ORIGINAL ARTICLE

Bali Medical Journal (Bali Med J) 2017, Volume 6, Number 1: 12-16
P-ISSN.2089-1180, E-ISSN.2302-2914

Published by DiscoverSys

The End-Tidal CO_2 correlation with a decreased cardiac output measured by ultrasonic cardiac output monitor in intubated ICU patients

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ABSTRACT

Background: Assessment of cardiac output is crucial in the management of critically-ill patients. Various types of tool are available to measure cardiac output. However, most has limitations such as invasive, expensive, and require special skill. Assessment of End-tidal Carbon Dioxide ($EtCO_2$) is expected to be used as an alternative estimation of cardiac output. It is based on the condition that when cardiac output is decreased, it decreased pulmonary blood flow and diffusion of CO_2 into the alveolar, thereby increasing alveolar dead space and lowering $EtCO_2$.

Objective: To find a correlation between $EtCO_2$ and decreased cardiac output measured by Ultrasonic Cardiac Output Monitor (USCOM) for intubated patients in ICU of Sanglah General Hospital, Denpasar, Bali.

Methods: A cross-sectional study was conducted from June to August 2016 in Sanglah General Hospital ICU. The study involved 75 eligible patients with a total population sampling technique. The intubated patients admitted to the ICU were evaluated for $EtCO_2$ and USCOM in the first 24 hours, simultaneously. The data was tested for normality distribution with a Shapiro-Francia test. A Pearson's correlation test was run to check the correlations between variables.

Results: The $EtCO_2$ value obtained was positively correlated with cardiac output values ($r=0.373$ $p=0.001$).

Conclusion: there is a correlation between $EtCO_2$ and decreased cardiac output measured by USCOM for intubated patients in ICU of Sanglah General Hospital, Denpasar

Keywords: *End-tidal* CO_2, cardiac output, USCOM, correlation.

Cite This Article: Senopathi, T., Wiryana, M., Sinardja, K., Widnyana, I., Panji, P., Warsito, W. 2017. The End-Tidal CO_2 correlation with a decreased cardiac output measured by ultrasonic cardiac output monitor in intubated ICU patients. *Bali Medical Journal* 6(1): 12-16. DOI:10.15562/bmj.v6i1.372

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Received: 30 October 2016
Accepted: 11 December 2016
Published: 2 January 2017

INTRODUCTION

Cardiac output is the amount of blood pumped by the heart (L/min). Cardiac output is measurement using a thermodilution technique via the pulmonary artery catheter (PAC) is the gold standard. But, the test is invasive, expensive, and requires a special skill.[1-6]

Noninvasive Doppler technology such as an ultrasonic cardiac output monitor (USCOM) can be used to measure cardiac output via transaortic or transpulmonary approach. This tool is non-invasive, easy and safe to use repeatedly to measure the cardiac output, and can be used in conscious patients.[7-10] In a study comparing the accuracy of the USCOM device with that of the thermodilution technique of PICCO in patients with septicemia, the correlation coefficient was 0.89.[11] A study comparing a USCOM cardiac monitor with pulmonary artery catheter thermodilution in patients undergoing liver transplantation found a correlation coefficient of 0.896.[12] But, an USCOM is expensive and not always available in every hospital.

End-tidal Carbon Dioxide ($EtCO_2$) is expected to be used as an alternative estimation of cardiac output. It is based on the theory that a low cardiac output will decrease pulmonary blood flow and diffusion of CO_2 into the alveolar, thus increasing alveolar dead space and lowering $EtCO_2$.[13-19]

The aim of this study is to evaluate an alternative technique which can be used to monitor cardiac output in ICU admitted patients. The technique should be non-invasive, easy, and inexpensive. Cardiac output assessment with $EtCO_2$ through capnograph is easy to do, easy to learn, always available, real-time, and can be carried out continuously without an additional cost to the patient. Thus, it is best to be used as a supporting tool to monitor or detect a decrease in cardiac output. Therefore, an intervention or a further treatment can be done as soon as possible.[14,16]

METHODS

This study is an observational study using a cross-sectional design. The study took place in the ICU of Sanglah General Hospital from June to August 2016. The inclusion criteria were: (1) the patient was intubated and attached to a mechanical ventilator in the ICU, (2) the patient was admitted to the ICU in the first 24 hours of his/her

Table 1 The Sample Characteristics

Characteristics	f (%)	Median (IQR) or Mean± SD
	n = 75	
Age (years)		42 (34)
Gender		
Male	38 (50.7)	
Female	37 (49.3)	
BMI (kg/m²)		22.9 (4.2)
Temperature (°C)		36.7 ± 0.3
Type of Case		
Surgery	59 (78.7)	
Non-Surgery	16 (21.3)	
Hemodynamic		
Systolic (mmHg)		116.01 ± 25.2
Diastolic (mmHg)		69.05 ± 17.17
MAP (mmHg)		85.867 ± 18.74
Mode of Ventilator		
PIP (mmHg)		17.48 ± 5.36
Tidal volume (ml)		411.93 ± 58.32
Frequency (times/minute)		14.57 ± 3.56
PEEP (mmHg)		5.24 ± 0.67

Table 2 $EtCO_2$ and Cardio Ouput Correlation Test

Variable	Normality test (p)	Mean ± SD	correlation coeficient (r)	p Value
$EtCO_2$	0.413	31.53 ± 8.33	0.373	<0.001
Cardio output	0.060	4.39 ± 1.9		

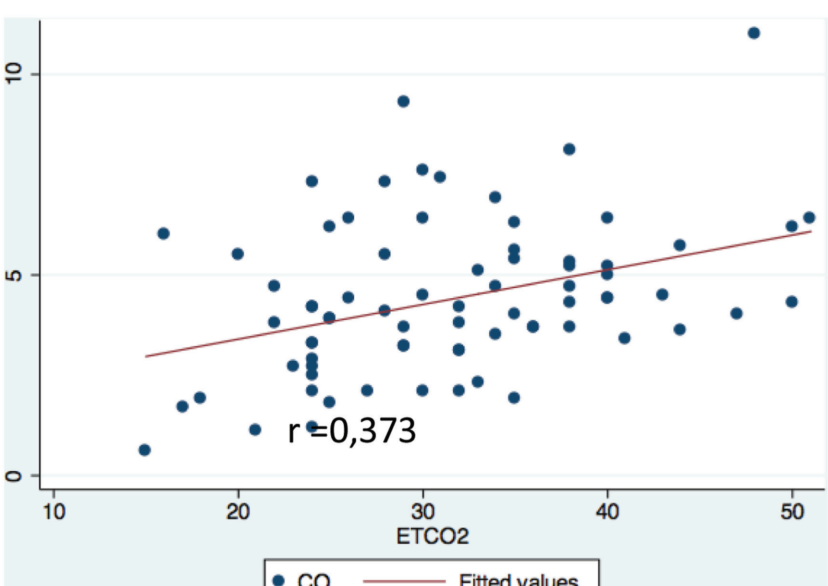

Figure 1 The scatterplot showed a correlation between $EtCO_2$ and cardio output measured by USCOM

hospital admission, (3) the $EtCO_2$ and USCOM was measured one hour after ventilator mode adjustment, (4) PEEP value was between 5-8 mmHg, (5) tidal volume reached around 6-8 ml/kg of ideal body weight, (6) aged 18-65 years. The exclusion criteria were: (1) the patient's family refused to participate in the study, (2) the patient had lung problems or diseases, (3) a fever (axillary temperature >38 °C), (4) heart valve abnormalities, (5) The $EtCO_2$ and USCOM measurement were not done simultaneously.

The sampling was done by using a total population sample. The eligible intubated patients were observed for $EtCO_2$ and then were measured for the cardiac output using USCOM. The result of this study was analyzed for $EtCO_2$ and decreased cardiac output correlation. We used Shapiro-Francia distribution test and Pearson's correlation test. Furthermore, an analysis of the receiver operating characteristic curve (ROC) was conducted to assess the ability of $EtCO_2$ to predict a decrease in cardiac output. We use Stata program SE 12.1.

RESULTS

There were 75 intubated patients in the ICU who were eligible. The patients' data were collected after obtaining the patient's family informed consent. There was no dropout. The characteristics of the study subjects include age, gender, Body Mass Index (BMI), body temperature, and type of case (surgical or non-surgical). The characteristic features are shown in Table 1.

The Shapiro-Francia test showed that the $EtCO_2$ (p=0.413) and the cardiac output (p=0.06) data were normally distributed. The correlation between the two variables using Pearson's Correlation Test is shown in Table 2. The correlation strength and direction was assessed by the correlation coefficient (r) and the scatter plot. The $EtCO_2$ mean was 31.5

Table 3 ROC Analysis for $EtCO_2$ and Cardio Output

Subject	ROC Area	*Std Error*	CI 95%
75	0.6499	0.0652	0.52213 – 0.77772

Table 4 The Occurrence of Low $EtCO_2$ and Low Cardio Output

$EtCO_2$	Cardio output: Decrease	Normal	Total
< 33 mmHg	31	14	45
≥ 33 mmHg	13	17	30
Total	44	31	75

Table 5 Validity Test

	Confidence Interval		
Prevalence	**59%**	**47%**	**69.90%**
Sensitivity	70.50%	54.80%	83.20%
Specificity	54.80%	36%	72.70%
ROC Area	0.626	0.514	0.739
LR (+)	1.56	1.01	2.4
LR (-)	0.539	0.309	0.94
Odds ratio	2.9	1.2	7.48
Positive predictive value	68.90%	53.4%	81.80%
Negative predictive value	56.70%	37.40%	74.50%

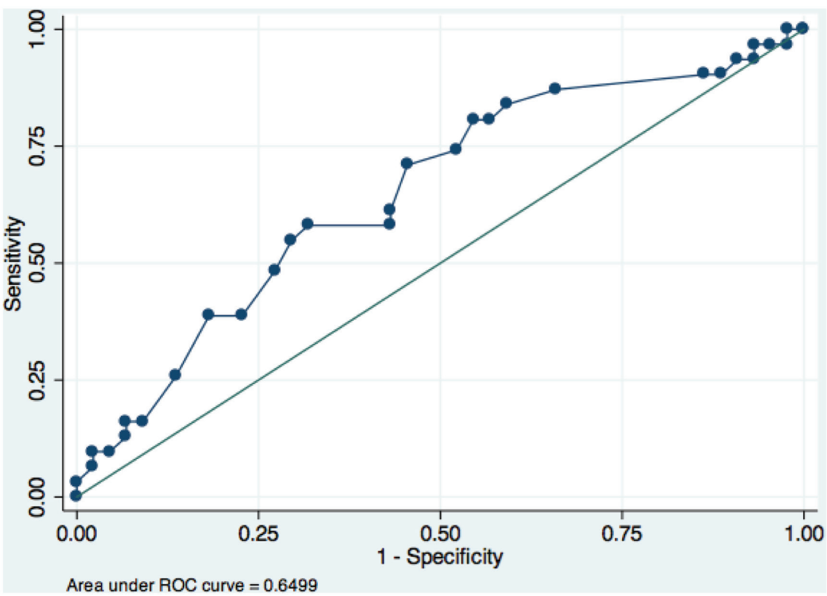

Figure 2 ROC curve of the ability $EtCO_2$ to detect a decreasing in cardiac output

mmHg (SD 8.3) and the cardiac output mean was 4.39 L/min (SD 1.9), r=0.373 (p<0.001). There was a statistically significant positive correlation between the $EtCO_2$ and the cardiac output.

The ROC showed the AUC value was 0.65. Based on the highest positive likelihood ratio (LR +) and the lowest negative likelihood ratio (LR-), the cutoff point of $EtCO_2$ in detecting a decrease in cardiac output was 33 mmHg. Based on $EtCO_2$ cutoff point of 33 mmHg, the sensitivity was 70.05% (CI 54.8% to 83.2%) and the specificity was 54.8% (CI 36% to 72.7%). The positive predictive value (PPV) was 68.9%, and the negative predictive value (NPV) was 56.7%.

DISCUSSION

$EtCO_2$ can be used to assess a patient cardiac output. When the cardiac output is decreased, then there will be a decreased pulmonary blood flow and a decreased diffusion of CO_2 to alveolar. Therefore, increasing the dead space ventilation or alveoli. Thus, the $EtCO_2$ decreases.[13,17,18,20]

In a June to December 2009 study conducted in a hospital emergency room, $EtCO_2$ was able to reflect any systemic hypoperfusion non-invasively in patients with clinical signs of shock. $EtCO_2$ value is influenced by cardiac output. When the cardiac output is decreased and the alveolar ventilation is constant, the $EtCO_2$ will be low. The average $EtCO_2$ was 29.64±11.49 mmHg in patients with hypovolemic shock, 28.60 mmHg±9.87 in cardiogenic shock, and 27.81±7.39 mmHg in septic shock. The $EtCO_2$ was significantly lower in deceased patients (p=0.005).[18,21-23]

In this study, we observed 75 intubated patients in Sanglah General Hospital ICU. Most of them were surgical patients (78.7%) who had a relatively stable hemodynamic condition. The systolic blood pressure mean was 116.01 mmHg (SD 25.2), diastolic blood pressure mean was 69.05 mmHg (SD 17.17), and MAP mean was 85.87 mmHg (SD 18.75).

Our study found a positive correlation and significant statistically between $EtCO_2$ and cardiac output using a USCOM (r=0.373 p=0.001). The result is similar to previous studies. A study involving 73 ventilated trauma patients in an emergency room from March until August 2011 found that a low $EtCO_2$ was associated with a low cardiac output (measured using Nicom). The $EtCO_2$ decreased significantly when the cardiac output is lower than 4.5 L/min (p<0.0001 r=0.60).[13] A study comparing the value of cardiac index, $EtCO_2$, $PaCO_2$, and P (a-Et) CO_2 at the time immediately before skin incision (point A) and during grafting (point B) in 50 patients who underwent an off-pump coronary artery bypass grafting showed a significant decrease in cardiac index from point A to point B (2.33 to 1.75 ml/min/m^2 p<0.001). A significant reduction was also seen in the $EtCO_2$ from 25.28 to 21.88 mmHg (p<0.001).[20]

Our study found a positive correlation confirming other studies, but with a lower $EtCO_2$. This may be caused by differences in the study subject characteristics. Most of our samples were postoperative patients (surgical case) with a relatively stable hemodynamic state. Therefore, the value of $EtCO_2$ and cardiac output obtained were relatively normal, with $EtCO_2$ mean 31.53 mmHg (SD 8.33) and cardiac output mean 4.39 ml/min (SD 1.9). It has been known that when cardiac output is normal, the $EtCO_2$ will reflect the patient's ventilation state.[15,16]

Even though there was a statistically significant positive correlation, the $EtCO_2$ for cardiac output assessment was better done in hemodynamically unstable patients.[18,21,24] In our study, the

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Table 6 The ROC Analysis of $EtCO_2$ Ability to Detect A Decrease In Cardiac Output

cutoff point	Sensitivity	Specificity	*Correctly Classified*	LR+	LR-
(>=15)	100.00%	0.00%	41.33%	10.000	
(>=16)	100.00%	2.27%	42.67%	10.233	0.0000
(>=17)	96.7%	2.27%	41.33%	0.9902	14.194
(>=18)	96.7%	4.55%	42.67%	10.138	0.7097
(>=20)	96.7%	6.82%	44.00%	10.386	0.4731
(>=21)	93.55%	6.82%	42.67%	10.039	0.9462
(>=22)	93.55%	9.09%	44.00%	10.290	0.7097
(>=23)	90.32%	11.36%	44.00%	10.190	0.8516
(>=24)	90.32%	13.64%	45.33%	10.458	0.7097
(>=25)	87.10%	34.09%	56.00%	13.215	0.3785
(>=26)	83.87%	40.91%	56.67%	14.194	0.3943
(>=27)	80.65%	43.18%	56.67%	14.194	0.4482
(>=28)	80.65%	45.45%	60.00%	14.785	0.4258
(>=29)	74.19%	47.73%	58.67%	14.194	0.5407
(>=30)	70.97%	54.55%	61.33%	15.613	0.5323
(>=31)	61.29%	56.82%	58.67%	14.194	0.6813
(>=32)	58.06%	56.82%	57.33%	13.447	0.7381
(>=33)	58.06%	68.18%	64.00%	18.249	0.6151
(>=34)	54.84%	70.45%	64.00%	18.561	0.6410
(>=35)	48.39%	72.73%	62.67%	17.742	0.7097
(>=36)	38.71%	77.27%	61.33%	17.032	0.7932
(>=38)	38.71%	81.82%	64.00%	21.290	0.7491
(>=40)	25.81%	86.36%	61.33%	18.925	0.8591
(>=41)	16.13%	90.91%	60.00%	17.742	0.9226
(>=43)	16.13%	93.18%	61.33%	23.656	0.9001
(>=44)	12.90%	93.18%	60.00%	18.925	0.9347
(>=47)	9.68%	95.45%	60.00%	21.290	0.9462
(>=48)	9.68%	97.73%	61.33%	42.581	0.9242
(>=50)	6.45%	97.73%	60.00%	28.387	0.9572
(>=51)	3.23%	100.00%	60.00%		0.9677
(>51)	0.00%	100.00%	58.67%		10.000

ROC analysis of the ability of $EtCO_2$ in detecting a decrease in cardiac output obtained an AUC of 0.65. We obtained a 70.05% sensitivity with CI 54.8% -83.2% and a specificity of 54.8% with CI 36% -72.7%.

CONCLUSION

The correlation analysis revealed a statistically significant positive correlation between the $EtCO_2$ and cardiac output measured by USCOM in intubated patients in our Sanglah General Hospital ICU (r=0.373 p=0.001). The ROC analysis found the 0.65 AUC. The $EtCO_2$ cutoff point for detecting a decrease in cardiac output was 33 mmHg.

The $EtCO_2$ and cardiac output value obtained in this study were relatively normal. Therefore, the $EtCO_2$ can be used to assess the patient's ventilation state. This research can be used as a reference in patients who were hemodynamically unstable or had a low cardiac output. Further studies are required regarding the $EtCO_2$ assessment in relation to a reduced cardiac output with more focus on patients who are hemodynamically unstable such as shock patients in an emergency room.

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