Volumetric Capnography: History, Function and Clinical Uses

Odair Henrique Gaverio Diniz[1]*, Marcos Mello Moreira[2]

[1]Department of Sciences of Surgery, University of Campinas, Sao Paulo, Brazil

[2]Department of Pneumology and Internal medicine, University of Campinas, Sao Paulo, Brazil

Mini-Review

Received: 20-Jun-2022, Manuscript No. JCROA-22-67019**; Editor assigned:** 22-Jun-2022**,** Pre QC No. JCROA-22-67019 (PQ); **Reviewed:** 07-Jul-22, **QC No.** JCROA-22-67019**;** **Revised:** 14-Jul-2022**,** **Manuscript No.** JCROA-22-67019 (R); **Published:** 21-Jul-2022**,** **DOI:**10.4172/jclinresp.4.S1.004

***For Correspondence:**

Dr. Odair Henrique Gaverio Diniz, Department of Sciences of Surgery, University of Campinas (UNICAMP), Campinas, Sao Paulo, Brazil

E-mail: ohgdiniz@gmail.com

Keywords: Capnography; Tidal volume; Carbon dioxide; Breathe

ABSTRACT

Introduction: The volumetric capnography is a quick, simple, cheap, and effective test for distal airways. The test is based on the volumetric concentration of expired CO_2 and Tidal Volume (CV) flow over a single exhalation.

Literature review: The exam makes it possible to observe the curve of expired CO_2, considering its concentration. These CO_2 curves are plotted, showing the inspired volume point by point, and the dead space volume can be calculated among the elimination of CO_2 with each breath. Showing us the different phases of breathing, seen in slopes, from 1 to 3.

Discussion: Several authors found valuable data when comparing volumetric capnography with other established tests, such as spirometry.

Conclusion: Despite the countless discoveries using capnography, we still need more tests and comparisons in other pathologies to better understand their most diverse peculiarities. Not forgetting that capnography is a complementary exam. We need other tests, such as computed tomography, to make a diagnosis and define an appropriate treatment for patients.

INTRODUCTION

The volumetric capnography is a quick, simple test and has proven to be of great value when it comes to distal airways. The test is based on the volumetric concentration of expired CO_2 and tidal volume flow over a single exhalation. Changes in the production and elimination of CO_2 can occur in metabolic and lung diseases. These changes in homeostasis can be detected by the partial pressure of CO_2 in arterial blood. With the difficulties of monitoring and measuring CO_2 levels in arterial blood by blood gas analysis, a convenient solution for CO_2 monitoring can be through non-invasive measurements, by analyzing expired air. The method of analyzing exhaled CO_2 in a non-invasive way is through the absorption of infrared light according to the Lambert-Beer laws, where it is possible to calculate the energy absorption of CO_2 by measuring its concentration through reducing the intensity of light in the passage of the CO_2 sample by the sensor, after a comparison of intensities with a normal sample, made possible by the polyatomic and asymmetric nature of CO_2 [1,2]. The first measurement of spectrum absorption using infrared was made in the 1860s by the physicist John Tyndall, by measuring expired CO_2, managing to quantitatively measure the physical values of the molecule. From this, it was possible to develop the capnographer as we know it today.

LITERATURE REVIEW

The volumetric capnography device can have a sidestream flow or mainstream flow respiratory gas monitor. The mainstream method has its infrared sensor close to the patient, where it is kept between the Y and the tracheal tube. The sidestream method, on the other hand, is more easily manageable and allows the monitoring of other gases, in addition to CO_2 [3,4]. The main difference between the methods is that the mainstream flow has a high precision, virtually instantaneous measurement of the CO_2 concentration. While the side stream flow method has a lower fidelity in the results and also presents a delay of a few seconds in the measurement of the sample compared to that seen in the analysis of the mainstream flow method [3]. The expired nitrogen curve shown is the same as that of CO_2, considering its concentration. Allowing you to separate the alveolar dead space from the anatomical dead space based on breathing [5]. Remembering that the respiratory system is composed by alveolar dead space plus anatomical dead space. The exam detects changes in dead space volumes, ventilation perfusion rates, pulmonary blood flow, and other respiratory changes. These CO_2 concentrations are plotted, showing the inspired volume point by point, and the dead space volume can be calculated between the elimination of CO_2 with each breath [5,6]. The slope 1 marks the exhaled tidal volume of the anatomical dead space airways, showing low concentrations of CO_2 or its absence. The slope 2 represents lung units, where we observed a practically linear increase in CO_2 coming from the transition among the anatomical dead space and the alveolar gas compartment, with normal values of 0.36 mmHg/mL 0.40 mmHg/mL. The slope 3 has its volumes attributed to the distribution of ventilation and lung profusion, CO_2 comes from the alveolar gas compartment, distal airways (characterized by the alveolar plateau, with normal values between 0.007 mmHg/mL 0.017 mmHg/mL [1,5].

These assays allow detection of pulmonary ventilation inhomogeneity and also allow an estimation of the anatomic location of the underlying disease process [7].

DISCUSSION

The capnography obtained several interesting results. One of the first results demonstrated by capnography was performed by Romeiro et al. where they carried out a study with normal patients and patients with Acute Respiratory Distress Syndrome (ARDS) on mechanical ventilation [8]. Concluding that CV index are important to detect heterogeneity in the distribution of ventilation in patients with ARDS, when compared to normal anesthetized and mechanically ventilated individuals. Among the indices studied, the relationship between effective alveolar ventilation volume and tidal volume seems to be the most sensitive and reproducible to assess ventilatory disorders.

In a study involving peripheral pulmonary obstruction in patients with cystic fibrosis, volumetric capnography was used as a technique for analysis gas elimination. In an attempt to obtain information on the distribution of pulmonary ventilation in the distal air spaces, involving the Multiple-Breath Washout (MBW) technique. The main finding of volumetric capnography was related to slope 3/CV. Proving to be more sensitive compared to spirometry, which indicated normal results. The slope 3 showed changes regardless of the stage of lung disease, involving patients with cystic fibrosis [9].

Through an experimental study on near-fatal pulmonary embolism, capnographic variables were tested in comparison with hemodynamic and blood gas measurements. The study involved six pigs intubated with an orotracheal tube to facilitate capnography data collection. The pigs were also sedated with 0.5% halothane while still maintaining spontaneous breathing in environmental air. Capnography data in the presence of hypercapnia were increased in respiratory variables involving the total minute volume, the minute volume of anatomical dead space, and finally, the alveolar minute volume. In conclusion, that the capnographic variables were effective in the assessment of acute obstructive disease in patients with pulmonary embolism [10].

Guang-Sheng et al. in a study in which they studied the ability of volumetric capnography to distinguish patients with Chronic Obstructive Pulmonary Disease (COPD) from normal individuals, concluded that some of the values determined, such as slope 2, slope 3 and the volume, in which the concentration of CO_2 rises from 25% to 50% of the value of mean End-Tidal Carbon Dioxide Pressure ($ETCO_2$), alone, are able to differentiate patients with COPD from normal individuals [11].

Schwardt, et al. proposed a method of retrieving information on the dimensions of distal air spaces and on the gas transport properties, from the volumetric spirogram of CO_2 in healthy individuals and in patients with COPD [12]. The dimensions of the different pulmonary structures used were those proposed by Weibel, Hansen and Ampaya, who specified the length of the air spaces, their diameter and the total cross-sectional area in each of the 23 (twenty-three) or 26 (twenty-six) generations (z) that start their bifurcation from the pharynx, larynx and trachea (since all these regions contribute to the anatomical dead space), where z=0 and end in the most peripheral of the alveolized generations (23 or 26), depending on the study used, either Weibel or Hansen [13,14]. The combination of the data obtained in real measurements with the computer simulation of the numerical values of CO_2 transport allowed the development of a computerized method of analysis of the CO_2 spirogram capable of estimating the loss of alveolized tissue and the limitation of gas transport in emphysema. It was able to determine the effects of the variation of acinar morphometry in the form of phase 3 of the volumetric CO_2 spirogram. Previous studies by Schwardt, et al. had already demonstrated that small tidal volume, reduction in the cross-sectional area of distal air spaces and any other changes that also produced a decrease in the interface area between the incoming new tidal volume and the volume of gas already present in the lung functional residual capacity, produce an increase in phase 3 slope [15].

Schwardt, et al. reached an important conclusion that the reduction in the total cross-sectional area of the peripheral airspaces, when combined with an increase in the length to be traveled by CO_2, until it reaches the mouth, in order to maintain similar volumes moved, causes an increase in phase 3 slope [12,15].

Veronez, et al. in a study carried out with cystic fibrosis and non-cystic fibrosis bronchiectasis patients, concluded that both groups of patients showed an increase in slope 3 when compared to the control group, a fact that would probably indicate the presence of diffuse small airway disease in both diseases, cause of ventilation heterogeneities [16].

The asymmetric branching of the bronchial tree produces parallel units (acins) that differ in axial length and volume, and this asymmetry explains the slight positive slope of the alveolar plateau at phase 3 of the capnogram in most normal people. In bronchiectasis, there is probably an accentuation of this asymmetry, which will be greater, more severe and diffuse the disease [17].

Diniz, et al. found that the greater the thickness of the bronchial wall, the greater the $ETCO_2$. And that increases in slope 3 indicate major damage to the distal airways and/or lung parenchyma [18].

Galvão, et al. volumetric capnography and exercise tolerance and reduction of dyspnea during activities of daily living [19]. The same was observed in patients grouped according to disease severity, with no differences among groups.

Luiz et al. in a study with Duchenne muscular dystrophy, found volumetric capnography parameters referring to higher heart rate and lower slope on slope 2 [20].

CONCLUSION

The volumetric capnography has a broad aspect of utility when it comes to the airways. Although little explored, the capnographer has an important power to discover the physiology and pathology in the small bronchioles, not so well evaluated by other exams, showing us its role in the understanding of respiratory diseases. Despite several studies using volumetric capnography, much work remains to be done. By gaining knowledge about the pathophysiology of diseases, we can improve the quality of health care, improving the quality of treatment of diseases and, consequently, improving the quality of life of patients.

AUTHOR CONTRIBUTION

Diniz OHG: conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing-original draft, writing-review & editing;

Moreira MM: conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing-original draft, writing-review & editing.

FINANCING

The project had no financial support.

CONFLICT OF INTEREST

The authors declare do not have any conflict of interest.

REFERENCES

1. Kremeier P, et al. Clinical use of volumetric capnography in mechanically ventilated patients. J Clin Monit Comput. 2020;34:7-16.
2. Jaffe MB. Infrared measurement of carbon dioxide in the human breath: “breathe-through” devices from Tyndall to the present day. Anesth Analg. 2008;107:890-904.
3. Jaffe MB. Respiratory Gas Analysis-Technical Aspects. Anesth Analg. 2018;1256:839-845.
4. Balogh AL, et al. Capnogram slope and ventilation dead space parameters: comparison of mainstream and sidestream techniques. Br J Anaesth. 2016;117:109-117.
5. Verscheure S, et al. Volumetric capnography: lessons from the past and current clinical applications. Crit care. 2016;23:184.
6. Brown RH, et al. Forced Expiratory Capnography and Chronic Obstructive Pulmonary Disease (COPD). J Breath Res. 2013;7:017108.
7. Robinson PD, et al. Inert gas washout: theoretical background and clinical utility in respiratory disease. Respiration. 2009;78:339-355.
8. Romero PV, et al. Physiologically based index of volumetric capnography in patients receiving mechanical ventilation. Er Respir J. 1997;10:1309-1315.
9. Ribeiro MÂ, et al. Volumetric capnography as a tool to detect early peripheric lung obstruction in cystic fibrosis patients. J Pediatr. 2012;88:509-517.
10. Pereira DJ, et al. Near-fatal pulmonary embolism in an experimental model: hemodynamic, gasometric and capnographic variables. Rev Bras Cir Cardiovasc. 2011;26:462-468.
11. Guang-Sheng Qi, et al. The ability of volumetric capnography to distinguish between chronic obstructive pulmonary disease patients and normal subjects. Lung. 2014;192:661-668.
12. Schwardt JD, et al. Noninvasive recovery of acinar anatomic information from CO_2 expirograms. Ann Biomed Eng. 1994;22:293-306.
13. Weibel ER. Why Measure Lung Structure? J Respir Crit Care Med. 2001;163:314-315.
14. Hansen JE, et al. Human air space shapes, sizes, areas, and volumes. J App Physiol. 1975;38:990-995.
15. Schwardt JD, et al. Sensitivity of CO2 washout to changes in acinar structure in a single-path model of lung airways. Ann Biomed Eng. 1991;19:679-697.
16. Veronez L, et al. Volumetric capnography for the evaluation of pulmonary disease in adult patients with cystic fibrosis and noncystic fibrosis bronchicasis. Lung. 2010;188:263-268.
17. Paschoal IA, et al. Capnografia volumétrica na bronquectasia: obtenção de informações anatômicas acinares de forma não invasiva. J Bras Pneumol. 2002;8:504.
18. Diniz OHG, et al. Correlations between volumetric capnography and automated quantitative computed tomography analysis in patients with severe COPD. J Resp. 2022;2:13-24.
19. Galvão F, et al. Effects of home-based inspiratory muscle training on Sickle Cell Disease (SCD) patients. Hematol Transfus Cell Ther. 2021;43:443-452.

20. Luiz LC, et al. Analysis of motor and respiratory function in duchenne muscular dystrophy patients. Respir Physiol Neurobiol. 2019;262:1-11.