Original Article/*Özgün Araştırma*

doi: 10.54875/jarss.2024.23500

Evaluation of Volume Status with Plethysmographic Variability Index and Vena Cava Inferior Diameter Before Sitting Position

Oturur Pozisyon Öncesinde Pletismografik Değişkenlik İndeksi ve Vena Kava İnferior Çapı Ölçümleri ile Volüm Durumunun Değerlendirilmesi

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ABSTRACT

Objective: Orthostatic hypotension is a frequently encountered problem after sitting position. The aim of our study was to evaluate the intravascular volume status with passive leg-raising maneuver (PLRM), vena cava inferior (VCI) diameter measurements and plethysmographic variability index- plethysmographic waveform amplitude (ΔPpleth) before sitting position and to investigate the effect of these on predicting hemodynamic changes that may develop after sitting position.

Methods: Fifty-three patients undergoing arthroscopic shoulder surgery under general anesthesia, aged 18-65, ASA I-II, were included in this prospective study. Mechanical ventilation was commenced with tidal volume of 6-8 mL kg^{-1}, 5 cm H_2O of PEEP. Heart rates, blood pressure and manually measured plethysmographic waveform amplitudes were recorded and VCI-distensibility index (VCI-DI) was calculated. Measurements were repeated after performing PLRM. Correlation of hemodynamic changes, observed after patients were placed in sitting position, with VCI-DI and variations in the ΔPpleth was evaluated.

Results: After induction, VCI-DI was >18% in 19 (35.8%) of 53 patients and in 14 (73.7%) of these, VCI-DI decreased with PLRM. In 14 (93.3%) of 15 patients with ΔPpleth >15% after induction, ΔPpleth decreased after PLRM. The decrease in VCI-DI and ΔPpleth with PLRM was statistically significant (p<0.001; p<0.001). Changes in VCI-DI were found to correlate with ΔPpleth (p<0.001). When patients were placed in sitting position, there was a significant decrease in heart rate, systolic blood pressure, mean arterial pressure (p=0.031; p<0.001), and a significant increase in ΔPpleth (p<0.001).

Conclusion: Plethysmographic waveform amplitude after PLRM can be used to predict the volume status and hemodynamic response of patients undergoing shoulder surgery in sitting position.

Keywords: Fluid responsiveness, inferior vena cava diameter, passive leg raise, plethysmography, sitting position

ÖZ

Amaç: Ortostatik hipotansiyon, oturur pozisyondan sonra sık karşılaşılan bir sorundur. Çalışmamızın amacı; oturur pozisyon öncesi yapılan pasif bacak kaldırma manevrası (PBKM), vena kava inferior (VKİ) çapı ölçümleri ve pletismografik değişkenlik indeksi- pletismografik dalga formu amplitüdündeki varyasyon (ΔPpleth) ile intravasküler volüm durumunun değerlendirilmesi ve bunların oturur pozisyon sonrası gelişebilecek hemodinamik değişikliklerin öngörülmesindeki etkisini araştırmaktır.

Yöntem: Bu prospektif çalışmaya 18-65 yaş arasında, ASA I-II, genel anestezi altında artroskopik omuz cerrahisi yapılacak olan 53 hasta dahil edildi. Hastalar 6-8 mL kg^{-1} tidal hacim, 5 cm H_2O PEEP ile ventile edildi. Kalp hızı, kan basıncı ve manuel ölçülen pletismografik dalga formu amplitüdleri kaydedildi, vena kava inferior gerilim indeksi (VKİ-Gİ) hesaplandı. Ölçümler, PBKM yapıldıktan sonra tekrarlandı. Hastalar oturur pozisyona getirildikten sonra görülen hemodinamik değişikliklerin, ölçülen VKİ-Gİ ve ΔPpleth ile korelasyonu değerlendirildi.

Bulgular: İndüksiyon sonrası 53 hastanın 19'unda (%35,8) VKİ-Gİ >%18 iken, bunların 14'ünde (%73,7) VKİ-Gİ'nin PBKM ile birlikte azaldığı görüldü. İndüksiyon sonrası ΔPpleth >%15 olan 15 hastanın 14'ünde (%93,3) PBKM sonrasında ΔPpleth'in azaldığı görüldü. Pasif bacak kaldırma manevrası ile VKİ-Gİ ve ΔPpleth'teki azalma istatistiksel olarak anlamlıydı (p<0.001; p<0.001). Ayrıca VKİ-Gİ'deki değişikliklerin ΔPpleth ile korele olduğu bulundu (p<0,001). Hastalar oturur pozisyona getirildiğinde; kalp hızı, sistolik ve diyastolik kan basınçlarında ve ortalama arter basıncında anlamlı azalma (p=0,031; p<0,001), ΔPpleth'te ise anlamlı artış (p<0,001) vardı.

Sonuç: Pasif bacak kaldırma manevrası sonrası ΔPpleth, oturur pozisyonda omuz cerrahisi geçirecek hastaların hemodinamik yanıtının ve volüm durumlarının tahmininde kullanılabilir.

Anahtar sözcükler: Sıvı yanıtlılığı, vena kava inferior çapı, pasif bacak kaldırma, pletismografi, oturur pozisyon

Received/Geliş tarihi : 01.12.2023
Accepted/Kabul tarihi : 23.07.2024
Publication date : 29.07.2024

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Cite as: Namli Emlek M, Donmez A, Polat R. Evaluation of volume status with plethysmographic variability index and vena cava inferior diameter before sitting position. JARSS 2024;32(3):174-181.

INTRODUCTION

There are various invasive (central venous pressure, pulse pressure variation, stroke volume variation, etc.) and non-invasive (mean arterial pressure, pulse oximetry plethysmographic waveform, etc.) methods used to detect fluid deficit in patients (1).

Complications such as infection, embolism, hematoma, pseudoaneurysm and bleeding limit the use of invasive methods. Both the passive leg raising manoeuvre (PLRM) and measurement of vena cava inferior (VCI) diameter with ultrasonography (USG) are non-invasive methods that have recently come into clinical use in the evaluation of the volume status of patients (2,3). The change in diameter is evaluated using the decrease in VCI diameter during inspiration in the spontaneously breathing patient (the collapsibility index=CI) and the increase in VCI diameter during positive pressure ventilation in the mechanically ventilated patient (the distensibility index =DI) (4).

It is accepted that the respiratory change in the waveform amplitude of pulse oximetry, which is one of the other non-invasive indicators, is sensitive to changes in ventricular *preload* and is an accurate indicator of fluid responsiveness (5).

Orthostatic hypotension is a problem that is frequently encountered during positioning in operations performed in the sitting position and is generally associated with the volume status of the patients (6). It has been shown that approximately 50% of patients who are hemodynamically unstable in the operating room respond to fluid replacement (1). With PLRM, 200-300 mL of blood from the lower extremities returns to the central circulation, increasing ventricular preload and cardiac output. This fluid movement is quickly reversed when the legs are brought back to the horizontal position. Thus, PLRM creates a reversible fluid movement in which hemodynamic changes can be measured (2).

The aim of this study was to evaluate the intravascular volume status by measuring the VCI diameter and pulse oximetry waveform amplitude changes in response to PLRM before the sitting position and to investigate their effect in predicting the hemodynamic changes after the sitting position.

MATERIAL and METHODS

This prospective observational study was conducted between December 2019 and March 2020 and was registered with Clinical Trial number NCT04152135. Approval for the study was granted by the Local Ethics Committee approval (10/07/2019, No: 67/17) and informed consent was obtained from all the patients. The study included 53 ASA I-II patients, aged 18-65 years, undergoing elective arthroscopic shoulder surgery under general anesthesia in the sitting position. Patients were excluded from the study if they were <18 years or > 65 years, were classified as ASA III-IV, had any heart or valve disease, or were not willing to participate in the study.

Heart rate (HR), peripheral oxygen saturations (SpO_2), and non-invasive blood pressure (NIBP) were monitored, and recorded (Dräger Infinity Delta XL, Germany). Following intravenous access, an isolyte-S infusion was initiated. From the plethysmographic waveform (PW), maximum and minimum values were measured manually in mm from the starting point of the waveform to the peak point by freezing the monitor image as shown in Figure 1.

After anesthesia induction with lidocaine (1 mg kg^{-1}), fentanyl (1 mcg kg^{-1}), propofol (2-4 mg kg^{-1}) and rocuronium bromide (0.6 mg kg^{-1}), all the patients were intubated and connected to the mechanical ventilator (Dräger, Primus). All patients were ventilated in volume controlled mode with tidal volume: 6-8 mL kg^{-1}, frequency: 12 min^{-1}, PEEP: 5 cm H_2O, flow: 3 L min^{-1}. Anesthesia was maintained with 2-3% sevoflurane and 40% O_2+ 60% air. Heart rate , SpO_2, BP, end-tidal carbon dioxide ($EtCO_2$), and maximum and minimum values of PW were recorded 2 minutes after intubation (T0).

Vena cava inferior diameters were measured using USG (*Esaote, MyLabSeven*) with a 1-5 MHz convex probe. The convex probe was held in the subxiphoid area, pointing to the right axilla, and the right atrium-VCI junction was viewed. At 1-3 cm distal to this junction, where the hepatic vein joins the VCI perpendicularly, the maximum and minimum VCI diameters were measured and recorded on the frozen image using M-mode as shown in Figure 2 (3).

After these measurements, the patient's legs were elevated for 2 min to perform PLRM. The VCI diameters were measured again, and HR, BP, PW were recorded (T1). Subsequently, patients were placed in the sitting position, and after 2 minutes, HR, BP, PW measurements were repeated (T2).

A decrease of >20% in systolic blood pressure compared to the previous value was accepted as the threshold value for perioperative hypotension.

The respiratory variation of the ΔPpleth from the measured PWs was calculated using the formula:

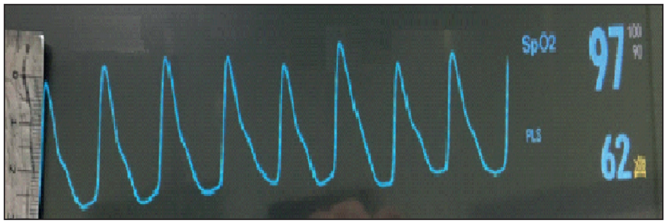

Figure 1. Plethysmographic waveform measurement method.

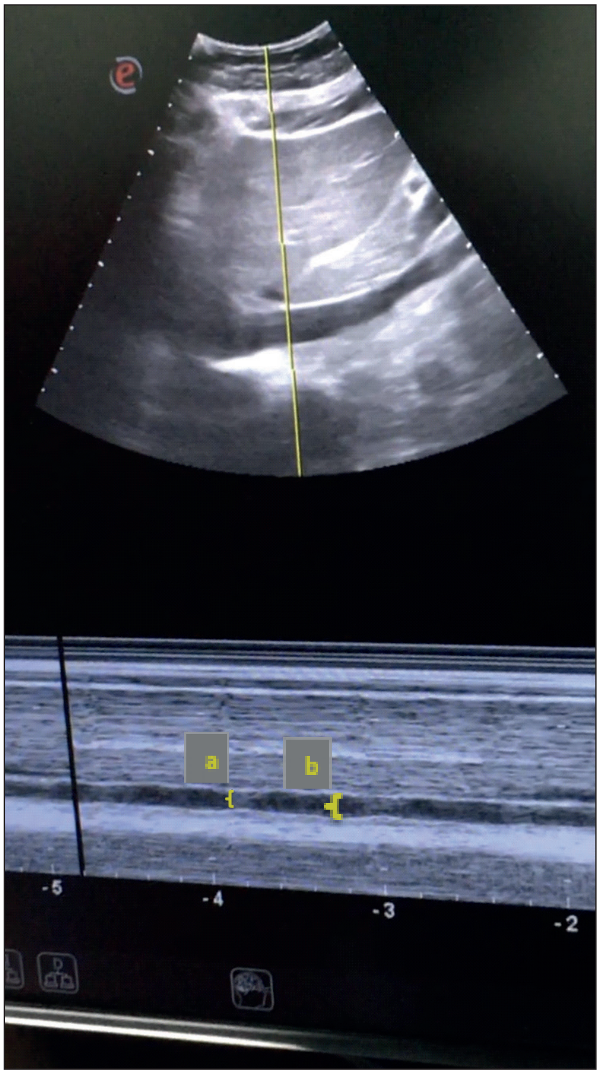

Figure 2. Measurement of the minimum and maximum diameters of the Inferior Vena Cava by Freezing the Screen in M-mode. **a:** minimum diameter on expiration, **b:** maximum diameter on inspiration.

ΔPpleth (%) = 100 x (Ppleth-max– Ppleth-min) / [(Ppleth-max+ Ppleth-min)/2].

The VCI-DI was calculated from the measured VCI max and min diameters using the formula:

VCI-DI: [(VCImax- VCImin) / VCImin] x 100.

ΔPpleth≤ 15% and VCI-DI ≤ 18% were accepted as normal values.

Statistical Methods

As a result of the power analysis, the minimum required sample size was calculated to be 46 patients to provide effect size of 1.43, study power of 90%, and Type I error of 0.05 (R 3.6.1. open source program). Statistical evaluation of the data was performed using the *Statistical Package for the Social Sciences (SPSS)* for Windows version 20.0 software. Descriptive statistics were presented as number (n) and percentage (%) for categorical variables, and as mean ± standard deviation (SD) or median, minimum-maximum values for numerical variables. The conformity of numerical data to normal distribution was examined with the *Shapiro-Wilk* test. The *Repeated Measures ANOVA* was used to compare more than two dependent groups of data with normal distribution, and the *Friedman* test was applied to more than two dependent groups of data not showing normal distribution. If there was a significant difference between the groups, *Bonferroni* correction was applied in post-hoc analyses. When there are only two dependent groups of data not showing normal distribution, the *Wilcoxon test* was applied. The analyses of categorical variables were performed using the *Chi Square* test or the *Fisher's Exact Test*. The data were analyzed at 95% confidence level and a value of p<0.05 was accepted as statistically significant. To determine cutoff values for the VCI-DI and ΔPpleth variables for diagnostic decision-making properties in predicting fluid sensitivity, Receiver Operating Characteristic (ROC) curve analysis with *Youden Index* was performed. The sensitivity, specificity, positive predictive and negative predictive values of these limits were calculated for the significant cutoff values.

RESULTS

Evaluation was made of 53 patients, comprising 31 females and 22 males. The demographic features of the patients are shown in Table I.

The comparisons of HR, systolic and diastolic BP (SBP, DBP), mean arterial pressure (MAP), ΔPpleth, and VCI-DI values of the patients before PLRM (T0), after PLRM (T1) and after the sitting position (T2) are presented in Table II. When the values measured before and after PLRM were compared, there was significant difference between the HR, DBP, ΔPpleth and VCI-DI values, but no significant difference in terms of SBP and MAP. When the hemodynamic values measured after PLRM and after the sitting position were compared, there was seen to be a significant difference between HR, SBP, DBP, MAP, and ΔPpleth values.

Table I. Demographic Features

	n	% or mean ± SD
Gender		
Female	31	58.5
Male	22	41.5
Age (year), mean ± SD	53	52.21 ± 11.65
BMI (kg m^{-2}), mean ± SD	53	28.93 ± 5.41

BMI: Body mass index, **SD:** Standard deviation.

Table II. Comparison of Hemodynamic Values Before Passive Leg Raising Maneuver, After Passive Leg Raising Maneuver and After Sitting Position

	T0 (mean ± SD) (median, min-max)	T1 (mean ± SD) (median, min-max)	T2 (mean ± SD) (median, min-max)	p
HR (beats min^{-1})	83.83 ± 14.33	76.15 ± 11.39[a]	73.60 ± 12.79 [b]	<0.001*
SBP (mmHg)	121.98 ± 22.98 (115, 83-173)	117.94 ± 20.87[c] (112, 90-189)	103.60 ± 20.33 [d] (104, 63-161)	<0.001ŧ
MAP (mmHg)	95.74 ± 18.79	92.09 ± 16.27[e]	81.79 ± 16.56 [f]	<0.001*
DBP (mmHg)	76.98 ± 16.43	72.51 ± 13.54[g]	65.98 ± 14.04 [h]	<0.001*
ΔPpleth (%)	11.36 ± 6.21 (9.2, 3.0-29.6)	7.19 ± 4.39[i] (6.0, 2.9-26.6)	12.59 ± 5.34 [j] (11.4, 5.7-27.0)	<0.001ŧ
VCI-DI (%)	16.40 ± 8.13 (14.3, 4.4-34.0)	11.92 ± 5.48[k] (10.9, 3.8-25.0)	-	-

T0: Before PLRM, **T1:** After PLRM, **T2:** After the sitting position, **SD:** Standard deviation, **HR:** Heart rate, **a:**T0xT1 (p<0.001), **b:** T1xT2 (p=0.031), **SBP:** Systolic blood pressure, **c:** T0xT1 (p=0.151), **d:** T1xT2 (p<0.001), **MAP:** Mean arterial pressure, **e:** T0xT1 (p=0.115), **f:** T1xT2 (p<0.001), **DBP:** Diastolic blood pressure, **g:** T0xT1 (p=0.015), **h:** T1xT2 (p=0.001), **ΔPpleth:** Variations in plethysmographic waveform amplitude, **i:** T0xT1 (p<0.001), **j:** T1xT2 (p<0.001), **VCI-DI:** Vena cava inferior distensibility index, **k:** T0xT1 (p<0.001). ***:** Repeated Measures ANOVA, **ŧ:** Friedman test, **k:** Wilcoxon test.
a, b, c, d, e, f, g, h, i, j: Post hoc analyses with significance p-value 0.017.

Table III. Analysis of Significant Changes in Vena Cava Inferior Distensibility Index and Variation of Plethysmographic Waveform Amplitude in all Patients After Induction and After Passive Leg Raising Maneuver

		VCI-DI		Total, n (%)
		A, n (%)	B, n (%)	
ΔPpleth	**C, n (%)**	11 (78.6)	3 (21.4)	14 (100.0)
	D, n (%)	3 (7.7)	36 (92.3)	39 (100.0)
Total	**n (%)**	14 (26.4)	39 (73.6)	53 (100.0)

VCI-DI: Vena cava inferior distensibility index, **A:** Patients with significant change in VCI-DI, **B:** Patients without significant change in VCI-DI, **C:** Patients with significant change in ΔPpleth, **ΔPpleth:** Plethysmographic waveform amplitude variation, **D:** Patients without significant change in ΔPpleth.

Post-induction VCI-DI was >18% in 19 (35.8%) of the total 53 patients. In 14 (73.7%) of these patients, VCI-DI decreased below 18% after PLRM was performed. Post-induction ΔPpleth was >15% in 15 of the total 53 patients, and in 14 (93.3%) of these patients, ΔPpleth was found to be <15% after PLRM. Before PLRM, 13 patients were determined with both VCI-DI and ΔPpleth above the thresholds supporting fluid deficit. *Chi-square* analysis was performed on the data of these patients to examine the relationship between VCI-DI and ΔPpleth. The results showed no statistically significant relationship (p=0.154, p>0.05).

To avoid data loss and to increase the number of patients, the analysis was repeated with all patient data, on the premise of "There is no significant change after PLRM" for patients with VCI-DI and ΔPpleth values already below the threshold value before PLRM (Table III). In 11 of the 14 patients with a significant change in VCI-DI, there was a significant change in ΔPpleth. There was no significant change in VCI-DI in 36 (92.3%) of 39 patients who did not have a significant change in ΔPpleth. The relationship between VCI-DI and ΔPpleth was determined to be statistically significant (*Chi-square*: p<0.001).

In the ROC analysis performed, area under the ROC Curve (AUC) for VCI-DI was calculated as 0.817 (0.685-0.949). The specificity and sensitivity values of the test in evaluating the response to PLRM in patients with fluid deficit were found to be 78.1% and 85.7%, respectively (p<0.001). The AUC for ΔPpleth was calculated as 0.780 (0.653-0.907). The specificity and sensitivity values of the test in the evaluation of PLRM response in patients with fluid deficit were found to be 71.4% and 71.9%, respectively (p=0.001) (Table IV). As the p values were found to be <0.05, the AUC values were determined to be significant for both variables. The specificity and sensitivity of VCI-DI were found to be higher than that of ΔPpleth, but both parameters can significantly distinguish fluid deficit. The ROC curve for VCI-DI and ΔPpleth according to the response to PLRM in patients with fluid deficit is shown in Figure 3.

Table IV. Receiver Operating Characteristic (ROC) Analysis Values for VCI-DI and ΔPpleth According to Their Response to Passive Leg Raising Maneuver in Patients with Fluid Deficit

Variables	Sensitivity	Specificity	AUC	PPV	NPV	p-value
VCI-DI	0.857	0.781	0.817 (0.685-0.949)	78.1	85.7	<0.001*
ΔPpleth	0.714	0.719	0.780 (0.653-0.907)	71.9	71.4	0.001*

ROC: Receiver operating characteristic, **AUC:** Area under the curve, **PPV:** Positive predictive value, **NPV:** Negative predictive value, **ΔPpleth:** Plethysmographic waveform amplitude.

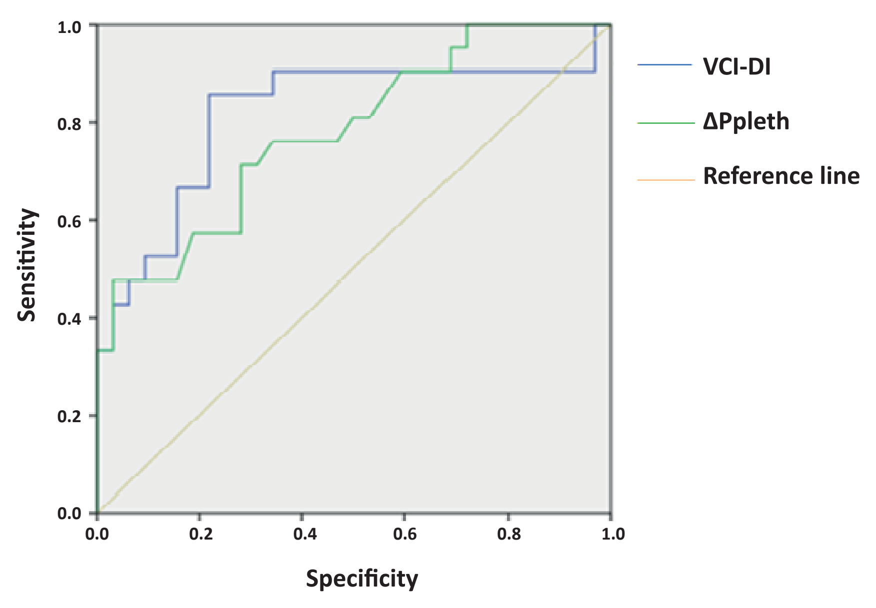

Figure 3. Receiver operating characteristic (ROC) curve for VCI-DI and ΔPpleth according to responses to passive leg raise maneuver in patients with fluid deficit.

DISCUSSION

In this study, evaluations were made of the intravascular volume status from the respiratory changes in the dynamic tests of VCI-DI and ΔPpleth, and the response to PLRM, and the role of these changes was investigated in respect of prediction of hemodynamic changes in the sitting position. The study results showed that both ΔPpleth and VCI-DI decreased with PLRM, and increased after the sitting position. These changes in PLRM and in the sitting position were determined to be correlated with each other. From these results, it can be considered that examining the VCI-DI and ΔPpleth measurements in intubated and positive pressure ventilated patients, and evaluating the volume status with PLRM can help to predict hypotension that may be associated with the sitting position.

Perioperative fluid management and assessment of intravascular volume status are crucial in anesthesia management as they affect patient outcomes (1,7). Many static and dynamic parameters are used to estimate volume deficit and fluid responsiveness. Fluid response is best evaluated with dynamic indicators in patients with regular heart rhythm, under controlled mechanical ventilation, no spontaneous respiratory effort, or not taking vasoactive medication (7). However, in general, these parameters require invasive procedures. Vena cava inferior-distensibility index, which is calculated by the respiratory change of VCI diameter on USG, is a dynamic indicator that is frequently used in the estimation of intravascular volume. Being a non-invasive and practical tool makes this method suitable for the determination of fluid sensitivity (3). Passive leg raising manoeuvre is also a non-invasive, simple, and applicable method for predicting fluid responsiveness in most cases (2). Fluid sensitivity measurement with PLRM can be performed in two different ways; the lower extremities of the patient are placed in the supine position after the semi-sitting position or elevated by 45° in the direct supine position. With PLRM, approximately 300 mL of volume passes from the lower extremity to the central compartment (8). As this study was conducted on intubated patients, PLRM in the supine position was applied. Although there are studies showing an increase in SBP, DBP, and MAP values with PLRM (9,10), some studies have failed to show a significant change in BP and others have shown decreased BP as in the current study (9,11,12). Kamran et al. showed that arterial dilatation caused by PLRM-induced hyperemia was the cause of the BP drop in healthy subjects (12). Passive leg raising manoeuvre performed after being brought from the semi-sitting position to the supine position may cause a more pronounced hemodynamic effect since the blood in the splanchnic venous reservoir will also enter the central circulation (1). The failure to see the expected increase in SBP, DBP, and MAP in the current study may have been due to the inability of the splanchnic venous reservoir to enter the circulation, arterial dilation induced by PLRM, or the lack of fluid deficit in these patients.

Passive leg raising manoeuvre is considered when there is a type of fluid overload, and measurement of VCI diameter on USG is valuable in predicting fluid responsiveness (13). It has been shown that there is a decrease in VCI diameter together with the decrease in intravascular blood volume in patients who have undergone ultrafiltration and in volunteers who donated blood (14,15). Although threshold values for VCI-DI range between 12-18% in the literature in response to fluid expansion, the most accepted value is 18% (16-19). Therefore, in the current study, a VCI-DI value >18% was accepted as the threshold to predict volume deficit. The study results showed post-induction VCI-DI of ≤ 18% in 64.2% of patients, while VCI-DI was > 18% in 35.8%. In 73.7% of these patients, VCI-DI significantly decreased below 18% with PLRM. Although post-induction VCI-DI was below the threshold value in 64.2% of patients, the decrease in VCI-DI seen after with the volume added to the circulation by performing PLRM was found to be statistically significant. Thus, that the volume returned to the central circulation with PLRM could be shown with VCI-DI measurements.

Respiratory variation of the ΔPpleth is also a measurement that can be used to predict fluid responsiveness (1,5,20). In the absence of invasive arterial monitoring, ventilation-induced plethysmographic waveform variability obtained from pulse oximetry is considered to be useful in the determination of hypovolemia (5). On spontaneously breathing volunteers, ΔPpleth has been shown to decrease significantly with PLRM (5,21). However, Demirci et al. reported that pleth variability index variation is not a reliable predictor of volume status changes induced by PLRM in spontaneously breathing, healthy patients (22). Chu et al. showed that it is an acceptable method for estimating fluid responsiveness in mechanically ventilated patients, but its applicability may be limited in the presence of spontaneous respiratory movement or arrhythmia (23).

Threshold values of 9-15% have been reported for the variability in plethysmographic waveform amplitude (20,24,25). In a study by Cannesson et al., which was the first to demonstrate a strong relationship between ΔPpleth and pulse pressure variation, it was reported that in mechanically ventilated patients, when ΔPpleth was >15%, arterial pulse pressure variation >13% can be accurately predicted (26). In another study, Natalini et al. reported a ΔPpleth of >15% for fluid responsiveness (20). In the current study, ΔPpleth> 15% was accepted as the threshold value, and while ΔPpleth was 11.36 ± 6.21% after induction, it was 7.19 ± 4.39% after PLRM. After the patients were placed in the sitting position, the mean ΔPpleth was 12.59 ± 5.34%, and although this increase was significant, it did not exceed the threshold value. This was thought to be secondary to the relative volume deficit due to peripheral pooling when the patients were placed in the sitting position. If the mean ΔPpleth value does not rise above the threshold value after induction and after the sitting position, it can be interpreted as showing that the patients did not have preoperative fluid deficits. However, the significant decrease in ΔPpleth value after PLRM is evidence of the volume expansion provided by the manoeuvre.

The incidence of intraoperative hypotension related to the sitting position in patients operated under general anesthesia, is 12-32% due to physiological changes which occur with the sitting position and associated with gravity (27). Decreased venous return during sitting position reduces cardiac output with the vasodilator and myocardial depression effects of anesthetic agents, and therefore, it may cause deterioration in organ perfusion. In the definition of perioperative hypotension, a decrease in SBP of more than 20% from the initial value is accepted as the threshold value (27,28). In the current study, this threshold was also used as a BP change from the baseline when putting the patient into the sitting position after PLRM. A significant decrease was determined in HR, SBP, DBP, MAP, and a significant increase in ΔPpleth. The reason for this is that the volume in the central compartment decreases due to the sitting position and consequently creates a relative volume deficit. There were 14 patients with VCI-DI >18% after induction and ≤18% with PLRM, and 14 patients with ΔPpleth> 15% after induction and ≤15% with PLRM, and these patients were considered to have a possible fluid deficit (4,16,26,29). A total of 11 patients in this study had a decrease in both VCI-DI and ΔPpleth with PLRM. Only 4 of these patients developed orthostatic hypotension after the sitting position. The hypothesis of this study was that there would be orthostatic hypotension in patients with fluid deficit which could be evaluated with VCI-DI and ΔPpleth, but the desired number of patients could not be reached. This may be due to the fact that the patients were ASA I-II, their fasting period was short, and they did not tend to hypotension because they were active in daily life. There is a need for further studies with larger numbers of patients and high-risk patients to be able to confirm this hypothesis.

There are different opinions about the change in HR in patients under general anesthesia who are brought from the supine position to the sitting position (27,30,31). Bradycardia is among the undesirable consequences of the sitting position in shoulder surgeries. This condition has been specifically named as “Hypotension-Bradycardia Episode/ Hypotensive-Bradycardic Events” (HBE) and has been reported to be seen in 6-27% of patients placed in a sitting position (31,32). It has been reported that HBEs may occur due to the activation of the Bezold-Jarisch reflex (BJR), which is defined as a reflex that occurs by mechanical or chemical stimuli, initiated by an increase in cardiac contractile state, resulting in bradycardia and hypotension which occurs with sympathetic blockade and increased vagal tone (32). In the current study, HR was seen to decrease significantly after the sitting position. This may have been due to the BJR.

Recently, it has been shown that dynamic parameters such as arterial pressure waveform and VCI-DI are more reliable than static parameters such as central venous pressure and right atrial pressure in the evaluation of the response of cardiac output to fluid administration (1). However, there is no indication for arterial catheterization in surgeries that take a short time, have a low probability of bleeding, have a relatively stable course, or do not require frequent blood gas monitoring. Therefore, non-invasive methods such as VCI-DI and ΔPpleth have recently become valuable (1). These two parameters are expected to be correlated in patients with fluid deficit. In the current study, sufficient hypovolemic patients could not be enrolled due to the characteristics of the patient group. Therefore, the data of all the patients were analyzed and VCI-DI and ΔPpleth were found to be correlated with each other in this analysis.

This observational study has limitations. The study measurements were made when the VCI, right atrium and hepatic vein were seen together in all patients whose data were taken. However, it may be difficult to see all three structures at the same time in obese or anatomically different patients. Therefore, patients who could not undergo appropriate imaging were not included in the study. Another limitation was that the study was conducted on mechanically ventilated patients who had no cardiac arrhythmia, and no need for vasoactive agents. However, in routine clinical practice many hemodynamically unstable patients with arrhythmias can be encountered and ΔPpleth assessment is not reliable in these patients. In addition, manual plethysmographic measurements were among the limitations of the study, as the general use may vary between practitioners.

CONCLUSION

The evaluation of VCI diameter takes time and may not always be appropriately evaluated. From the results of this study showing that VCI-DI and ΔPpleth are correlated, in it can be considered that ΔPpleth calculated by pulse oximetry can be used instead of the VCI diameter for the prediction of fluid responsiveness.

In the current study patients with ΔPpleth >15% and VCI-DI >18% after induction, it was seen that this deficit was closed with PLRM. Therefore, the effectiveness of PLRM should be kept in mind for reducing hypotension due to the sitting position and related mortality.

Plethysmographic waveform amplitude, which is used in routine monitoring, and PLRM, which is easy to apply, can be used more widely in predicting the volume status of patients.

AUTHOR CONTRIBUTIONS

Conception or design of the work: MNE, AD

Data collection: MNE, AD

Data analysis and interpretation: MNE, AD, RP

Drafting the article: MNE, AD

Critical revision of the article: AD, RP

The author (MNE, AD, RP) reviewed the results and approved the final version of the manuscript.

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