed that age, infection, heart rate, PaO₂/FiO₂, ALB, and APACHE II scores were related to the prognosis of ARDS patients after abdominal surgery ($P < 0.05$), while PCT levels were not related to their prognosis ($P > 0.05$, Table V).

Discussion

Pathogenesis of ARDS mainly includes direct and indirect lung injury. Trauma is one of the main causes of indirect lung injury-induced ARDS, and surgery is also a type of trauma. It has been reported that approximately 25% of multiple trauma patients and approximately 40% of emergency infusion patients are complicated by ARDS. Although in recent years, due to the application of mechanical ventilation in clinical treatment and

the improved cognition on ARDS, mortality rate of patients with ARDS has declined, but is still high (10-12). Therefore, our study aimed to identify risk factors and prognostic factors of patients with postoperative ARDS, and provide references for clinical treatment and prognosis of patients with ARDS.

In this study, clinical data of 532 patients undergoing surgical treatment in Dongyang People's Hospital due to simple abdominal trauma were retrospectively analyzed. Among them, ARDS occurred in 113 patients and incidence was approximately 21.2%, which is consistent with previous studies (13,14). Significant differences in age, infection, heart rate, PaO₂/FiO₂, PCT levels, ALB levels, APACHE II scores, trauma-to-surgery time, blood glucose, blood loss, blood transfusion volume, and infusion volume were found between two groups. We first analyzed risk factors for ARDS after abdominal surgery. Logistic regression analysis showed age, infection, heart rate, PaO₂/FiO₂, PCT levels, blood loss, blood transfusion, and infusion volume were closely correlated with the occurrence of ARDS. Older patients have poor organ storage function compared to younger patients, and have less resistance to post-traumatic infections and stress responses, and are more prone to organ damage (15). Results of this study also showed that patients with ARDS after surgery are older and had higher infection rates than patients without ARDS. PCT test results also showed that patients with ARDS had higher PCT levels than patients without ARDS. ALB is an acute phase protein. It has been reported that hypoproteinemia is an independent risk factor for severe ARDS patients complicated with ARDS, leading to a significant increase in mortality (16,17).

Hypoproteinemia also affects the patient's colloidal osmotic pressure, promotes pulmonary edema, and affects patient's oxygenation capacity (18). Results of this study also showed that ALB levels and PaO₂/FiO₂ in patients with postoperative ARDS were significantly lower than those in patients without ARDS. Amount of blood loss, blood transfusion, and infusion volume in ARDS patients were significantly higher than those in patients without ARDS. Excessive infusion during surgical operation can dilute blood and decrease plasma colloid osmotic pressure, further promoting the aggregation of pulmonary edema and reducing oxygenation ability. Some denatured proteins may also present in blood with longer storage time and affect patients' coagulation function (19,20). Therefore, effectively shortening operation time, effectively and quickly treating the wound, and timely regulating liquid input during operation may be an effective means for preventing postoperative ARDS.

We then analyzed the prognostic factors of ARDS. In this study, among 113 patients, 45 patients died of ARDS after surgery, and the mortality rate was 39.8%, which is consistent with the findings in previous studies (21,22). Prognostic factors of ARDS have long been a focus of clinical concern. Some studies have reported that mortality of patients with ARDS is closely related to age, oxygenation index, MODS score, and APACHE II score (23,24). Consistently, we also found that the patient's age, oxygenation index, MODS score, and APACHE II are closely related to prognosis. APACHE II score is more comprehensive than MODS score. Studies have reported that many patients with ARDS have organ damage, and APACHE II score is also more sensitive to the prognosis of patients with ARDS (25,26). Therefore, MODS was not used in this study. Sensitivity of elderly patients to drug treatment is poor, which

may be a cause of poor prognosis in elderly patients. Moreover, immune function of elderly patients is relatively poor, and immunosuppressants can be used during treatment to support systemic treatment. Tracheal intubation and mechanical ventilation may also be performed to avoid the occurrence of multiple infections. This study also has limitations. Due to the limited experimental resources, some indicators, such as status of infected bacteria, have not been included in the study. We will include those factors in our future studies.

In summary, age, infection, heart rate, PaO₂/FiO₂, PCT levels, blood loss, blood transfusion, and infusion volume may be risk factors for ARDS after abdominal surgery. Age, infection, heart rate, PaO₂/FiO₂, ALB and APACHE II scores may be related to the prognosis of patients with ARDS after abdominal surgery.

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Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Authors' contributions

BX wrote the manuscript. BX and YG treated patients and collected the basic data of patients. YL worked on ARDS treatment program for patients. QC and HZ were responsible for prognostic analysis. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Dongyang People's Hospital (Dongyang, China). Signed informed consents were obtained from the patients or the guardians.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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