Pulmonary edema and hemorrhage as complications of acute airway obstruction following anesthesia

Irena Agnietė Marchertienė, Andrius Macas, Aurika Karbonskienė
Department of Anesthesiology, Kaunas University of Medicine, Lithuania

Key words: airway obstruction; pulmonary edema; pulmonary hemorrhage; ketamine anesthesia.

Summary. Airway obstruction is a quite common complication while its conditioned pulmonary edema – rare. Causes associated with anesthesia are various. Forced inspiratory efforts against an obstructed upper airway generate peak negative intrathoracic pressure. This may cause pulmonary edema and in some cases pulmonary hemorrhage. Last-mentioned is extremely rare.

Pulmonary edema may arise soon after airway obstruction as well as later, after some hours. Damage of bronchi is found seldom during bronchoscopy in case of pulmonary hemorrhage, while more often alveolar damage is observed due to alveolar membrane damage. Hemorrhage is conditioned by hydrostatic pressure level, level of hypoxia, damage to bronchi or alveoli (disruption of alveolar membrane).

Early diagnosis of negative-pressure pulmonary edema or pulmonary hemorrhage is very important, because this affects postoperative morbidity and mortality of the patients.

Two cases of pulmonary edema and hemorrhage after upper airway obstruction as well as literature overview are presented in this article. Pulmonary hemorrhage developed during anesthesia with ketamine, conditioned by increment of hydrostatic pressure, hypoxia, and effects of ketamine on hemodynamics.

Background
Negative-pressure pulmonary edema (NPPE) as a complication of upper airway obstruction is well known and it has been described in the literature on anesthesia since 1977 (1). The incidence of NPPE among complications of general anesthesia reaches 0.1% according to different authors (2, 3). In pediatric patients, this complication is observed even more often (9.4–9.6%) (4, 5).

As this condition might be life threatening, NPPE is an important cause of perioperative morbidity and mortality (6–9).

Its mechanism is upper airway obstruction and subsequent increase in negative intrathoracic pressure (10). This results in increased preload to right parts of the heart, causing increment of hydrostatic pressure in pulmonary capillaries, which subsequently leads to fluid transudation to alveoli (11). Typical clinical findings such as frothy sputum and easily recognizable radiological changes are observed. Pulmonary hemorrhage following upper airway obstruction is an extremely rare phenomenon. Vasoconstriction due to hypoxia and hyperadrenergic state is among possible factors for the development of such edema and hemorrhage.

Further, we report two cases: severe postobstructive pulmonary edema following laryngospasm in a pediatric patient and negative-pressure pulmonary hemorrhage during ketamine anesthesia in an adult patient.

Case 1
A 14-year-old boy (weight, 53 kg) was hospitalized to the Clinic of Pediatric Surgery for an urgent appendectomy. His medical history and preoperative examination did not reveal any signs of pathology. The diagnosis of appendicitis was based on echoscopic findings. The decision to perform appendectomy was made within one hour after hospitalization. Anesthesia was induced with 450 mg of sodium thiopental, 100 µg of fentanyl citrate, and 25 mg of atracurium besylate. Tracheal intubation, anesthesia,
mechanical ventilation, and surgery were uneventful. Anesthesia was maintained with halothane (minimum alveolar concentration (MAC), 0.7–0.8) and 200 μg of fentanyl citrate. During the procedure, the patient had stable blood pressure and oxygen saturation (SpO₂ 98–99%); ETCO₂ ranged from 32 to 36 mm Hg. The duration of surgery was 50 min. A volume of 1000 mL of Ringer lactate solution was administered (the patient did not receive any infusion therapy the day before surgery).

When the operation ended and the patient woke up, endotracheal tube was removed. After the extubation, intensive cough has started. The patient became agitated, and marked inspiratory stridor developed. Status was assessed as laryngospasm. The anesthesiologist attempted to ventilate the patient through the mask; despite this, oxygen saturation has decreased to 80%.

After administration of 5 mg diazepam and 100 mg succinyl methonium, the patient was re-intubated and ventilated at a fraction of inspired oxygen (FiO₂) of 1.0. SpO₂ increased to 96–98%. After 30 min, the patient was woken up with SpO₂ of 98–99% at FiO₂ of 0.6. Cardiovascular status was stable. Respiratory sounds were normal. The patient was extubated because of intolerance to endotracheal tube.

After the extubation, severe inspiratory stridor (laryngospasm) reoccurred. Inspiratory efforts were insufficient despite active work of respiratory muscles. He continued to make inspiratory “crowing” sounds. Oxygen therapy through mask was ineffective during 15 min; hypoxia (SpO₂ 96–78%), hypercapnia (ETCO₂ 39–50%), and tachycardia (up to 120 beats/min) have progressed. Sodium thiopental at a dose of 100 mg and succinyl methonium at a dose of 50 mg were administered, and the patient was re-intubated again. Auscultation revealed moist rales. During suction, foamy secret was evacuated from the endotracheal tube. This status was defined as postobstructive pulmonary edema. The diagnosis was confirmed by x-ray examination (signs of stasis and interstitial changes in both lungs). Mechanical ventilation with application of positive-end expiratory pressure (up to 6 cm of water) was continued. After the stabilization of status (FiO₂ 0.7, SpO₂ 96%, ETCO₂ 45 mm Hg), the patient was transferred to pediatric intensive care unit continuing mechanical ventilation with a portable mechanical ventilator.

The patient was sedated by intravenous administration of diazepam and ventilated for 9 h applying positive end expiratory pressure (PEEP) regimen up to 5 cm of water, later – continuous positive airway pressure (CPAP) regimen. During all this period, foamy secret was evacuated from the endotracheal tube. The need of oxygen therapy was decreased progressively during the following day. The patient was extubated only after 24 h. Chest x-ray examination performed after 9-hour mechanical ventilation revealed a progressive resolution of pulmonary edema – interstitial changes in the right upper lobe were still observed despite reduction of edema signs in other parts of the lungs. Regressing rales were auscultated for 36 hours. The patient was discharged to a regular ward, the Department of Pediatric Surgery, after 34 h from the admission to the pediatric intensive care unit (PICU). Further postoperative period was uneventful. The patient was successfully discharged for outpatient follow-up on the 7th day of hospitalization. Changes in blood gases are presented in Table.

### Case 2
A 40-year-old man was admitted for urgent surgery due to acute paraproctitis. Previously subjectively healthy patient had no complaints except tenderness

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before last intubation</th>
<th>2 hours after admission to PICU</th>
<th>4 hours after admission to PICU</th>
<th>12 hours after admission to PICU</th>
<th>17 hours after admission to PICU</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>7.17</td>
<td>7.41</td>
<td>7.427</td>
<td>7.524</td>
</tr>
<tr>
<td>pCO₂, mm Hg</td>
<td></td>
<td>71.5</td>
<td>36.9</td>
<td>25.5</td>
<td>24.6</td>
</tr>
<tr>
<td>pO₂, mm Hg</td>
<td></td>
<td>71.8</td>
<td>381.4</td>
<td>165.8</td>
<td>165</td>
</tr>
<tr>
<td>BE</td>
<td></td>
<td>−9.1</td>
<td>−0.6</td>
<td>−5.8</td>
<td>−0.7</td>
</tr>
<tr>
<td>SpO₂, %</td>
<td></td>
<td>89.9</td>
<td>99.9</td>
<td>99.3</td>
<td>99.4</td>
</tr>
<tr>
<td>FiO₂</td>
<td></td>
<td>0.7</td>
<td>0.6</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>MV</td>
<td>MV</td>
<td>MV</td>
<td>MV</td>
</tr>
</tbody>
</table>

MV – mechanical ventilation, CPAP – continuous positive airway pressure; PICU – pediatric intensive care unit; BE – base excess.

*Medicina (Kaunas) 2008; 44(11)*
Pulmonary edema and hemorrhage as complications of acute airway obstruction following anesthesia

1.0. ETCO

... cm, body mass index – 32.8 kg/m
min. The weight of patient was 110 kg, height – 184
...paring revealed blood pressure of 148/94 mm Hg,
...ection revealed blood pressure of 148/94 mm Hg,

Spinal anesthesia was recommended for the pa-
...performed incision and drainage of subcutaneous ab-
...ity: pH, 7.28; pO
...ptune remained 86–87% despite the

...ation was deepened by administration
...ed by 60 to 43 mm
Hg after intubation. Soon after intubation, bloody
sputum was observed in the endotracheal tube.

Urgent bronchoscopy was performed in the ope-
rating room to exclude possible aspiration, as satura-
after intubation remained 86–87% despite the
ventilation by applying 100% oxygen. Bronchoscopy
did not reveal any signs of aspiration or bronchial
damage; only bloody sputum was found in trachea
and principal bronchi. Saturation was gradually in-
creased from 86 to 97%, despite the application of
PEEP up to 8 cm H
...O. Blood gases showed hypoxe-

...ed to transfer patient to the intensive
care unit (ICU) for further mechanical ventilation and
postoperative care.

Chest x-ray examination was performed in the ICU,
which revealed the signs of stasis and interstitial ede-
ma in both lungs progressing to alveolar edema in the
right lung.

After 2 h, the patient was extubated, but signs of
respiratory insufficiency exacerbated due to this
patient was re-intubated and mechanical ventilation
was extended applying PEEP (up to 6 cm H
O). The
patient was treated with diuretics, furosemide at a dose
of 80 mg intravenously. Other medications included
10 mg of morphine hydrochloride and 10 mg of dia-
zepam for sedation of the patient, 500 mg of metro-
nidazole.

Bloody sputum was observed in endotracheal tube
during the first 3 h of the treatment in the ICU. Clinical
signs of pulmonary edema disappeared after 4 h from
admission to ICU. Subsequent x-ray examination was
performed showing reduction of interstitial and stasis
changes in both lungs. After 5 h, the patient was
extubated. Next morning, the patient was discharged
to surgical department and after two days for
outpatient follow-up.

Discussion

We have presented a case of 15-year-old pediatric
patient who underwent routine surgery performed
under conditions of general anesthesia and who ex-
perienced hypoxemic respiratory failure following
extubation due to prolonged laryngospasm. Vigorous
inspiratory efforts in the case of obstructed airway
led to the development of NPPE. Resolution of this
edema was slow; duration of treatment in the in-
tensive care unit was relatively prolonged.

NPPE due to upper airway obstruction is a well-
recognized problem.

The most common reason of NPPE is laryngos-
spasm (12–17), and less common reasons are as follows: endotracheal tube (18) or laryngeal mask (19, 20) clench during wake up after general anesthesia, intensive hiccup during anesthesia (21), aspiration (8), or bilateral palsy of vocal chords (22).

An extremely rare case of NPPE was described, induced by direct suction of endotracheal tube adapter (23). During postanesthesia, NPPE is observed more often among obese patients, patients with short neck or with sleep apnea (24), and patients who underwent ear, nose, and throat surgery (6, 25).

Recently, original papers have been published describing data of Australian Incident Monitoring Study (AIMS) concerning 4000 incidences during anesthesia (8, 12, 26). According to some authors, NPPE is rather common and is considered to occur in up to 4% of all incidence reports of laryngospasm, and only in two cases (among 4000), pulmonary edema developed due to other etiology of acute airway obstruction.

What influences the occurrence of NPPE?

Intrathoracic pressure during obstruction seems to be the most significant in NPPE pathogenesis. This leads to subsequent increment of venous blood return and intrathoracic blood volume, decreases pulmonary venous outflow resulting in decreased cardiac output. In turn, increment of hydrostatic pressure gradient in pulmonary capillaries induces fluid transudation to alveoli and development of edema (7, 27, 28).

Maximal negative inspiratory pressure exceeds –50–100 cm H₂O during acute airway obstruction in adults, especially after vigorous inspiratory efforts (29), while in pediatric patients it reaches –24–50 cm H₂O (28). Normal inspiratory pressure ranges from –2.5 to –10 cm H₂O.

As we experienced in our cases, respiratory efforts are more prominent among young, athletic men with good thoracic musculature (30), as well as children with greater chest wall compliance are able to generate more negative pressure (28).

Hypoxemia is among other reasons, possibly causing the development of pulmonary edema (31, 32). Vasoconstriction, conditioned by hypoxemia and increment of catecholamines due to stress and subsequent increment of left ventricle afterload, plays a great role in the development of such type edema. On the other hand, hypoxemia and stress activate sympathetic nervous system and subsequently increase venous blood return, induce vasoconstriction of pulmonary capillaries, thus favoring a hydrostatic fluid shift into the interstitium (33).

Hydrostatic mechanism of pulmonary edema development without alveolo-capillary membrane lesion was proved by studies measuring the ratio of total protein concentration between pulmonary edema fluid and plasma of adults and pediatric patients (34, 35). A ratio of less than 0.65 is characteristic of hydrostatic pulmonary edema, whereas a ratio between 0.75–1.0 is characteristic of acute lung injury.

NPPE diagnosis after acute airway obstruction is confirmed by clinical and x-ray findings. On the other hand, chest x-ray examination is not always performed after airway obstruction (36). According to this, it would be fair enough to acknowledge that NPPE ratio following anesthesia is greater than is diagnosed. One study reported that chest x-ray examination revealed up to 29% of pulmonary edema cases following airway obstruction with no clinical evidence of pulmonary edema (37). In case of high hydrostatic pressure, erythrocytes might diffuse through alveolo-capillary membrane, resulting in pink frothy sputum, while blood (hemoptyis) indicates the damage to alveolo-capillary membrane.

Negative-pressure pulmonary hemorrhage conditioned by acute airway obstruction is an extremely rare condition. Diffuse alveolar hemorrhage for the first time was described by Schwartz et al. in 1999 (30) and later by other authors (2, 9, 36–39). As no signs of tracheal and bronchial mucous damage were found during bronchoscopy, and fresh blood was aspirated during broncho-alveolar lavage (9, 30, 39), this pathology was qualified as negative-pressure alveolar hemorrhage. Analysis of hemorrhagic fluids aspirated during bronchoscopy showed rather high levels of hemoglobin (40). Only Koch et al. found hemorrhage lesion lining the trachea and main airways (41).

The mechanism of negative-pressure pulmonary hemorrhage remains unclear. It is discussed that mechanical rupture of alveolo-capillary membrane due to increased negative intrathoracic pressure conditions diffuse damage of pulmonary capillaries. Rare cases of hemoptyis are described due to clench of the endotracheal tube after general anesthesia, which lasted in one case only 20 s (9), while in other case –1–2 min (38).

Recently, Pandey et al. discussed that some agents used in anesthesia, such as ketamine, could be responsible for the development of pulmonary edema (42). They report a case of pulmonary edema after intramuscular injection of ketamine in a previously healthy girl who underwent necrectomy because of burns. There is at least one report of pulmonary hypertension and pulmonary edema following ketamine administration in a patient who had a history of crack.

Medicina (Kaunas) 2008; 44(11)
Pulmonary edema and hemorrhage as complications of acute airway obstruction following anesthesia

Ketamine is a potent sympathomimetic. Even in healthy patients, ketamine produces an increased pulmonary artery pressure and increases pulmonary vascular resistance (44–46). The cardiovascular effects produced by ketamine resemble sympathetic nervous stimulation. The mechanism for the ketamine-induced cardiovascular effects is complex. Direct stimulation of the central nervous system leading to increased sympathetic nervous system outflow seems to be the most important mechanism (47).

Pulmonary hemorrhage as it was presented in our second case (the only case in our clinic) was associated with increment of intrathoracic pressure due to vigorous inspiratory efforts produced by the patient. Most probably negative pressure was the leading cause of it, while other additional factors such as hypoxia and impact of ketamine may be important in the development of pulmonary hemorrhage. Although the precise etiology of the bleeding in pulmonary hemorrhage is uncertain, the disruption of pulmonary capillaries could play a role. The application of term “negative-pressure pulmonary hemorrhage” is recently under discussion and seems to be acceptable to describe the development of diffuse alveolar hemorrhage following exposure to negative intrathoracic pressure.

Neigiamo slėgio plaučių edema ir plaučių hemoragija, sąlygota po anestezijos atsiradusios kvėpavimo takų obstrukcijos

Irena Agnietė Marchertienė, Andrius Macas, Aurika Karbonskienė
Kauno medicinos universiteto Anesteziologijos klinika

Raktažodžiai: kvėpavimo takų obstrukcija, plaučių edema, plaučių hemoragija, ketamino anestezija.


Plaučių eduma gali išsyvystyti tuojo pat po kvėpavimo takų obstrukcijos, tačiau atskirais atvejais gali atsirasti praėjus nuo keliomis valandoms po buvusios kvėpavimo takų obstrukcijos. Plaučių hemoragijos atveju bronchų pažeidimas bronchoskopijos metu pastebimas retai, o alveolių pažeidimas yra sąlygotas alveolių membranos pažeidimo. Hemoragija yra sąlygota padidėjusio hidrostatinko slėgio, hipoksi jos, bronchų ir alveolių pažeidimo (alveolės membranos išpyšimas).

Ankstyva neigiamo slėgio plaučių edumą ir plaučių hemoragijos diagnostika yra labai svarbi, nes tai turi įtakos pooperaciniam pacientų sergamumui ir mirštamumui.


Adresas susirašinėti: I. A. Marchertienė, KMU Anesteziologijos klinika, Eivenių 2, 50009 Kaunas
El. paštas: irena.marchertiene@kmuk.lt

References