Full Airway Drainage by Fiber Bronchoscopy Through Artificial Airway in the Treatment of Occult Traumatic Atelectasis

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Abstract The objective of this study is to investigate the effects of full airway drainage by fiber bronchoscopy through artificial airway in the treatment of traumatic atelectasis with occult manifestations. From May 2006 to May 2011, 40 cases of occult traumatic atelectasis were enrolled into our prospective study. Group A ($n=18$) received drainage by nasal bronchoscope; group B underwent airway drainage by fiber bronchoscopy through artificial airway ($n=22$). The effects of treatment were evaluated by the incidence of adult respiratory distress syndrome (ARDS), lung abscess, and the average length of hospital stay. Compared with nasal fiber-optic treatment, airway drainage by fiber bronchoscopy through artificial airway reduced the incidence of ARDS ($p=0.013$) and lung abscess ($p=0.062$) and shortened the mean length of stay

($p=0.018$). Making the decision to create an artificial airway timely and carry out lung lavage by fiber bronchoscopy through artificial airway played a significant role in the treatment of occult traumatic atelectasis.

Keywords Fiber bronchoscopy · Artificial airway · Occult traumatic atelectasis · ARDS · Lung abscess

Introduction

Multiple rib fracture and hemopneumothorax are common in thoracic trauma patients; however, pulmonary atelectasis caused by airway injury with bleeding is more likely to be exacerbated by acute respiratory distress syndrome (ARDS) and pneumonia [1]. The therapeutic principle for this condition is timely full drainage of sputum and blood at early stage. Although use of an artificial airway and fiber bronchoscopy for the treatment of severe traumatic atelectasis with dyspnea or massive hemoptysis is now accepted [2, 3], there still remain several problems as follows: first, for young patients with atypical manifestations and sufficient compensation of pulmonary function, it is difficult to make the decision to create an artificial airway to drain sputum and blood. But the pathological injury might be aggravated gradually without timely drainage; second, manipulation of the fiber bronchoscope through the nasal cavity may lead to patients' resistance and breath-holding, which can make it difficult for the patients to tolerate repeated treatment within a short period of time; on the other hand, breath-holding can increase the airway pressure, thereby exacerbating the original airway injury, or even burst, which may cause a pneumothorax or pneumomediastinum. Up to now, there were no relevant studies comparing the effect of lung lavage by fiber bronchoscopy through the nasal cavity and artificial airway on such occult traumatic atelectasis patients. We observed 40 cases of early

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traumatic atelectasis without symptoms of ARDS within 24 h of hospitalization, admitted from 2006 to 2011 in a prospective randomized control study and determined the efficacy of fiber bronchoscopy through artificial airway.

Methods

Inclusion Criteria

The inclusion criteria for occult traumatic atelectasis were listed as follows (Fig. 1):

1. Patient aged 18–50 years, male or female.
2. Traumatic injury mainly to the chest and single injuries to extrathoracic regions with Abbreviated Injury Scale (AIS) score ≤ 1 [4], multiple injuries to extrathoracic regions with Injury Severity Score (ISS) ≤ 3 [4].
3. Unilateral closed thoracic trauma with pulmonary laceration in one to three lung lobes (AIS 2–4) with or without subcutaneous muscle injury to the chest (AIS ≤ 2),

hemopneumothorax (AIS 2–3), or rib fracture (AIS 2–4) (Table 1). Additionally, there is no airway fracture.

4. Patient was admitted to hospital within 12 h of trauma, and the diagnosis of airway injury accompanied by pulmonary atelectasis was made within 24 h of hospitalization. The diagnostic criteria include hemoptysis, aspiration of bloody sputum on fiber bronchoscopy, and unilateral atelectasis with or without fluid level in cavity (Fig. 2) indicated by thoracic CT.
5. No symptoms of ARDS within 24 h after patient assessment and no indications for mechanical ventilation.
6. APACHE II score ≤ 8 within 24 h after admission, and no emergency occurred such as severe hemoptysis or hemothorax accompanied by shock.
7. Hemothorax controlled with closed thoracic drainage.

Patient Information

Forty patients were included, 31 males and 9 females, aged 18–48 years with an average age of 34.4 ± 7.9 years. Thoracic

Fig. 1 A sketch map of inclusion, grouping, treatment, complication, and prognosis

Table 1 General conditions and treatment

		Group A (n=18)	Group B (n=22)	p value
Patients' conditions				
Age (year)		34.9±5.6	33.8±9.3	0.675
Gender (male/female)		14/4	17/5	0.971
Oxygen index (mmHg) ^a		169.7±33.4	180.5±41.7	0.382
APACHE II evaluation ^b		5.39±1.53	5.18±1.87	0.715
AIS [4] evaluation	Pulmonary contusion ^c	2.556±0.705	2.636±0.79	0.737
	Subcutaneous injury ^d	1.44±0.511	1.5±0.512	0.734
	Hemothorax and pneumothorax ^e	2.61±0.5	2.41±0.5	0.214
	Ribs fracture ^f	2.11±0.83	2.18±0.8	0.786
Complications				
ARDS		11	5	0.013
Pulmonary abscess		7	2	0.062
Treatment				
Times of fiber bronchoscopy		2.72±0.3	3.05±0.31	0.466
Mechanical ventilation (cases)		11	5	0.013
Closed thoracic drainage (cases)		15	18	0.769
Surgery (cases)		4	1	0.229
Prognosis				
Average length of stay (days)		21.5±2.07	14.5±0.86	0.018
Mortality		0 %	0 %	—

^a Lowest oxygen index within 24 h after being hospitalized^b Highest APACHE II evaluation within 24 h after being hospitalized^c Lung contusion: 441407.2 (unilateral, mild, ≤1 lobe); 441408.3 (unilateral, severe, 1–3 lobe) lung laceration: 441431.3 (unilateral, mild, ≤1 lobe); 441432.4 (unilateral, severe, 1–3 lobe)^d Subcutaneous muscle injury: 410202.1 (abrasion), 410402.1 (contusion, hematoma), 410602.1 (superficial laceration), 410604.2 (length >20 cm, deep into subcutaneous tissue), 410802.1 (deletion of superficial tissue ≤100 cm²), 410804.2 (tissue deletion >100 cm²)^e Hemopneumothorax: 442200.3 (hemothorax, unilateral <1,000 ml), 442202.2 (pneumothorax, unilateral pulmonary compression <50 %, without durative lung leakage), 442205.3 (hemopneumothorax, unilateral <1,000 ml)^f Rib fracture: 450201.1 (unilateral, one rib fracture), 450202.2 (unilateral, two ribs fracture), 450203.3 (unilateral, more than three ribs fracture)**Fig. 2** Thoracic trauma with pulmonary cavity on the right lobe (**a**, **b**, see red arrow). The condition improved after drainage (**c**, **d**)

trauma was characterized by closed multiple rib fractures on one side, complicated by pulmonary laceration accompanied by airway injury and pulmonary atelectasis. There were no indications for the use of mechanical ventilation such as coma, asphyxia, or acute respiratory failure, nor for emergency exploration of the thorax with hemostasis and repair. There were no severe injuries to organs or tissues outside the thoracic region. Nineteen patients were victims of traffic accidents, ten of falls, seven of crush injuries, and four of blunt injuries.

Treatment

Common Treatments

The 40 patients were admitted to the emergency intensive care unit under vital signs monitoring. Fluid resuscitation, wound dressing, chest bandage fixation, and closed thoracic drainage were completed within 2 h.

Preliminary Treatment for Airway Injury

Nasal fiber bronchoscopy was performed to confirm the diagnosis of airway injury and to aspirate sputum and blood clots which may block the bronchus. Hemostatic agents such as reptilase or norepinephrine [5, 6] were administered locally to patients with active mucosal bleeding. Biopsy forceps were used when it was difficult to aspirate secretions or blood clots, along with repeated flushing and aspiration with 10–20 ml of warm normal saline to a total of less than 100 ml. Sputum or lavage fluid was sent for bacteriologic examination. Negative suction pressure was maintained at less than 13.3 kPa throughout treatment.

Treatment of Study Groups

The 40 cases were divided randomly into group A and B. Conservative but not passive treatment, such as hemostasis, anti-inflammatory drugs, and nutritional support, was given to the 18 patients in group A, as well as oxygen through a nasal catheter or mask, combined with nasal fiber bronchoscopy when necessary. The 22 cases in group B received aggressive but not excessive treatment; tracheal intubation (four cases, 18.2 %) and percutaneous tracheostomy (18 cases, 81.8 %) were performed, together with airway humidification, controllable oxygen inhalation, and periodic deep sputum aspiration. Fiber bronchoscopy via the artificial airway was performed when necessary (Fig. 1). The artificial airways were kept in trachea for 9.05 ± 3.28 days, and there were no complications associated with artificial airway.

Treatment for Complications

Treatment with internal pneumatic stabilization [7] (continuous positive pressure ventilation and a positive end-expiratory pressure of 8–10 cm H₂O) was performed immediately when patients suffered ARDS attack. Anti-infection measures and sputum drainage were used to treat lung abscess, once the diagnosis had been made based on persistent fever, increased white blood cells, and CT information. Surgical thoracic drainage was performed when necessary (Fig. 1).

Observation and Statistical Methods

The development of ARDS and lung abscess in the two groups were observed for 14 and 21 days, respectively, which were evaluated by Kaplan–Meier survival analysis. Times of fiber bronchoscopy, hospital stay, and mortality were presented as mean $\pm$ SEM and analyzed by one-way analysis of variance. $p \leq 0.05$ was considered to indicate a significant difference.

Results

Comparison of the General Condition and Severity of Injury Between two Groups

There were no significant differences between the two groups in terms of age, gender, AIS for pulmonary laceration, thoracic subcutaneous muscle injury, hemopneumothorax and rib fracture, or lowest oxygen index and highest APACHE II score within 24 h of admission to hospital (Table 1).

Comparison of Complications

The incidence of ARDS in the early stage ($p=0.013$) and pulmonary abscess in the mid- or late stage ($p=0.062$) was higher in group A than in group B, although difference in pulmonary abscess was not statistically significant (Table 1 and Fig. 3). All complications were cured by mechanical ventilation, anti-inflammatory drugs, drainage, or surgery (Fig. 1).

Treatment and Hospital Stay

There were no difference in the numbers of the cases who received closed thoracic drainage ($p=0.769$) and the times of fiber bronchoscopy treatment ($p=0.466$) between two groups. Patients in group A received more treatments such as mechanical ventilation ($p=0.013$) and surgery ($p=0.229$) than group B, although difference in surgery was not statistically significant. The hospitalization period in group A was significantly

Fig. 3 **a** Longitudinal study of traumatic pulmonary atelectasis accompanied by ARDS. A significant difference in the incidence of ARDS was observed between the two groups ($p=0.013$). **b** Longitudinal study of traumatic pulmonary atelectasis accompanied by pulmonary abscess.

longer than that in group B ($p=0.018$), and all patients were cured (Table 1).

Discussion

Atelectasis was the most common complication of thoracic trauma, with an incidence from 7.4 [8] to 14.6 % [9] in all cases. Pulmonary contusion caused by thoracic trauma can lead to airway bleeding, which may cause bronchial obstruction; cough and respiratory movement are limited by pain, which may inhibit full thoracic expansion and lead to accumulation of blood clots and sputum; severe thoracic trauma can cause pneumonia and type II alveolar epithelial cell injury, both of which may affect the production and action of pulmonary surfactant, which lead to increased alveolar surface tension and pulmonary atelectasis [10]. In addition, hemopneumothorax after trauma may also promote pulmonary atelectasis due to compressing lungs. Increased intrapulmonary shunt caused by pulmonary atelectasis can induce emergent hypoxemia, which may result in serious consequences if not diagnosed and treated in a timely manner [11].

The clinical status deteriorates due to the occurrence of bronchial obstruction and infection. Usually, the symptoms in the early stage are nonspecific, such as a stuffy feeling in the chest, shortness of breath, palpitations, etc., which can be confused with the thoracic trauma itself [12]. Gradual worsening of atelectasis induced by the limited cough and respiratory movement may result in sudden dyspnea, cyanosis, and increased thoracic pain. Thus, we should pay more attention to

Compared with group B, the tendency of a higher incidence of pulmonary abscess was observed in group A ($p=0.062$), although the difference was not statistically significant

the occurrence of such occult traumatic pulmonary atelectasis from the start. Forty patients with atypical unilateral traumatic pulmonary atelectasis were included in the present study in the early stage, and sixteen cases were complicated by ARDS and nine by lung abscess.

Full airway drainage is the therapeutic principle to halt the pathologic process of traumatic atelectasis. The current method of airway drainage is deep sputum aspiration repeatedly though fiber bronchoscopy or an established artificial airway [13, 14]. Nasal fiber bronchoscopy is becoming popular for its minimal invasion and its accuracy [15], but a great number of patients cannot tolerate repeated treatment within a short period of time [16–18]. Combination of the advantage of artificial airway and fiber bronchoscopy may greatly increase the duration and frequency of deep sputum aspiration as well as the safety [19, 20]. However, it is still difficult for doctors to decide which pathway is to be used for fiber bronchoscopy, nasal or artificial airway, in individual patients until the onset of dyspnea.

Pulmonary contusion may cause ARDS and lung abscess, and whether early establishment of artificial airway and drainage can reduce the complications were rarely reported. Huf [21] reported that early intubation and drainage can reduce the incidence of complications such as ARDS and pneumonia rates. Three hundred seventy-seven patients with lung contusion were evaluated in his study, a reduction of pneumonia rates was found in the group of early intubation and drainage (23.7 to 13.2 %), and the ARDS rate was reduced too, although both differences were not significant (p -pneumonia=0.053, p -ARDS=0.117). But the severity of all the 377 patients was not classified in this study. Most of all, it is difficult to make the decision to create an artificial airway to

drain sputum and blood on the pulmonary contusion patients with atypical manifestations, and related reports were even more rarely. On the other hand, there were no relevant studies comparing the effect of lung lavage by fiber bronchoscopy through the nasal cavity and artificial airway on such occult traumatic atelectasis patients. In our prospective study, we find that earlier establishment of an artificial airway combined with fiber bronchoscopy drainage can reduce the incidence of ARDS (61.1 to 22.7 %) and pulmonary abscess (38.9 to 9.1 %) and shorten the patient's stay in hospital.

Some suggestions are proposed based on these findings. The presence of airway injury and pulmonary atelectasis should be determined as soon as possible in thoracic trauma patients with hemoptysis or unstable oxygen saturation levels. An artificial airway should be established immediately once the diagnosis is clear, and mechanical ventilation should be applied when ARDS occurs. Despite intensive airway nursing and deep sputum aspiration, fiber bronchoscopy should be used when necessary so as to stop bleeding, aspirate sputum, and perform bronchial lavage.

Conclusion

Fiber-optic bronchoscopy is not only of value in the early diagnosis of airway injuries complicated by pulmonary atelectasis but also has a role in the treatment of traumatic atelectasis with the aid of an artificial airway.

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