Negative Pressure Pulmonary Edema: A Case Series

Yashasa Poudel, MBBS, (FCPS); Anisha Basnet, MBBS, (FCPS); Prabhat R Baral, MBBS, MD; Bhakta B Burathoki, MBBS, MD
Department of Anesthesia and Critical Care, B & B Hospital, Gwarko, Lalitpur, Nepal

Address for Correspondence:
Yashasa Poudel, MBBS, (FCPS)
Department of Anesthesia and Critical Care, B & B Hospital, Gwarko, Lalitpur, Nepal
Email: pyashasa124@gmail.com

Received, 10 December, 2018
Accepted, 24 December, 2018

The case series shows a rapid onset of negative pressure pulmonary edema after acute upper airway obstruction, due mainly to laryngospasm in the postoperative period. Negative pressure pulmonary edema appeared more frequent in healthy American Society of Anesthesiologists (ASA) physical status I and II, young and male patients. The resolution was relatively rapid after reestablishment of the airway, adequate oxygenation, and positive airway pressure application. The clinical course was uncomplicated in all the patients.
Keywords: airway obstruction, laryngospasm, negative pressure, pulmonary edema.

Negative-pressure pulmonary edema (NPPE) or post-obstructive pulmonary edema is cause of acute respiratory failure that occurs after intense inspiratory effort against an obstructed airway, usually from upper airway infection, tumor, or laryngospasm. Patients with NPPE generate very negative airway pressures, which augment transvascular fluid filtration and precipitate interstitial and alveolar edema. Pulmonary edema fluid collected from most patients with NPPE has a low protein concentration, suggesting hydrostatic forces as the primary mechanism for the pathogenesis of NPPE. Supportive care should be directed at relieving the upper airway obstruction by endotracheal intubation or cricothyroidotomy, institution of lung-protective positive-pressure ventilation, and diuresis unless the patient is in shock. Resolution of the pulmonary edema is usually rapid, in part because alveolar fluid clearance mechanisms are intact.[1] Young, healthy, athletic patients seem to be at risk for this disorder, and the prevalence of postoperative NPPE is approximately

0.1%.[2,3] In patients developing acute postoperative upper airway obstruction, NPPE has been reported at an incidence of up to 11%.[4] Case reports and retrospective data suggest that the patient characteristics that increase the risk of NPPE seem to include younger patients in ASA physical status categories I and II, who are thought to be most capable of generating highly negative intrathoracic pressures during an obstructing event. Of note, one study reported a higher incidence of NPPE among men (80%) following laryngospasm, and in patients categorized as ASA (American Society of Anesthesiologists) status I or II (73%).[1]

Case Reports

Case 1

A 21-year-old male (55 kgs) presented to the operation room for open reduction and internal fixation with plating of left tibia fracture sustained by falling off a scooter. The patient's medical history was significant only for his history of occasional smoking and operation for club foot 15 yrs back under General anesthesia (GA) which was uneventful. He denied previous problems with GA, and his baseline peripheral oxygen saturation (Spo2) was 99% on ambient air and other vital parameters were within normal limits. Preoperatively, his chest examination results were normal and a chest radiograph indicated clear lung fields. The patient was premedicated with 1.5mg intravenous (iv) midazolam, and 100 mcg iv fentanyl was given for analgesia and anesthesia was induced with 150 mg iv propofol, and 6 mg iv vecuronium for facilitation of tracheal intubation. He was intubated with an 8-mm internal diameter (ID) endo tracheal tube using a no. 4 Macintosh laryngoscope with direct visualization of the vocal cords. Bilateral breath sounds were confirmed. Intra operative oxygenation and lung mechanics were normal. The patient was hemodynamically stable with minimal blood loss and was easily ventilated and oxygenated. Maintenance of anesthesia was done with isoflurane, vecuronum, oxygen and positive pressure ventilation. A total of 1300 ml lactated Ringer's solution was administered during the 2hrs 30-mins surgical procedure. Reversal of neuromuscular (NM) blocker was done with 2.5 mg iv neostigmine and 0.6 mg iv glycopyrrolate. Suctioning of oropharynx was done and patient was extubated.

Immediately after extubation there was profuse secretion along with drop in spo2 to nearly 60% due to laryngospasm. Patient coughed against mask ventilation and spo2 started to improve along with regular breathing efforts. After about a minute the patient suddenly coughed out pink frothy sputum, was dyspneic and tachypneic. Also, sp02 again dropped to 50% with tachycardia. On auscultation bilateral coarse crackles and crepitation were heard. The patient was managed with positive pressure ventilation, hydrocortisone 100mg iv, dexamethasone 8mg iv, furosemide 20mg iv, Inj morphine 3 mg iv and high flow oxygen (8-10 litre). Patient's condition started to improve. He was shifted to ICU where chest X-ray and ABG

was done. The chest X-ray showed diffuse, bilateral interstitial opacities in both lungs, with normal lung volumes, normal heart size, and no pleural effusions and Arterial Blood Gas (ABG) findings were normal. A diagnosis of NPPE was made. The morning of first post-operative day, clinical symptoms relieved and Chest X-ray findings showed relatively clear lung fields. Examination revealed clear lungs bilaterally and Spo2 of 95–97% on ambient air. With supplemental oxygen, diuretics treatment, and bronchodilator inhalation, iv morphine and antibiotics his respiratory status continued to improve with peripheral oxygen saturation of 99% on ambient air 24hrs after surgery along with normal chest X-ray and ABG findings.

Case 2

A 17-year-old male (65 kgs) presented to the operation room for open reduction and internal fixation with pinning of right distal fibula fracture and debridement of lacerated right elbow and forearm sustained in a high-speed motor vehicle accident. The patient's medical history was significant only for his history of occasional alcohol consumption. He denied previous problems with general anesthesia, and his baseline spo2 was 99% on ambient air and other vital parameters were within normal limits. Preoperatively, his chest examination results were normal and a chest radiograph indicated clear lung fields. The patient was premedicated with 2mg iv midazolam, and 100 mcg iv fentanyl was given for analgesia and anesthesia was induced with 150 mg iv propofol, and 8 mg iv vecuronium for facilitation of tracheal intubation. He was atraumatically intubated with an 8-mm ID endotracheal tube using a no. 4 Macintosh laryngoscope with direct visualization of the vocal cords. Bilateral breath sounds were confirmed. The intraoperative course was unremarkable. Intraoperative oxygenation and lung mechanics were normal. The patient was hemodynamically stable with minimal blood loss and was easily ventilated and oxygenated. Maintenance of anesthesia was done with isoflurane, vecuronum, oxygen and positive pressure ventilation. A total of 1000 ml lactated Ringer's solution and 1-pint whole blood was administered during the 2hrs 50-mins surgical procedure. Reversal of NM blocker was done with 2.5 mg iv neostigmine and 0.6 mg iv glycopyrrolate. Suctioning of oropharynx was done and patient was extubated. Immediately after extubation patient coughed and there was profuse secretion along with drop in spo2 to nearly 70%. Large amount of pink frothy sputum along with coughing, dyspnea, tachycardia(130-140bpm) and tachypnea was seen. On auscultation bilateral coarse crackles and crepitations were heard, more pronounced on left side of the chest.

The patient was managed with positive pressure ventilation, hydrocortisone 200mg iv, dexamethasone 8mg iv, furosemide 20mg iv, fluid resuscitation and monitoring. Immediately a chest X-ray was done. Patient's condition gradually started to improve. The chest X-ray showed diffuse, bilateral, hazy, and interstitial opacity throughout both lungs, **(Figure 1, 2)** with normal lung volumes, normal heart

size, and no pleural effusions. A diagnosis of NPPE was made.

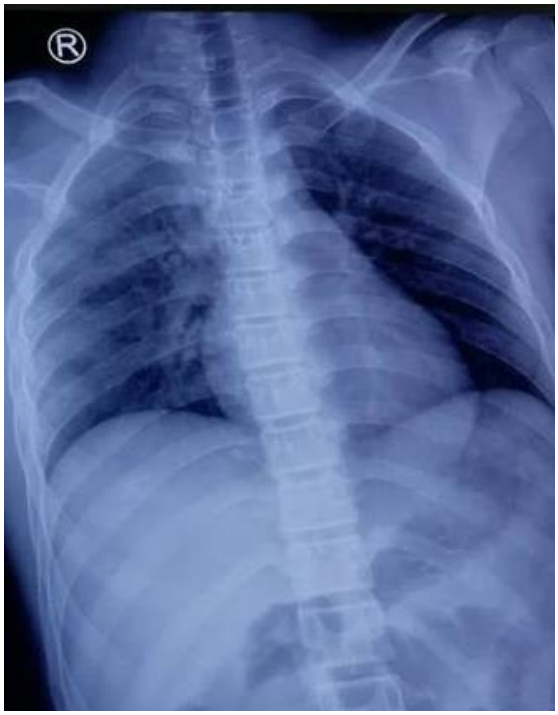

Figure 1: Normal Chest X-Ray

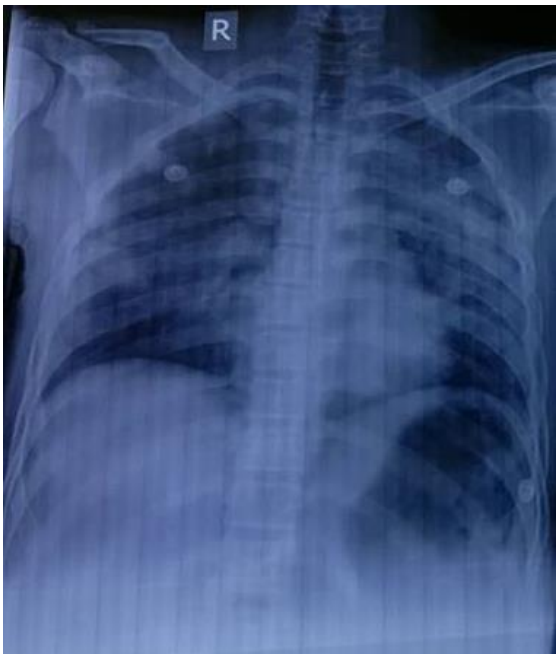

Figure 2: Diffuse, bilateral, hazy, and interstitial opacity throughout both lungs

Patient was transferred to ICU for observation. The morning of first post-operative day clinical symptoms relieved and chest X-ray findings were better. With supplemental oxygen, diuretics treatment, and bronchodilator inhalation, his respiratory status continued to improve with peripheral oxygen saturation greater than 94% on ambient air 12h after surgery. Examination revealed clear lungs bilaterally and peripheral oxygen saturation of 95–97% on ambient air. Symptoms resolved completely nearly after 24hrs.

Discussion

Intensive care unit diagnostic evaluation and treatment

The patient's history, operating theatre course of events, clinical examination and chest X-ray findings were all consistent with the diagnosis of NPPE. This case description illustrates the most salient aspect of NPPE. This form of pulmonary edema appears to be related to markedly negative intrathoracic pressure due to forced inspiration against a closed upper airway resulting in transudation of fluid from pulmonary capillaries to the interstitium. Postanesthetic laryngospasm is the most common cause of pulmonary edema in adults (11/26 cases).[5] The edema usually clears rapidly with supportive care. Aggressive diagnostic and therapeutic interventions may be avoided if the syndrome is recognized. Maintenance of oxygenation and a patent airway are the mainstays of treatment.[5]

Since 1973, when the first clinical report of NPPE was published, multiple case reports and series have appeared in the literature, and several clinical causes of NPPE have been identified. Most of the reported cases in children have been caused by glottic or

subglottic obstruction due to acute infectious croup or epiglottitis. In adults, airway obstruction leading to NPPE is most often reported in the context of post extubation laryngospasm following surgery. The incidence of NPPE following laryngospasm is difficult to compute from case series data, although one study derived from the Australian Incident Monitoring Study (AIMS) reported 189 cases of laryngospasm in 4,000 anesthesia adverse events. There were five cases of NPPE, an incidence of 3% of those with laryngospasm. [1]

In our cases, there were no findings of cardiogenic or neurogenic pathology and no anaphylaxis. The X-ray of symmetric bilateral pulmonary interstitial infiltrates would be unusual for aspiration pneumonitis, which typically shows a localized infiltrate. In the instant setting, acute lung injury or acute respiratory distress syndrome couldn't be ruled out, but the severity of respiratory failure and the time track of clinical and radiologic recovery were not ultimately consistent with this etiology.

In our patients, intraoperative fluid overload as a mechanism of pulmonary edema was not considered reasonable because the patients had only 1 to 1.3 liters isotonic solution and one-pint whole blood administered intraoperatively, no history of left heart failure, and had been fasting overnight. With these considerations and the clinical picture of laryngospasm, we concluded that in both the cases pulmonary edema was likely induced by negative intrathoracic pressure, resulting from strong inspiratory efforts in the setting of laryngospasm.

In both our cases management was done with noninvasive positive pressure ventilation for about 10minutes and conservative treatment with supplemental oxygen administered as 100% oxygen by a non-rebreather mask (flow, 10 l/min), 20 mg furosemide intravenously, and bronchodilators was started and also morphine sulphate was given. The rapid improvement of both the patients' disease represents them as typical cases of acute postoperative pulmonary edema.

Pathogenesis

The pathophysiology of NPPE stems from the markedly negative thoracic pressure induced by inspiratory effort against an obstructed glottis, known as the Müller maneuver. Healthy adults can generate as much as –140 cm H_2O negative inspiratory pressure. However, early reports were conflicting as to whether high negative inspiratory pressures result in high-permeability or hydrostatic edema formation. The primary determinants of the rate of pulmonary edema formation, or fluid flux, from the capillary to the alveolar interstitium are transvascular hydrostatic and protein osmotic pressure gradients and vascular permeability, as modeled by the Starling equation for transcapillary fluid flux:

$$Qf=K[(Pmv-Pi)-\sigma(\pi mv-\pi i)]$$

where Qf is net fluid flux from the capillary lumen to the alveolar interstitium; K is the coefficient of capillary permeability; Pmv is the capillary lumen hydrostatic pressure; Pi is the

alveolar interstitial hydrostatic pressure; σ is the reflection coefficient (the effectiveness of the vascular barrier in preventing diffusion of protein); πmv is the microvascular protein osmotic pressure; and πi is the interstitial protein osmotic pressure.

The normal hydrostatic difference between the intravascular and extravascular compartments in the lung favors steady state fluid filtration from the capillaries into the interstitium; this filtrate is cleared by the lung lymphatic. If a positive balance develops from increases in either the hydrostatic or the protein osmotic gradient, lung lymphatic flow rises. When the rate of interstitial fluid accumulation outpaces the capacity for lymphatic drainage, edema fluid accumulates in the interstitium and floods the alveolus, becoming clinically detectable either by arterial oxygen desaturation, new opacities on chest radiographs, the appearance of edema fluid in the endotracheal tube, or expectoration by the non-intubated patient.[1]

Treatment

The first treatment is relief of the airway obstruction and correction of hypoxemia. The next step is to address the pulmonary edema with a diuretic unless the patient is hypovolemic. Effective airway management and immediate treatment with oxygen and diuretics is sufficient in most cases of NPPE. Persistent airway obstruction may necessitate an artificial airway, and acute respiratory failure would require artificial ventilation with oxygen and appropriate levels of PEEP. If the airway obstruction is due to the patient biting down on the endotracheal tube, a dose of succinylcholine (0.1–0.2 mg/kg) may be needed to relax the jaw muscles. Controversial use of steroids in NPPE has been reported in different case reports.[2, 6,7] The pulmonary edema is self-limited, usually resolving within 12 to 24 hours, and in most cases nothing more than supportive care, including oxygen administration, is required. In both adults and children, 85 per cent required tracheal intubation for a short period, which emphasizes the importance of ensuring a patent upper airway. Analysis of the case reports indicates that approximately 50 per cent of the patients required pulmonary ventilation and about 50 per cent of the patients required continuous positive airway pressure or positive end-expiratory pressure (i.e., CPAP and PEEP, respectively). Mechanical ventilation and PEEP should be reserved for the treatment of patients in whom adequate oxygenation cannot be maintained despite the maintenance of a patent upper airway and the administration of supplemental oxygen.[8] Evidence suggests that noninvasive respiratory support may be an effective strategy to reduce intubation rates and morbidity and mortality in postoperative patients.[9,10] The aims of noninvasive respiratory support in the context of NPPE include the following: to partially compensate for the affected respiratory function by reducing the work of breathing; to improve alveolar recruitment with better gas exchange; and to reduce left ventricular after load, increasing cardiac output and improving

hemodynamic.[11] β agonists may increase the rate of alveolar fluid clearance via increased active cation transport. Diuretics are often administered, but their use is controversial.[12]

Conclusion

With prompt diagnosis and therapeutic action, NPPE resolves generally within 24h. However, when recognition is delayed, patients with NPPE have mortality rates ranging from 11% to 40%. Therefore, early recognition of NPPE is crucial to decrease morbidity in these patients.[13]

Conflict of Interest: None

References

1. Bhattacharya M, Kallet RH, Ware LB, Matthay MA. Negative-pressure pulmonary edema. Chest 2016;150:927-33.
2. Willms D, Shure D. Pulmonary edema due to upper airway obstruction in adults. Chest 1988;94:1090-2.
3. Deepika K, Kenaan CA, Barrocas AM, Fonseca JJ, Bikazi GB. Negative pressure pulmonary edema after acute upper airway obstruction. Journal of clinical anesthesia 1997;9:403-8.
4. Tami TA, Chu F, Wildes TO, Kaplan M. Pulmonary edema and acute upper airway obstruction. The Laryngoscope 1986;96:506-9.
5. Willms D, Shure D. Pulmonary edema due to upper airway obstruction in adults. Chest 1988;94:1090-2.
6. Cascade PN, Alexander GD, Mackie DS. Negative-pressure pulmonary edema after endotracheal intubation. Radiology 1993;186:671-5.
7. Holmes JR, Hensinger RN, Wojtys EW. Postoperative pulmonary edema in young, athletic adults. The American journal of sports medicine 1991;19:365-71.
8. Lang SA, Duncan PG, Shephard DA, Ha HC. Pulmonary oedema associated with airway obstruction. Canadian Journal of Anaesthesia 1990;37(2):210-8.
9. Pelosi P, Jaber S. Noninvasive respiratory support in the perioperative period. Current Opinion in Anesthesiology 2010;23:233-8.
10. Pelosi P, Jaber S. Noninvasive respiratory support in the perioperative period. Current Opinion in Anesthesiology 2010;23:233-8.
11. Patton WC, Baker JC. Prevalence of negative-pressure pulmonary edema at an orthopaedic hospital. Journal of the Southern Orthopaedic Association 2000;9:248-53.
12. Koh MS, Hsu AA, Eng P. Negative pressure pulmonary oedema in the medical intensive care unit. Intensive care medicine 2003;29:1601-4.
13. Mehta VM, Har-El G, Goldstein NA. Postobstructive pulmonary edema after laryngospasm in the otolaryngology patient. The Laryngoscope 2006;116:1693-6.