Evaluation Physiological Measurement Mode in Ventilator

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ABSTRACT

By offering temporary rest and allowing the body to recover, ventilators serve as a bridge to recovery for those grappling with severe respiratory illnesses. It is important to note that providing ventilator support requires the expertise of skilled medical professional. Their expertise ensures accurate configuration and continuous monitoring of devices, thereby safeguarding patient well being during this critical phase of their medical journey. This research uses three factors: temperature, pressure and relative the degree of saturation of the gas with water vapor must be considered, especially when gas volumes are compared below different environmental conditions and subsequent use in metabolic and physiological calculations. That standard provides a frame of reference for expressing the volume of a gas is STPD, BTPS or ATP. BTPS Correction is used to convert flow and volume measured at ambient conditions to the conditions within the lungs. Ambient conditions are called ATP (ambient temperature, pressure) the conditions within the lungs are called BTPS (body temperature, pressure, water vapor saturated). STPD refers to the volume of a gas expressed under Standard conditions of Temperature (273°K or 0°C), Pressure (760 mm Hg), and Dry (no water vapor). Conversion of ATPS volume to BTPS volume by the application of Boyle"s and Charles" laws and the known values of water vapour partial pressure at different temperatures. Detailed investigation of a single patient requires that these steps should be repeated many times. Hence a welcome contribution was the provision of a set of factors for the second calculation in the range 20-37ºC. (Comroe, Forster, Dubois, Briscoc, and Carlsen, 1962), barometric pressure changes between 750 and 770 mm. Hg having been shown to be insignificant. These factors are therefore primarily dependent upon laboratory temperature. Extends the range of the Comroe factors to 15-40º"C. Ventilator as a breathing aid for patients who have independent breathing problems, in this study, data was collected to find out whether the data produce using the psychological measurement mode as recommended by the manufacturer is appropriate or whether STPD can be used if it is not stated on the ventilator technical guide.

***Keyword** : Ventilator, SIMV, BTPS, ATP, STPD*

1. INTRODUCTION

In the field of modern medicine, ventilators play an important role in maintaining and restoring respiratory function balance for individuals facing critical health challenges. A ventilator, also known as a mechanical ventilator or breathing machine[8], is a sophisticated medical device that can help patients who have difficulty breathing independently and is widely used to care for critical patients in the ICU room[9]. By delivering controlled amounts of oxygen and air the lung,

ventilators provide important support for those with respiratory insufficiency or failure.

Ventilators operate on the principle of positive pressure ventilation which involves creating a gentle flow of air to the lungs to facilitate exchange of life sustaining gases oxygen and carbon dioxide. This intervention not only ensures that oxygen reaches the bloodstream, nourishing every cell, but also helps remove carbon dioxide, a waste product of metabolism.

In a controlled hospital environment, ventilators are used with varying understanding of each patient's unique needs. Medical professionals adeptly select from a variety of ventilation modes, such as assisted control and synchronized intermittent mandatory ventilation, customizing the operation of the device to suit the specific challenges facing the patient.

Ventilator is a capable respirator work automatically is also a result of technological sophistication is the creation of tools that called a ventilator machine that is useful for helps respiratory function[1]. Modern ventilators are equipped with an array of sensors and monitors, which provide real time information about the patient's breathing pattern, lung pressure, and oxygen saturation level. These valuable metrics guide medical teams in making quick and appropriate decisions to optimize ventilation settings and improve patient comfort.

The use of ventilator is especially important in situations where conditions such as acute respiratory distress syndrome (ARDS), pneumonia, and chronic obstructive pulmonary disease (COPD) have disrupted the natural process of breathing. ARDS is a medical condition that was first described in 1967 and is made up of pulmonary infiltrates, decreased lung compliance, and acute hypoxemia [2]. By offering temporary rest and allowing the body to recover, ventilators serve as a bridge to recovery for those grappling with severe respiratory illnesses.

It is important to note that providing ventilator support requires the expertise of skilled medical professional. Their expertise ensures accurate configuration and continuous monitoring of devices, thereby safeguarding patient well being during this critical phase of their medical journey.

Chapter 1 explains the background knowledge of this research, Chapter 2 explains the research methods, Chapter 3 explains the results and analysis of the research, Chapter 4 explains the results of the study, compares with previous researchers and the implications of the research, Chapter 5 explains the conclusions and future research.

2. MATERIALS AND METHODS

A. Experimental Setup

A Ventilator is a medical device designed to provide mechanical ventilation by moving breathable air in and out of the lungs of a patient who is unable to breathe sufficiently on their own. Ventilator are commonly used in hospitals, especially in intensive care (ICU), to support patients with respiratory insufficiency or failure.

Key functions of a ventilator include :

a. Assisted Breathing

Ventilators can assist patients who are breathing inadequately or not at all. They deliver a controlled mixture of oxygen and air to the patients lung.

b. Positive Pressure

Vebtilators generate positive pressure to inflate the lungs and push air into the respiratory system, helping with gas exchange.

c. Tidal Volume Control

The device controls the volume of air and the rate at which its delivered to the patients lungs, ensuring proper oxygenation and removal of carbon dioxide.

d. Oxygen Concentration

Ventilator can adjust the concentration of oxygen in the delivered air to meet the patient's specific needs.

e. Monitoring

Modern ventilators come with various sensors and monitors that provide real time data on the patients breathing patterns, lung pressures and oxygen levels.

f. Modes

Ventilator offer different ventilation modes, such as assist control, pressure support, Synchronized Intermitternt Mandatory Ventilation (SIMV), and more. These modes cater to different patient conditions and requirements.

Its important to note that the use of ventilators requires skilled medical professionals to set up and monitor the device, as well as to adjust its settings based on the patients evolving condition.

1) MATERIALS AND TOOLS

This study used a ventilator analyzer as a standard measurement tool and several brands of ventilators in the hospital to obtain data on differences in tidal volume values between BTPS, ATP and STPD. To find out how much the difference in tidal volume is if a ventilator is used. STPD (Standard Temp and Pressure, Dry), ATP (Ambient Temperature and Pressure), or BTPS (Body Temperature and Pressure, Saturation) The Conditions of temperature, pressure and saturation which express the physiologically relevant with volume of respiratory gas are often overlooked and many do not know about them when clinical practice is carried out. In this study, we conducted research on the effect of gas volume correction in natural or artificial lungs which can change metabolism and main components on breathing and critical consequences [21].

2) EXPERIMENT

In this study, there were 3 types of ventilators using the physiological measurements modes listed in the technical guide. At the beginning of testing the performance of the ventilator, connect it with the power supply, compressed air and oxygen before the ventilator is turned on. Make sure the breathing circuit connected to the patient is the breathing circuit recommended by the manufacturer in accordance with the brand of ventilator to be tested. Press the power button to turn on the ventilator, perform internal calibration of the ventilator [10]and routine disinfectant procedures on the components of the ventilator.

Adjust the mode used; Select Adult usage, then select Volume Controlled mode. To default setting for the first time, set the ventilator at the tidal volume setting value of 400 ml, Breath rate 15, FIO2 21% and I: E Ratio 1: 3. Some units do not come with I:E settings, but I:E settings done by setting Time Inspiration. Turn on the gas flow analyzer, warm up for 5 minutes. Input the actual values of ambient temperature and humidity on the gas flow analyzer. Perform the installation as shown below :

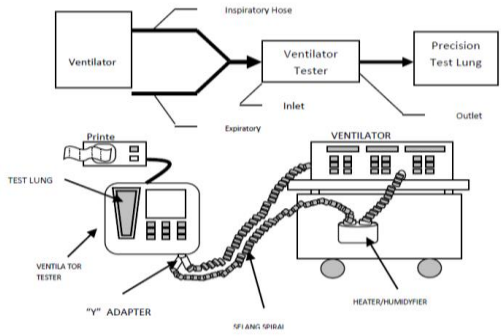

FIGURE 1. Ventilator calibration instalation

The ventilator uses the Synchronized Intermittent Mandatory Ventilation (SIMV) mode when measuring performance so that it can learn and understand the physiological

measurement modes listed in the technical guide in accordance with the results of the measurement that have been carried out.

Data was collected using a ventilator analyzer to obtain tidal volume, heart rate, IE ratio, minute volume, PEEP, MAP, PIP, inspiration time, and expiration time values which then used the physiological measurement mode listed in the technical guide. Data collection was carried out in three ways, namely a ventilator using the physiological measurement mode according to what is stated in the technical guide, and using ATP or BTPS or STPD.

The resulting data will be analyzed by comparing the values that are appropriate to use if using a physiological measurement mode that is in accordance with those listed in the technical guide.

Statistical analysis was carried out in this study to determine the error rate of this study by calculating the correction value and standard deviation stated in the ventilator calibration uncertainty formula [6]. Pay attention to the alarm indicator, if the ventilator alarm sounds perform standard actions to turn off the alarm refer to on the ventilator operating instructions. View alarm indicators and perform parameter and boundary adjustments alarm of each parameter (refer to the operating instructions of the ventilator) until the alarm does not sound. Parameter tuning is based on alarm display information.

3. METHODS

This research uses three factors: temperature, pressure and relative the degree of saturation of the gas with water vapor must be considered, especially when gas volumes are compared below different environmental conditions and subsequent use in metabolic and physiological calculations. That standard provides a frame of reference for expressing the volume of a gas is STPD, BTPS or ATP [3].

BTPS Correction is used to convert flow and volume measured at ambient conditions to the conditions within the lungs. Ambient conditions are called ATP (ambient temperature, pressure); the conditions within the lungs are called BTPS (body temperature, pressure, water vapor saturated) [7].

STPD refers to the volume of a gas expressed under Standard conditions of Temperature (273°K or 0°C), Pressure (760 mm Hg), and Dry (no water vapor) [3]. Conversion of ATPS volume to BTPS volume by the application of Boyle's and Charles' laws and the known values of water vapour partial pressure at different temperatures. Detailed investigation of a single patient requires that these steps should be repeated many times. Hence a welcome contribution was the provision of a set of factors for the second calculation in the range 20-37ºC. (Comroe, Forster, Dubois, Briscoc, and Carlsen, 1962), barometric pressure changes between 750 and 770 mm. Hg having been shown to be insignificant. These factors are therefore primarily dependent upon laboratory temperature. Extends the range of the Comroe factors to 15-40º'C[8].

B. The Flowchart

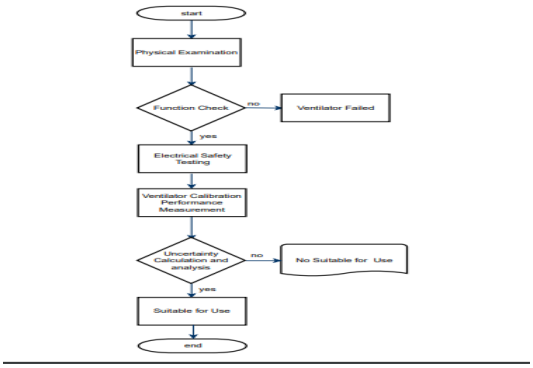

FIGURE 2. In the Flowchart describes the testing and calibration process for the ventilator. From this flow, it can be seen that the results of the calibration test can determine whether a ventilator can be used for patients or whether it cannot be used for patients.

FIGURE 4. The Flowchart of stages and data collection process during ventilator calibration. The ventilator is connected to the ventilator analyzer, after the data is seen on the ventilator analyzer, the data will be analyzed he ventilator can be used or not used on the patient.

FIGURE 3 Flow diagram of stages and processes data collection during ventilator calibration. First, carry out a physical and functional examination of the ventilator and data will be collected. If the physical examination and function are good, you can continue with electrical safety testing on the ventilator. Next, carry out internal calibration on the ventilator before connecting process on the ventilator analyzer, once the ventilator is stable, data can be taken and viewed on the ventilator analyzer, then the data will be analyzed. Then it will be known whether the ventilator can be used or cannot be used for the patient.

After the process has been carried out according to FIGURE 3 when analyzing the data produced by the ventilator, is it in accordance with the measurement points determined with a tolerance of 10% of the setting value as explained in FIGURE 4 if it does not match the value read on the ventilator analyzer, you can The next analysis carried out is whether the psychological measurement that is being measured, such as BTPS, ATP or STPD. If it is not appropriate, then carry out data collection according to what is stated in the ventilator's technical guide. If it is not there, you can use STPD in the setting psychological measurements mode on the ventilator analyzer.

4. RESULT

Ventilator as a breathing aid for patients who have independent breathing problems, in this study, data was collected to find out whether the data produce using the psychological measurement mode as recommended by the manufacturer is appropriate or whether STPD can be used if it is not stated on the ventilator technical guide.

REFERENCES

[1] Yesi Maria and Syahrizal Syarif, "Factors related to Ventilator Associate Pneumonia in the Intensive Care Unit Room of Tangerang Regency General Hospital," Indonesian Journal of Health Epidemiology, Research Article, vol 6 , no Desember 2022, doi: 10.7454/epidkes.v6i2.6367.

[2] Michael C. Sklar MD, Laveena Munshi MD, MSc, "Advances in Ventilator Management for Patients with Acute Respiratory Distress Syndrome," Clinics in Chest Medicine, vol 43, pp. 499-509, 2022 doi: 10.1016/j.ccm.2022.05.002.

[3] aAppendix D Copyright 1991, 1999 by Fitness Technologies, Inc, 5043 Via Lara Lane, Santa Barbara, CA, 93111.

[4] [5] N. H. Wijaya, A. G. Alvian, A. Z. Arfianto, J. E. Poetro, and F. Waseel, "Data Storage Based Heart and Body Temperature Measurement Device," J. Robot. Control, vol. 1, no. 1, pp. 11–14, 2020.

[6] J. Duvernoy, "Guidance on the Computation of Calibration Uncertainties," World Meteorol. Organ., no. 119, 2015, [Online]. Available: http://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html%0D

[7] © ndd Medizintechnik AG, 02-2013, CB 1 / 1 AppNote BTPS Correction V01R.docx.

[8] Devi K Panjaitan, Jadeny Sinatra, Dwi L Siahaan, "Hubungan Penggunaan Ventilator Mekanik Terhadap Kejadian Ventilator Associated Pneumonia (VAP)," J. Kedokteran Methodist, vol. 14, no. 1, juni 2021.

[9] Nur Khayati, Nana Rohana, Rista Apriana. " Faktor-Faktor yang Berhubungan dengan Kejadian Ventilator Associated Pneumonia pada Pasien yang menggunakan Ventilator Mekanik," J. Ners Widya Husada, vol. 4, no. 3, hal 85 - 94, November 2017, p-ISSN 2356-3060, 2017.

[10] Didier Tassaux, Philippe Jolliet, Jean-Marc Thouret, Jean Roeseler, Rene Dorne, and Jean Claude Chevrolet, "Calibration of Seven ICU Ventilators for Mechanical Ventilation with Helium–Oxygen Mixtures," Am J Respir Crit Care Med 1999; 160:22-32

[11] Appendix D Copyright 1991, 1999 by Fitness Technologies, Inc, 5043 Via Lara Lane, Santa Barbara, CA, 93111.

[12] Mats Wallin, Göran Hedenstierna, "Tidal volumes: cold and dry or warm and humid, does it matter?," Journal of Clinical Monitoring and Computing, 2019, doi.org/10.1007/s10877-019-00416-7

[13] Wallon G, Bonnet A, Guerin C. Delivery of tidal volume from four anaesthesia ventilators during volume-controlled ventilation : a bench study. Br J Anaesth. 2013; 110(6):1045–51. https://doi.org/10.1093/bja/aes594

[14] ISO 80601-2-12:2011. Particular requirements for basic safety and essential performance of critical care ventilators. 2011.

[15] ISO 80601-2-13:2011. Particular requirements for basic safety and essential performance of an anaesthetic workstation. 2011.

[16] Andrew D Marchese, Demet Sulemanji MD, Daniel Chipman RRT, Jesu´s Villar PhD MD, and Robert M Kacmarek PhD RRT FAARC, "Performance of Current Intensive Care Unit Ventilators During Pressure and Volume Ventilation, " Respiratory Care, Juli 2011 vol 56 no. 7.

[17] T. A. Larkin and G. O'Reilly, "Performance evaluation and testing of adult critical care ventilators," Current Anaesthesia and Critical Care (1997) 8, 174-179.

[18] Hidayat, Iman Satria, Arnita, Seflahir Dinata, "Perancangan dan Implementasi Ventilator Friendly sebagai Alat Bantu Pernapasan," EPIC (Journal of Electrical Power, Instrumentation and Control), Teknik Elektro – Universitas Pamulang, vol. 5, No. 1, Juni 2022, Hal 10 – 19, http://openjournal.unpam.ac.id/index.php/jit , doi : 10.32493/epic.v5i1.18524

[19] Imanuel Jefri B.S,Yola Errisa M.A,Zulfikar N.H, "Pengembangan Dan Desain Otomatis Ventilator Mekanik,"Jurnal Pengembangan Rekayasa dan Teknologi," vol.18, No.2, Desember 2022, pp. 26 – 32 p-ISSN: 1410-9840 & e-ISSN: 2580-8850, https://journals.usm.ac.id/index.php/jprt

[20] Franc¸ois Lellouche, Solenne Taille´, Salvatore M. Maggiore, Siham Qader, Erwan L'Her, Nicolas Deye, and Laurent Brochard, "Influence of

Ambient and Ventilator Output Temperatures on Performance of Heated-Wire Humidifiers," American Journal of Respiratory and Critical Care Medicine, vol 170, 2004.

[21] Rosanna D'Albo, Federica Romitti, Luigi Camporota, Onnen Moerer, Mattia Busana, and Luciano Gattinoni, "Gas volume corrections in intensive care unit: needed or pointless?,"J Appl Physiol 135: 334–342, 2023, June 22, 2023; doi:10.1152/japplphysiol.00225.2023

[22] M. Fajar Sadli, Doddy Tavianto, Ike Sri Redjeki," Gambaran Pengetahuan Klinisi Ruang Rawat Intensif mengenai Ventilator Associated Pneumonia (VAP) Bundle di Ruang Rawat Intensif RSUP Dr. Hasan Sadikin Bandung, "Jurnal Anestesi Perioperatif [JAP. 2017;5(2): 85-93, p-ISSN 2337-7909; e-ISSN 2338-8463; http://10.15851/jap.v5n2.1108

[23] Leonardo Govoni, Raffaele L Dellaca, Oscar Peñuelas, Giacomo Bellani, Antonio Artigas, Miquel Ferrer, Daniel Navajas, Antonio Pedotti, Ramon Farré, "Actual performance of mechanical ventilators in ICU: a multicentric quality control study, "Medical Devices: Evidence and Research 2012:5 111–119.

[24] Kellogg RH. Laws of physics pertaining to gas exchange. In: Handbook of Physiology: The Respiratory System, Gas Exchange, edited by Fishman AP, Farhi LE, Tenney SM, Geiger SR. Bethesda, MD: American Physiological Society, 1987, p. 13–30.

[25] Goligher EC, Amato MBP, Slutsky AS," Applying precision medicine to trial design using physiology. Extracorporeal CO2 removal for acute respiratory distress syndrome, " Am J Respir Crit Care Med 196: 558–568, 2017. doi:10.1164/rccm.201701-0248CP.

[26] Maj R, Palermo P, Gattarello S, Brusatori S, D'Albo R, Zinnato C, Velati M, Romitti F, Busana M, Wieditz J, Herrmann P, Moerer O, Quintel M, Meissner K, Sanderson B, Chiumello D, Marini JJ, Camporota L, Gattinoni L, "Ventilatory ratio, dead space, and venous admixture in patients with acute respiratory distress syndrome," Br J Anaesth 130: 360–367, 2023. doi:10.1016/j.bja.2022.10.035.

[27] Richard JC, Carlucci A, Brenton L, Langlais N, Jaber S, Maggiore S, et al. Bench testing of pressure support ventilation with three different generations of ventilators. Intensive Care Med 2002;28(8):1049- 1057.