ORIGINAL ARTICLE

Easy method to determine fluid responsiveness in septic shock patients: end-tidal CO_2 – a prospective observational study

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ABSTRACT

BACKGROUND: In critically ill patients, especially those with septic shock, fluid management can be a challenging aspect of clinical care. One of the primary steps in treating patients with hemodynamic instability is optimizing intravascular volume. The Passive Leg Raising (PLR) maneuver is a reliable test for assessing fluid responsiveness, as demonstrated by numerous studies and meta-analyses. However, its use requires the measurement of cardiac output, which is often complex and may necessitate clinician experience and specialized equipment. End-Tidal Carbon Dioxide ($ETCO_2$) measurement is relatively easy and is generally stable under steady metabolic conditions. It depends on the body's CO_2 production, diffusion of CO_2 from the lungs into the bloodstream, and cardiac output. If the other two parameters (metabolic conditions and minute ventilation) are constant, $ETCO_2$ can provide information about cardiac output. The aim of the present study is to investigate the sensitivity of $ETCO_2$ measurement in demonstrating fluid responsiveness.

METHODS: All patients diagnosed with septic shock and meeting the inclusion criteria were subjected to a passive leg raising test, and cardiac outputs were measured by echocardiography. An increase in cardiac output of 15% or more was considered indicative of the fluid responder group, while patients with an increase below 15% or no increase were classified as the non-responder group. Patients' intensive care unit admission diagnoses, initial laboratory parameters, tidal volume, minute volume before and after the PLR maneuver, mean and systolic blood pressure, heart rate, Pulse Pressure Variation (PPV) values, and $ETCO_2$ values were recorded.

RESULTS: Before and after the $ETCO_2$ test, there was no statistically significant difference between the two groups. However, the change in $ETCO_2$ ($\Delta ETCO_2$) was significantly higher in the responder group. In the non-responder group, $\Delta ETCO_2$ was 2.57% (0.81), whereas it was 5.71% (2.83) in the responder group ($p<0.001$). Receiver Operating Characteristic (ROC) analysis was performed for $\Delta ETCO_2$, baseline Stroke Volume Variation (SVV), ΔSVV, baseline Heart Rate (HR), ΔHR, baseline PPV, and ΔPPV to predict fluid responsiveness. $\Delta ETCO_2$ predicted fluid responsiveness with a sensitivity of 85% and a specificity of 86% when it was 4% or higher. When $\Delta ETCO_2$ was 5% or higher, it predicted fluid responsiveness with a specificity of 99.3% and a sensitivity of 75.5%, with an Area Under the Curve (AUC) of 0.89 (95% confidence interval, 0.828-0.961).

CONCLUSION: This study demonstrates that in septic patients, $ETCO_2$ during the PLR test can indicate fluid responsiveness with high sensitivity and specificity and can be used as an alternative to cardiac output measurement.

Keywords: Septic shock; end-tidal CO_2; passive leg raising test.

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INTRODUCTION

In critically ill patients, particularly those with septic shock, fluid management can be a challenging aspect of clinical care for clinicians.[1,2] One of the primary steps in treating patients with hemodynamic instability is the optimization of intravascular volume.[3] Consequently, fluid resuscitation in shock patients is a critical issue, closely related to their mortality and morbidity.[4,5] Adequate fluid resuscitation increases cardiac preload, thereby enhancing cardiac output and improving tissue perfusion by delivering more oxygen to the tissues.

Studies have shown that approximately half of the critically ill patients admitted to intensive care units respond to fluids.[6] However, fluid overload can flatten the Frank-Starling volume-pressure curve, leading to complications. These complications include tissue edema, pulmonary edema, impaired oxygenation, prolonged mechanical ventilation, extended stays in the intensive care unit, and increased mortality.[5,7,8]

Several methods have been proposed to assess fluid responsiveness in shock patients. Static parameters, such as mean arterial pressure, central venous pressure, global end-diastolic volume, intrathoracic volume, and inferior vena cava diameter, have limited utility in evaluating fluid responsiveness. Dynamic parameters including inferior vena cava collapsibility/distensibility index, pulse pressure variation (PPV), stroke volume variation (SVV), end-expiratory occlusion maneuver, and fluid or mini-fluid challenge, are recommended. However, the reliability of most of these methods remains a subject of debate. Many are invasive, and some require specialized expertise.

Passive Leg Raising (PLR) is a maneuver in which patients are moved from a semi-upright position to a supine position with their legs raised. During this maneuver, additional blood flow is directed from the lower extremities and splanchnic bed to the heart, resulting in an increase in stroke volume (SV) and cardiac output (CO) in responsive patients. The PLR maneuver is a reliable test for assessing fluid responsiveness, as demonstrated by numerous studies and meta-analyses.[9-12] However, its use requires the measurement of cardiac output, which is often challenging and may necessitate clinician experience and the use of specialized equipment.

End-tidal carbon dioxide ($ETCO_2$) measurement is relatively easy and is generally stable under steady metabolic conditions because it depends on the body's CO_2 production, the diffusion of CO_2 from the lungs into the bloodstream, and cardiac output.[13] If the other two parameters (metabolic conditions and minute ventilation) are constant, $ETCO_2$ can provide information about cardiac output.[14,15]

The aim of the present study is to investigate the sensitivity of $ETCO_2$ measurement in demonstrating fluid responsiveness.

MATERIALS AND METHODS

This prospective observational study was conducted in the intensive care units of a tertiary teaching hospital between July 1st, 2022, and September 30th, 2023, following approval from the hospital's local ethics committee. The study was prospectively registered in the Protocol Registry System of ClinicalTrials.gov (registration number: NCT05557461) and was conducted in accordance with the Helsinki Declaration.
Participants in the study included patients admitted to the General Intensive Care Unit of the Health Sciences University Izmir Training and Research Hospital, diagnosed with septic shock. The diagnosis of sepsis was made following the recommendations of the Surviving Sepsis Guidelines, considering the following criteria: presence of an obvious sign or suspicion of infection, hypotension (systolic blood pressure below 90 mmHg or mean arterial pressure below 65 mmHg), use of vasopressors or inotropic agents, oliguria (urine output less than 0.5 ml/kg/hour), impaired peripheral perfusion (evidenced by skin mottling or prolonged capillary refill time, lactate level above 2 mmol/L in blood gas analysis), and mechanical ventilation.

Patients were excluded from the study if they were pregnant, under 18 years of age, had advanced heart failure (ejection fraction < 40%), were diagnosed with any type of lung cancer, unable to undergo the PLR test (due to conditions such as lower extremity amputation, acute fractures in the lower extremities and pelvis, acute trauma, suspected increased intracranial pressure, or had undergone major abdominal surgery within the last 15 days). Additionally, patients with any arrhythmia or chronic obstructive pulmonary disease (COPD) were also excluded.

Study Protocol

All patients included in the study were mechanically ventilated using the synchronized intermittent mandatory ventilation mode with volume control. According to the protocol, all patients received a tidal volume of 8 ml/kg (based on ideal body weight) and a positive end-expiratory pressure (PEEP) of 6 cmH_2O for at least 15 minutes before the study. Hamilton Medical Galileo ventilators (Hamilton Medical AG, Rhäzüns, Switzerland) were used for all patients. Patients who exhibited more than a 10% change in respiratory parameters (tidal volume and/or minute ventilation) during the study were excluded. Propofol and remifentanil infusions were used for sedation to maintain a score between 1 and -3 on the Richmond Agitation-Sedation Scale.

The following data were recorded for patients: intensive care unit admission diagnoses, initial laboratory parameters, tidal volume and minute volume before and after the PLR maneuver, mean and systolic blood pressure, heart rate, pulse pressure variation (PPV) values, and end-tidal carbon dioxide ($ETCO_2$) values.

For $ETCO_2$ measurement and monitoring, a Philips MX550 bedside monitor and its mainstream CO_2 sensor were used.
Monitoring
Invasive arterial pressure measurement was performed in all patients using intra-arterial cannulation. The radial artery was

the preferred site for arterial pressure measurement. If bilateral radial artery cannulation was unsuccessful, the dorsalis pedis artery was the first alternative, followed by the right femoral artery. Arterial pressure transducers were zeroed at the mid-axillary line of the patients. A Philips MX550 bedside monitor (Philips Medical Systems, Best, The Netherlands) was used for monitoring.

PLR Maneuver

All patients were initially kept in a 45-degree semi-upright position for at least 2 minutes. They were then placed in the supine position, and their lower extremities were elevated to a 45-degree angle. Two healthcare workers held the patient's legs in the elevated position for 2 minutes, and cardiac output measurement was performed using transthoracic echocardiography. Echocardiographic cardiac output measurements were evaluated by a cardiologist using Toshiba 880CV equipment (Toshiba Medical System Corporation, Japan). In cases where a cardiologist was not available for immediate evaluation, the measurement was performed by an intensive care specialist, and a consultation with a cardiologist was conducted via video consultation. Cardiac output was calculated using the subaortic flow velocity time integral (VTI) in the cardiac apical five-chamber view. An increase in cardiac output of 15% or more was considered indicative of the fluid responder group, while patients with an increase below 15% or no increase were classified as the non-responder group. The percentage change in all other parameters was calculated using the following formula:

ΔParameter = (Value before the test - Value after the test) / Value before the test

Statistical Analysis

IBM's Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM Corp, Somers, NY, USA) was used for statistical analysis. The Kolmogorov-Smirnov test was used to assess normality. Continuous data, normally distributed and expressed as mean ± SD, were compared using an independent sample t-test. Non-normally distributed data, expressed as median and interquartile range (IQR), were compared using the Mann-Whitney U test. Categorical data are expressed as a number (n) and percentage (%) and compared using Pearson's chi-squared test. The data were analyzed at a 95% confidence level. A P-value of less than 0.05 was considered statistically significant.

The receiver operating characteristic (ROC) curve was used to evaluate the cut-off values of independent numerical variables with a P-value less than 0.05. Youden's indices were calculated, and the maximum Youden's index was used as the cut-off value in the ROC curve. Cut-off values for the passive leg raising test were separately analyzed. Area under the curve (AUC) values of 0.9-0.99, 0.8-0.

RESULTS

A total of 155 patients were included in the study, but 47

Table 1. Demographic data and first day laboratory data

	Non-Responder	Responder	p-value
Age[1]	55 (26)	65 (21)	0.112
Sex[1] (F/M; n)	31/24	26/27	0.447
APACHE-2[1]	19 (10)	22 (11)	0.145
ICU Admission Diagnosis (n) %			0.568
Pneumonia	13 (21.8%)	13 (24.5%)	
Neurological Disease	12 (23.6%)	9 (17%)	
Urological Disease	5 (9.1%)	5 (9.4%)	
Intra-Abdominal Disease	14 (25.5%)	11 (20.8%)	
Cardiological Diseases	5 (9.1%)	6 (11.3%)	
Trauma	6 (10.9%)	8 (15.1%)	
Hematologic Diseases	0	1 (1.9%)	
Urea[1]	56 (42)	65 (65)	0.362
Creatinine[1]	1 (0.34)	0.96 (0.73)	0.220
Sodium[1]	140 (7)	141 (5)	0.187
Potassium[1]	4.03 (1.32)	4.31 (1.76)	0.073
Calcium[1]	7.9 (1)	8.7 (1.2)	0.101
Procalcitonin[1]	2.3 (9.5)	2 (6.79)	0.177
C-Reactive Protein[1]	164 (95)	163 (52)	0.160

1: Median (Interquartile Range).

Table 2. Hemodynamic parameters at baseline and after passive leg raising

	Non-Responder	Responder	p-value
HR[1]	102 (20)	94 (18)	0.062
HR PLR[1]	105 (24)	93 (16)	0.035
ΔHR[1]	1.01 (3.62)	1.03 (3.7)	0.182
SBP[1]	115 (22)	118 (25)	0.768
SBP PLR[1]	115 (20)	122 (22.5)	0.500
ΔSBP[1]	-0.67 (7.03)	1.70 (4.17)	0.007
CVP[1]	9 (4)	8 (4)	0.309
PPV[1] pre PLR	9 (4)	13 (2.5)	<0.001
PPV PLR[1]	10 (4)	11 (2)	<0.001
ΔPPV[1]	0 (8.3)	13.3 (9.5)	<0.001
$ETCO_2$[1]	39 (8)	37 (10)	0.963
$ETCO_2$ PLR[1]	40 (7)	39 (11)	0.387
$\Delta ETCO_2$[1]	2.57 (0.81)	5.71 (2.83)	<0.001
CO[1]	5.25 (1.38)	5.06 (0.63)	0.213
CO PLR[1]	5.35 (1.97)	6.03 (0.74)	0.018
ΔCO[1]	4.35 (7.71)	20 (4.72)	<0.001

[1]: Median (Interquartile Range). CVP: Central Venous Pressure; ETCO2: End-Tidal CO_2; HR: Heart Rate; PPV: Pulse Pressure Variation; SBP: Systolic Blood Pressure; SV: Stroke Volume.

were excluded for various reasons: 15 due to poor transthoracic insonation, 15 due to arrhythmia, 7 due to COPD, 3 due to severe heart failure, 2 due to pelvic fracture, and 5 due to acute intracranial hemorrhage. The analysis was conducted with the remaining 108 patients. Of these, 57 were female and 51 were male (p=0.447). The median (IQR) Acute Physiology and Chronic Health Evaluation II (APACHE-2) score in the non-responder group was 19 (10), while it was 22 (11) in the responder group (p=0.145). There was no statistically significant difference in the distribution of admission diagnoses (p=0.668). Similarly, there was no statistically significant differences between the two groups in terms of laboratory parameters recorded at the time of initial admission (Table 1). Among the parameters examined before the PLR test in both groups, only PPV and cardiac output showed statistically significant differences. PPV was 9 (4) in the non-responder group and 13 (2.5) in the responder group (p<0.001). Cardiac output was 4.35 (7.71) L/min in the non-responder group and 20 (4.72) L/min in the responder group (p<0.018). There was no statistically significant difference in $ETCO_2$ values before and after the test between the two groups. However, the change in $ETCO_2$ ($\Delta ETCO_2$) was significantly higher in the responder group. In the non-responder group, $\Delta ETCO_2$ was 2.57% (0.81), whereas it was 5.71% (2.83) in the responder group (p<0.001). After the test, there was a difference in heart rate between the responder and non-responder groups (p=0.035), but this difference was not significant before the test (p=0.062). No statistically significant difference was found between the groups in terms of the percentage change in heart rate (p=0.182). Other parameters examined are presented in Table 2.

ROC analysis for $\Delta ETCO_2$, baseline SVV, ΔSVV, baseline HR, ΔHR, and baseline PPV and ΔPPV was performed to predict fluid responsiveness (Fig. 1). $\Delta ETCO_2$ predicted fluid responsiveness with a sensitivity of 85% and a specificity of 86% when it was 4% or higher. When $\Delta ETCO_2$ was 5% or higher, it

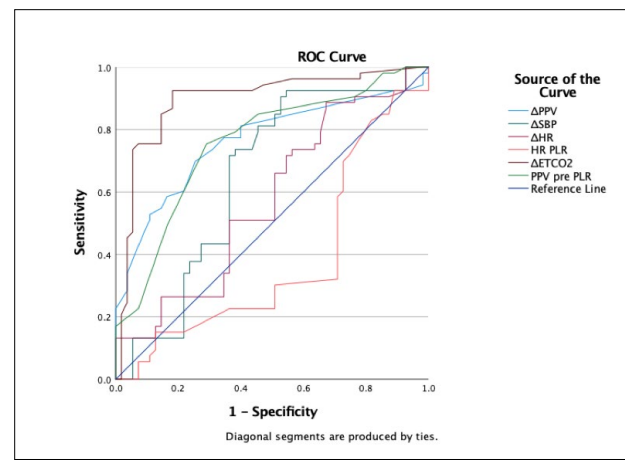

Figure 1. Comparison of the performance of the tested indices. Receiver operating characteristic curve analysis for each parameter to detect fluid responsiveness.

ΔPPV: Change in Pulse Pressure Variation; ΔSBP: Change in Systolic Blood Pressure; ΔHR: Change in Heart Rate; HR PLR: Heart Rate during the Passive Leg Raising Maneuver; ΔETCO2: Change in ETCO2; PPV pre PLR: Pulse Pressure Variation before the Passive Leg Raising Maneuver.

Table 3. Factors associated with response to passive leg raising

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
ΔPPV	0.763	0.047	0.000	0.670	0.856
ΔSBP	0.650	0.055	0.007	0.542	0.757
ΔHR	0.574	0.055	0.182	0.466	0.683
HR PLR	0.383	0.056	0.036	0.274	0.492
$\Delta ETCO_2$	0.894	0.034	0.000	0.828	0.961
PPV pre PLR	0.757	0.047	0.000	0.665	0.849

$\Delta ETCO_2$: Change in $ETCO_2$; ΔHR: Change in Heart Rate; ΔPPV: Change in Pulse Pressure Variation; ΔSBP: Change in Systolic Blood Pressure; HR PLR: Heart Rate during Passive Leg Raising Maneuver; PPV pre PLR: Pulse Pressure Variation before Passive Leg Raising Maneuver.

predicted fluid responsiveness with a specificity of 99.3% and a sensitivity of 75.5%, with an area under the curve (AUC) of 0.89 (95% confidence interval, 0.828-0.961) (Table 3).

DISCUSSION

The main finding of this study is that $\Delta ETCO_2$ is a reliable and accurate indicator for assessing fluid responsiveness during the PLR test in mechanically ventilated patients. When a cut-off value of 4% was used, $\Delta ETCO_2$ detected fluid responsiveness with a sensitivity of 84% and a specificity of 86%. Additionally, among the other parameters examined in the study, ΔSVV, heart rate during the test, PPV, and ΔPPV were less successful in predicting fluid responsiveness, demonstrating lower sensitivity and specificity.

Optimization of intravascular volume is extremely important in shock patients. Determining cardiac output, which largely depends on cardiac preload, is crucial for assessing peripheral perfusion and oxygen delivery, essential aspects of the patient's condition.[16] Optimization of intravascular volume in patients on the steep portion of the Frank-Starling volume-pressure curve can increase cardiac output. However, in cases with a flat portion, an increase in intravascular volume can lead to numerous complications. Therefore, the PLR maneuver is particularly useful for assessing fluid responsiveness because it does not introduce an additional fluid load to the patients and evaluates fluid responsiveness through an autotransfusion mechanism. Many tests are used to detect fluid responsiveness (e.g., inferior vena cava collapsibility/dilatation, PPV, fluid challenge, mini-fluid challenge), but these tests can be influenced by various conditions or require expertise in their use. Factors affecting these tests include arrhythmias, inadequate tidal volume, high intrathoracic/intra-abdominal pressure, equipment limitations, or lack of experience.[17-25] Due to all these limitations and sensitivity issues, clinicians often face challenges in fluid management.

$ETCO_2$ is dependent on body CO_2 production, minute ventilation, and pulmonary blood flow. When minute ventilation and CO_2 production are constant,[13] $ETCO_2$ depends on pulmonary blood flow and, consequently, on right heart output. Therefore, $ETCO_2$ measurement may be considered a good option for cardiac output measurement. The increase in end-tidal CO_2 during the PLR maneuver is explained by two mechanisms.[26-28] First, the PLR maneuver increases pulmonary blood flow by enhancing venous return to the right heart, leading to an increase in CO_2 during exhalation. Second, it improves the ventilation-perfusion balance by increasing pulmonary perfusion pressure. During the PLR maneuver, approximately 300 ml of blood rapidly enters the systemic circulation from the lower extremities and the splanchnic bed, increasing cardiac preload.[29-31] Several studies have shown that an increase of over 15% in cardiac output during the PLR test indicates a fluid deficit in the patient and suggests that fluid transfusion can increase cardiac output. However, measuring cardiac output during the PLR test requires invasive and difficult-to-access devices, or it may necessitate a trained person for echocardiography and the use of this device. In contrast, $ETCO_2$ measurement is a non-invasive and easily accessible method available in many bedside monitors. The study found that the change in end-tidal CO_2 could be a strong alternative to all these devices and invasive methods.

Monnet et al. conducted a study with 65 patients in the intensive care unit, where 40 patients were determined to be fluid responsive. They found that a 5% increase in end-tidal CO_2 detected fluid responsiveness with a sensitivity of 71% and a specificity of 100%.[32] In a 2012 study by Monge et al., which included 37 patients, a 5% increase in end-tidal CO_2 predicted fluid responsiveness with a sensitivity of 90.5%, a specificity of 93.7%, and an area under the curve (AUC) of 0.94 (0.82-0.99).[33] In a study by Toupin et al. involving 90 patients, an increase of 2 mmHg in $ETCO_2$ determined fluid responsiveness with a sensitivity of 75% and a specificity of 70%, with an AUC of 0.80 (0.70-0.90).[34] In the present study, when a cut-off value of 4% for $\Delta ETCO_2$ was used, it detected fluid responsiveness with a sensitivity of 84% and a specificity of 86%.

Among the parameters examined in the study, the second parameter with the highest sensitivity and specificity before and after the PLR test was PPV and ΔPPV. However, it is known that changes in PPV are affected by many factors, and there are many factors that limit its use as an alternative to CO. Examples of these factors include changes in arterial tone and distribution differences between compartments in septic shock patients. In our study, we aimed to exclude factors that may affect PPV. For this reason, patients with arrhythmias were not included in our study. ΔPPV and PPV may show promising results, but it is known that they are greatly affected by varying tidal volumes and arrhythmias, which limits their reliability. Although heart rate during the PLR test and ΔSVV were statistically significant in the study, their sensitivity and specificity were quite low compared to $\Delta ETCO_2$.

Limitations

This study has some limitations. Firstly, a larger sample size may lead to statistically stronger results. Additionally, the fact that the tidal volume values of the patients were constant and other patients were not evaluated means that the results are only valid for patients under sedation and with stable mechanical ventilation support. Therefore, we cannot comment on the significance of $ETCO_2$ in predicting fluid responsiveness in spontaneously breathing patients with different tidal volumes. Patients with Chronic Obstructive Pulmonary Disease (COPD) were excluded from the study. However, many previous studies did not exclude COPD patients and obtained similar results.

CONCLUSION

This study demonstrates that in septic patients, $ETCO_2$ during the PLR test can indicate fluid responsiveness with high sensitivity and specificity and can serve as an alternative to cardiac output measurement. We believe that $ETCO_2$ and $\Delta ETCO_2$ measurements can be easily used by clinicians to assess fluid responsiveness because they are readily available, inexpensive, and easier to interpret than standard monitoring methods in intensive care units. Furthermore, we believe that studies evaluating the predictability of $ETCO_2$ for fluid responsiveness across different tidal volumes and in spontaneously breathing patients are needed.

Ethics Committee Approval: This study was approved by the İzmir Bozyaka Training and Research Hospital Ethics Committee (Date: 08.06.2022, Decision No: 2022/96).

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Authorship Contributions: Concept: H.Ö., Ö.Ö., Z.T.T.; Design: H.Ö., O.U.; Supervision: Ö.Ö., M.C.Ö.; Resource: H.Ö., Ö.Ö., O.U.; Materials: M.U.B., M.S., Ç.Y.; Data collection and/or processing: Ö.Ö., O.U.; Analysis and/or interpretation: M.U.B., H.H.S.; Literature search: M.S., O.U., Ş.Y.; Writing: H.Ö., O.U.; Critical review: Z.T.T., H.H.S.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Septik şok hastalarında sıvı duyarlılığını belirlemede kolay yöntem, end-tidal CO_2: Prospektif gözlemsel bir çalışma

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AMAÇ: Kritik hastalarda, özellikle septik şok hastalarında, sıvı yönetimi klinisyenler için zorlayıcı olabilmektedir. Hemodinamik instabilitesi olan hastaların tedavisinde birincil adımlardan biri intravasküler hacmin optimize edilmesidir. PLR manevrası, çok sayıda çalışma ve meta-analizle gösterildiği gibi sıvı duyarlılığını değerlendirmek için güvenilir bir testtir. Bununla birlikte, kullanımı kardiyak output ölçülmesini gerektirir, bu da genellikle kolay değildir ve klinisyen deneyimi ve özel ekipman kullanımı gerektirir. End-tidal karbondioksit ($ETCO_2$) ölçümü nispeten kolaydır ve vücudun CO_2 üretimine, CO_2'nin akciğerlerden kan dolaşımına difüzyonuna ve kardiyak debiye bağlı olduğu için sabit metabolik koşullar altında genellikle stabildir. Diğer iki parametre sabitse (metabolik koşullar ve dakika ventilasyonu), $ETCO_2$ kalp debisi hakkında bilgi sağlayabilir. Bu çalışmanın amacı, $ETCO_2$ ölçümünün sıvı duyarlılığını göstermede ne kadar hassas olduğunu araştırmaktır.

GEREÇ VE YÖNTEM: Septik şok tanısı alan ve dahil edilme kriterlerini karşılayan tüm hastalara pasif bacak kaldırma testi uygulandı ve ekokardiyografi ile kardiyak output ölçüldü. Kalp debisinde %15 veya daha fazla artış olan hastalar sıvıya yanıt veren grup olarak kabul edilirken, %15'in altında artış olan veya hiç artış olmayan hastalar yanıt vermeyen grup olarak sınıflandırıldı. Hastaların yoğun bakım ünitesine kabul tanıları, başlangıç laboratuvar parametreleri, PLR manevrası öncesi ve sonrası tidal volüm ve dakika volümü, ortalama ve sistolik kan basıncı, kalp hızı, pulse pressure varyasyonu (PPV) değerleri, $ETCO_2$ değerleri kaydedildi.

BULGULAR: $ETCO_2$ PLR testinden önce ve sonra, iki grup arasında istatistiksel olarak anlamlı bir fark yoktu, ancak $ETCO_2$ değişimi ($\Delta ETCO_2$) yanıt veren grupta anlamlı olarak daha yüksekti. Yanıt vermeyen grupta $\Delta ETCO_2$ %2.57 (0.81) iken yanıt veren grupta %5.71 (2.83) idi ($p<0.001$). Sıvı yanıtını öngörmek için $\Delta ETCO_2$, başlangıç SVV, ΔSVV, başlangıç KAH, ΔKAH ve başlangıç PPV ve ΔPPV için ROC analizi yapılmıştır. $\Delta ETCO_2$, %4 veya daha yüksek olduğunda sıvı duyarlılığını %85 duyarlılık ve %86 özgüllük ile öngörmüştür. $\Delta ETCO_2$ %5 veya daha yüksek olduğunda, eğri altındaki alan (AUC) 0.89 (%95 güven aralığı, 0.828-0.961) ile %99.3 özgüllük ve %75.5 duyarlılıkla sıvı yanıtını öngörmüştür.

SONUÇ: Bu çalışma, septik hastalarda PLR testi sırasında $ETCO_2$'nin sıvı duyarlılığını yüksek duyarlılık ve özgüllükle gösterebileceğini ve kalp debisine alternatif olarak kullanılabileceğini göstermektedir.

Anahtar sözcükler: End-tidal CO_2; pasif bacak kaldırma testi; septik şok.

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