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Saved by the PEEP: Resolution of Complete Unilateral Lung Collapse Secondary to Mucus Plugging With Ventilator Technique

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Abstract

Bronchoscopy can be used to resolve respiratory failure caused by tenacious mucus plugs. However, emergent bronchoscopy to resolve mucus plugging is not always available in small rural hospitals around the country. We present a case in which increasing the positive end-expiratory pressure settings on the ventilator resulted in immediate improvement in patient oxygenation and imaging findings during a respiratory emergency caused by mucus plugging.

Keywords

positive end-expiratory pressure, mucus plug, mechanical ventilation, critical care, PEEP, mucus plugging and ventilatory settings

Introduction

Mucus is a normal product of the tracheobronchial tree consisting of mucin, ion, water, protein, and lipids.[1] However, some pathological processes in the respiratory system can cause mucus to become abnormally thick in consistency, forming a mucus plug.

Mucus plugging can sometimes lead to respiratory compromise. Initial management involves proper hydration, humidification, bronchodilation, and use of mucolytic agents via nebulization.[1] However, these measures do not always suffice and advanced bronchoscopy may be required. We present a case whereby mucus plugging was resolved using appropriate ventilatory technique in the absence of bronchoscopy.

Case Report

A 65-year-old woman with history of breast cancer presented with complaint of decreased food intake and general decline in health. She was hypotensive on arrival with elevated lactic acid and procalcitonin. Computed tomography (CT) scan of the abdomen and pelvis revealed ileus and possible small bowel obstruction with mild opacities at bilateral lung bases.

Sepsis protocol was initiated with administration of weight-based fluid boluses and empiric antibiotics.

Surgery was consulted and initiated patient on nasogastric tube to intermittent suction. Patient's hospital course was complicated with worsening hypoxia and encephalopathy requiring endotracheal intubation. She was extubated 2 days later in the early morning hours.

However, later that night, patient became increasingly tachypneic and hypoxic requiring re-intubation. Her endotracheal (ET) tube was set at 23 cm. Her fraction of inspired oxygen (FiO_2) was set at 100%, tidal volume (VT) at 6 mL/kg, and positive end expiratory pressure (PEEP) at 10 cm H_2O.

Chest X-ray (CXR) performed after re-intubation revealed mildly worsening left lower lobe opacity. It also showed optimal placement of ET tube, with ET tube being 4 cm above the carina. 1.5 hours later, patient decompensated with oxygen saturation in the 40s. Bag mask ventilation was initiated with her saturation mildly improving to the 60s.

Stat CXR obtained showed complete opacification of the left lung with leftward shift of mediastinum and volume loss suggestive of mucus plugging. Endotracheal tube was retracted from original 23 cm to 21 cm. In addition, ET tube was suctioned and patient received Mucomyst via nebulization; however, her oxygen saturation did not improve.

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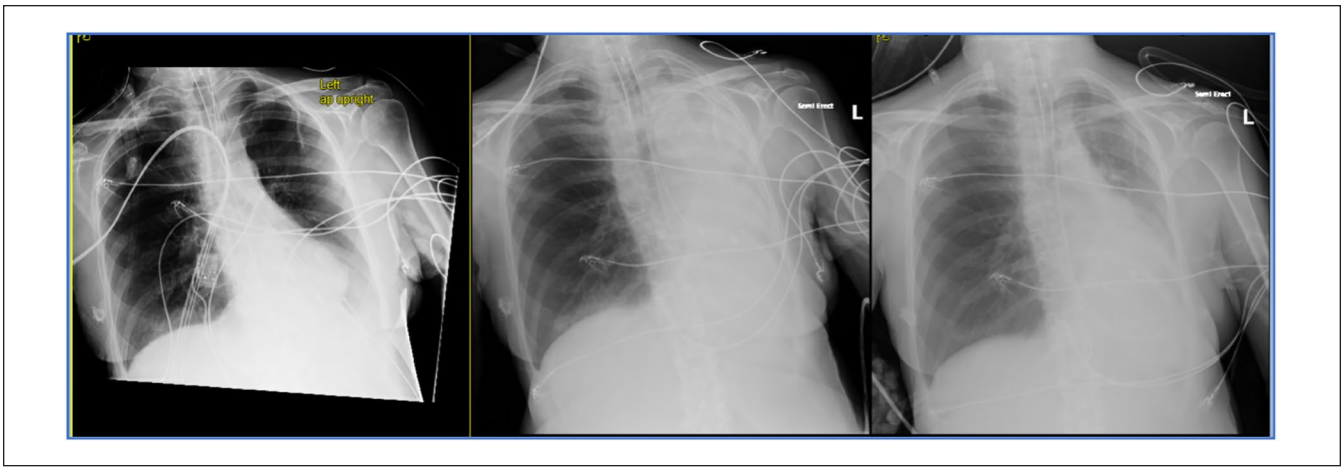

Figure 1. From farthest left (L on the imaging) to right.
Left: CXR obtained soon after re-intubation; Middle: CXR obtained 1.5 hours after intubation; Right: CXR obtained 6 hours after increasing PEEP.
Abbreviations: CXR, chest X-ray; PEEP, positive end-expiratory pressure.

Emergent bronchoscopy was not available, so patient's PEEP was increased from 10 to 16 cm H_2O leading to increase in her oxygen saturation to the mid 90s. The rest of her ventilation settings remained the same, VT of 400 mL and FiO_2 of 100% on assist-control volume control ventilation. Repeat CXR obtained showed resolution of left lung collapse.

Discussion

Our patient likely had complete left lung collapse caused by mucus plugging of the lower airways. This mucus plugging was likely as a result of aspiration of abdominal contents in setting of ileus/small bowel obstruction and altered mental status. Endotracheal suctioning can be used to clear secretions but is limited to the upper, larger airways.[2] Mucus plugs can clog the segmental airways and cause resistance to airflow. This resistance might be worse in patients with emphysema who have lost their collateral airways. When thick secretions and mucus plugs cause occlusion in smaller airways, they cause life-threatening ventilation/perfusion mismatch and impaired gas exchange that can be fatal if the obstruction is not relieved in a timely manner. Emergent bronchoscopy can allow retrieval of the mucus plugs and secretions from these airways and relieve the obstruction. However, in cases where bronchoscopy is not readily available, increasing PEEP can assist in dislodging large mucus plugs.[3]

Positive end expiratory pressure by definition maintains pressure at the end of expiration, thereby maintaining recruited alveoli and preventing their collapse. Increasing PEEP can cause redistribution of gas to the distal airways, overcoming respiratory resistance and opening airways previously collapsed by mucus and dislodging such mucus.[4]

This technique has also been used in animal studies with pigs to enhance mucociliary clearance[5] but not much has been reported in human studies.

Another technique, positive expiratory pressure (PEP), has been used noninvasively in patients with cystic fibrosis[6,7] to enhance clearance of mucus and overcome airway resistance; however, this technique is different from PEEP in that it only provides expiratory resistance without an additional overpressure at the end of expiration.

With PEEP, an extra pressure is required in addition to the expiratory resistance, in order that the pressure does not drop at the end of the expiration.[8]

Some other studies have also reported on the use of "PEEP-ZEEP" maneuver[9] in which the PEEP is increased to 15 cm H_2O with peak inspiratory pressure limited to 40 cm H_2O and then rapidly decreased to 0 cm H_2O (ZEEP) to generate an expiratory flow bias where the peak expiratory flow (PEF) is greater than the positive inspiratory flow (PIF). This expiratory flow bias helps propels mucus toward the glottis.

However, this technique has only been studied in combination with other mucociliary clearance techniques such as ventilator hyperinflation and expiratory rib cage compression.[3,10]

Our case report highlights a new technique that could possibly clear mucus plugging and reverse collapse of airways in an emergent situation by overcoming segmental airway resistance and potentially dislodging the mucus from occluded airways.

However, this technique should be used with discretion as high PEEP can be detrimental to patients with lower levels of recruitable lung by causing overdistension of the areas of the lung that are already open, leading to further lung injury.[11,12] This can be observed by decreases in oxygen saturation with higher PEEP levels.

It is worth noting that the optimal level of PEEP required to increase arterial oxygenation lies in the balance between the number of recruited alveoli that participates in ventilation and the amount of lung that is overdistended when PEEP is applied.[13,14]

Over the years, different strategies have been proposed to determine optimal PEEP level in patients. The National Institutes of Health ARDS Network designed a table that adjusted PEEP levels with FiO_2 levels to maintain a balance that prevents overdistension and circulatory depression while improving oxygenation without oxygen toxicity.[15]

Another randomized trial studied the impact of increased recruitment of alveoli while limiting hyperinflation by increasing PEEP until inspiratory plateau pressures of 28 to 30 cm of water.[16] While this did not decrease mortality, it did improve lung function and decrease the duration of mechanical ventilation and organ damage.

An older study in 1975[17] attempted to predict the optimal level of PEEP by measuring respiratory system compliance (Crs). Compliance was obtained by dividing the VT by the difference between the plateau pressure and positive end-expiratory pressure. It is worth noting that this difference between plateau pressure and PEEP is called driving pressure and later studies would expand more on it.[18]

The authors found that oxygen transport was maximal when tidal ventilation takes place on the steepest part of the patient's pressure-volume curve—that is, when the highest compliance is achieved. An increase in compliance was achieved with the re-expansion of atelectatic areas by PEEP as well as increase in resting lung volume produced by the increase in airway pressure.

However, the authors found that "best PEEP" varied among patients and higher levels of PEEP were more beneficial in patients with low functional residual capacity (FRC) who needed higher recruitment of alveoli. In contrast, patients with high FRC levels such as patients with emphysema were harmed by higher levels of PEEP given that their alveoli were already near maximum distention.

Another study suggested that driving pressure may also be used as a tool to help set PEEP.[18] In patients without respiratory effort, driving pressure is the plateau airway pressure minus the PEEP. Mathematically, it is a ratio of VT divided by Crs.[19] It has been hypothesized that adjusting PEEP to lower driving pressures ($<$14-16 cm H_2O) could help reduce mortality by increasing lung compliance without causing overdistension.[20]

Another suggested strategy is adjusting PEEP using transpulmonary pressures which is the difference between alveolar and pleural pressures. Although not often used, this strategy may be needed in the most critical patients such as patients with ARDS and obesity. Transpulmonary pressures can be measured by insertion of esophageal balloons. The esophageal pressure acts as a surrogate for pleural pressure,[21] and the rationale is to adjust PEEP to values assuring a positive end-expiratory transpulmonary pressure of 0 to 10 cm H_2O.[22] Based on the definition of transpulmonary pressure, titration of mechanical ventilation to these values would avoid end-expiratory alveolar collapse.

In conclusion, our patient did not suffer any pneumothorax or lung injury from the use of high PEEP, and although she died 2 weeks later for other reasons, our brief recruitment of her airways helped solve a respiratory emergency in the middle of the night in the absence of emergent bronchoscopy.

Conclusion

Increasing the ventilator PEEP settings can be a temporizing measure to clear smaller airways of mucus plug in respiratory emergencies when emergent bronchoscopy is not available.

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Prior Presentation of Abstract Statement: This case report has not been presented elsewhere.

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Ethics Approval

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Informed Consent

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