Severe thoracic trauma caused left pneumonectomy complicated by right traumatic wet lung, reversed by extracorporeal membrane oxygenation support—a case report

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Abstract

Background: Double lumen intubation and one-lung ventilation should be applied without delay in cases of traumatic main bronchial rupture. In most cases, when the patients’ vital signs have been stabilized, the repair can be performed. However, when one-lung ventilation is complicated by traumatic wet lung, the mortality rate is likely to be much higher.

Case presentation: In this case, the patient experienced a left main bronchial rupture, bilateral traumatic wet lung, and acute respiratory distress syndrome (ARDS) because of severe thoracic trauma. Though the patient was treated with intubation and mechanical ventilation (MV), his oxygenation was still not stable. Thus, veno-venous extracorporeal membrane oxygenation (V-V ECMO) was initiated; upon improvement of oxygenation, the patient received an exploratory thoracotomy. Unfortunately, the rupture proved to be irreparable, resulting in a total left pneumonectomy. As there was severe ARDS caused by trauma, ECMO and ultra-low tidal volume (VT) MV strategy (3 ml/kg) were utilized for lung protection post-op. ECMO was sustained up to the 10th day, and MV until the 20th day, post-operation. With the support of MV, ECMO and other comprehensive measures, the patient made a recovery.

Conclusion: V-V ECMO and ultra-low VT MV helped this thoracic trauma patient survive the lung edema period and prevented ventilator associated pneumonia (VAP). In extreme situations, with the support of ECMO, the tidal volume may be lowered to 3 ml/kg.

Keywords: Thoracic trauma, Acute respiratory distress syndrome, Extracorporeal membrane oxygenation, Traumatic wet lung, One lung ventilation

Background

Blunt traumatic thoracic injuries are often seen in traffic accidents. Unlike usual injuries such as lung contusions, pneumothorax and rib fractures, tracheal ruptures or main bronchial ruptures are uncommon [1]. Taken together the analysis of clinical manifestation, bronchoscopy and computed tomography (CT) scan, the diagnosis usually isn’t difficult to make. After double-lumen intubation and one-lung ventilation (OLV), in the absence of any surgical contraindication, the repair can be performed in most cases [2, 3]. Severe lung contusions or traumatic wet lung are the common causes of acute respiratory distress syndrome (ARDS) [4]. The patient had severe ARDS after severe thoracic trauma, the exaggerated response of innate immunity and the amplification of inflammation were important etiologies for ARDS in the early phase. Research has indicated that the mortality of patients with traumatic lung injuries requiring pneumonectomy is as...
high as 70%—100% [5, 6]. In the case here addressed, the left main bronchial rupture was irreparable; consequently, the patient had a total left pneumonectomy. The medical focus of this case is OLV complicated by traumatic wet lung, which made the treatment more intricate and decreased the chances of success. However, with the support of mechanical ventilation, extracorporeal membrane oxygenation (ECMO) and other comprehensive measures, the patient survived the right-side traumatic wet lung and ARDS after the left pneumonectomy.

**Case presentation**

A 47-year-old male patient, who has no specific past medical history, suffered severe thoracic trauma in a forklift accident 14 h before he was transferred to our hospital. After having his chest crushed by a forklift, the patient instantly had hemoptysis and showed serious signs of respiratory distress. At the local hospital, the physical examination revealed pulse oxygen was at approximately 80%; there was subcutaneous emphysema in the neck and chest; breathing was inaudible by auscultation in the left lung; and, there were moist rales in the right lung. The patient immediately received single-lumen intubation and mechanical ventilation (MV). The CT scan showed left-side pneumothorax, right-side pneumo-hemothorax, bilateral traumatic wet lung, and multiple rib fractures. The bronchoscopy also indicated a left main bronchial rupture. Therefore, the patient was treated immediately with bilateral closed thoracic drainage, fluid infusion, and immobilization of the chest wall.

Treatment notwithstanding, there was no alleviation of the patient’s symptoms, and his pulse oxygen remained consistently low (approximately 80%). Consequently, he was transferred directly to our department. The minute ventilation volume was only 2 to 3 L/min by single-lumen mechanical ventilation. Therefore, the single-lumen tube was replaced with a double-lumen tube, with ventilation only to the right lung to prevent leakage. Nevertheless, the patient's pulse oxygen remained low, with no remediation of his respiratory distress. On admission, after running the necessary checks and analyses, with his APACHE II score at 25, the predicted odds of mortality was 51%. His blood gas revealed both respiratory acidosis and metabolic acidosis, with both exacerbating gradually. Figure 1 exhibited the chest x-rays at different times, before pneumonectomy (Fig. 1a) and after the withdrawal of ECMO (Fig. 1b).

At that critical moment, ECMO was initiated without delay. Upon selection of the veno-venous (V-V) ECMO model, catheters were inserted into the right jugular vein (arterial catheter, the tip nearly reached right atrium) and right femoral vein (venous catheter, the tip located at inferior vena cava). Specifically, blood was drawn out from the right atrium to the ECMO device (Maquet, ROTAFLOW Console), after oxygenation it was infused into the right femoral vein, with the gas flow at 4-6 L/min, fraction of inspiration O2 (FiO2) at 100% and the pump operating at 3480—3610 rpm. Upon receipt of ECMO and MV, the patient’s oxygenation stabilized; his pulse oxygen rose to 97%—100%; and his respiratory distress was alleviated significantly, thus permitting urgently needed surgery. With the consent of his family members, the patient had an emergency, video-assisted thoracoscopic exploratory thoracotomy. The edema and consolidation of the entire left lung were severe. 1 cm from the tracheal carina, the postero-lateral wall of the left main bronchus experienced an 8 cm long and irregular rupture, which spread to the distal end of the secondary bronchus of the upper and inferior lobes. The rupture was unable to be ordinarily repaired and anastomosed, so the patient required a total left lung resection. The thoracoscopic pictures during the surgery are exhibited in Fig. 2.

After left lung resection, with the support of ECMO, the parameters of ventilator (PURITAN BENNETT 840) were set as follows, mode: Synchronized Intermittent

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**Fig. 1 a** was the x-ray taken on admission, there were bilateral pneumothorax, bilateral traumatic wet lung, and multiple rib fractures. **b** was the x-ray taken after ECMO was weaned, the condition of the right lung recovered significantly, edema and exudation alleviated; the left lung was removed.
Mandatory Ventilation (SIMV), Frequency(F): 12 times/min, V_T: 200 ml, FiO2: 40%, and positive end expiratory pressure (PEEP): 8cmH2O. Gradually, with ECMO and low tidal volume (V_T) MV (V_T 200 ml) as the main therapy, assisted by anti-inflammatories, antibiotics, sedatives, and analgesics, the patient made a recovery. ECMO was sustained up to the 10th day, and MV until the 20th day, post-operation. After the initiation of ECMO, heparin was micro-pump injected (125u-750u/hour), and activated clotting time (ACT) was monitored every 2 h. ACT was expected to remain between 160 s to 180 s, which was fluctuating between 130 s to 210 s without severe bleeding complication occurring. After the initiation of ECMO, arterial and venous blood gas were tested every 6 h; 24 h before the patient’s ECMO weaning, the gas flow was reduced to 2 L/min; 6 h before weaning to 0 L/min; FiO2 was reduced to 80%, the O2 and CO2 partial pressure of blood gas were dynamically stable, then ECMO was weaned and the related catheters were removed. During the ECMO treatment, infections such as catheter-related bloodstream infection or ventilator associated pneumonia (VAP) should be anticipated, and antibiotics for most gram-negative and some of the sensitive gram-positive bacteria should be applied. In this case, the culture of sputum samples and broncho-alveolar lavage fluid or blood samples were all negative. In the first week after the operation, piperacillin-sulbactam was used to prevent possible lung infections, later to be replaced by imipenem and levofloxacin when the fever and white blood cell count climbed. Ulinastatin, a glycoprotein found in human urine and blood, proved to be a multivalent, Kunitz-type serine protease inhibitor and exhibited moderate anti-inflammatory effects without any immunosuppression side-effects [7]; it was used for immuno-modulation and anti-inflammation in our case. Because the invasive double-lumen intubation and right-side multiple rib fractures caused considerable pain, appropriate analgesics and sedatives were essential for the post-op compliance of the patient. The combination of dexmedetomidine and fentanyl or midazolam and morphine were used alternatively for sedation and analgesia. The alteration reduced the risk of drug accumulation while keeping a satisfying effectiveness. Finally, considering the subcutaneous emphysema in the neck and the edema of bronchial local tissue, a tracheotomy was not performed in the early phase, but a double-lumen tube was retained until the 10th day to cope with possible leakage in the bronchial stump.

**Discussion**

This report was about a patient who underwent severe thoracic trauma, resulting in left main bronchial fracture, traumatic wet lung and pneumothorax in both lungs, and multiple rib fractures, the combination of which was very rare, complicated, and fatal. After closed thoracic drainage for both lungs and one-lung ventilation (OLV), the condition of the patient was still aggravating, manifested as severe ARDS, severe acidosis, and hypotension. The deterioration contraindicated anesthesia and decreased the patient’s chances of surviving major surgery—a sure indication for initiating ECMO treatment. The patient was a middle-aged male with no underlying heart disease, and ultrasound showed cardiac function was normal; thus, V-V ECMO was selected. Regularly, after a pneumonectomy, when the function of the contralateral lung is normal, ECMO and MV may be weaned at an early phase. Here, because severe edema and atelectasis of the patient’s right lung caused severe ARDS, lengthened ECMO and

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**Fig. 2** a, b and c were the thoracoscopic pictures taken during the surgery, there were severe edema and congestion in the local tissue; the rupture was shown from different angles, which was irregular and unable to be repaired. d was the entire left lung after resection, which was dark red, exhibited serious signs of edema and congestion.
Mandatory. The blood flow was sustained at a constant rate of
between 70 to 100% without further reduction in the treat-
sake of lung protection, the FiO2 of ECMO was kept be-
artrial and venous blood gas. In spite of this, for the
repair, concomitantly, the oxygen partial pressure esca-
plantation [12]. Along with the progress in lung injury
is mainly utilized in severe heart failure or heart trans-
prove oxygenation, as well as provide cardiac support, it
oxygenation [9–11]. Since veno-arterial ECMO can im-
prove oxygenation, as well as provide cardiac support, it
is mainly utilized in severe heart failure or heart trans-
plantation [12]. Along with the progress in lung injury
repair, concomitantly, the oxygen partial pressure escala-
ted and the CO2 partial pressure deescalated in both
arterial and venous blood gas. In spite of this, for the
sake of lung protection, the FiO2 of ECMO was kept be-
tween 70 to 100% without further reduction in the treat-
ment. The blood flow was sustained at a constant rate of
4.0–4.5 L/min. As higher FiO2 and blood flow represent-
ing more oxygenation support, would ensure the ventila-
tor functioning at low parameters to protect the injured
lung. In the ECMO treating period, appropriate anti-
coagulation measures should be applied to prevent throm-
ysis from occurring in the device. However, in traum-
atic and post-operation patients, anti-coagulation
might cause severe organ bleeding complications, which
should be alerted during the treatment. A comparatively
higher blood flow means the ECMO would work at a
comparably higher pump speed, which would not only
reduce the risk of blood clotting in the device but also
reduce bleeding complications as less heparin would be
needed. In our case, though the trauma was extensive
and severe, the high blood flow of ECMO and low dos-
age of heparin post-op reduced the bleeding risk ideally.

The robust oxygenation support by ECMO not only
let us keep V_T at 200 ml, F at 12 times/min constantly to
decrease the risk of barotrauma and let the lung have
sufficient rest, but also allowed the FiO2 of ventilator to
be kept constantly at 40%, a relatively low value, to fur-
ter decrease oxidative stress injury and prevent pul-
monary fibrosis. Since OLV and severe acute lung injury
simultaneously exist, low tidal volume ventilation is a
crucial strategy for lung protection. With the support of
ECMO, regardless of the severe lung edema caused by
trauma, the oxygen supply was sufficient and CO2 could
be removed swiftly from the blood. Therefore, V_T could
be lowered to 3.0 ml/kg, which is beneficial for lung re-
pair, but might increase the odds of atelectasis. Lung re-
cruitment maneuvers and selection of an appropriate
PEEP might be suitable measures for coping with this
concern. Though V_T and F were kept low for lung pro-
tection, PEEP was kept at 5–8 cmH2O to prevent lung
atelectasis before ECMO weaning. With reference to
blood gas and chest x-rays, when lung recruitment was
deeded necessary, for the sake of lung protection, a re-
spiratory balloon was used manually to expand the lung,
no other measures taken in this case. The patient had
injured both lungs as well as the pneumothorax in both
sides, any lung recruitment measures that may signifi-
cantly increase airway pressure were not considered.
Recently, similar ultra-low tidal volume, protective
ventilation strategy and extracorporeal CO2 removal
membrane were also used successfully to treat near-fatal
asthma [13]. In extremely severe cases, in combination
with ECMO and MV, prone positioning may provide
some extra respiratory support [14, 15]. The patient’s
multiple rib fractures were the main reason prevented us
from using this therapy; fortunately, after ECMO initi-
ation, the patient’s vital signs stabilized.

Conclusion
Multi-disciplinary cooperation is needed for the treatment
of severe thoracic trauma. A main bronchial rupture may
be complicated by contralateral conditions such as tra-
umatic wet lung, which could dramatically increase treat-
ment difficulty. Severe traumatic wet lung may result in
ARDS, which may need ECMO for advanced life support
when necessary. In the acute lung edema phase, low tidal
volume ventilation should be favored to reduce baro-
trauma as well as to sustain the patient.

Abbreviations
ARDS: Acute respiratory distress syndrome; CT: Computed tomography;
ECMO: Extracorporeal membrane oxygenation; MV: Mechanical ventilation;
PEEP: Positive end expiratory pressure; VAP: Ventilator Associated Pneumonia

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References
1. Klein Y, Cohn SM, Proctor KG. Lung contusion: pathophysiology and management. Curr Opin Anaesthesiol. 2002;15(1):65–8.
2. Lin WT, Su SY, Hsieh CF, Lai CC, Chao CM. Traumatic thoracic burst fracture associated with bronchial rupture. J Emerg Med. 2017;53(2):260–1.
3. Kim HK, Jun JH, Lee HS, Choi YR, Chung MH. Left mainstem bronchial rupture during one-lung ventilation with Robertshaw double lumen endobronchial tube - a case report. Korean J Anesthesiol. 2010;59(Suppl):S21–5.
4. Haider T, Halat G, Heinz T, Hajdu S, Negrin LL. Thoracic trauma and acute respiratory distress syndrome in polytraumatized patients: a retrospective analysis. Minerva Anestesiol. 2017;83(10):1026–33.
5. Karmy-Jones R, Jurkovich GJ, Shatz DV, Brundage S, Wall MJ Jr, Engelhardt S, et al. Management of traumatic lung injury: a Western trauma association multicenter review. J Trauma. 2001;51(6):1049–53.
6. Huh J, Wall MJ Jr, Estrella AL, Soltero RR, Mattox KL. Surgical management of traumatic pulmonary injury. Am J Surg. 2003;186(6):620–4.
7. Haniuda M, Morimoto M, Sugeno Y, Iida F. Suppressive effect of ulinastatin on plasma fibronectin depression after cardiac surgery. Ann Thorac Surg. 1988;45(2):171–3.
8. Cordell-Smith JA, Roberts N, Peek GJ, Firmin RK. Traumatic lung injury treated by extracorporeal membrane oxygenation (ECMO). Injury. 2006;37(1):29–32.
9. Chen TH, Shih JY, Shih JJ. Early percutaneous heparin-free Veno-venous extra corporeal life support (ECLS) is a safe and effective means of salvaging hypoxemic patients with complicated chest trauma. Acta Cardiologica Sinica. 2016;32(1):96–102.
10. Skarda D, Henniksen JW, Rollins M. Extracorporeal membrane oxygenation promotes survival in children with trauma related respiratory failure. Pediatr Surg Int. 2012;28(7):711–4.
11. Liu C, Lin Y, Du B, Liu L. Extracorporeal membrane oxygenation as a support for emergency bronchial reconstruction in a traumatic patient with severe hypoxaemia. Interact Cardiovasc Thorac Surg. 2014;19(4):699–701.
12. Kim HK, Kim KJ, Jung SW, Mun HS, Cho JR, Lee N, et al. Successfully treated acute fulminant myocarditis induced by ulcerative colitis with extracorporeal life support and infliximab. J Cardiovasc Ultrasound. 2016;24(2):163–7.
13. Pavot A, Mallat J, Vangrunderbeek N, Thevenin D, Lemyze M. Rescue therapeutic strategy combining ultra-protective mechanical ventilation with extracorporeal CO2 removal membrane in near-fatal asthma with severe pulmonary barotraumas: a case report. Medicine. 2017;96(41):e8248.
14. Voggenreiter G, Aufmkolk M, Stiletto RJ, Baacke MG, Waydhas C, Ose C, et al. Prone positioning improves oxygenation in post-traumatic lung injury—a prospective randomized trial. J Trauma. 2005;59(2):333–41 discussion 41-3.
15. He H, Wang H, Li X, Tang X, Wang R, Sun B, et al. Successful rescue combination of extracorporeal membrane oxygenation, high-frequency oscillatory ventilation and prone positioning for the management of severe methicillin-resistant Staphylococcus aureus pneumonia complicated by pneumothorax: a case report and literature review. BMC Pulm Med. 2017;17(1):103.