

Application Effect Analysis of Three Methods of Heating and Humidification for Weaning Patients in ICU

Yongxing Wu

Xi'an Jiaotong University

Jiyu Bai

Xi'an Jiaotong University

XingQing Zhu

Xi'an Shiyou University

Zhijing Zhu (✉ 1290224385@qq.com)

Xi'an Jiaotong University

Research Article

Keywords: Venturi device, thermostatic humidification T-tube, PEEP valve, Mechanical ventilation, Artificial nose

Posted Date: August 4th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-170217/v2>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Objectives Adequate humidity and temperature of the inhaled mixed air are important for patients weaning from ventilators. It can not only prevent the damage of dry gas on respiratory tract, but also facilitate the discharge of sputum. We aim to investigate the humidification and heating effects of artificial nose, Venturi device plus thermostatic humidification T-tube (referred as VT), Venturi device plus thermostatic humidification T-tube and PEEP valve (referred as VTP) in critical ill patients with tracheotomy in ICU.

Design:

Retrospective cohort study.

Setting:

Tertiary academic medical center.

Patients:

A total of 166 patients were engaged in this study. Clinical and laboratory examination data were used to determine the heating and humidification performance of 3 different methods.

Methods A retrospective, single-center cohort study was conducted in all critically ill patients ready to be weaned from mechanical ventilators. Three groups of patients were compared in terms of vital signs, the effect of artificial airway heating and humidification, and blood gas indicators. Basic patient data (age, gender, mechanical ventilation duration, ICU stay, disease type) were recorded. Vital signs include heart rate, blood pressure, respiratory rate, oxygen saturation; The performance of heating and humidifying the artificial airway were defined as the number of sputum suction and coughing within 24 hours, sputum characteristics, whether there is bloody sputum formation, whether there is phlegm callus formation; Blood gas indicators include pH, oxygen partial pressure, carbon dioxide partial pressure, lactic acid, residual base, and bicarbonate.

Results In terms of the heating and humidification performance of patients in ICU, the VT method and the VTP method were significantly superior to those of artificial nasal method.

SpO₂ was significantly higher in patients treated with the VTP method than that in patients treated with VT.

Conclusion

Compared with the artificial nose method, the VTP method and VT methods are better. In terms of improving oxygenation, the VTP method could improve the patient's oxygen sum more than the VT method.

Introduction

For patients to be weaned from mechanical ventilation, airway management is the key to keep the airway open and prevent pulmonary infection. After the establishment of the artificial airway, the upper airway loses its function of warming and humidifying the inhaled air during inhalation, resulting in increased water loss of the lower respiratory tract, mucosal drying, secretion drying and phlegm excretion obstruction, etc. Heating and humidification can make the cilia of the tube wall move actively and push up the mucus attached to the cilia continuously, which is conducive to discharge. Therefore, it is very important to humidify the airway of patients while weaning.^{1 2}

According to the “2012 Guidelines of American College of Respiratory Therapy for Airway Humidification”², the air inhaled through artificial airways must be at the normal temperature (37°C) in order to ensure the normal movement of mucosal cilia. It is suggested that long-term oxygen treatment is needed (100% relative humidity, absolute humidity (44 mg/L). It was also recommended that oxygen humidifier should be used in patients with poor secretion discharge.³

Artificial nose is routinely used to prevent airway exposure in patients undergoing tracheotomy after weaning. However, its heating and humidifying effect is not ideal, and it is easy to be blocked by sputum.⁴ Recent years other humidifying methods were used by physicians. Corley et al. used nasal cannulation for high-flow oxygen therapy and t-tube for low-flow tracheotomy for oxygen therapy.^{5,6} Hypermobile oxygen therapy improves oxygen balance by providing an exogenous positive pressure. Clinical researchers have also used respiratory humidification therapy devices with active humidifiers and heating pipes, venturi mass flow humidification oxygen therapy devices to treat patients undergoing tracheotomy. In recent clinical studies, the application of respiratory humidification therapy in tracheotomy is limited⁷. Venturi humidification oxygen therapy system regulates gas flow oxygen flow and oxygen concentration by regulating gas flow standard Venturi air oxygen mixer. However, the precise mechanism and its operation are still controversial⁸.

The purpose of this paper is to explore the application effects of three heating and humidification methods for weaning patients in ICU: artificial nose method, Venturi device and thermostatic heating and humidification + T-tube method (hereinafter referred to as VT), Venturi device and thermostatic heating and humidification T-tube + PEEP valve method (referred as VTP).

Materials And Methods

1.1 Ethical

This study was approved by the Ethics Committee of Xi'an Jiaotong University, under the approval number XJTU1AF2021LSK-190, June 11, 2021. All research was performed in accordance with relevant guidelines/regulations, and where applicable informed consent was obtained from all participants and/or their legal guardians.

1.2 Clinical Data

Finally 166 patients to be weaned from mechanical ventilation in ICU of the First Affiliated Hospital of Xi'an Jiaotong University (Xi'an, China) from December 2017 to December 2019 were engaged, including 85 males and 81 females. The average age is 63 years.

Artificial nose method: The oxygen tube is connected to the artificial nose, which is consequently connected to the artificial airway.

VT method: the central oxygen supply device is connected to the bubble flowmeter humidification bottle, Venturi device, electric thermostatic steam generator (humidification tank), disposable threaded pipeline (with heating guide wire inside) and T-tube in accordance with the ventilation sequence. One end of the T-tube is connected to the patient's artificial airway. The humidifying liquid in the humidifying tank is sterilized water. The schematic model was shown in Fig. 1.

The VTP method: the central oxygen supply device is connected to the bubble flowmeter humidification bottle, the Venturi device, the electric thermostatic steam generator (the humidification tank), the disposable threaded pipeline (with heating guide wire inside the pipeline) and the T-tube in accordance with the ventilation sequence. One end of the T-tube is connected to the opening end of the patient's artificial airway. The other end of the T tube was connected to the PEEP valve. The humidifying liquid in the humidifying tank is sterilized water. As shown in Fig. 2.

1.3. Evaluation Criteria And Observation Indexes

1.3. Determination of sputum viscosity and humidification effect

Nurses were trained for the management of tracheotomy in the ICU, including oral hygiene. Sputum suction is performed when required according to clinical conditions. The suction catheter is gently inserted into the endotracheal tube for a maximum of 15 cm or until resistance is detected; The time limit for sputum suction procedure was less than 15 seconds. Sputum viscosity was measured by trained nurses. The sputum viscosity is divided into three grades: first grade: dilute or foam like soup; no sputum remains on the inner wall of the pipe; second grade: medium adhesion; lower sputum suction; a small amount of sputum remains on the inner wall of the pipe, but it can be easily removed by flushing with water. Level III: Viscous and yellow, large amounts of adhesive remain on the inner wall of the straw, rather than being easily removed by washing with water. ⁶

Formation of phlegm scab: to observe whether the patient cough or phlegm scab when cough or suction, or the patients manifested as a rapid breathing, blood oxygen saturation or restlessness.

1.3.2 Comparison of arterial blood gas indexes was carried out 2h after treating with one of the 3 methods, and airway heating and humidification effects were conducted 24h after treating with one of the 3 methods.

1.4 Statistical Methods

SPSS 22.0 statistical software was used. The count data were presented by case number and per cent. Chi-square test and analysis of variance were performed, with $P < 0.05$ was considered statistically significant.

Results

Of the 201 patients screened, 166 cases were finally included for further analyzation. 6 cases were excluded for age lower than 18 years, 4 cases were excluded for pregnancy, and 25 were excluded for mechanical ventilation time less than 48 hours. The result was shown in Fig. 3.

The baseline statistics of patients are shown in Table 1, and no significant difference was found between the 3 groups.

We first compared the vital signs of patients treated with different methods. As shown in Table 2, there was no significant difference in the vital signs.

We further analyzed the humidification effect of 3 humidifying ways (defined as the sputum suction frequency (times/hour), sputum scab and cough times), and we found that the VT method and the VTP method were significantly superior to the artificial nasal method (Number of sputum aspiration: $P = 0.0001$; Sputum callus: $P = 0.03$; Number of cough: $P = 0.007$).

The blood gas indexes were also analyzed. As shown in Table 2. We found SpO_2 of patients treated with VTP method was significantly improved compared with that of patients treated with the VT method ($P = 0.004$). There was no significant difference in other indexes.

As shown in Table 3, our data showed that the humidifying effect (defined as sputum viscosity) of VT method and VTP method was superior to that of artificial nose method ($P < 0.001$).

Discussion

When the patient weaned from mechanical ventilation, it is not only disuse of the nasal cavity, secondary infection, and nasal mucosal ciliary dysfunction, but more importantly, inhaled gas is all warmed and humidified by the trachea and the respiratory tract below, which is difficult to achieve the desired effect, and the loss of exhaled air and water is significantly increased.⁹

Therefore, for patients with artificial airways, the humidification process of inhaled gas should be accompanied by heating and tempering. No matter what kind of humidification, the gas temperature in the proximal airway should reach 37°C and the relative humidity should reach 100%. It is an important nursing measure to ensure the effect of airway humidification and temperature.

The Venturi device uses the negative pressure generated by the oxygen jet to bring a certain amount of air from the side hole ¹⁰, in order to dilute the oxygen to achieve the required inhalation oxygen concentration, so as to achieve the purpose of controlled oxygen therapy. Its advantage is that the air oxygen mixture has a large flow rate and a fast flow rate. Theoretically, the upper oxygen mixture flow rate can reach 45L/min, which can better meet the patient's inspiratory flow rate, reduce repeated breathing, and thus prevent CO₂ retention. Venturi devices can precisely control oxygen concentration, especially in patients with chronic obstructive pulmonary disease. Combining the venturis with the heating and humidifying device and T tube can better approach to human physiological conditions, so as to achieve the optimal heating and humidifying.

In terms of the heating and humidifying effect, the VTP method were obviously superior to the traditional artificial nasal method, as shown in Tables 2 and 3: The number of sputum suction, sputum scab and cough were all less than that of the artificial nasal method. Sputum viscosity is artificial nose method ∅ degree of phlegm accounted for more than (46.7%). This is due to the artificial nasal method, for patients to use their own exhaled gas to actively heat and humidify, and more prone to sputum obstruction, resulting in frequent replacement. The VT method, the VTP method can not only make use of the precise oxygen concentration of Venturi, but also passively heat and humidify, which is more effective and closer to the physiological needs of patients, and can be widely used in clinical practice.

For example, in patients with poor performance of PEEP, the PEEP valve can be connected to the end of the T tube, so as to give the patient an exogenous PEEP to improve the patient's dead cavity, thereby improving the risk of oxygen and carbon dioxide retention, which is a great deal. As shown in Table 2, SPO₂ was significantly higher in the VTP method than in the VT method.

In addition, the connection of Venturi and the humidification device is simple, convenient, easy to grasp, and does not increase the workload of nurses, nor is it as frequent as the replacement of artificial nose, which reduces the pain and economic burden of patients.

It is also interesting to note that the VT method, and VTP method have less lactic acid (LAC) than the artificial nose method. We speculate the reason is that the VT method, and the VTP method have more artificial nasal method for patients with neurological diseases, such patients have strong central driving force, and respiratory excitement leads to the decrease of lactic acid.

However, this study is not without limitations. The study did not consider the effect of different diseases on the results. For example, patients with neurological and non-neurological diseases. In addition, latency, nutritional status (such as albumin), immunosuppressive status (such as diabetes), and antibiotic use are all taken into account and should be observed in further studies.

Conclusion

To sum up, due to the clinical situation, a large number of patients need long-term indwelling tracheotomy catheter for oxygen therapy. It is particularly important for patients to humidify the respiratory airway by

heating. In this study, three methods of heating and humidifying oxygen therapy were compared, and the efficacy of heating and humidifying oxygen therapy in patients undergoing tracheotomy was compared. The conclusion is as follows: compared with the traditional artificial nose method, the humidification effect of venturi device and thermostatic heating humidification T-tube method, venturi device and thermostatic heating humidification T-tube + PEEP valve method is better. In addition, compared with the Venturi device and the thermostatic humidifying T tube + PEEP valve, the Venturi device and the thermostatic humidifying T tube + PEEP valve can better improve the patient's oxygen and do not cause carbon dioxide retention. More patient populations will need to be studied in the future to observe the effects of the three methods of heating and wetting in patients with different diseases.

Declarations

Ethical Approval and Consent to participate

Ethical Approval is applicable. The ethical number is XJTU1AF2021LSK-190.

Acknowledgements

The authors would like to thank professor Yu Liu for scientific guidance into this field.

Funding

Funding information is not applicable.

Conflicts of interest

The authors declare no conflict of interest.

Consent for publication

Not applicable.

Availability of data and material

All datasets analyzed during the study are available from the corresponding author on reasonable request.

Contributions

ZJZ designed the study and is accountable for all aspects of the work. JYB and XQZ performed the statistical analyses, interpreted the results. YXW compiled the manuscript, interpreted the results and provided critical revisions for the manuscript.

References

- 1 Pham, T., Brochard, L. J. & Slutsky, A. S. Mechanical Ventilation: State of the Art. *Mayo Clinic proceedings***92**, 1382-1400, doi:10.1016/j.mayocp.2017.05.004 (2017).
- 2 Restrepo, R. D. & Walsh, B. K. Humidification during invasive and noninvasive mechanical ventilation: 2012. *Respir Care***57**, 782-788, doi:10.4187/respcare.01766 (2012).
- 3 O'Driscoll, B. R., Howard, L. S., Earis, J. & Mak, V. BTS guideline for oxygen use in adults in healthcare and emergency settings. *Thorax***72**, ii1-ii90, doi:10.1136/thoraxjnl-2016-209729 (2017).
- 4 Restrepo, R. D. & Walsh, B. K. Humidification During Invasive and Noninvasive Mechanical Ventilation: 2012. *Respiratory Care***57**, 782, doi:10.4187/respcare.01766 (2012).
- 5 Corley, A. *et al.* High-flow oxygen via tracheostomy improves oxygenation in patients weaning from mechanical ventilation: a randomised crossover study. *Intensive Care Med***43**, 465-467, doi:10.1007/s00134-016-4634-7 (2017).
- 6 Del Sorbo, L., Vendramin, A. & Mehta, S. High flow oxygen therapy in adult critically ill patients. *Minerva anesthesiologica***83**, 402-411, doi:10.23736/s0375-9393.16.11608-6 (2017).
- 7 Yang, M., Song, Y., Pan, L. & Xie, X. Evaluation of the effect of two active warming and humidifying high-flow oxygen therapy systems in patients with tracheotomy. *Biomed Rep***11**, 31-37, doi:10.3892/br.2019.1219 (2019).
- 8 Soto-Ruiz, K. M., Peacock, W. F. & Varon, J. The men and history behind the Venturi mask. *Resuscitation***82**, 244-246, doi:10.1016/j.resuscitation.2010.11.016 (2011).
- 9 Rathgeber, J., Henze, D. & Züchner, K. [Air conditioning with a high-performance HME (heat and moisture exchanger)—an effective and economical alternative to active humidifiers in ventilated patients. A prospective and randomized clinical study]. *Der Anaesthetist***45**, 518-525, doi:10.1007/s001010050285 (1996).
- 10 Zhang, J. X. Analysis on the effect of venturi tube structural parameters on fluid flow. *Aip Adv***7**, doi:Artn 06531510.1063/1.4991441 (2017).

Tables

Due to technical limitations, Tables are only available as a download in the Supplemental Files section.

Figures

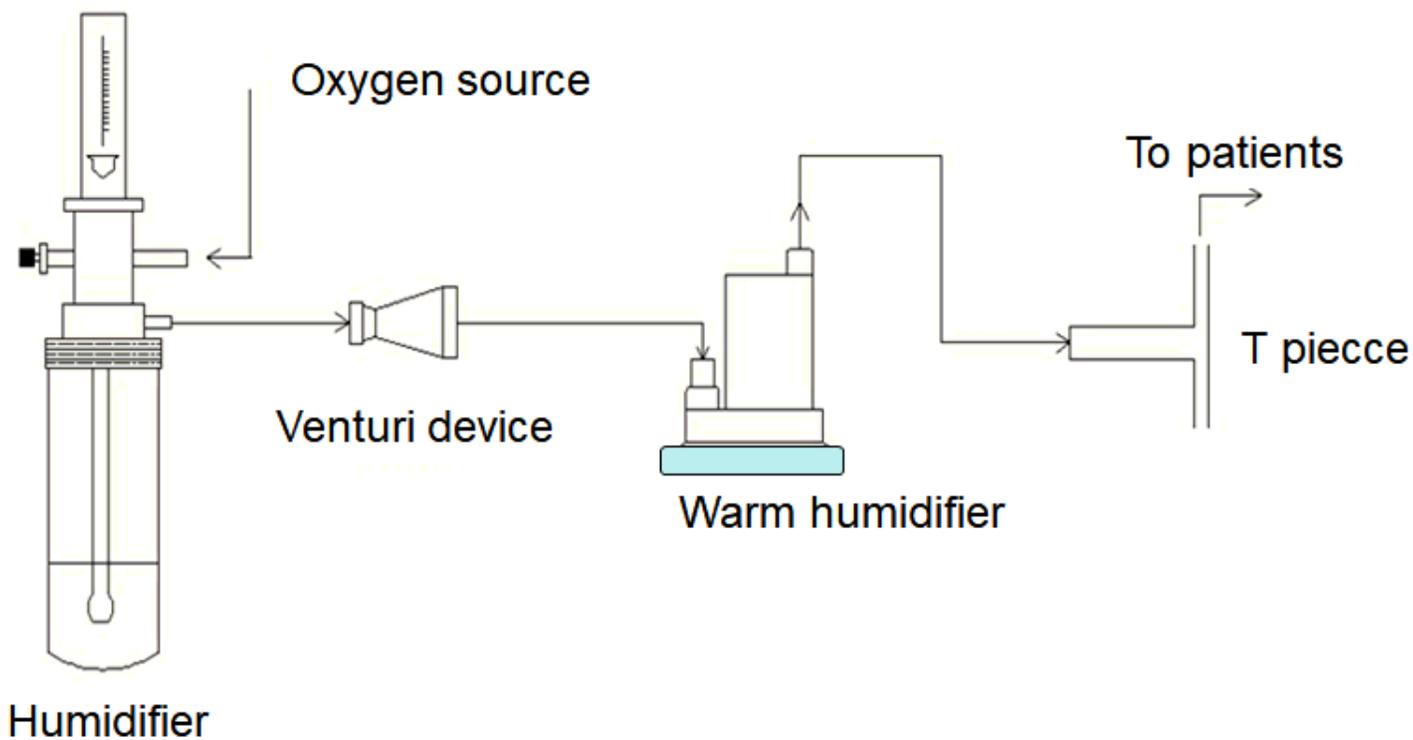


Figure 1

The Schematic diagram of VT method.

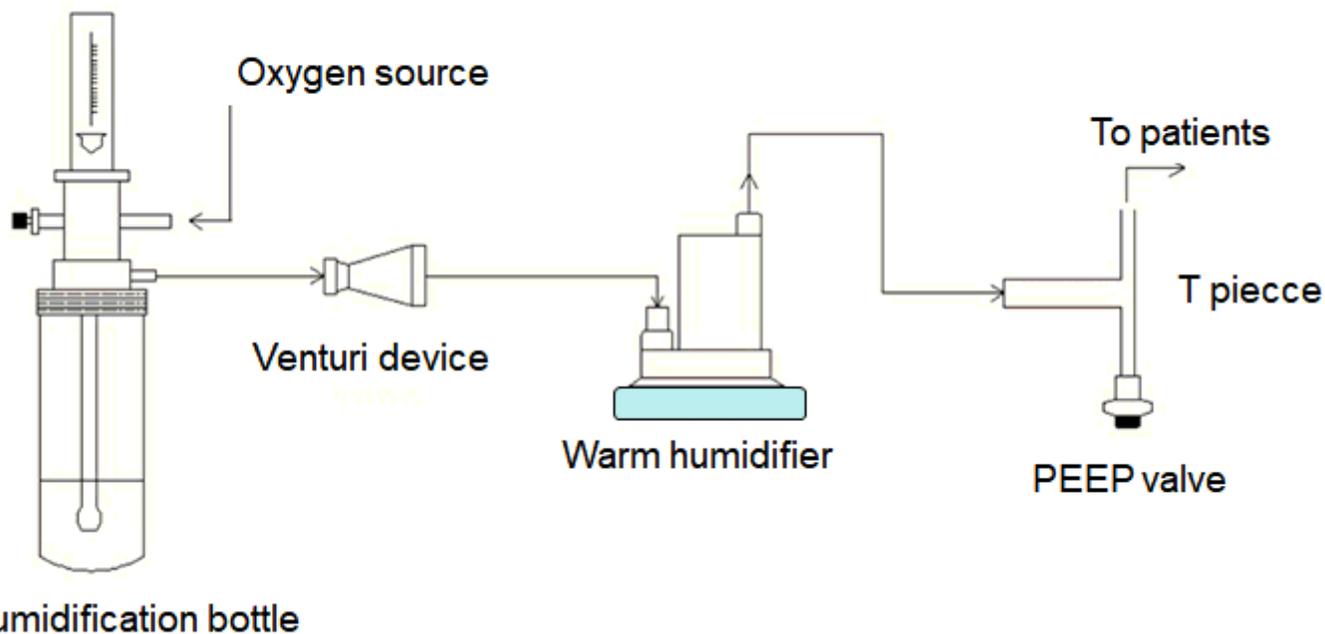


Figure 2

The Schematic diagram of VTP method.

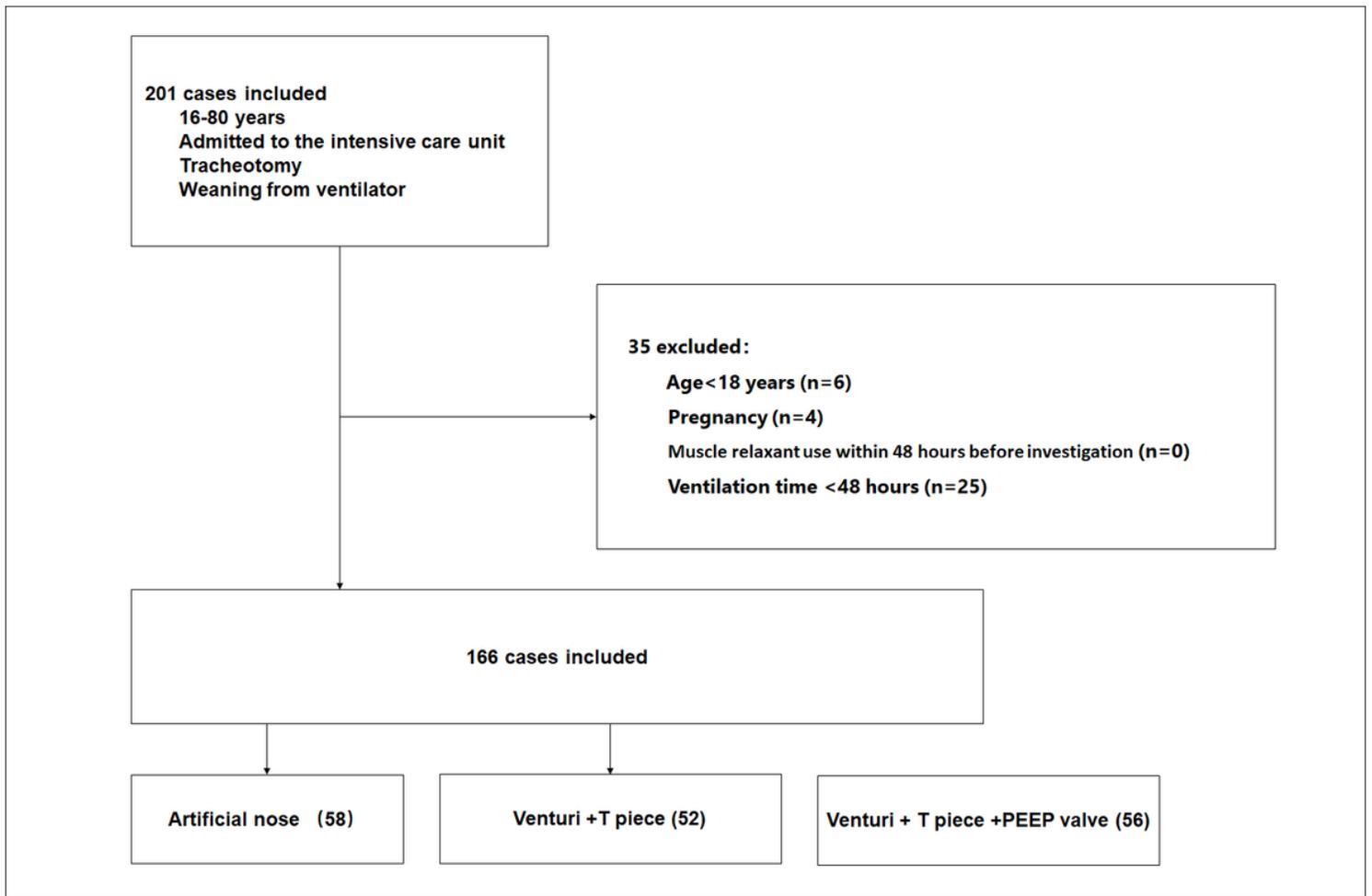


Figure 3

The main patient results of three humidifying ways.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table1.xlsx](#)
- [Table2.xlsx](#)
- [Table3.xlsx](#)