Prediction of Factors Influencing the Timing and Prognosis of Early Tracheostomy in Patients with Multiple Rib Fractures using Propensity Score Matching Analysis

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Original research

Keywords: early tracheostomy, multiple rib fractures, propensity score matching

Posted Date: November 10th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-1026962/v1>

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Abstract

Objective To explore the factors affecting the timing and prognosis of early tracheostomy (within 7 days after tracheal intubation) in patients with multiple rib fractures.

Methods A retrospective analysis of the medical history of 222 patients with multiple rib fractures who were admitted to the department of emergency intensive care unit (EICU) of the affiliated hospital of Yangzhou University from February 2015 to October 2019 underwent early tracheostomy. According to the time from tracheal intubation to tracheostomy after admission, the patients were divided into two groups: early tracheostomy group (within 7 days after tracheal intubation, ET) and late tracheostomy group (after the 7th day, LT). The propensity score matching analysis technique was used to compare the differences between the two groups in a 1:1 ratio.

Results A total of 222 patients were enrolled, with 118 in the ET group and 104 in the LT group. After matching, 87 in the ET group and 87 in the LT group. The proportion of acute respiratory distress syndrome (ARDS) [59 (67.8%)], the volume of pulmonary contusion (VPC) [33.8 ± 11.4], and number of total rib fractures (NTRF) [10.8 ± 2.7] in the ET were significantly higher than those in the LT group, $P < 0.05$. Binary Logistic regression analysis showed that ARDS [OR = 3.740, 95%CI (1.441, 9.711)], VPC [OR = 1.087, 95%CI (1.052, 1.124)], and NTRF [OR = 1.775, 95%CI (1.439, 2.188)] were independent risk factors for ET. The Pearson analysis showed that VPC and NTRF had significant correlation ($R = 0.369$, $P = 0.01$), ARDS and VPC had low degree correlation ($R = 0.179$, $P = 0.018$), while ARDS and NTRF had no significant correlation ($R = 0.132$, $P = 0.110$). Receiver operating characteristic (ROC) curve analysis showed that the area under VPC and NTRF curves [0.832 (95%CI: 0.770 ~ 0.893), 0.804 (95%CI: 0.740 ~ 0.868)] were significantly more than the number of rib fractures (NFR), glasgow coma scale (GCS), and injury severity score (ISS), $P < 0.05$. COX regression analysis showed that patients with underwent ET survived significantly better than the LT, $P < 0.05$.

Conclusions We found that ARDS, VPC, and NTRF were independent risk factors for ET; $VPC \geq 23.9\%$ and (or) $NTRF \geq 8.5$ could be used as predictors of ET in patients with multiple rib fractures. There was a linear relationship between NTRF and VPC. ET might benefit patients with multiple rib fractures.

Introduction

Multiple rib fractures (the number of fractured ribs is more than 3) are usually caused by chest trauma, which might be combined with pulmonary contusion, hemothorax, pneumothorax, and possibly life-threatening lung injury^[1]. Patients with multiple rib fractures and pneumonia might require tracheostomy. It was reported that incidence of tracheostomy in critically injured patients with acute respiratory failure was up to 59.0%, with an average of 19.6%^[2].

ET may benefit patients with multiple rib fractures. These benefits include shortening the time of sedation^[3], reducing the time of ventilator use, shortening the ICU length of stay (ICULOS) and hospital length of stay (HLOS)^[4], and even reducing the incidence of pneumonia and short-term mortality^[3-6]. However, tracheostomy can also cause complications such as bleeding, tracheal stenosis, incision skin ulcers^[7,8]. Therefore, how to predict the timing and prognosis of ET is a difficult problem for clinicians. However, there

were very few relevant studies at present, only single-center and retrospective studies. It has been reported that severe GCS score (≤ 8), flail chest, and severe trauma score were risk factors that might cause patients with multiple rib fractures to prolong the time of mechanical ventilation^[9]. Some researchers had also found that the clinical application of tracheostomy predictive models were limited because of poor predictive sensitivity and the positive predictive value of only 30-45%^[10].

Therefore, we used propensity score matching analysis to verify the general data and clinical results of patients with multiple rib fractures. Our purpose was to find suitable indicators to predict the timing and prognosis of early tracheostomy in patients with multiple rib fractures.

1. Patients And Methods

1.1 Research object

This was a retrospective cohort study. Our study subjects were patients with multiple rib fractures who underwent tracheostomy and were radiologically confirmed (computed tomography scans, CTs) in the ICU of the affiliated hospital of Yangzhou University between February 2015 and October 2019. Other data were extracted from the inpatient registries and patient electronic medical records. Our inclusion criteria: age > 18 years; multiple rib fractures diagnosed by computer tomography; due to chest injury, patients underwent tracheostomy treatment after admission. We excluded patients who were < 18 years old, who were cardiac arrest, and who were underwent tracheostomy due to severe traumatic brain injury, burn, and spine injury. According to the 2009 tracheostomy timing management guide^[11], the patients were divided into two groups: ET was defined as tracheostomy within 7 days after tracheal intubation, and LT was after the 7th day.

1.2 Data collection

We collected variables included age, gender, glasgow coma scale (GCS), injury severity score (ISS), complications (cardiovascular disease and lung disease), traumatic brain injury (TBI), acute respiratory distress syndrome (ARDS), volume of pulmonary contusion (VPC), number of ribs fractured, number of total fractures of the ribs (NTRF), first rib fracture, flail chest, sternum fractures, spine coinjuries, maxillofacial coinjuries, initial value of blood lactate, hemothorax, pneumothorax, timing of tracheostomy, duration of mechanical ventilation, duration of tracheostomy, hospital length of stay (HLOS), ICU length of stay (ICULOS), thoracic close drainage, number of fiberbronchoscope, multidrug resistance bacteria, ventilator associated pneumonia, antibiotic use day, sedatives and analgesics use day, and 28-day mortality. Each slice of the admission spiral chest CTs was documented and reconstructed in 3D by Advantage Workstation 4.3 computer software (GE Healthcare, Waukesha, WI), so that precise contusion volumes could be measured. Bilateral pulmonary fields were also reconstructed and pulmonary volume was measured. Total PC volume for both pulmonary fields was expressed as a percentage of total pulmonary volume. We defined ARDS according to the Berlin definition^[12].

1.3 Treatment method

All patients received standard treatments: analgesia and sedation, bronchoscopy and alveolar lavage, and chest physical therapy. (1) Analgesia and sedation are all systemic drugs, our purpose is to enable patients to breathe effectively, promote airway secretion clearance and reduce the formation of atelectasis; (2) Bronchoscopy and alveolar lavage It can further optimize the removal of patients' airway secretions and the prevention of pneumonia; (3) Chest physical therapy includes sputum suction, artificial airway management (turning over and buckling the back to promote sputum drainage), mechanical sputum assisted removal of airway secretions, chest belt external fixation, closed thoracic drainage, nasal or oral endotracheal intubation to establish artificial positive airway pressure and tracheostomy treatment. Tracheostomy was performed according to classic indications^[13]. All operations were performed by physicians with extensive clinical experience. The specific methods were carried out in accordance with the latest guidelines^[14].

1.3 Statistical analysis

IBM SPSS software version 22.0 (IBM, Armonk, NY) for statistical analysis, continuous variables and normal distribution data were represented by mean $\pm$ standard deviation, non-normal distribution was represented by median (inter quartile range), and categorical variable data was represented by percentage (rate). The control cohort of early and late tracheostomy patients obtained by propensity score matching method, the matching ratio is 1:1, the caliper value is 0.2, and age, ISS and tracheostomy time are used as covariates without replacement. The logistic regression was used to predict the independent risk factors of early tracheostomy, and Pearson correlation analysis was performed on the independent factors generated. ROC curve compared the significance of the risk factors affecting early tracheostomy. Kaplan-Meier and COX survival analysis were used to analyze the influencing factors of patients' 28-day survival.

2. Results

2.1 Characteristics of patients

A total of 251 patients with tracheostomy were involved, of which 29 were excluded [8 cases age < 18 years old, 5 cases with cardiac arrest, and tracheostomy due to severe traumatic brain injury(9 cases), burn(2 case), and (5 cases)], therefore, 222 patients finally met the enrollment criteria. The average age is 50 years old, 160 males (72.1%). The most common injury was traffic accident injuries (156 cases, 70.3%), followed by high fall injuries (41 cases, 18.5%), fall injuries (12 cases, 5.4%), and crush injuries (11 cases, 4.9%) , unexplained injury (2 cases, 0.9%). Among patients who underwent tracheostomy within 7 days after intubation, 118 cases (53.2%) met the ET, and 104 cases (46.8%) were included in the LT. On account of propensity score matching analysis, There were 87 patients in the ET group and LT group respectively. Hence , a total of 174 patients were sampled for result analysis (Figure 1).

Before propensity score matching, significantly difference in cardiovascular disease, ARDS, VPC, NTRF, and hemothorax between the ET and the LT. After propensity score matching, ARDS, VPC, and NTRF were significantly different; Nevertheless, Age, male, GCS, ISS ,lung disease , TBI , number of fractured ribs, first rib fracture , combined injury (flail chest, maxillofacial, spine, hemothorax, pneumothorax) and initial value of

blood lactate were not significantly different; In addition, Timing of tracheostomy for patients in ET and LT were (4.1 ± 1.3) days VS (12.5 ± 3.0) days, which were significantly different (Table 1).

2.2 Outcome of patients

Before propensity score matching, the ratio of closed thoracic drainage and fungal infection in the ET was higher than that of the LT, while no significant difference between after matching. the 28-day mortality of the ET group was lower than that of the LT, and there was a statistical difference (Table 2).

The results of binary logistic regression analysis of multiple factors showed that ARDS, VPC and NTRF were three independent risk factors for patients with multiple rib fractures who underwent early tracheostomy (Figure 2). Pearson correlation analysis of three independent factors showed that: VPC and NTRF are moderately related, $R=0.369$, $P=0.001$; ARDS and VPC are lowly related, $R=0.179$, $P=0.018$; NTRF and ARDS are not obviously correlation, $R=0.132$, $P=0.110$ (Figure 3).

ROC curve analysis showed that the area under the curve of VPC and NTFR were 0.804 and 0.832, respectively, $P=0.001$. While that of GCS, ISS and NFR had no significant difference, $P\text{-value} \geq 0.05$ (Figure 4). We calculated the maximum value of the VPC's Youden index [sensitivity - (1-specificity)] is 0.633, corresponding sensitivity=0.828. SPSS statistical software could calculate the corresponding value of VPC is 23.9. As well, we could also calculate that the maximum value of the NTFR's Youden index is 0.474, corresponding sensitivity=0.839. SPSS statistical software could also calculate the corresponding value of NTFR is 8.5.

Kaplan-Meier survival analysis showed that the 28-day survival of ET was significantly better than that of LT, $P=0.01$ (Figure 5). In addition, COX survival analysis showed that the timing of tracheostomy ($HR=2.51$ 95%CI 1.12-5.57, $P=0.004$) and age ($HR=1.53$ 95%CI 1.00-2.05, $P=0.042$) of patients had a significant impact on the 28-day survival of patients with multiple rib fractures.

Table 1

Comparison of baseline data of patients before and after propensity score matching

Variables	Before propensity matching			After propensity matching		
	ET N=118	LT N=104	P- value	ET N=87	LT N=87	P- value
Age, years, points	50.5±15.6	47.5±18.2	0.196	48.2±16.1	47.6±20	0.818
Male sex, n (%)	84 (71.1)	76 (73.1)	0.754	67 (77.0)	59 (67.8)	0.175
GCS at admission, points	9.1±4.3	9.0±4.5	0.893	9.2±4.3	8.9±4.6	0.660
ISS, points	38.9±7.2	40.1±9.4	0.294	39.3±7.8	40.0±8.8	0.580
Cardiovascular diseases, n (%)	21 (17.8)	8 (7.7)	0.026	13 (14.9)	8 (9.2)	0.245
Lung disease, n (%)	12 (10.2)	12 (11.5)	0.743	9 (10.3)	10 (11.5)	0.808
Traumatic Brain Injury, n (%)	84 (71.2)	72 (69.2)	0.750	60 (69.0)	62 (71.3)	0.740
Acute Respiratory Distress Syndrome, n (%)	76 (64.4)	48 (46.2)	0.006	59 (67.8)	37 (42.5)	0.001
Volume of pulmonary contusion, points	21.1±18.0	5.9±8.7	0.000	33.8±11.4	20.1±9.8	0.000
Number of ribs fractured, points	5.8±2.1	6.1±2.1	0.218	5.7±2.1	6.2±2.1	0.167
Number of total rib fractures, points	9.1±2.4	7.9±2.2	0.001	10.8±2.7	7.9±2.0	0.001
First rib fractures, n (%)	40 (33.9)	34 (32.7)	0.849	30 (34.5)	29 (33.3)	0.873
Sternum fractures, n (%)	37 (31.4)	31 (29.8)	0.803	26 (29.9)	24 (27.6)	0.738
Flail chest, n (%)	20 (16.9)	24 (23.1)	0.253	14 (16.1)	22 (25.3)	0.134
Spine coinjuries, n (%)	12 (10.2)	4 (3.8)	0.069	10 (11.5)	4 (4.6)	0.094
Maxillofacial coinjuries, n (%)	8 (6.9)	12 (11.5)	0.232	8 (9.4)	9 (10.3)	0.838
initial value of blood lactate, points	4.0±2.9	4.1±2.2	0.836	4.1±2.9	3.8±2.1	0.509
Hemothorax, n (%)	58 (49.2)	32 (32.0)	0.010	41 (47.1)	31 (35.6)	0.124
Pneumothorax, n (%)	70 (59.3)	56 (53.8)	0.411	50 (57.5)	51 (58.6)	0.878
Timing of tracheostomy, day, points	4.0±1.3	12.6±3.1	0.000	4.1±1.3	12.5±3.0	0.001

ET, early tracheostomy; LT, late tracheostomy; GCS, glasgow coma scale; ISS, injury severity score.

Table 2						
Comparison of clinical outcomes of patients before and after propensity score matching						
Outcomes	Before propensity matching			After propensity matching		
	ET N=118	LT N=104	P-value	ET N=87	LT N=87	P-value
Duration Of mechanical ventilation, days	13.5±4.1	15.7±5.5	0.078	13.9±3.0	15.9±4.7	0.190
Duration of tracheostomy, days	27.3±6.5	35.8±8.2	0.180	28.4±6.1	39.4±7.1	0.143
Hospital lenght of stay, days	18.3±6.0	17.7±5.1	0.855	19.3±6.6	17.0±5.8	0.521
ICU lenght of stay, days	7.1±2.7	11.5±3.6	0.145	8.7±2.1	11.6±2.7	0.412
Thoracic close drainage, n (%)	66(55.9)	44(42.3)	0.043	46(52.9)	39(44.8)	0.288
Number of fiber bronchoscope use, points	2.5±5.4	1.7±2.9	0.194	2.8±5.9	1.7±2.8	0.129
Multidrug resistance bacteria, n (%)	36(30.5)	34(32.6)	0.335	29(33.3)	28(32.2)	0.732
Ventilator associated pneumonia, n (%)	24(20.3)	20(19.2)	0.657	18(20.7)	19(21.8)	0.732
Antibiotic use, days	10.0±3.4	9.2±2.6	0.722	13.5±4.3	14.1±4.6	0.876
Sedatives and analgesics use, days	11.4±9.1	13.7±8.6	0.060	11.6±9.2	13.5±8.3	0.151
28-day mortality, n (%)	14(11.9)	29(27.9)	0.003	9(10.3)	28(32.2)	0.001
ICU, intensive care unit; ET, early tracheostomy; LT, late tracheostomy.						

3. Discussion

Many researchers tried to predict the influencing factors of early tracheostomy in ICU patients. Most of these studies focused on specific subgroups, such as patients with multiple injuries (cranial trauma, spinal injury, burns) ^[15-18], spontaneous cerebral hemorrhage^[19-20], and hypoxic/hypoxic-ischemic encephalopathy^[21]. However, there was a lack of large-scale observational studies on patients with chest trauma, especially multiple rib fractures.

Three key findings were drawn from this study. First, ARDS, VPC, and NTFR were independent risk factors for ET; Secondly, VPC $\geq 23.9\%$ and (or) NTRF ≥ 8.5 could be used as predictors of ET in patients with multiple rib fractures. **In addition**, there was a significant correlation between VPC and NTFR. With the increase of NTFR, VPC also tended to increase significantly. Finally, we found that ET might benefit patients with multiple rib fractures.

Several retrospective studies had shown that severe brain injuries, flail chest, severe thoracic trauma score, lung contusion, and rib fractures^[22-23] were the risk factors of multiple rib fractures patients with mechanical ventilation for more than 7 days. Nevertheless, our study excluded patients whose coma was longer than 72 hours due to TBI, in order to reduce the impact of tracheostomy for prolonged coma. In addition, we counted the NTFR in each enrolled patient, which quantified the severity of chest injury more than flail chest. Fokin et al^[24] found that no matter the total number of rib fractures ≥ 5 or ≥ 6 , the timing of tracheostomy was not affected. However, our study found that when the NTFR ≥ 8.5 , patients might require early tracheostomy, and benefit patients with multiple rib fractures. We believe that this may be the threshold of the number of rib fractures affecting the outcome of the patient. The studies of Battle et al^[25] and Shulzhenko et al^[26] also showed the same results. In addition, previous studies found that VPC could quantify the severity of lung contusion^[11,27-28]. For the first time, we used VPC as a research variable for patients with multiple rib fractures underwent tracheostomy, and reached a conclusion. When $VPC \geq 23.9$, it indicated that the patient might need early tracheostomy, and it was also related to the patient's survival benefit. The studies of Mahmood et al^[27] and Wang et al^[28] were consistent with ours. Finally, we found that there was a significant correlation between NTFR and VPC. Trinkled et al^[29] also confirmed that flail chest-related respiratory insufficiency was caused by a potential lung contusion, and that the shear force generated by the fracture caused lung tissue and blood vessel damage^[30].

Several studies had shown that surgical internal fixation significantly reduced HLOS, ICU LOS, and the incidence of pneumonia^[31-32]. However, our study showed that there were no significant differences between the two groups. The population included in our study was patients with severe chest trauma who received mechanical ventilation. Such patients often had longer hospital stay and high incidence of ventilator-associated pneumonia. Our study found that the 28-day mortality of patients in ET group was lower than that in LT group, and the results of survival analysis also verify that the 28-day survival of patients in ET was better than that in LT. This indicated that early tracheostomy also was related to the patient's survival benefit, which was consistent with the view of Raimondi et al^[33]. However, Fokin et al^[23] and Kang et al^[34] reported that early tracheostomy did not reduce the mortality of trauma patients. The reason was that they found that mortality was related to traumatic brain injury and GCS was less than 8 on admission, and most deaths occurred in 3 to 5 weeks after admission. We believed that the cause of the difference in mortality might be due to selection bias or different monitoring modes. In addition, we believed that if the patients were found to be a high-risk group of tracheostomy, ET might benefit them. Finally, we emphasized the individualized treatment plan, and should not choose ET in order to reduce the mortality.

However, our report had several limitations. First of all, it was a retrospective and observational study, so subject to the limitations of this type of research and only involves data from one city in Country. But we believed that our study contained a large amount of data for all this group, so it was a good representation of the characteristics of this type of trauma patients. In addition, we speculated that there may be other undiscovered indicators. In the future, it is an urgent need to establish a more complete prediction model to predict the timing and prognostic of early tracheostomy in patients with multiple rib fractures.

Conclusion

We found that ARDS, VPC, and NTRF were independent risk factors for ET; $VPC \geq 23.9\%$ and (or) $NTRF \geq 8.5$ could be used as predictors of ET in patients with multiple rib fractures. There was a linear relationship between NTRF and VPC. ET might benefit patients with multiple rib fractures.

Abbreviations

EICU, emergency intensive care unit; ET, early tracheostomy; LT, late tracheostomy; ARDS, acute respiratory distress syndrome; VPC, volume of pulmonary contusion; NTRF, number of total rib fractures; ROC, receiver operating characteristic; NFR, number of rib fractures; GCS, glasgow coma scale; ISS, injury severity score; ICULOS, intensive care unit length of stay; HLOS, hospital length of stay; CTs, computed tomography scans; TBI, traumatic brain injury; HR, hazard ratio; 95%CI, 95% confidence interval.

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Our study was discussed and approved by the Ethics Committee of the Affiliated Hospital of Yangzhou University. Ethical Review Opinion No.2020-YKL12-23-(01).

CONSENT FOR PUBLICATION

Any individual person's data in our study (including individual details and images) had been obtained from that person.

AVAILABILITY OF DATA AND MATERIALS

Please contact author for data requests.

COMPETING INTERESTS

The authors declare that they have no competing interests.

FUNDING

This study was supported by Science and technology innovation cultivation fund of Yangzhou University (2019CXJ208) and Jiangsu Province 333 High-level Talent Training Project (BRA2020176).

AUTHORS' CONTRIBUTIONS

GL, and YW contributed to determining variables, extracting variables from the trauma registry, providing input, and finally approving the manuscript. Besides, YL was a contributor to the research design, responsible

for providing input data and finalizing the draft.

ACKNOWLEDGEMENTS

Not applicable.

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Table

Table 3 is not available with this version.

Figures

Figure 1

flow chart of study design and patient selection

Figure 2

Results of multivariate logistic regression analysis of patients.

Figure 3

Correlation analysis results of volume of pulmonary contusion and total number of total fractures of the ribs.

Figure 4

Results of ROC curve analysis.

Figure 5

Kaplan-Meier survival analysis based on 28-day mortality.