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CASE REPORT / *OLGU SUNUMU*

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The Success of ECMO in Flail Chest and ARDS Following Thoracic Gunshot Wound

Ateşli Silahla Toraks Yaralanması Sonrası Yelken Göğüs ve ARDS Gelişen Hastada Veno-venöz ECMO Kullanımı

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ABSTRACT Extracorporeal membrane oxygenation (ECMO) may be the last option in patients with severe acute respiratory distress syndrome (ARDS) in whom conventional methods have failed. The best results are obtained in patients with severe ARDS after trauma. Injured lungs can recover completely with ECMO therapy. A 44-year-old male patient was brought to the emergency department after sustaining severe thoracic gunshot injury. The patient was rushed into emergency surgery; however, pneumonectomy could not be performed due to morphological variation and widespread contusion in the lungs. The patient had flail chest with extensive damage of the ribs. Titanium plates could not be placed, as there was a major loss in the bone tissue. After cutting the fractured rib ends, the open chest wall was repaired with dual mesh and covered with serratus and latissimus dorsi muscles. However, the flail chest could not be corrected. During the follow-up in the intensive care unit, the patient developed ARDS and conventional therapies were unsuccessful. Thus, ECMO was used to allow lung healing. ECMO treatment was continued for seven days and was completed without any complications. The patient was transferred to the regular ward after 29 days. ECMO can be used as a life-saving treatment that allows lung healing in case conventional treatment methods have failed.
Keywords: Flail chest, ARDS, ECMO, gunshot, trauma injury

ÖZ Konvansiyonel yönetimin başarısız olduğu şiddetli akut respiratuvar distres sendromu (ARDS) olan hastalarda ekstrakorporeal membran oksijenasyonu (ECMO) son seçenek olarak kullanılabilir. En iyi sonuçlar travma sonrası şiddetli ARDS olan hastalarda elde edilmektedir. Yaralanan akciğerler ECMO tedavisi ile tamamen iyileşebilir. Acil operasyona alınan hastaya akciğerindeki morfolojik varyasyon ve yaygın kontüzyon nedeniyle pnömonektomi yapılamadı. Kotlarda büyük bir hasarı olan hastada yelken göğüs mevcuttu. Kemik dokuda büyük kayıp mevcut olduğundan kotlara çelik plak koyulamadı. Hastanın fraktüre kosta uçları kesildikten sonra dual mesh ile açık olan göğüs duvarı onarıldı ve üzeri serratus ve latissimus dorsi kaslarıyla kapatıldı. Yelken göğüs düzeltilemedi. Yoğun bakım takibinde akut respiratuvar distres sendromu gelişen hastada konvansiyonel yönetimle başarı sağlanamadı ve akciğerlerin iyileşmesine imkan sağlamak amacıyla ECMO kullanıldı. Hastaya uygulanan ECMO tedavisi 7 gün sürdü ve herhangi bir komplikasyon olmaksızın tamamlandı. Hasta 29 gün sonra servise transfer edildi. Bu olgu sunumunda ateşli silah ile ciddi toraks yaralanması sonucu acil servise getilen 44 yaşında erkek hastada konvansiyonel yönetimle başarı sağlanamadığından akciğerlerin iyileşmesine imkan sağlayan hayat kurtarıcı bir tedavi olarak ECMO'nun kullanımını bildiriyoruz.
Anahtar Kelimeler: Yelken göğüs, ARDS, ECMO, ateşli silah, travma yaralanma

Introduction

Severe thoracic injuries are responsible for 25% of deaths caused by trauma (1). Thoracic injuries can be caused by penetrating or blunt traumas. Penetrating traumas may include sharp object injuries and gunshot injuries (2).

It was reported in the literature that flail chest can develop secondary to the disruption of the chest wall anatomy when two or more ribs are fractured as a result of severe thoracic trauma (3). Flail chest is characterized by a free chest wall segment moving independent from the rest of the chest wall. Severe pain occurs as a result of paradoxical chest segment movement and muscle spasm, and this prevents the formation of adequate tidal volume and causes the formation of atelectatic regions in the lung. The presence of accompanying hemothorax, pneumothorax, and lung contusion further aggravate the condition (3). Flail chest occurs in approximately 10% of patients with chest trauma. The presence of flail chest alone is related to a mortality rate between 10% and 15% (4). The degree of ventilation-perfusion mismatch and progressing hypoxemia determines morbidity and mortality (3).

Acute respiratory distress syndrome (ARDS) is one of the complications that may develop during the follow-up of trauma patients in the intensive care units (5). Bilateral pneumonia and pulmonary causes including aspiration along with secondary causes such as sepsis, trauma, and massive transfusion are among the causes of ARDS (6). ARDS is characterized by new onset hypoxemia and bilateral pulmonary infiltrations consistent with pulmonary edema that is not caused by the heart failure (7). Despite the improvements in intensive care in recent years, mortality and morbidity rates are still high in patients with ARDS (8).

There is a particularly interest to the treatment of thoracic trauma due to its high mortality and morbidity rates. There are ongoing improvements in this field. Currently, lung-protective noninvasive ventilation protocols are used along with early extubation in order to prevent ventilation-related lung damage (9). In cases where other rescue strategies have failed, extracorporeal membrane oxygenation (ECMO) is recommended as a further treatment method for severe ARDS (10). The use of ECMO can improve the outcomes in severely injured patients even in conditions such as hemorrhagic shock or coagulation disorder (11).

In this case report, our aim was to present successful use of ECMO in a patient who developed flail chest and extensive lung contusion as a result of severe thoracic gunshot injury and who subsequently developed ARDS.

Case Report

A 44 year-old male patient was brought to the emergency department after sustaining thoracic gunshot injury. The entrance hole of the bullet was at the level of left lateral 6th rib and the exit hole was around the left scapula. In the initial evaluation at the emergency department, it was determined that the patient' general condition was poor, he was conscious, agitated, his blood pressure was 90/60 mmHg, pulse rate was 115 bpm, and respiratory rate was 22 breaths per minute. Transthoracic echocardiogram showed normal findings. Thoracic computed tomography (CT) scans obtained in the emergency department (Figure 1) revealed laceration and contusion in the upper lobe of the left lung, displaced fractures in the lateral sections of the 2nd-6th ribs in the left hemithorax, pleural effusion, and pneumothorax.

After informing the patient's relatives and obtaining written informed consent, the patient was rushed into the operation room for emergency surgery. The patient experienced cardiopulmonary arrest during monitoring. Cardiac rhythm was restored after endotracheal intubation with double lumen tube and concurrent cardiopulmonary resuscitation for 30 seconds. Catheters were inserted into the right internal jugular vein and right radial artery. The patient has hypotension; 20 μcg/kg/min dopamine and 0.8 μcg/kg/min noradrenaline infusion was initiated in addition to fluid replacement therapy.

The operation was started urgently with left posterolateral thoracotomy. There was massive injury and bleeding in the left lung of the patient. 1,500 mL hematoma was evacuated from the thoracic cavity. It was observed that the patient had lung malformation and the left lung had three and the right lung had two lobes. There were multiple fractures in the left 3rd-7th ribs, laceration in the upper lobe of the left lung, and severe contusion in the other two lobes of the left lung and both lobes of the right lung.

The patient developed deep hypoxemia and hypotension when the left main bronchus was clamped for the purpose of pneumonectomy. It was thought that this condition was caused by the contusion in both lobes of the right lung. Clamp was dislodged and pneumonectomy was abandoned. Lacerated areas in the parenchyma were repaired. The defect in the left chest wall of the patient was large and there was flail chest. Plate could not be placed, as there was extensive damage in the bone tissue. After the fractured rib ends were cut, the open chest wall was repaired with dual mesh and covered with serratus and latissimus dorsi muscles. Flail chest could not be repaired. The operation was completed by inserting 2 chest tubes to the left hemithorax. A total of 6 U of erythrocyte suspensions and 4 U of fresh frozen plasma were transfused during the operation.

The patient remained intubated after surgery and he was transferred to the intensive care unit. The patient was connected to the mechanical ventilator in Synchronized Intermittent Mandatory Ventilation (P-SIMV) mode [FiO_2:

60%, positive end-expiratory pressure (PEEP): 10 cm H_2O, PS: 14 cm H_2O, f: 12 dk^{-1}] and monitorization was started. Piperacillin-tazobactam (4x4.5 g IV) was initiated as antibiotherapy. Midazolam (7 mg h^{-1} IV) and remifentanil (0.5 µg kg^{-1} dk^{-1} IV) infusions were initiated for the purpose of sedoanalgesia, as the patient had flail chest. Not necessary noradrenalin and dopamine infusions.

The patient developed persistent hypoxemia, respiratory acidosis, and hypotension in postoperative day 4 when he was still intubated and connected to the mechanical ventilator in the SIMV mode. In arterial blood gases analysis, pH was 7.24, PCO_2 was 73.6 mmHg and PaO_2 was 64.2 mmHg, when positive end-expiratory pressure (PEEP) was 12 cm H_2O and respired oxygen (FiO_2) was 100%. The patient was evaluated according to the Berlin Criteria (12). PaO_2/FiO_2 was ≤100 mmHg + PEEP was ≥5 and the patient was considered to have severe ARDS. It was decided to perform veno-venous (VV) ECMO along with the use of treatment methods and optimal mechanical ventilation in order to promote lung healing. Respiratory Extracorporeal Membrane Oxygenation Survival Prediction Score was determined as 1, and the chance of survival with ECMO was determined as 57%. The patient was connected to ECMO at postoperative day 5 (13).

Cannulation was performed with Maquet cannula (24 and 22 F) for drainage in the right femoral vein and for infusion in the right internal jugular vein. Medos oxygenator was then set to O_2 of 100%, flow of 3.5 L/min, and speed of 7500/min. Heparine 1000 IU IV bolus was administered for anticoagulation in the ECMO circuit and then IV infusion was initiated at a rate of 500 IU/hr. The aPTT was kept between 60-80 sec. and the ACT value was kept between 180-220 sec. Deep sedoanalgesia was provided with ketamine (0.5 mg kg^{-1} h^{-1}), midazolam (7 mg h^{-1}) and remifentanil (0.5 µg kg^{-1} dk^{-1} IV) infusion.

The mechanical ventilation mode during ECMO was set to pressure-controlled mode. The patient was ventilated with 200 mL tidal volume by setting the frequency to 5/min, FiO_2 to 0.4, PEEP to 10 mmHg, and auto-PEEP pressure to 8 mmHg. The average airway pressure was between 17-20 mmHg.

An improvement was observed in the arterial blood gases 24 hours after connecting the patient to ECMO device. It was determined that pH was 7.354, pCO_2 was 44.0 mmHg, and pO_2 was 90.3 mmHg.

The secretions and blood clots in the airway of the patient were cleaned by bronchoscopy performed 3 times with one-day interval between days 2 and 6. The patient had fever and infiltrative appearance in the lungs after initiation of ECMO, and vancomycin (Loading dose: 35 mg kg^{-1} 4 h^{-1}, 30 mg kg^{-1} 24 h^{-1}) and meropenem (Loading dose: 4 g, 6x1 in 3 h^{-1} infusion) were started according to the culture-antibiogram results. Moreover, HA-330 sepsis adsorbtion column with separate catheter from ECMO was used for two hours a day for 5 days.

Thoracic CT scans obtained in the 2nd day of ECMO (Figure 2) revealed widespread contusion areas and pneumatocele measuring 4 cm in diameter with an impacted metallic foreign body in millimetric size in the upper lobe of the left lung, pleural effusion reaching 15 mm thickness in the left hemithorax. The patient has 2 chest tubes to the left hemithorax and 1 chest tubes to the right hemithorax. Widespread contusion in the upper lobe of the right lung, and subpleural focal thickening and linear densities in the lower lobe.

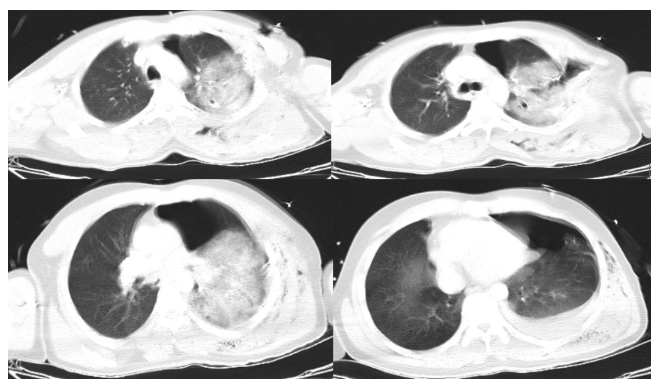

Figure 1. Thoracic computed tomography image obtained upon admission to the emergency department

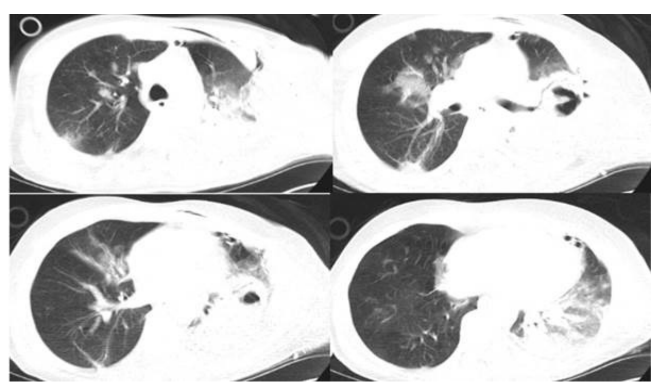

Figure 2. Computed tomography image obtained in the 2nd day of extracorporeal membrane oxygenation

On the 6th day of ECMO, mechanical ventilator was set to a frequency of 12/min, FiO_2 of 0.6, and above PEEP: 14 cm H_2O. The oxygenator was set to O_2 40% and a flow of 3.5 L/min. Arterial blood gases of the patient were stabilized; ECMO cannula was clamped and removed and ECMO was discontinued at day 7 without any complications.

Percutaneous tracheostomy was opened at postoperative day 14. While the patient was tracheostomized and connected to the mechanical ventilator in P-SIMV mode (FiO_2: 60%, PEEP: 10 cm H_2O, PS: 14 cm H_2O, f: 10 dk^{-1}), thoracic CT scans (Figure 3) obtained at postoperative day 16 revealed a consolidated area of 4 cm in diameter located in the upper lobe of the left lung, passive atelectatic densities in the basal segments of the lower lobe of both lungs, volume loss in the left hemithorax, pleural effusion in both hemithoraces that was more prominent in the right side, and edematous thickening in the lateral wall of the left hemithorax.

The medications started for the purpose of sedoanalgesia were discontinued at postoperative day 16 to prepare the patient for weaning, as the patient's vital findings were stable and arterial blood gases returned to normal levels. The patient was transferred from the intensive care unit to the department of thoracic surgery 29 days after cessation of ECMO therapy. The patient was discharged as mechanical ventilation treatment discontinue and decanulation after 4 days of hospitalization for follow-up with the advice of attending control visit at the outpatient clinics. Control chest X-ray performed 3 months after the discharge showed that the lungs almost completely recovered (Figure 4).

Figure 3. Thoracic computed tomography scan obtained at postoperative day 16

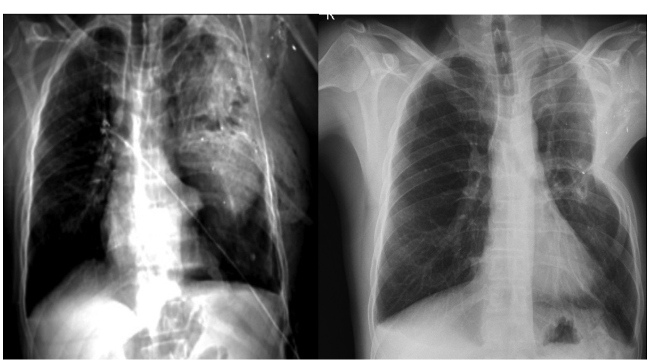

Figure 4. Posteroanterior chest X-ray on admission and 3 months after discharge

Discussion

Hemothorax, pneumothorax and lung contusion accompanying the flail chest that may develop after thoracic trauma may further aggravate the existing pathology (3). It has been reported in some studies that mechanical ventilation time and pulmonary complication rates increase in the presence of flail chest along with pulmonary contusion after thoracic trauma (14). ARDS is one of the complications which may develop as a result of these pathologies (15).

The treatment of flail chest that may develop as a result of severe thoracic trauma can be surgical and non-surgical depending on the extensiveness of the damage and the state of the patient (3). The studies in the literature reported shorter stay in the intensive care unit, decrease in the need of mechanical ventilator, decrease in the hospitalization time, and lower incidence of pneumonia and tracheostomy, and lesser need for re-intubation in patients with flail chest who underwent surgical stabilization (14). In our case, the defect in the chest wall was very extensive and the rib damage was severe; thus, surgical stabilization could not be performed and the defect was covered with a mesh. Flail chest could not be corrected surgically.

The presence of bilateral widespread lung contusion and extensive tissue defect in the left hemithorax in addition to flail chest were the factors that paved the way for the development of ARDS. Moreover, there was a morphological variation in our case with 2 lobes in the right lung and 3 lobes in the left lung. During surgery, left-sided pneumonectomy could not be performed due to extensive contusion and morphologic variation in the other lung. The lacerated areas in the parenchyma were repaired and the patient was taken to the intensive care unit. The patient developed ARDS at postoperative day 4 while he was on follow-up in the intensive care unit.

There are various anatomic variations reported in the literature. In their study, Thapa and Suresh (16) found that the prevalence of 2 lobes in the right lung as in our case was 20%. However, this rate varies between 6.8% and 40% when other studies are examined (16). In terms of encountering three lobes in the left lung, accessory fissure was encountered in the left lung in 10% of the cadavers in the study by Meenakshi et al. (17).

ARDS is a condition which can develop after thoracic trauma and which severely affects the clinical status of the patient (10). The prevalence of ARDS in trauma patients is reported to be 4.6% (10). The mortality rate can reach 60% in patients with severe ARDS (18). ECMO can be a life-saving option in cases where conventional treatment methods have failed (10).

Since respiratory failure was more prominent in our case, we used VV ECMO with drainage from the right femoral vein and return from the right internal jugular vein. We did not encounter any complications during the cannulation procedure or the use of ECMO.

In the literature, there has been an increase in the number of publications regarding the use of ECMO in cases with severe ARDS in recent years. In the CESAR study analyzing 180 patients with severe respiratory failure, conventional treatment and ECMO groups were compared and mortality or severe morbidity was detected in 37% of the patients in the ECMO group and 53% of the patients in the conventional treatment group. According to the results of this study, the authors concluded that ECMO therapy can significantly increase survival without causing severe disability in patients with severe but potentially reversible respiratory failure (19).

Survival rates ranging from 39.4% to 68% have been determined in other studies evaluating ECMO use and survival rates in patients with severe ARDS (1,20). Moreover, in 2018, in the study conducted on patients who developed ARDS after avian flu, Huang et al. (21) concluded that ECMO is effective in improving oxygenation and ventilation. They detected that starting ECMO at the early period with appropriate intermittent positive-pressure ventilation settings and anticoagulation strategies decreases complications.

In some studies examining the factors affecting survival, it has been stated that advanced age, prolonged ventilation time before ECMO, diagnosis of the patient, high minute ventilation requirement, and development of complications during ECMO are related to mortality (1). Young age of the present patient, shorter ventilation time before ECMO (4 days), and lack of comorbidities and lack of complications during ECMO were factors that had a positive effect on the survival of our patient.

In conclusion, we believe that the use of ECMO in the early period in order to decrease lung damage and provide healing in the presence of severe lung problems such as flail chest and severe ARDS developing after thoracic gunshot injury will have a significant effect on the survival of the patient.

Ethics

Informed Consent: We had all necessary consents from patients involved in the study, including consent to participate in the study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.Y., Concept: A.Y., Design: A.Y., Data Collection or Processing: C.K.K., Analysis or Interpretation: A.Y., Literature Search: O.U., Writing: A.Y.

Conflict of Interest: No conflict of interest was declared by the authors.

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