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Echocardiography Evaluation of the Effects of Midazolam on Passive Leg Raising Test in Critically ill Patients in the Intensive Care Unit, Diagnosed with Sepsis, determined to be Hypovolemic and responding to Fluid Treatment

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Abstract

Background: In this study, we aimed to investigate the effects of midazolam sedation on intravascular volume in intubated patients diagnosed with sepsis and treated with invasive mechanical ventilation in continuous positive airway pressure mode using echocardiography (ECHO) parameters.

Methods and Results: One hundred fifty-two intensive care unit patients aged 30-50 years with spontaneous breathing who were intubated, ventilated in continuous positive airway pressure mode via invasive mechanical ventilation, were determined to have fluid deficit. Cardiac index, cardiac out-put and velocity time integral measurements were performed by passive leg rising test before and after midazolam sedation in hypovolemic patients that were determined to respond to fluid treatment and changes in passive leg rising test before and after midazolam were compared. >15% cardiac out-put, >10% cardiac index, and >15% velocity time integral increase in passive leg rising test before midazolam administration showed that patients were hypovolemic and responded to fluid therapy. <15% cardiac out-put, <10% cardiac index, and <15% velocity time integral increase in passive leg rising test after midazolam administration showed that patients were not hypovolemic.

Conclusion: We recommend that passive leg raising test, which is performed to determine the intravascular volume status of critically ill intensive care unit patients determined to be hypovolemic and responding to fluid therapy, should be performed before midazolam sedation.

Keywords: Hemodynamic • Sedative drugs • Morbidity • Heart • Hypovolemia

Introduction

Preservation of intravascular volume, vasopressor treatment and hemodynamic optimization play an important role in preventing morbidity and mortality in ICU patients with sepsis [1-4]. Sepsis has been defined as life-threatening organ dysfunction caused by the irregular host response to infection [2]. Patients with sepsis constitute a majority of critically patients hospitalized in the ICU [5]. While providing hemodynamic stabilization of patients with sepsis, airway control also plays an important role in mortality and morbidity [2]. Providing sedation is also important in patients with sepsis undergoing orotracheal incubation because of airway control [2,6]. Sedative drugs are frequently used in ICU patients [6]. Most of these drugs cause relative hypovolemia as they disrupt compensatory mechanisms [7-15].

Midazolam is one of the sedative drugs frequently used in ICUs [6]. Various animal studies have shown that midazolam can cause vasodilation with its effects on vascular smooth muscle cells and the heart [16-19].

Static and dynamic parameters (central venous pressure (CVP), vena cava inferior collapsibility index (VCI-CI), vena cava inferior disability index (VCI-DI), Delta velocity peak (Delta V_{peak}), pulse pressure variation (PPV), stroke volume variation (SVV), passive leg raising test (PLRT)) are used in estimating cardiac preload [2,20-23]. VCI-CI can also define hypovolemia without performing PLRT [24-27]. Evaluation with PLRT and hypovolemia can also be defined by echocardiography (ECHO) parameters [24,28-37]. It is a reliable test to determine whether there is response to fluid in patients who are hypovolemic in PLRT [28,29].

ECHO is an important tool to identify hypovolemia and monitor fluid resuscitation, especially in critically ill patients, as it is a non-invasive test, it can be performed bedside and frequently repeated [32].

Relative hypovolemia induced by midazolam can change the axis of fluid therapy that is regulated through PLRT and may cause normovolemic and unresponsive appearance in fluid treatment in patients who have fluid deficit identified with PLRT and normally respond to fluid treatment.

In this study, we aimed to investigate the effects of midazolam sedation on PLRT using ECHO parameters in intubated ICU patients diagnosed with sepsis and proved to have fluid deficit with VCI-CI and PLRT and shown to respond to fluid treatment with PLRT, whose respiration is provided through invasive mechanical ventilation in continuous positive airway pressure (CPAP) mode at a positive end expiratory pressure (PEEP) of 5 cm H_2O.

Research Methodology

This study was carried out between September 2017 and February 2019 in Gazi Yaşargil Training and Research Hospital, Anaesthesiology and Reanimation Clinic ICU. The study was designed as an observational prospective study and in accordance with the Strobe statement. Permission was obtained from the local ethics committee (Ethics committee approval was obtained from the TR. HSU. Gazi Yaşargil TRH, Date:14.12.2018/Number:179) hospital ethics committee, and written informed consent was obtained from

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the 1st degree relatives of the patients included in the study. The study was carried out in accordance with the 2008 Helsinki declaration. In the pilot study conducted with 30 patients, CO measurements were performed, and a sample size of N = 152 was obtained for Type 1 error 0.05, Type 2 error 0.20, Effect size 0.20, and SD of the change in the outcome 0.88 when mean CO was 8.71 ± 3.37 L/min following PLRT prior to midazolam administration and 7.83 ± 3.78 L/min following PLRT after midazolam administration. Patients in the pilot study were included in the study.

The patients were diagnosed with sepsis according to the 2016 sepsis guideline [2]. Patients with hypoxia or hypercarbia in their arterial blood gas (ABG) and with Glasgow Coma Scale (GCS)<10 were intubated with 1mg/kg propofol and 1μg/kg remifentanil administered intravenously with fluid replacement and vasopressor therapy. Patients with restored spontaneous breathing were connected to the mechanical ventilator in CPAP mode at 5 cm H_2O PEEP, and all measurements were made after this procedure.

Inclusion criteria

1. 30-50 years old patients hospitalized in the ICU
2. Intubated patients with spontaneous breathing, ventilated with invasive mechanical ventilation at 5cmH_2O PEEP in CPAP mode
3. Patients with a Ramsey sedation scale (RSS) score of 5-6 at 5 minutes after midazolam administration,
4. Patients with fluid deficit. (Patients with >42% VCI-CI and > 12% increase in SAP in PLRT)
5. Patients who were hospitalized and taken to the emergency department with a blue code, who presented directly to the emergency department, or who developed sepsis while in the ICU.
6. Patients with >15% CO, ≥ 10% CI, and >15% VTI increase in PLRT before midazolam administration [37-39].

Exclusion criteria

1. Patients with serious cardiac disease (cardiac pathology, pulmonary hypertension)
2. Patients with intra-abdominal pressure >12 mmHg
3. Patients with VCI-CI <42%
4. Patients with VCI-CI> 42% but without >12% increase in systolic arterial pressure after PLRT
5. Hypotensive patients (patients with SAP<90 mmHg despite initiation of fluid replacement and noradrenaline infusion above 1 μg/kg/min.
6. Patients with arrhythmia
7. Patients with a body temperature <37.5°C
8. Patients without spontaneous breathing
9. Patients with APACHE II scores below 25.
10. Patients in the supine position from whom five spaces could not be obtained from the 5th intercostal space and images could not be obtained from the parasternal long axis.
11. Patients with acute and chronic renal failure.
12. Patients with liver failure.

Patients' age, body temperature, height, weight, duration of intensive care stay, peak heart rate (PHR), peripheral oxygen saturation (SpO_2), intra-arterial pressures and peripheral body temperatures were recorded before the study procedure was performed. All ECHO (GE Healthcare Vivid S70N made in Germany), Measurements were first performed by the cardiology specialist of the study, and the second measurement was made by the intensive care specialist of the study. Measurement results were obtained by the intra-observer anaesthesiologist and given to the interobserver anaesthesiologist, and all evaluations were made by the interobserver anaesthesiologist. Thus, the experts who made the measurements were blinded to each other. Again, the interobserver anaesthesiologist was also blinded to the experts making the measurements. All data were evaluated by taking the average of the two measurements.

Hemodynamic monitoring

Electrocardiography (ECG), SpO_2, intraarterial cannulation followed by continuous invasive arterial pressure measurement, and peripheral body temperature follow-up monitoring were performed in supine position using a bedside monitor (Philips medizin system MX550, made in Germany), as routinely applied to all patients hospitalized in the ICU.

VCI-CI measurement

The positive end-expiratory pressure (PEEP) value was set to 5 mmHg when the mechanical ventilator was in CPAP mode in patients in the supine position. VCI, aorta and vertebra were initially visualized in out-plane position using B-Mode ECHO from the subxiphoid window in a longitudinal section with the ECHO probe (Figure 1). The ECHO probe was turned counter-clockwise without changing its location, and VCI was displayed in the in-plane position (Figure 2).

By visualizing the exit of the VCI from the heart and the hepatic vein, the ECHO cursor was placed approximately 1 cm distal to the hepatic vein, and the M-Mode ECHO was turned on. VCI diameter was monitored for several breath periods, and the screen was frozen to measure VCI diameter from the narrowest and widest points (Figure 2).

Passive Leg raising test

When the patient was lying in supine position, the head was raised 45° above the waist and kept in this position for 2 minutes, and the systolic arterial pressure (SAP) on the monitor was recorded in mmHg. Then, the legs were raised 45° from the waist and the head was restored to its original position, and SAP on the monitor was recorded in mmHg after 1 minute. An increase of >12% in the measured SAP was evaluated in favour of hypovolemia and the test was considered positive [40].

Aortic diameter and VTI measurement

The patient was brought to the supine position, and aortic diameter was measured between the adhesion points of the aortic valve from the aortic anulus line by two-dimensional imaging of the parasternal long axis with the ECHO probe (Figure 3). In the apical window, VTI values of the left ventricular outflow systolic flow velocity (Figure 4) were recorded during a single breath cycle with PW (pulsed wave) Doppler 1 cm below the aortic valve.

Study Procedure

1. Patients were diagnosed with sepsis according to the 2016 Sepsis guideline [2].

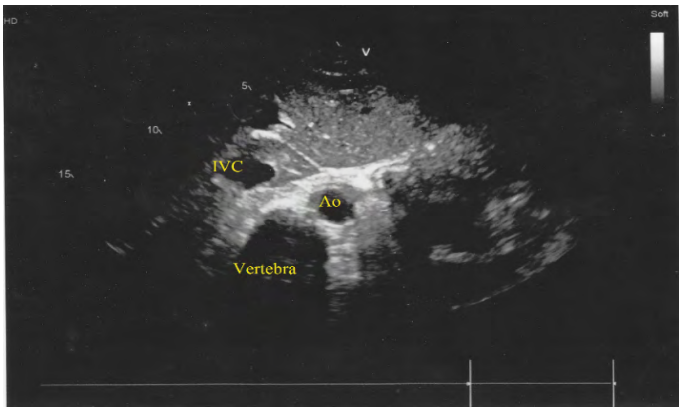

Figure 1. B-Mode ECHO from the subxiphoid window in a longitudinal section with the ECHO probe. (IVC: Inferior vena cava; Ao: Aorta).

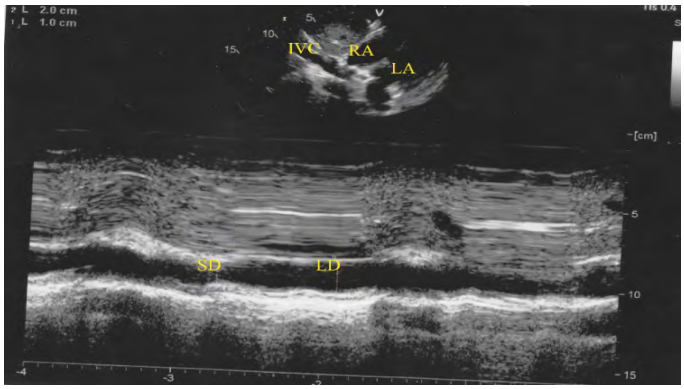

Figure 2. The ECHO probe was turned counter-clockwise without changing its location, and VCI was displayed in the in-plane position. (IVC: Inferior Vena Cava; RA: Right Atrium; LA: Left Atrium; SD: Small Diameter; LD: Large Diameter).

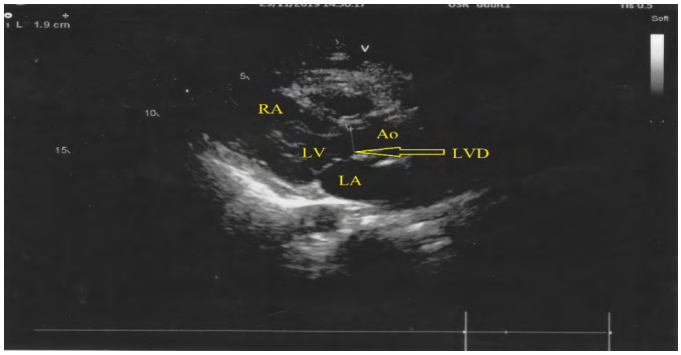

Figure 3. Adhesion points of the aortic valve from the aortic anulus line by two-dimensional imaging of the parasternal long axis with the ECHO probe. (RA: Right Atrium; LV: Left Ventricle; LA: Left Atrium; Ao: Aorta; LVD: LVOT: Left Ventricular Out Flow Tract).

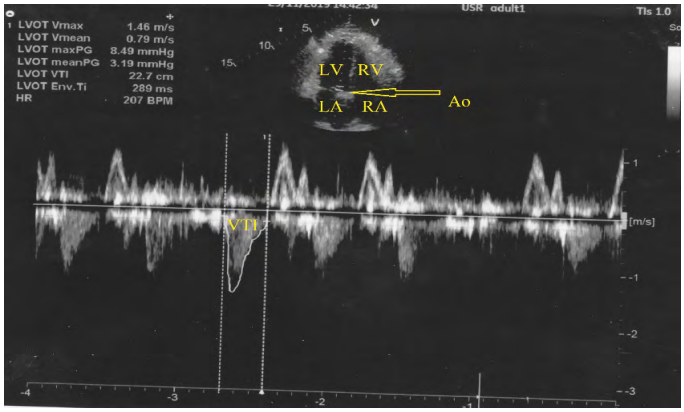

Figure 4. The apical window, VTI values of the left ventricular outflow systolic flow velocity. (LV: Left Ventricle; RV: Right Ventricle; LA: Left Atrium; RA: Right Atrium; Ao: Aorta; VTI: Velocty Time Integrale).

2. In monitored patients, PHR and SAP were measured in the supine position. The maximum and minimum VCI diameter was measured and recorded. VCI-CI was calculated, and the study was continued in patients with >42% VCI-CI.
3. VTI was measured in these patients in supine position by ECHO.
4. SAP and PHR measurements were repeated after PLRT without any medication. The study was continued in patients with >12% increase in systolic arterial pressure in the supine position. In these patients, VTI measurements were repeated by ECHO and recorded.
5. 0.1 mg/kg midazolam was administered according to the ideal weight of the patients.
6. No procedure was carried out for five minutes.
7. 5 minutes after midazolam administration, SAP and PHR were measured again and recorded, and VTI was measured again in the supine position by ECHO.
8. PLRT was performed again, and SAP and PHR measurements were recorded. VTI was measured again with ECHO and recorded.

Calculations were made from the recorded data using the following formulas:

With measurements in the supine position:

1. Aortic area (AA) was calculated as follows: $AA = (\pi \times A_0D^2)/4$
2. VCI-CI = $(V_{max} - V_{min})/Vmax$

Data calculated four times with measurements before and after PLRT before midazolam administration and before and after PLRT after midazolam administration:

1. SV: VTI × (πr^2)
2. CO: SV × HR
3. CI: CO/Body surface area (m^2)

Statistical Analysis

Statistical Package for Social Sciences (SPSS) Mac version 11.5 (SPSS Inc. Chicago, IL, USA) software program was used to evaluate the research data. Normality of distribution of the data was evaluated by Shapiro-Wilk normality test. If $p>0.05$, it was accepted that data was normally distributed, and $p<0.05$ indicated that data was not normally distributed. Data with normal distribution were compared with the Paired Samples t-test and the results were given as mean ± SD. Wilcoxon Test was used to compare the data that did not fit normal distribution, and the results were given as median ± Min-Max. $p<0.05$ was considered statistically significant in all analyses.

Results

Demographic and clinical data of the patients are given in Table 1.

The source that caused sepsis in patients and the microorganisms grown in the blood are given in Table 2.

When the effect of PLRT on SAP after the administration of midazolam was examined, it was found that SAP was 114.62 ± 24.40 mmHg before PLRT and 117.72 ± 23.55 mmHg after PLRT. Although mean SAP increased after PLRT, this increase was not statistically significant ($p>0.05$) (Table 3). There was a significant difference between SAP before PLRT before and after midazolam administration (128.32±25.30-114.62 ± 24.40 mmHg) and after PLRT before

Table 1. Patients' demographic data, temperature, ICU length of stay, SpO_2, Aortic diameter and VCI-CI values (Mean ± SD-Min-Max).

Parameters	Mean ± SD (Min-Max)
Age (Year) (n=152)	48.98 ± 10.19 (30-50)
Gender F/M (n=152)	88/74
Weight (kg) (n=152)	67.63 ± 15.89 (50-120)
Height (cm) (n=262)	166.22 ± 9.73 (167-194)
Temperature (°C) (n=262)	36.61 ± 0.23 (36-37.5)
ICU length of stay (Day) (n=152)	54.28 ± 23.67 (10-157)
SpO_2 % (n=152)	97.70 ± 1.94 (90-100)
Aortic diameter (mm) (n=152)	25.70 ± 3.00 (22-34)
VCI-CI % (n=152)	50.95 ± 6.77 (44-70)

F: Female
M: Male
Kg: kilogram
ICU: Intencive Care Unit
SpO_2: Peripheral Oxygen Saturation
VCI-CI: Inferior Vena Cava-Collapsebility İndex

and after midazolam administration (154.03 ± 18.58-117.72 ± 23.55 mmHg). SAP was lower after midazolam administration (Table 3) (p<0.05).

A statistically significant increase in PHR was observed in the PLRT performed before midazolam administration (Table 3) (p<0.05). There was a significant difference between PHR before PLRT before and after midazolam administration (113.53 ± 19.18-101.80 ± 21.62 beats/min) and after PLRT before and after midazolam administration (121.43 ± 16.65-106.45 ± 20.65 beats/min). PHR was lower after midazolam administration (Table 3) (p<0.05).

When the effect of PLRT on CI before midazolam administration was examined, it was found that CI was 4.14 ± 1.26 L/min/m^2 before PLRT, and 5.47 ± 1.28 L/min/m^2 after PLRT. The mean CI increase after PLRT was statistically significant (p<0.01) (Table 4). There was a significant difference between CIs before PLRT before and after midazolam administration (4.14 ± 1.26-4.02 ± 1.74) and after PLRT before and after midazolam administration (5.47 ± 1.28-4.39 ± 1.72). CI was lower after midazolam administration (Table 4) (p<0.05).

While mean CI following PLRT after midazolam administration was 4.02 ± 1.74 L/min/m^2, it was 4.39 ± 1.72 L/min/m^2 after PLRT after midazolam administration. It was observed that midazolam caused an increase in mean CI after PLRT, and this difference was statistically significant (p<0.05) (Table 4). When the effect of PLRT on CO before midazolam administration was examined, it was found that CO was 6.71 ± 1.40 L/min before PLRT and 8.37 ± 1.60 L/min after PLRT. The mean CO increase after PLRT was statistically significant (p<0.01) (Table 4). When the effect of PLRT on CO after midazolam administration was examined, it was found that CO was 6.22 ± 1.57 L/min before PLRT and 6.40 ± 1.67 L/min after PLRT. PLRT after midazolam administration significantly increased mean CO levels (p>0.05) (Table 4). There was a significant difference between COs before PLRT before and after midazolam administration (6.71±1.40-6.22 ± 1.57) and after PLRT before and after midazolam administration (8.37 ± 1.60-6.40 ± 1.67). CO was lower after midazolam administration (Table 4) (p<0.05). When the effect of PLRT on VTI before midazolam administration was examined, it was found that VTI was 19.11 ± 4.05 cm before PLRT and 22.52 ± 4.42 cm after PLRT. The mean VTI increase after PLRT was statistically significant (p<0.01) (Table 4). When the effect of PLRT on VTI after midazolam administration was examined, it was found that VTI was 18.35 ± 4.28 cm before PLRT and 19.39 ± 4.95 cm after PLRT. The mean VTI increase after PLRT was statistically significant (p<0.05) (Table 4). There was a statistically significant difference between VTIs before PLRT before and after midazolam administration (19.11 ± 4.05-18.35 ± 4.28) and after PLRT before and after midazolam administration (22.52 ± 4.42-19.39 ± 4.95). VTI was lower after midazolam administration (Table 4) (p<0.05).

Table 2. Microorganisms produced from focus and blood samples taken when the patient was first seen.

Sepsis Source	Focus+Blood
Pulmonary (n=61)	1- *Acinetobacter baumannii* (n=21)
	2- *Klebsiella pneumoniae* (n=17)
	3- *Staphylococcus aureus* (n=12)
	4- *Streptococcus pneumonia* (n=2)
	5- *Candida albicans* (n=4)
	5- *Staphylococcus aureus* in focus could not be produced in blood (n=5)
Intra-abdominal (n=34)	1- *Escherichia coli* (n=21)
	2- *Klebsiella pneumoniae* (n=7)
	3- *Candida albicans* (n=3)
	4- *Unclear* (n=2)
	5- *Acinetobacter baumannii* (n=1)
Urinary (n=23)	1- *Escherichia coli* (n=14)
	2- *Klebsiella pneumoniae* (n=6)
	3-*Enterobacter spp* (n=1)
	4- *Candida albicans* (n=1)
	5- *Candida albicans* in focus could not be produced in blood (n=1)
Skin (n=4)	1- *Staphylococcus aureus* (n=2)
	2- Group A *streptococci* (n=1
	3- Group A streptococcus in focus could not be produced in blood (n=1)
Central nervous system (n=8)	1- *Streptococcus pneumonia* (n=6)
	2- *Neisseria meningitidis* (n=1)
	3- *Escherichia coli* in focus could not be produced in blood (n=1)
Intrauterine (n=5)	1- *Escherichia coli* (n=3)
	2- *Enterobacter faecalis* (n=2)
Bone (n=17)	1- *Staphylococcus aureus* (n=11)
	2- *Pseudomonas aeruginosa* (n=5)
	3- *Hemophilus influenza* (n=1)

Table 3. Comparison of patients SAP and HR values (Mean ± SD).

Parameters	Before PLRT Mean ± SD	After PLRT Mean ± SD	P-value
SAP before midazolam (mmHg)	128.32 ± 25.30	154.03 ± 18.58	<0.001*
SAP after midazolam mmHg)	114.62 ± 24.40	117.72 ± 23.55	0.051
p-value	<0.001*	<0.001*	
HR before midazolam (Beat/Minute)	113.53 ± 19.18	121.43 ± 16.65	0.001*
HR after midazolam (Beat/Minute)	101.80 ± 21.62	106.45 ± 20.65	0.509
p-value	0,049*	0,001*	

SAP: Systolic Artery Pressure
HR: Heart Rate
PLRT: Passive Leg Rise Test

Table 4. Comparison of patients CI, CO, VTI values (Mean ± SD).

Parameters	Before PLRT mean ± SD	After PLRT mean ± SD	P-value
CI before midazolam (L/dk/m^2)	4.14 ± 1.26	5.47 ± 1.28	<0,001*
CI after midazolam (L/dk/m^2)	4.02 ± 1.74	4.39 ± 1.72	0,001*
p-value	0.034*	<0.001*	
CO before midazolam (L/dk)	6.71 ± 1.40	8.37 ± 1.60	<0,001*
CO after midazolam (L/dk)	6.22 ± 1.57	6.40 ± 1.67	0,001*
p-value	<0.001*	0.001*	
VTI before midazolam (cm)	19.11 ± 4.05	22.52 ± 4.42	<0,001*
VTI after midazolam (cm)	18.35 ± 4.28	19.39 ± 4.95	<0,001*
p-value	<0.001*	<0.001*	

CI: Cardiac İndex
CO: Cardiac Output
VTI: Velocity Time İntegral
PLRT: Passive Leg Rise Test

Discussion

Sedative and anaesthetic drugs are frequently used in critically ill patients in intensive care units [41]. Baroreceptors play a very important role in the regulation of dynamic blood pressure [41]. Baroreceptors are depressed throughout general anaesthesia [41]. Most anaesthetics directly act on myocardial contractility and vascular resistance [41]. This clinical condition contributes to a drop in blood pressure, causes hemodynamic instability, and creates hypovolemia at the same time [41]. One of the sedative agents, propofol reduces systemic vascular resistance and CO, and increases venous capacitance, but does not affect PHR that much [41]. Sedative and anaesthetic drugs prepare the ground for relative hypovolemia by increasing venous capacitance, and as a result, lead to decreased blood volume, CO, inability to meet the oxygen demand in tissues, and potentially hypoxia [41,42]. Therefore, when using sedative and anaesthetic drugs, drugs with a broad therapeutic index and the least cardiovascular side effects and known antagonists should be used [41,42]. Midazolam is a benzodiazepine with known effects on cardiac functions that is well tolerated, has a broad therapeutic index and a known antagonist, and its levels can be easily adjusted, especially in patients who will remain intubated for long periods of time [43-49].

In the present study, we initially determined that patients were hypovolemic with VCI-CI (> 2% significant for hypovolemia) [24], which we performed in supine position and which is an indicator of hypovolemia. We performed PLRT to see if there was fluid response in patients who were considered hypovolemic according to VCI-CI (50.95 ± 6.77 (44-70)) measurement. Based on SAP measurement results in supine position before PLRT (128.32 ± 25.30 mmHg) and SAP measurement results after PLRT (154.03 ± 18.58 mmHg), an increase of 15.3984 (>12%) [41] in SAP before PLRT before midazolam administration is an indication that patients were hypovolemic and responded to fluid. In the present study, the increase in SAP in supine position after PLRT was 25.71 mmHg, which indicated that patients were hypovolemic and responded to fluid therapy.

In a study by a group of authors, VCI-CI was measured by transthoracic ECHO before and 15 minutes after 500 ml (130/0.4)-6% hydroxyethyl starch infusion, VTI was measured afterwards, and a 15% increase in VTI after fluid administration was considered as fluid response. In the same study, they considered the patient to be hypovolemic when VCI-CI was >40% [34]. In another study, CO was measured by transthoracic ECHO before and after 500 ml (130/0.4)-6% hydroxyethyl starch infusion, and PLRT was evaluated. They considered a 10% increase in CO as a positive fluid response and found a statistically significant and strong positive correlation with PLRT. They accepted VCI-CI >42% as the cut-off point for hypovolemia [24]. In one study, they measured CO by transthoracic ECHO before and after 500 ml (130/0.4)-6% hydroxyethyl starch infusion, and they evaluated 15% increase in CO as a positive fluid response [35]. In another study, CI and SV were shown to have a high degree of correlation with fluid responsiveness [36]. In the present study, we performed PLRT twice, the first one was performed before midazolam administration and we evaluated this test with SAP, CI, CO, and VTI. Before midazolam administration, there was a statistically significant increase in SAP, CO, CI and VTI after PLRT. We measured SAP in supine position as 128.32 ± 25.30 mmHg before midazolam administration and as 154.03 ± 18.58 mmHg after PLRT, and comparing these values, we found that SAP increased significantly after PLRT. A 15.3984 mmHg (12% increase compared to basal value) increase in SAP before PLRT is an indication that patients are hypovolemic; an increase of 25.71 mmHg was found in the present study. This was an indication that our patients were hypovolemic and responded to fluid therapy. When we evaluated the effect of PLRT before midazolam administration on VTI, we found that VTI was 19.11 ± 4.05 cm before PLRT and 22.52 ± 4.42 cm after PLRT. The increase in mean VTI after PLRT was statistically significant. An increase of 2.8665 (15% increase compared to basal value) in VTI before PLRT before midazolam administration is required to diagnose hypovolemia; and in the present study, there was an increase of 4.0184 cm, which indicated that our patients were hypovolemic and responded to fluid therapy. We measured CO as 6.71 ± 1.40 L/min in supine position before midazolam and as 8.37 ± 1.60 L/min after PLRT, and comparing these values, we found that PLRT caused a statistically significant increase in CO. We considered an increase of 1.0065 L/min in CO (15% increase compared to basal value) before PLRT as an indicator of hypovolemia, and the CO increase in PLRT before midazolam administration was 2.0706 L/min in our study. This indicated that our patients were hypovolemic and would respond to fluid therapy. We measured CI as 4.14 ± 1.26 L/min/m^2 in supine position before midazolam administration and as 5.47 ± 1.28 L/min/m^2 after PLRT and compared these values. PLRT caused a statistically significant increase in CI. We considered an increase of 0.414 L/min/m^2 in CI (10% increase compared to basal value) before PLRT as an indicator of hypovolemia, and CI increase in PLRT before midazolam administration was 1.33 L/min/m^2 in the present study, which indicated that our patients were hypovolemic and responded to fluid therapy.

There was no statistically significant increase in SAP in PLRT after midazolam administration; however, there was a statistically significant increase in VTI, CO and CI measurements. We measured SAP at supine position after midazolam administration as 114.62 ± 24.40 mmHg and SAP after PLRT as 117.72 ± 23.55, and comparing these values, we found no statistically significant difference. An increase of 13.7544 (12%) mmHg in SAP before PLRT after midazolam administration is an indication that patients are hypovolemic. In the present study, there was an increase of 2.7045 mmHg. The increase in SAP in PLRT compared to the measurement before midazolam administration decreased, in fact, SAP values decreased in some patients compared to pre-PLRT levels. When we evaluated the effect of PLRT on VTI after administration of midazolam, we found that VTI was 18.35 ± 4.28 cm before PLRT and 19.39 ± 4.95 cm after PLRT. The increase in mean VTI after PLRT was statistically significant. In order to diagnose hypovolemia, VTI should have increased by 2.7525 cm (15%) after PLRT after midazolam administration, but in our study, there was an increase of 1.04 cm. This indicated that our patients were not hypovolemic. The increase in VTI caused by PLRT after midazolam decreased compared to the increase in VTI after PLRT before midazolam administration. CO measured in the supine

position was 6.22 ± 1.57 L/min after midazolam administration and 6.40 ± 1.67 L/min after PLRT. An increase of 0.933 (15%) L/min in CO in PLRT after administration of midazolam would be significant in terms of hypovolemia; however, in the present study, the increase in CO after midazolam was 0.18 L/min. This indicated that our patients were not hypovolemic. The increase in CO after PLRT decreased after midazolam administration and CO levels even decreased in some patients. There is a statistically significant increase in CO before and after PLRT after midazolam administration, but this increase is not significant enough to indicate hypovolemia. CI measured in the supine position was 4.02 ± 1.74 L/min/m^2 after midazolam and 4.39 ± 1.72 L/min/m^2 after PLRT. When we compared CI, we found a statistically significant increase. An increase of 0.402 L/min/m^2 (10% increase compared to basal value) in CI before PLRT was an indication of hypovolemia; however, CI increase in PLRT before midazolam administration in our study was 0.37 L/min/m^2, which indicated that our patients were not hypovolemic.

Midazolam is frequently used in the sedation of critically ill patients in the terminal period and is a drug selected for palliative sedation [44-47]. Midazolam has a two-phase metabolism [43]. First phase is hydroxylation via CYP3A, the main metabolite turns into alpha-hydroxy midazolam and a small amount turns into 4 hydroxy midazolam [43]. Alpha hydroxy midazolam is 80-100% as active as midazolam [43]. After hydroxylation, alpha hydroxy midazolam is converted to glucuronite via UDP-glucuronyl transferase, and this metabolite is slightly active (10% of midazolam) [43]. Peripheral vascular resistance basically controls blood pressure [16-41]. Peripheral vascular resistance is directly dependent on vascular tone arising from the balance between vasodilator and vasoconstrictor factors affecting vascular smooth muscle cells [16-41]. Vasodilation depends on the endothelium [16-41]. Endothelial factors such as nitric oxide (NO) reduce the endothelial calcium content and lead to relaxation in vascular smooth muscle cells, which causes vasodilation [16-41]. Drugs that increase NO are quite effective in lowering blood pressure [16-41]. Benzodiazepines have a direct vascular vasodilator effect on both arteries and veins [16-41]. In addition, benzodiazepines can reduce blood pressure indirectly with the control of the baroreflex system and central inhibition of the autonomic neurocardiac system [16-41]. Benzodiazepines also regulate chloride ion channels, which may mediate benzodiazepine-induced vascular effects [16-41]. In addition, vascular calcium channels sensitive to membrane voltage changes may be inhibited by high concentrations of benzodiazepines [16-41]. Benzodiazepines in nanomolar concentration bind to non-neurological receptors in peripheral tissues [16-41]. Peripheral receptors are called peripheral type benzodiazepine receptors [16-41]. In a study, the systemic administration of $GABA_A$ agonist midazolam to Python Molorus caused a statistically significant bradycardia, but the direct cardiac effect of midazolam could not be demonstrated, and this effect was attributed to midazolam decreasing the cardiac adrenergic tone and increasing the cholinergic tone [50]. The mean arterial serum concentration of midazolam following intravenous induction (0.2 mg/kg) has been reported to be 1.3620.209 pg/mL in patients with ischemic heart disease [18]. This is a 95% sufficient dose for unconsciousness [18]. Only high dose midazolam inhibits noradrenaline release during electrical stimulation and alpha-1, alpha-2 agonist contraction effect [18]. Clinical concentrations of midazolam do not inhibit NA release from sympathetic nerve endings and smooth muscle cell vasoconstriction caused by alpha-adrenoceptors [18]. These animal and human studies led us to believe that the results observed in the present study depend on peripheral vascular vasodilation and cardiac depressant effect of midazolam. We thought that PLRT may not be significant after administration of midazolam, because fluid responsiveness decreases. To the best of our knowledge, there is no study in the literature examining the effects of midazolam on intravascular volume status of patients or on PLRT.

Conclusion

Our findings show that in hypovolemic patients with sepsis (VCI-CI> 42%) who are determined to be responding to fluid therapy with PLRT (SAP>12%), and demonstrate significant results in CO (>15%), CI (>10%), VTI (>15%) in PLRT in terms of hypovolemia and fluid responsiveness prior to midazolam administration, a significant increase was observed in SAP, CI, CO and VTI values in PLRT after midazolam administration; however, this increase was not enough to diagnose hypovolemia. This shows that the administration of midazolam makes PLRT meaningless. If PLRT is to be applied to patients, it should be performed before midazolam administration for sedation.

Limitations

In this study, we evaluated the effect of midazolam on PLRT with SAP, CI, CO and VTI in patients diagnosed with sepsis and who were found to be hypovolemic with VTC-CI and responsive to fluid therapy with PLRT. We did not evaluate the effect of midazolam on dynamic parameters during PLRT by thermodilution method independently and objectively and did not evaluate its correlation with ECHO parameters. We believe that there is a need for further observational prospective studies investigating the correlation between the parameters measured by the thermodilution method and the dynamic parameters viewed by ECHO, and for human studies investigating the effect of midazolam on vascular smooth muscles.

Conflict of Interest

The authors declare there is no conflict of interest.

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