THE RELATIONSHIP BETWEEN END-TIDAL CARBON DIOXIDE LEVELS AND PATIENT POSITIONS

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ABSTRACT

Introduction*: End-tidal carbon dioxide partial pressure is a widely used measurement in clinical practice to monitor the current condition of the respiratory system. The aim of the present study is to demonstrate the changes in the levels of end-tidal carbon dioxide partial pressure during supine, Trendelenburg, and reverse Trendelenburg positions in healthy individuals.*

Materials and methods: *The end-tidal carbon dioxide partial pressure were measured in supine, Trendelenburg (30%), and reverse Trendelenburg (30%) positions using a facemask connected to an anesthesia machine (Siemens Kion, Sweden) after fixing the patient on the related position for five minutes. A 30-minutes resting period was provided to the patient for the accuracy of the end-tidal carbon dioxide partial pressure measurements following each positioning.*

Results: *The mean end-tidal carbon dioxide partial pressure level in reverse Trendelenburg position was significantly lower than in supine position ($p < 0.01$). The mean end-tidal carbon dioxide partial pressure level in Trendelenburg position was found to be higher when compared to reverse Trendelenburg position ($p < 0.01$). In supine and Trendelenburg positions, the mean end-tidal carbon dioxide partial pressure level was higher in males than in females ($p = 0.026$ and $p = 0.043$, respectively).*

Conclusion: *The findings of the present study revealed that Trendelenburg position may cause increased end-tidal carbon dioxide partial pressure levels while reverse Trendelenburg leads to a decrease in levels.*

Key words*: carbon dioxide, capnography, Trendelenburg position, supine position.*

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Introduction

Human physiology is a complex mixture of biological and biochemical events occurring at every moment of life. It begins with oxygen metabolism, which is the most vital part of the process. Briefly, the oxygen that enters from the lungs into the system is used for the production of ATP (Adenosine triphosphate) in the mitochondria, which is the site of aerobic metabolism in the cells. In this process, oxygen is the final electron acceptor in the electron transport chain, forming water in the end. Oxygen consumption results in carbon dioxide production in the tissues, and it is transported to the lungs by the blood. Finally, carbon dioxide is removed from the body by the lungs through expired air[1].

End-tidal carbon dioxide partial pressure ($ETCO_2$) is described as the partial pressure of carbon dioxide at the end of expiration, and closely correlates with arterial carbon dioxide tension ($paCO_2$)[2]. Therefore, measurement of $ETCO_2$ is recommended for the non-invasive estimation of $paCO_2$[3]. It is clinically used to detect the correctly placed endotracheal tube, valve dysfunction, or disconnection from the ventilator in anesthesia practice[4]. Pansard et al. showed that both $paCO_2$ and $ETCO_2$ increase in patients under general anesthesia during lateral decubitus position, which is required for renal surgery[5].

Another study conducted by Choi et al. reported that end-tidal carbon dioxide pressure gradient increases gradually with time during general anesthesia in the Trendelenburg position[6]. Several studies have evaluated the changes in $paCO_2$ and $ETCO_2$ under general anesthesia in various positions; however, limited studies showed the influences of positions on $ETCO_2$ in normal healthy subjects[5,6,7]. We hypothesized that various patient positions could alter the $ETCO_2$levels. Therefore, the overall aim of this study is to demonstrate the effects of supine, Trendelenburg, and reverse Trendelenburg positions on $ETCO_2$ in healthy individuals.

Materials and methods

After approval from Gaziosmanpasa University Clinical Research Ethics Committee (15-KAEK-133), patients aged between 18 and 40 years, who were, scheduled for elective surgery between August 2015 and December 2015, were enrolled in the study. The following parameters were the exclusion criteria: patients with an American Society of Anesthesiologists (ASA) score greater than or equal to a III, patients scheduled for abdominal surgery or any intervention to the upper airway, and patients with chronic obstructive or restrictive pulmonary disease. The demographic characteristics including age, gender, height, weight, and ASA score were recorded into a data sheet. The $ETCO_2$ was measured in supine, Trendelenburg (30%), and reverse Trendelenburg (30%) positions using a facemask connected to an anesthesia machine (Siemens Kion, Sweden) after fixing the patient in the required position for five minutes. A 30-minute resting period was provided to the patient for the accuracy of the $ETCO_2$ measurements following each positioning.

Assuming a 60% proportion rate on the relationship between $ETCO_2$ and patient position, with a two-sided type I error of 0.05, and a power of 0.80, 41 subjects were calculated as adequate to find a significant difference.

Statistical analysis

Normality and variance were tested using the one-sample Kolmogorov-Smirnov test for each variable. Quantitative data were presented as means and standard deviation, and qualitative data as frequency and percentage. The intergroup comparisons were performed by using the Wilcoxon rank sum test, while gender differences were analyzed by the Mann-Whitney U test. A linear regression model using backward elimination was performed. The backward stepwise elimination method was used to confine the suppressor effects, in which a predictor has a significant effect only when another variable is held constant, and to limit the risk of making a type II error, thereby missing a substantial predictor. The variable with the highest p value, which has no significance at the 0.05 level, was excluded at each step. Analyses were carried out by using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL) version 20.0 program. The statistical significance for all analyses was set at $P < 0.05$.

Results

A total of 44 patients were included in the study. The demographic characteristics of the subjects are presented in Table 1. The mean $ETCO_2$ level in reverse Trendelenburg position was significantly lower than in supine position ($p < 0.01$). The mean $ETCO_2$ level in Trendelenburg position was found to be higher compared to reverse Trendelenburg position ($p < 0.01$), (fig. 1).

	Mean±SD	n (%)	95% CI	Min - Max	Median
Age (years)	26.47±6.98		24.35 - 28.60	18 - 45	26
Gender (F/M)		18 (40.9%)			
		26 (59.1%)			
Height (cm)	169.95±10.40				
Weight (kg)	72.95±17.04				
BMI (kg/m2)	25.17±5.34				

Table 1: Demographic characteristics of the study subjects.
SD, standard deviation; CI, confidence interval, BMI, body mass index, F, female; M, male.

In supine and Trendelenburg positions, the mean $ETCO_2$ level was higher in males than in females ($p = 0.026$ and $p = 0.043$, respectively; Table 2).

A multivariate linear regression analysis using backward stepwise elimination method on age, gender, height, weight, and body mass index (BMI) as candidate-independent variables and the $ETCO_2$, as a dependent variable showed that gender was the only related predictor for $ETCO_2$, in supine and Trendelenburg position ($\beta = 2.645$, $p = 0.011$ and $\beta = 2.513$, $p = 0.044$, respectively). The correlation analysis between age and $ETCO_2$ levels in supine, Trendelenburg, and reverse Trendelenburg positions revealed no significance ($r = -0.074$, $p = 0.631$; $r = -0.095$, $p = 0.539$; $r = -0.004$, $p = 0.978$, respectively).

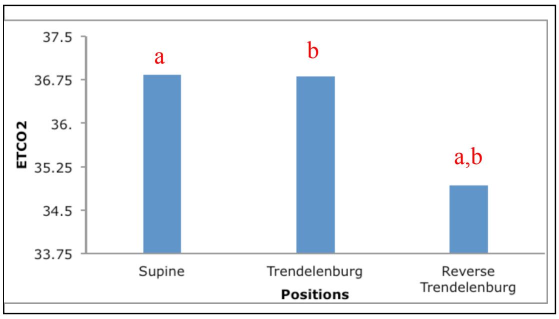

Fig. 1: The distribution of ETCO2 levels among different patient positions.
$ETCO_2$, end-tidal carbon dioxide partial pressure.
Wilcoxon rank sum test.
Significant differences between the $ETCO_2$ levels of patient positions:
[a]p < 0.01; [b]p < 0.01.

	Female	Male	p
	Mean±SD	Mean±SD	
Supine Position	35.27±3.08a	37.92±3.35c	**0.026***
Trendelenburg Position	35.33±4.04b	37.84±3.88d	**0.043***
Reverse Trendelenburg Position	33.77±4.06a,b	35.73±4.38c,d	0.137

Table 2: The comparison of $ETCO_2$ levels among patient positions and gender
SD, standard deviation; $ETCO_2$, end-tidal carbon dioxide partial pressure.
**p<0.05, Mann-Whitney U test.*
Significant differences in intra-group comparisons (Wilcoxon rank sum test):
[a]p = 0.028; [b]p = 0.007; [c]p = 0.001; [d]p = 0.001.

Discussion

The present study revealed that there was a close relationship between patient position and $ETCO_2$, levels. The $ETCO_2$ was decreased in both females and males by changing the position from supine to reverse Trendelenburg or from Trendelenburg to reverse Trendelenburg. It is known that $ETCO_2$ is defined as the partial pressure of carbon dioxide at the end of expiration and reflects the arterial carbon dioxide tension[2]. Monitoring $ETCO_2$ is a widely-used method for ensuring safety in modern anesthetic practice. Intra-operative mishaps including inadvertent esophageal intubation, valve dysfunction or disconnection from the ventilator may be identified by observing the changes in $ETCO_2$.

Furthermore, non-invasive measurement of $ETCO_2$ leads to a quick diagnosis and management of several problems encountered in the intra-operative period. Despite limited studies involved in the association between patient position and $ETCO_2$ levels, Pansard et al.[5] investigated the effects of lateral decubitus position (kidney position for renal surgery) under general anesthesia and demonstrated that the $ETCO_2$ levels were increased. In relation, a study conducted by Choi et al.[6] in patients with pneumoperitoneum during Trendelenburg position revealed that the $ETCO_2$ levels remained stable in Trendelenburg position compared to supine. Moreover, Mishra et al.[8] showed a mean difference of 5 mmHg in $ETCO_2$ levels after positioning from supine to Trendelenburg and pneumoperitoneum. Another study by Cheng et al. investigated the changes between $ETCO_2$ and $paCO_2$ in patients under total intravenous anesthesia, breathing spontaneously through normal airway.

The authors showed that $ETCO_2$ values significantly increased after 20 minutes of positioning from supine to Trendelenburg. They concluded that $paCO_2$ monitoring is still a vital part of clinical practice[9]. In the present study, the $ETCO_2$ levels in Trendelenburg position were consistent with supine levels. Interestingly, $ETCO_2$ value was obviously decreased in reverse Trendelenburg position compared to supine and Trendelenburg. Our explanation for this could be that the effect of position change on $ETCO_2$ level may require time, or perhaps the respiratory system is involved in decreasing the $ETCO_2$ level by increasing the frequency/depth of breathing.

However, the latter explanation could come into contradiction with the lower level of $ETCO_2$ in reverse Trendelenburg position. It is known that Trendelenburg and reverse Trendelenburg positions reduce pulmonary compliance by changing the location of intra-abdominal contents and diaphragm, thereby heightening the airway pressure and decreasing the functional residual capacity[10]. Additionally, Sprung et al.[11] demonstrated that the average $ETCO_2$ is lowered by increasing the tidal volume in patients under general anesthesia. It is evident that there is a close relation between $ETCO_2$ level and respiratory dynamics.

In contrast to the findings of the present study, Rauh et al.(12) showed that position changes did not affect respiratory dynamics in patients with pneumoperitoneum during laparoscopic surgery in Trendelenburg position. They also reported that the rise in intra-abdominal pressure due to pneumoperitoneum pushed the diaphragm to the maximum extension that positioning to Trendelenburg did not show any affect. In addition, Suh et al.(13) indicated that generous Trendelenburg position has little effect on pulmonary functions, since overt Trendelenburg may cause more. In the context of the above-mentioned studies, positional changes directly or indirectly can lead to alterations on pulmonary dynamics along with $ETCO_2$. Parallel with the technological advancements, new surgical methods requiring patient positioning have been developed. Therefore, the effects of positional changes becomes a priority for anesthesiologists when , the patient has limited pulmonary functions.

This study had some limitations. First, arterial gas sampling was not performed on patients during positional changes. Arterial gas sampling requires additional time that would have unethically prolonged the duration of the preoperative period. Second, we did not investigate the $ETCO_2$ levels of patients under anesthesia, which has been previously reported in such studies(5,12,13).

Conclusion

The present study revealed that patient positioning leads to significant $ETCO_2$ changes. Therefore, anesthesiologists should pay attention to pulmonary functions in patients under regional or general anesthesia in any kind of surgical positions, thus preventing postoperative pulmonary complications.

References

1) Geers C, Gros G. C*arbon dioxide transport and carbonic anhydrase in blood and muscle*. Physiol Rev 2000; 80: *681-715*.
2) Bhavani-Shankar K, Moseley H, Kumar AY, Delph Y. *Capnometry and anaesthesia*. Can J Anaesth 1992; 39: *617-32*.
3) Badgwell JM, McLeod ME, Lerman J, Creighton RE. *End-tidal PCO_2 measurements sampled at the distal and proximal ends of the endotracheal tube in infants and children*. Anesth Analg 1987; 66: *959-64*.
4) Satoh K, Ohashi A, Kumagai M, Sato M, Kuji A, Joh S. *Evaluation of Differences between PaCO2 and ETCO2 by Age as Measured during General Anesthesia with Patients in a Supine Position*. Journal of Anesthesiology 2015; Article ID 710537, *5* pages, 2015.
5) Pansard JL, Cholley B, Devilliers C, Clergue F, Viars P. *Variation in arterial to end-tidal CO_2 tension differences during anesthesia in the "kidney rest" lateral decubitus position*. Anesth Analg 1992; 75: *506-10*.
6) Choi DK, Lee IG, Hwang JH. *Arterial to end-tidal carbon dioxide pressure gradient increases with age in the steep Trendelenburg position with pneumoperitoneum*. Korean J Anesthesiol 2012; 63: *209-15*.
7) Casati A, Salvo I, Torri G, Calderini E. *Arterial to end-tidal carbon dioxide gradient and physiological dead space monitoring during general anaesthesia: effects of patients' position*. Minerva Anestesiol 1997; 63: *177-82*.
8) Mishra SK, Sivaraman B, Balachander H, Naggappa M, Parida S, Bhat RR, Yuvaraj K. *Effect of pneumoperitoneum and Trendelenberg position on oropharyngeal sealing pressure of I-gel™ and ProSeal LMA™ in laparoscopic gynecological surgery: A randomized controlled trial*. Anesth Essays Res 2015; 9: *353-8*.
9) Cheng KI, Tang CS, Tsai EM, Wu CH, Lee JN. *Correlation of arterial and end-tidal carbon dioxide in spontaneously breathing patients during ambulatory gynecologic laparoscopy*. J Formos Med Assoc 1999; 98: *814-9*.
10) O'Malley C, Cunningham AJ. *Physiologic changes during laparoscopy*. Anesthesiol Clin North America 2001; 19: *1-19*.
11) Sprung J, Whalley DG, Falcone T, Warner DO, Hubmayr RD, Hammel J. *The impact of morbid obesity, pneumoperitoneum, and posture on respiratory system mechanics and oxygenation during laparoscopy*. Anesth Analg 2002; 94: 1*345-50*.
12) Rauh R, Hemmerling TM, Rist M, Jacobi KE. *Influence of pneumoperitoneum and patient positioning on respiratory system compliance*. J Clin Anesth 2001; 13: *361-5*.
13) Suh MK, Seong KW, Jung SH, Kim SS. *The effect of pneumoperitoneum and Trendelenburg position on respiratory mechanics during pelviscopic surgery*. Korean J Anesthesiol 2010; 59: *329-34*.

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