Could the unexpected excessive airway pressure be caused by water in the ventilator circuit?: a case report

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INTRODUCTION

Humidification and warming of inhaled gases has been standard of care in mechanical ventilation therapy. Adding the heat and moisture of the inhalation gas during mechanical breathing is essential to maintain the function of the respiratory mucosa and to reduce the core temperature drop. Respiratory care providers have been utilizing external humidifiers to compensate for the lack of natural humidification mechanisms when the upper airway is bypassed by endotracheal intubation [1]. To date, humidification devices can be divided into active heated humidifiers (HHs) and passive devices such as heat and moisture exchangers (HMEs) [2]. The active humidifier has a relatively constant humidification effect regardless of the patient’s body temperature or minute ventilation [3]. In addition, HHs are known to have little effect on airway pressure unlike HMEs [1]. However, complications associated with the use of HHs have also been reported. HHs can cause electrical shock, hyperthermia, and thermal injury to the airway [2]. Inadvertent overfilling of the ventilator circuit may also result in unintentional tracheal lavage [4]. We report a case of unexpected high inspiratory pressure and auto-positive end-expiratory pressure (PEEP) undergoing mechanical ventilation using humidifier with heated wire circuit.
CASE REPORT

A 52-year-old woman (height 157.0 cm, weight 55.0 kg) was scheduled for intramedullary nailing due to right femur subtrochanteric pathologic fracture. She had a history of thyroid cancer that had been surgically removed two years ago and multiple metastatic spine tumors from originating breast cancer. The patient underwent a C5-7 corpectomy due to a C6 burst fracture, but there was no restriction on cervical motion. Laboratory tests including the thyroid function test were within normal ranges. Preoperative electrocardiogram (ECG) was normal sinus rhythm and chest X-ray revealed improvement of pulmonary congestion.

Prior to the induction of anesthesia, positive pressure leak test was performed and no abnormalities were found. The patient’s initial vital signs were blood pressure 125/82 mmHg, heart rate 77 beats/min, and oxygen saturation 97% at room air. Anesthesia was induced with 1% propofol (2.0 mg/kg), rocuronium (0.6 mg/kg), and remifentanil (0.1 μg/kg/min) intravenously. There was a slight tight feeling in the manual ventilation using the mask, but there was no problem in the ventilation. Complete muscle relaxation was confirmed by Train of four (TOF) before endotracheal intubation. Endotracheal intubation was done using a video-laryngoscope, and the endotracheal tube was fixed at 21 cm from upper incisor. The chest moved evenly and the breathing sound was clear in both lung fields during auscultation. General anesthesia was maintained by sevoflurane (2.0 vol%) followed by continuous intravenous infusion of remifentanil. In addition, invasive arterial line on left radial artery using 20 G catheter was inserted and bispectral index system (BIS; Covidien, Mansfield, MA, USA) was monitored.

Ventilator (S/5 Advance; Datex Ohmeda, Helsinki, Finland) were set as FiO₂ 0.5, total flow 3.0 L/min, tidal volume 8 ml/kg (predicted body weight), respiratory rate 14/min, I:E ratio 1:2, PEEP 0 cm H₂O. After a while, switching from manual ventilation to mechanical ventilation, the ventilator’s high-peak airway pressure alarm has begun. Ventilator screen showed that peak airway pressure was over 39 cm H₂O, PEEP 12 cm H₂O and end tidal CO₂ (ETCO₂) was 36 mmHg (Fig. 1A). The patient’s blood pressure was 97/51 mmHg, heart rate 146 beats/min, and oxygen saturation was 100%. It was decided to maintain mechanical breathing with a slight decrease tidal volume and find the cause of high airway pressure. The fixed position of the endotracheal tube remained intact, and there was no change in breath sounds such as wheezing or rale. There was no abnormality in the scavenger system or valve movement. However, strange sounds and vibrations were found in the ventilator circuit (Heated and humidified anesthesia wick breathing circuit, ANAPOD™; Westmed Inc., Tucson, AZ, USA) during ventilation. A considerable amount of water was found moving through the inspiratory limbs of ventilator circuit while trying to find the source of the strange sound. After pouring about two-thirds of the sterile water in the ventilator circuit (Fig. 2B), airway parameters changed as peak airway pressure was 25 cm H₂O, PEEP 2 cm H₂O and ETCO₂ was 35 mmHg (Fig. 1B).

There was no high inspiratory pressure or auto-PEEP during the surgery for 4 hours after the washout. She was transferred to the post anesthetist care unit (PACU) without pulmonary complication. Later, we found that the person

![Fig. 1.](image-url)
preparing the ventilator circuit mistakenly injected water twice (Fig. 2A).

**DISCUSSION**

Humidifiers are devices that add heat and moisture to inhalation gas. There are two commonly practiced techniques for humidification of inspiration gas to a patient undergoing mechanical ventilation. These are active humidifiers such as HHs and passive humidifiers such as HMEs [1]. HMEs are passive humidifiers and work by recycling the heat and moisture of the patient’s exhaled gas back to the patient on inhalation. These devices are simple, light, cheap and easily available. But, they are placed before the ‘Y’ in the circuit, they increase the instrumental dead space and the airway resistance. So, most complication with humidifier reported with HMEs, not HHs. Active humidifiers act by allowing air passage inside a heated water reservoir. These devices are placed in the inspiratory limb of the ventilator circuit, proximal to the ventilator. After the air is loaded with water vapor in the reservoir, it travels along the inspiratory limb to the patient’s airway [1]. So, active humidifiers do not add instrumental dead space and can offer accurate temperature.

In this case, Active heated humidification system (ANAP-ODTM) was used. According to the product instruction manual, one bottle of sterile water has a capacity of 100 mL and it is recommended that approximately 75% of sterile water be poured into the ventilator circuit. The sterile water that was introduced into circuit (approximately 75%) should be sufficient to provide up to 4 hours of operation. If the case runs longer, or condensation is no longer visible within the inspiratory tubing, add more water. Add approximately 12 mL of water for each additional hour of humidity.

There are various reasons for increased airway pressure during mechanical ventilation [5]. There are equipment factors include obstructed endotracheal tube, failed scavenger system, high fresh gas flow rate with uncompensated ventilator, and stuck expiratory valve [6]. In addition, improperly placed or used passive humidifiers can also raise airway pressure [7,8].

It is known that as the internal diameter of the endotracheal tube decreases, the airway pressure increases. [9]. In the case we experienced, the airway pressure changed with the presence of water in the inspiratory limb. It seems that excessive water in the circuit cause effect of narrowing of the inner diameter. That is why, the airway pressure decreased after removing excessive water in the heated circuit.

In normal situation, the end-expiratory lung volume is similar to the relaxation volume of the respiratory system. But, in circumstance with airflow obstruction, the end-expiratory volume may excess predicted FRC. Then, lung emptying is delayed and the next inspiratory efforts interrupt the expiration, before reaching the static equilibrium volume. This phenomenon is dynamic hyperinflation and cause auto-PEEP. Auto-PEEP can induce hemodynamic instability and pulmonary barotrauma. Airflow obstruction can be observed in most asthma and chronic obstructive pulmonary disease patients with mechanical ventilation [4].

The occurrence of PEEP is assumed to involve two steps. First, at the time of inspiration, the tidal volume from the bellow is blocked by the water and only partly transferred to
the patient. The remaining part of the tidal volume remains between the water and the inspiratory valve. Second, the air trapped by the water constantly produces pressure towards the endotracheal tube. This pressure is added to the PEEP that occurs naturally by bellows weight. It is presumed that water in the circuit added functionally bellows weight. Normally ascending limb bellows ventilators produce 2–4 cm H$_2$O of PEEP by bellows weight [6].

The reason why the airway pressure did not increase during mask ventilation is probably two reasons. First, we think that the degree of summation of the water has changed due to the difference in height and angle of the ventilator circuit during mask ventilation and after intubation. Second, there would be no tight sealing between the face and the mask.

In conclusion, we experienced unexpected high inspiratory pressure and auto-PEEP, which might have been caused by excess sterile water contained in the ventilator circuit using active humidifier with heated wire circuit. This problem solved after pouring about two-thirds of the sterile water in the ventilator circuit. Therefore, if sudden high peak airway pressure and auto-PEEP are encountered upon ventilation, the ventilator circuit status should be checked for the safety of patient.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Al Ashry HS, Modrykamien AM. Humidification during mechanical ventilation in the adult patient. Biomed Res Int 2014;2014:715434.
2. Vargas M, Chiumello D, Sutherasan Y, Ball L, Esquinas AM, Pelosi P, et al. Heat and moisture exchangers (HMEs) and heated humidifiers (HHs) in adult critically ill patients: a systematic review, meta-analysis and meta-regression of randomized controlled trials. Crit Care 2017;21:123.
3. Plotnikow GA, Accoce M, Navarro E, Tiribelli N. Humidification and heating of inhaled gas in patients with artificial airway. A narrative review. Rev Bras Ter Intensiva 2018;30:8697.
4. Saito S, Asakura N, Naito H. Massive water infusion into the patient’s trachea during the use of cascade type heated humidifier. Masui 1990;39:1055-8. Japanese.
5. Covert T, Niu NT. Differential diagnosis of high peak airway pressures. Dimens Crit Care Nurs 2015;34:19-23.
6. Jain RK, Swaminathan S. Anaesthesia ventilators. Indian J Anaesth 2013;57:525-32.
7. Ricard JD, Le Mière E, Markowicz P, Lasry S, Saumon G, Djedaïni K, et al. Efficiency and safety of mechanical ventilation with a heat and moisture exchanger changed only once a week. Am J Respir Crit Care Med 2000;161:104-9.
8. Doyle A, Mariyasevam M, Wijewardena G, English N, Gent E, Young P. The simultaneous use of a heat and moisture exchanger and a heated humidifier causes critical airway occlusion in less than 24 hours. J Crit Care 2015;30:863.e1-3.
9. Shapiro M, Wilson RK, Casar G, Bloom K, Teague RB. Work of breathing through different sized endotracheal tubes. Crit Care Med 1986;14:1028-31.