Journal of Research in Clinical Medicine

J Res Clin Med, 2023, 11:32
doi: 10.34172/jrcm.2023.33335
https://jrcm.tbzmed.ac.ir

TUOMS PRESS

Original Article

Association of end-tidal and venous carbon dioxide in intubated and ventilated children

Amir Hossein Jafari-Rouhi[1], Samad Shams Vahdati[2], Asghar Jafari-Rouhi[3], Amin Khameneh[4], Leila Vahedi[5*], Reza Azadi[6], Naier Moharrami[6], Pooneh Navidi[6], Fatemeh Zeynalzadeh[6]

[1]Tuberculosis and Lung Diseases Research Center, Tabriz University of Medical Sciences, Tabriz, Iran
[2]Emergency and Trauma Care Research Center, Tabriz University of Medical Sciences, Tabriz, Iran
[3]Faculty of Medicine, Zanjan University of Medical Sciences, Zanjan, Iran
[4]Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran
[5]Road Traffic Injury Research Center, Tabriz University of Medical Sciences, Tabriz, Iran
[6]Pediatric Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran

Article info
Article History:
Received: August 10, 2022
Accepted: January 22, 2023
e-Published: November 19, 2023

Keywords:
Association, Carbon dioxide, Child, Tidal volume, Veins

Abstract

Introduction: The end-tidal CO2 pressure (PetCO2) monitoring which is a non-invasive method than PvCO2 (venous pressure of carbon dioxide), could determinate a graph depicting the carbon dioxide concentration in blood. The aim of this study was to investigate the correlation between PetCO2-PvCO2 in ventilated children.

Methods: All children intubated in the PICU of Children hospital Tabriz, Iran from 2019 to 2020 using the census method were assessed in terms of initial diagnosis, age, sex, PetCO2, and PvCO2 during a prospective cross-sectional study. Associations between variables were calculated for total patients and patients in the subgroups. Descriptive statistics were used to describe the quantitative analysis of data and the Pearson correlation coefficient and Linear Regression Test were used for the evaluation of the relationship between variables and for assessing the predictive values of PvCO2 using SPSS.26. A *P* value <0.05 was considered statistically significant.

Results: Out of 61 samples, 42 (68.9%) patients were males with a median age of 48 months. The mean of PetCO2 and PvCO2 were 20.3 ± 8.5 and 43 ± 12.3 mm Hg, respectively. The correlation of PetCO2-PvCO2 was significant in total patients (*P* value $=0.003$, $r=0.379$) and group 1 (*P* value $=0.009$, $r=0.374$). Furthermore, the results presented the predictive values of PvCO2 for PetCO2 while for one unit increase in the PvCO2 variable, PetCO2 could increase 0.372 units (*P* value $=0.005$, Slope $b=0.24$, Beta coefficient $=0.372$).

Conclusion: In most intubated children, PetCO2 may estimate the ventilation and change concentrations of CO2. It is necessary that the sample size of future studies will become large due to the weak correlation.

Introduction

Capnometry (capnography), called the CO2 measurement of respiratory gases, is widely used in operating rooms and intensive care units.[1] A device called a capnometer is commonly used to measure expiratory end-tidal carbon dioxide and display a capnogram waveform.[2] Capnography provides a timely interpretation of expiratory CO2 changes.[1]

In spontaneous breathing, the respiratory center controls the rate of respiration to keep the pH and PaCO2 (pressure arterial CO2) within the normal range.[3] However, in critically condition such as severe respiratory distress, patients undergoing mechanical ventilation and respiration is not positively under the control of the respiratory center.[4] Therefore, the physicians and medical staff determine the amount of ventilation according to the serial ABG/VBG (arterial/venous blood gas analysis). The ABG/VBG is an invasive and painful procedure (in the absence of an arterial line) and provides only a cross-sectional view of respiratory status.[5] End-tidal carbon dioxide pressure (PetCO2) measurement is a non-invasive and actual method for measuring PaCO2/PvCO2 (venous pressure of carbon dioxide) levels that do not have a delay time like ABG/VBG.[6]

Capnography is a convenient and valuable way to identify clinical problems quickly such as endotracheal ventilator dysfunction and other life-threatening problems, and could also be used to estimate the body's

***Corresponding Author:** Leila Vahedi, Emails: vahedi.l49@gmail.com, vahedil@tbzmed.ac.ir

metabolism and nutritional requirements of patients.[7]

PetCO2 monitoring has many benefits for the patients including; reducing blood sampling, reducing the number of venous catheter insertions, and as a result, the risk of infection and hospitalization, and medical costs are reduced.[8]

The relationship between PetCO2 and PaCO2/PvCO2 is affected by ventilation and perfusion.[8] The perfect matching between ventilation and perfusion leads to a stronger relationship in the fields. So that, in critically ill patients, which have usually disturbed the ventilation-perfusion ratio the use of capnometry in ICU wards is limited.[5] However, some studies have shown a good relationship between PetCO2 and PaCO2 /PvCO2 in seriously ill patients.[9]

Conventionally in patients, venous blood is used to measure carbon dioxide, since this is an invasive and painful method and obtaining blood from children may be difficult and potentially hazardous.[10] Therefore, the current study was conducted to compare the PaCO2/PvCO2 with PetCO2. If we do not observe any statistically significant difference between these two methods, Capnography which is a non-invasive, painless and simple method, will use for assessment the body's dioxide status in pediatric patients undergoing mechanical ventilation.

Methods

Study design and population

The current investigation was a prospective cross-sectional study that performed on children intubated at PICU of Children hospital, Tabriz, Iran using the census method from September 2019 to September 2020. The educational and training children's hospital is a general, governmental, and referral hospital with 150 beds and six wards in northwestern Iran.[11]

After obtaining the approval of the ethics committee and considering the inclusion and exclusion criteria, data including initial diagnosis, age, sex, PvCO2, and PetCO2 were provided for all patients intubated and ventilated in pediatric intensive care unit (PICU) using census method from September 2019 to September 2020.

The PvCO2 was measured after blood sampling from a vein, while the PetCO2 was calculated in the exhaled air using the capnography device. Blood sampling and capnography were performed on the first day of hospitalization in the morning shift by three observers (NM, PN, and FZ). For monitoring CO2 of the expiratory end three examiners used a capnometer device. Agreement (Cohen's kappa) between two measurements were more than 85%.

This study was blinded so that the analyzer, supervisor, laboratory staff, and two nurses who performed the capnography did not know the results of each patient. In addition, a comparison was also performed between patients with respiratory and non-respiratory disorders.

Inclusion and exclusion criteria

Inclusion criteria for children, including (1) age less than 12 years, (2) hospitalized in PICU, (3) under tracheal intubation, and (4) under mechanical ventilation.

Exclusion criteria for children, including (1) ventilated through a tracheostomy tube, (2) with cyanotic heart, (3) age less than one month.

Data analyses

The data were analyzed by descriptive statistical methods for means (standard deviations), and median and (interquartile ranges) in normally and non-normally distributed quantitative variables, respectively. Frequency, and percentage were used for qualitative variables. In all quantitative variables, the Kolmogorov-Smirnov test was used for checking the normality of variables when the P value > 0.05, the variables were considered to have a normal distribution. The Pearson correlation coefficient was used for the evaluation of the associations between variables. The Linear Regression test was also used for assessing the predictive values of PvCO2 for PetCO2. The confounding factors were not assessed due to low-prevalence children intubated in PICU and low diversity of causative diseases. It should be noted the children intubated due to trauma are not admitted to this center. A P value < 0.05 was considered as a significance level.

Results

Participants

In this prospective cross-sectional study, at first, 64 eligible patients were included in the study, of which 3 patients due to reasons (failure to perform 2 types of sampling at the same time, sampling error, arrest of the patient after performing one type of sampling) excluded from the study. Finally, out of 61 samples, 42 (68.9%) patients were males and 19 (31.1%) patients were females. The characteristics of patients are shown in Table 1.

The results of the Pearson correlation model showed that the correlation of PetCO2 and PvCO2 was significant (P value = 0.003, r = 0.379) as a weak positive correlation. This correlation was observed in group 1 (P value = 0.009, r = 0.374). The Correlation of PetCO2 with other variables (age and sex) was not significant (Table 2)

Table 3 presents the predictive values of PvCO2 for PetCO2. According to the Linear *Regression* Test results, there was a relationship between PetCO2 and PvCO2 (P value = 0.005). As for one unit increase in the PvCO2 variable, PetCO2 could increase 0.372 units (Table 3 and Figure 1).

Discussion

In this study, the correlation of PetCO2-PvCO2 was statistically significant as a positive, direct correlation but it is not very strong. This correlation also was observed between PetCO2 and PvCO2 in group 1. Furthermore, the PvCO2 variable was able to express PetCO2 changes

Table 1. The characteristics of children intubated in Tabriz children's hospital PICU

Variables	Items	Results
Age (month)	Mean	37.9
	Median	48.0
	Standard deviation	29.35
	Minimum	3.0
	Maximum	96
Pvco2 (mm Hg)	Mean	43
	Median	42.4
	Standard deviation	12.3
	Minimum	24.8
	Maximum	76.5
Petco2 (mm Hg)	Mean	20.3
	Median	18
	Standard deviation	8.5
	Minimum	9
	Maximum	57

PICU, pediatric intensive care unit.

as for one unit increase in the PvCO2 variable, PetCO2 could increase by 0.372 units.

Advances in CO2 measurement technology have associated with increased use and importance in patients' clinics. The importance of measuring expiratory CO2 is more important than blood samples. The CO2 measurement is a proven mechanism to confirm tracheal intubation, diagnosis of accidental esophageal intubation, diagnosis of airway outflow, displacement, and obstruction, monitoring of respiratory distress during anesthesia and after surgery.[12]

Another vital importance of capnography is the evaluation the effectiveness of cardiopulmonary resuscitation (CPR) and the condition of ventilation and pulmonary perfusion. It is also used to estimate the metabolism and nutritional needs of critically patients.[13] The importance of expiratory CO2 monitoring has led to the development of recommendations for various guidelines, including the American Society of Anesthesiology (ASA), the American Heart Association (AHA), the American Respiratory Care Association, and the Medicare and Medicaid service centers. However, the examination of CO2 exhalation is often neglected.[14]

In a study conducted by McDonald et al on 129 children intubated in PICU, a significant correlation was observed between PaCO2 and PetCO2. Nevertheless, only lung damage had a negative effect on PetCO2-PaCO2. The results strongly supported the use of end-tidal CO2 monitoring to assess non-invasive ventilation in critical patients except in cases with severe lung injury.[5]

In a study on 38 shocked patients, a relationship was examined between PetCO2 and cardiac output. The results of this study showed that the evaluation of PetCO2 changes could be used for cardiac output monitoring and

Table 2. Correlation between PetCO2 with PvCO2, sex, and age for children intubated in Tabriz children's hospital PICU

Group	Variables	Pearson Correlation Test	
		PetCO2	
		P value	Pearson's correlation
Total	Pvco2	0.003	0.379
	Age	0.4	-0.1
	Sex	0.3	0.12
Group 1	Pvco2	0.009	0.374
	Age	0.4	-1.22
	Sex	0.6	0.074
Group 2	Pvco2	0.07	0.504
	Age	0.9	-0.02
	Sex	0.06	0.528

PICU, pediatric intensive care unit.
Group 1: Patients with pulmonary disorders, Group 2: Patients with non-pulmonary disorders.

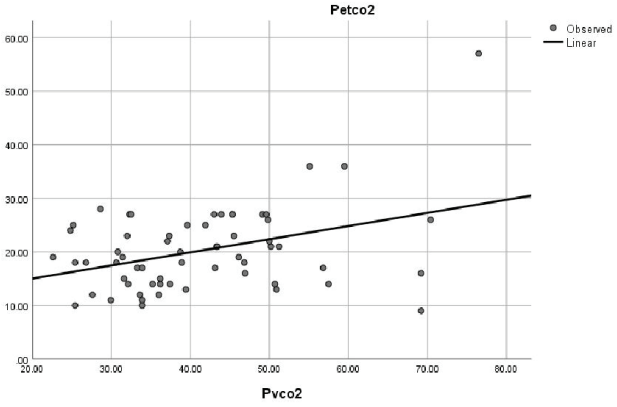

Figure 1. The PvCO2 for predicting PetCO2 in children intubated in Tabriz children's hospital PICU based on curve estimation.

the influence of fluid injection in patients.[15]

In study of Phishbin et al, on patients with metabolic acid-base disorders observed relationship between end-tidal carbon dioxide and arterial blood gas items and therefore, end-tidal carbon dioxide could be a suitable parameters for estimating blood carbon dioxide in emergency cases.[10]

In a pilot study conducted by Baudin et al from 2013 to 2014 on 65 children under mechanical ventilation in the PICU, the mean gradient between Paco2 and PetCO2 was 3.35 mm Hg, and PaC02 was measured using PetCO2 with an accuracy of ± 5 mm Hg in 95% of cases. Therefore, using non-invasive methods including the measurement of PCO2 is performed via exhalation could determinate the PaCO2 levels. It should be noted, due to the small number of studies in this field, further studies have been recommended.[16]

In another study conducted in 2014 on 66 infants and 60 children under mechanical ventilation, a positive correlation was reported between PetCO2 and paco2 with r = 0.836 in infants and r = 0.914 in children. A

Table 3. The predictive values of PvCO2, age and sex for PetCO2 in children intubated in Tabriz Children's Hospital PICU

Group	Variables	Linear regression test						
		PetCO2						
		Slope b	Std. Error	Beta coefficient	Tolerance	*P* value	95% CI	
							Lower bound	Upper bound
Total	Pvco2	0.24	0.08	0.372	2.91	0.005	0.07	0.40
	Age	0.003	0.03	0.013	0.09	0.9	-0.06	0.06
	Sex	0.91	2.19	0.054	0.41	0.6	-3.47	5.29

CI, confidence interval.

low Pao2/Fio2 ratio (less than 200) was effective in this relationship.[17]

Study limitations

This study has a number of limitations. This was done on intravenous samples of children and the samples were not repeated.

Conclusion

The results showed that there is a significant correlation between PetCO2 and PvCO2 in children under mechanical ventilation when this correlation was positive, direct, but weak. Therefore, it is recommended that capnometry maybe used to monitor the adequacy of ventilation in intubated children. In addition, PetCO2 could be a predictor factor for depicting blood carbon dioxide changes and ventilation. As the correlation was weak we suggested the future studies should be performed with more with large sample size.

Strengths and weaknesses points

The low sample size of study is the weaknesses point of this study. Strength point is the comparison of venous blood CO2 (PvCO2) with expiratory air (PetCO2) because the most studies have compared arterial blood (PaCO2) with PetCO2, which is much more difficult to prepare arterial blood in children.

Acknowledgments

We would like to thank the patients for participating in this study and staffs of children hospital PICU, Tabriz, Iran because of their cooperation in the progression of this study.

Study Highlights

What is current knowledge?

- The results of the current study showed that there is a positive relationship between PetCO2 and PvCO2 in children under mechanical ventilation.

What is new here?

- For the first time, the correlation between PetCO2 and PvCO2 has been performed because it is difficult to provide blood in children and the maintenance of blood gases is very important in children.

Authors' Contribution

Conceptualization: Amir Hossein Jafari-Rouhi, Samad Shams Vahdati, Asghar Jafari-Rouhi.
Data curation: Amir Hossein Jafari-Rouhi, Samad Shams Vahdati, Asghar Jafari-Rouhi, Reza Azadi.
Formal Analysis: Leila Vahedi, Amin Khameneh.
Funding acquisition: Amir Hossein Jafari-Rouhi, Reza Azadi.
Investigation: Naier Moharrami, Pooneh Navidi, Fatemeh Zeynalzadeh.
Methodology: Leila Vahedi, Amin Khameneh.
Project administration: Amir Hossein Jafari-Rouhi, Samad Shams Vahdati, Asghar Jafari-Rouhi, Reza Azadi.
Resources: Reza Azadi,Naier Moharrami, Pooneh Navidi, Fatemeh Zeynalzadeh.
Software: Naier Moharrami, Pooneh Navidi, Fatemeh Zeynalzadeh, Leila Vahedi, Amin Khameneh.
Supervision: Amir Hossein Jafari-Rouhi, Samad Shams Vahdati, Asghar Jafari-Rouhi.
Validation: Amir Hossein Jafari-Rouhi, Leila Vahedi.
Visualization: Amir Hossein Jafari-Rouhi, Samad Shams Vahdati, Asghar Jafari-Rouhi, Leila Vahedi.
Writing–original draft: Leila Vahedi, Reza Azadi, Amin Khameneh.
Writing–review & editing: Amir Hossein Jafari-Rouhi, Samad Shams Vahdati, Asghar Jafari-Rouhi, Reza Azadi, Leila Vahedi, Amin Khameneh, Naier Moharrami, Pooneh Navidi, Fatemeh Zeynalzadeh.

Competing Interests

The authors declare that they have no competing interests.

Ethical Approval

The present study was conducted after obtaining approval from the ethics committee of Tabriz University of Medical Sciences. All patients' information was stored confidentially. At first, informed consent was obtained from each family patient after explaining the goals of the project and the study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee. Finally, no additional costs were received from patients for performing interventions during the study and all costs were covered by the Vice Chancellor for Research, Tabriz University of Medical Sciences (IR.TBZMED.REC.957).

Funding

This study was supported in part by grant IR.TBZMED.REC.957 from the National by the Vice Chancellor for Research, Tabriz University of Medical Sciences of Health and by a teaching and research scholarship from the Pediatric Health Research Center College of Physicians (Dr Mohammad Barzegar).

References

1. Soleimanpour H, Taghizadieh A, Niafar M, Rahmani F, Golzari S, Mehdizadeh Esfanjani R. Predictive value of capnography for suspected diabetic ketoacidosis in the emergency department. West J Emerg Med. 2013;14(6):590-4. doi: 10.5811/westjem.2013.4.14296.
2. Fearon DM, Steele DW. End-tidal carbon dioxide predicts the presence and severity of acidosis in children with diabetes. Acad Emerg Med. 2002;9(12):1373-8. doi: 10.1111/j.1553-2712.2002.tb01605.x.
3. Jonkman AH, de Vries HJ, Heunks LMA. Physiology of the respiratory drive in ICU patients: implications for diagnosis and treatment. Crit Care. 2020;24(1):104. doi: 10.1186/s13054-020-2776-z.
4. Fan E, Brodie D, Slutsky AS. Acute respiratory distress syndrome: advances in diagnosis and treatment. JAMA. 2018;319(7):698-710. doi: 10.1001/jama.2017.21907.
5. McDonald MJ, Montgomery VL, Cerrito PB, Parrish CJ, Boland KA, Sullivan JE. Comparison of end-tidal CO2 and Paco2 in children receiving mechanical ventilation. Pediatr Crit Care Med. 2002;3(3):244-9. doi: 10.1097/00130478-200207000-00008 .
6. Monge García MI, Gil Cano A, Gracia Romero M, Monterroso Pintado R, Pérez Madueño V, Díaz Monrové JC. Non-invasive assessment of fluid responsiveness by changes in partial end-tidal CO2 pressure during a passive leg-raising maneuver. Ann Intensive Care. 2012;2:9. doi: 10.1186/2110-5820-2-9.
7. Manifold CA, Davids N, Villers LC, Wampler DA. Capnography for the nonintubated patient in the emergency setting. J Emerg Med. 2013;45(4):626-32. doi: 10.1016/j.jemermed.2013.05.012.
8. Phan CQ, Tremper KK, Lee SE, Barker SJ. Noninvasive monitoring of carbon dioxide: a comparison of the partial pressure of transcutaneous and end-tidal carbon dioxide with the partial pressure of arterial carbon dioxide. J Clin Monit. 1987;3(3):149-54. doi: 10.1007/bf01695936.
9. Mehta H, Kashyap R, Trivedi S. Correlation of end tidal and arterial carbon dioxide levels in critically Ill neonates and children. Indian J Crit Care Med. 2014;18(6):348-53. doi: 10.4103/0972-5229.133874.
10. Pishbin E, Doostkhah Ahmadi G, Sharifi MD, Talebi Deloei M, Sepehri Shamloo A, Reihani H. The correlation between end-tidal carbon dioxide and arterial blood gas parameters in patients evaluated for metabolic acid-base disorders. Electron Physician. 2015;7(3):1095-101. doi: 10.14661/2015.1095-1101.
11. Vahedi L, Jabarpoor-Bonyadi M, Ghojazadeh M, Hazrati H, Rafeey M. Association between outcomes and demographic factors in an Azeri Turkish population with cystic fibrosis: a cross-sectional study in Iran from 2001 through 2014. Iran Red Crescent Med J. 2016;18(4):e29615. doi: 10.5812/ircmj.29615.
12. Siobal MS. Monitoring exhaled carbon dioxide. Respir Care. 2016;61(10):1397-416. doi: 10.4187/respcare.04919.
13. Nassar BS, Schmidt GA. Capnography during critical illness. Chest. 2016;149(2):576-85. doi: 10.1378/chest.15-1369.
14. Berg MD, Schexnayder SM, Chameides L, Terry M, Donoghue A, Hickey RW, et al. Part 13: pediatric basic life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2010;122(18 Suppl 3):S862-75. doi: 10.1161/circulationaha.110.971085.
15. Abdelfattah WM, Saad-Eldeen Elgammal S, Elsayed KM, Mowafy SM, Abdalla RM. End-tidal carbon dioxide can track cardiac output changes during fluid challenge in shocked mechanically ventilated patients. Zagazig Univ Med J. 2021;27(2):238-46. doi: 10.21608/zumj.2019.14222.1295.
16. Baudin F, Bourgoin P, Brossier D, Essouri S, Emeriaud G, Wysocki M, et al. Noninvasive estimation of arterial CO2 from end-tidal CO2 in mechanically ventilated children: the GRAeDIENT pilot study. Pediatr Crit Care Med. 2016;17(12):1117-23. doi: 10.1097/pcc.0000000000000935.
17. Mehta H, Kashyap R, Trivedi S. Correlation of end tidal and arterial carbon dioxide levels in critically Ill neonates and children. Indian J Crit Care Med. 2014;18(6):348-53. doi: 10.4103/0972-5229.133874.