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Özgün Araştırma / *Original Article*

Efficacy of Pleth Variability Index (PVI) to Evaluate Intraoperative Fluid Management During Orthopedic Spinal Surgery: A Randomized Controlled Trial

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Ortopedik Spinal Cerrahi Olgularında İntraoperatif Sıvı Yönetimini Değerlendirmede Pleth Değişkenlik İndeksinin Etkinliği: Randomize Kontrollü Çalışma

ABSTRACT

Objective: *To prevent complications during major surgery, it is important to monitor blood and fluid treatment. The Pleth Variability İndex (PVI) allows noninvasive assessment of fluid management. It is based on respiratory changes in arterial pulse pressure. In our study, we aimed to compare the management in terms of variations in PVI in response to fluid loading in the monitorization of intraoperative fluid management in major surgery using classical calculation method and CVP*

Method: *The patients were randomized into two equal (n=50) groups. In Group C, the required amount of fluid replacement was carried out with crystalloid solutions using the 4-2-1 rule and by calculating fasting, maintenance, and insensible losses. In the PVI group, 250 mL of crystalloid solution was administered in 5 minutes to patients with a PVI greater than 14%, patients with a PVI less than 14% were administered a fluid infusion with an initial dose of 4 mL kg^{-1} h^{-1}.*

Results: *In the comparison of intraoperative fluid management the amount of intraoperative fluid replacement was 3522±1098.1 mL in Group C and 1914±542.86 mL in Group PVI (p<0.05). The mean amount of intraoperative red blood cell transfusion was 0.42±0.57 unit in Group C and 0.08±0.27 unit in Group PVI (p<0.05). There were no significant differences between the groups in terms of postoperative red blood cell transfusion (p>0.05) or intraoperative hemoglobin levels (p>0.05).*

Conclusion: *It has been thought that PVI assessment is more valuable than CVP monitoring because it is noninvasive and thus provides better cardiac stabilization with less fluid replacement. It can also provide more accurate results when evaluating intravascular volume status.*

Keywords: *Spinal surgery, Pleth variability index, fluid management, noninvasive*

ÖZ

Amaç: *Majör cerrahilerde komplikasyonları önlemek için, kan ve sıvı tedavisini izlemek önemlidir. "Pleth Değişkenlik İndeksi" (PDİ) sıvı tedavisinin invaziv olmayan ölçümüne olanak sağlayan, temeli arteriyel nabız basıncındaki solunumsal değişikliklere dayanan bir yöntemdir. Çalışmamızda, majör cerrahide intraoperatif sıvı yönetiminin, klasik hesaplama yöntemi ve SVB ile takibinin, sıvı yüklemesine verilen PVI değişikliklerine göre yönetimin karşılaştırılması amaçlanmıştır.*

Yöntem: *Hastalar randomize olarak 2 eşit gruba (n=50) ayrıldı. Grup C'de sıvı gereksinimi açlık, idame ve insensibl kayıp 4-2-1 kuralına göre hesaplanarak kristalloid ile karşılandı. Grup PDİ'de PDİ değeri 14'ün üstünde olan hastalara 250 mL kristalloid 5 dk'da gidecek şekilde verildi. PDİ değeri 14'ün altında olan hastalara 4 mL kg^{-1} sa^{-1} sıvı infüzyonu açıldı.*

Bulgular: Grupların intraoperatif sıvı yönetimlerinin karşılaştırmasında; Grup C'de intraoperatif verilen sıvı miktarı 3522±1098.1 mL ve Grup PDİ de intraoperatif verilen sıvı miktarı 1914±542.86 ml (p<0.05). Grup SVB'de intraoperatif verilen eritrosit süspansiyonu 0.42±0.57 ünite ve Grup PDİ'de intraoperatif dönemde verilen eritrosit süspansiyonu 0.08±0.27 ünitedir (p<0.05). Gruplar arasında postoperatif eritrosit süspansiyonu transfüzyonu miktarı ve intraoperatif hemoglobin düzeyleri arasında anlamlı fark yoktur (p>0.05).

Sonuç: *Sonuç olarak, PDİ yöntemi ile sıvı takibinin SVB izlemi ile takibe göre noninvaziv olması, daha az sıvı ile daha iyi kardiyak stabilizasyon sağlanabilmesi ve hastanın intravasküler volümünü değerlendirmede daha doğru sonuçlar verebilmesi nedeniyle değerli bir yöntem olduğu düşünüldü.*

Anahtar kelimeler: *Spinal cerrahi, Pleth variability index, sıvı yönetimi, noninvaziv*

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INTRODUCTION

No standard of intraoperative fluid management during major surgical interventions has yet been established. However, excessive fluid replacement harms cardiac and pulmonary functions, gastrointestinal motility, tissue oxygenation, wound healing, and coagulation, while the life-threatening consequences of inadequate fluid support include lactic acidosis, acute renal insufficiency, and multiple organ failure [1,2].

Conventionally, parameters such as heart rate, blood pressure, urine output, and central venous pressure (CVP) are measured during surgery to calculate blood loss and the necessary amount of fluid [3,4]. Currently, invasive measures, such as pulse pressure variation (PPV) and stroke volume variation (SVV) have been used instead of static measurement of cardiac filling pressures. These parameters are dynamic and based on interaction between the heart and lungs during mechanical ventilation. However, invasive monitoring is often difficult, and thus minimally invasive methods are preferred [4]. In particular, transesophageal and transthoracic echocardiography constitute minimally invasive functional hemodynamic monitoring. These methods measure the respiratory changes in blood flow [5,6].

Recently, the Pleth Variability Index (PVI) has been used increasingly for noninvasive assessment of fluid management. It is based on respiratory changes in arterial pulse pressure [7]. The PVI is preferred because (1) it is noninvasive, (2) the sensor can be easily inserted, and (3) it allows continuous measurement at the bedside [3].

In the present study, to monitor fluid management during major surgical interventions, we aimed to compare fluid loading-induced changes as assessed using PVI, CVP and classical parameters.

MATERIALS and METHODS

The present study was carried out in patients who underwent elective posterior lumbar stabilization surgery at the Medical Faculty Hospital of Celal Bayar University between December 17, 2014 and December 17, 2015. The study was approved in advance by the Non-Interventional Clinical Trials Ethics Committee of Celal Bayar University Faculty of Medicine (registration number: 20478486-404). On the basis of a sample size analysis with a power of 0.70 and an effect size of 0.50, 100 patients aged > 18 years and with an ASA status of I or II were included in the present study. The patients were randomly divided into two groups of 50 using the closed-envelope method. The cut-off value of PVI was established as 14% [8]. We excluded patients who (1) provided no written consent, (2) were under 18 years of age, (3) had peripheral arterial disease, (4) showed echocardiographic findings of systolic or diastolic heart failure, cardiac arrhythmia, or renal insufficiency with associated fluid electrolyte imbalance, and (5) had received any fluid infusion in the 24 hours before surgery.

The patients were premedicated with intravenous midazolam at a dose of 0.01 mg kg^{-1} in the operation room, and monitored using standard methods (electrocardiogram, noninvasive blood pressure, peripheral oxygen saturation, end-tidal CO_2 pressure [$ETCO_2$], nasopharyngeal temperature and bispectral index [BIS; Aspect 1000 Systems, Aspect Medical Systems Inc., Natick]).

The patients were administered propofol (2 mg kg^{-1}), fentanyl (2 µg kg^{-1}), and rocuronium (0.6 mg kg^{-1}) to induce anesthesia, and endotracheal intubation was then performed. Arterial monitoring was performed using the radial artery, while central venous catheterization was carried out using the internal jugular vein. A mixture of sevoflurane (2%), air (50%), and oxygen (50%) was used to maintain anesthesia. Ventilation was performed in a volume-controlled manner, with a tidal volume of 7 mL kg^{-1} and a respiratory rate of 12-16/min to provide an ultimate $ETCO_2$ of 32-35 mmHg. In Group C, fluids were replaced with crystalloid solutions using the 4-2-1 rule and by calculating fasting, maintenance, and insensible losses. In Group PVI, a PVI probe (Radical-7®; Masimo Corp., Irvine, CA, USA) was placed on the patients' index finger and protected from light; no invasive arterial monitoring was carried out. A peripheral oxygen saturation probe was placed on the index finger of the other hand. In patients with a PVI greater than 14%, 250 mL of crystalloid solution was administered every 5 minutes, whereas a fluid infu-

sion was delivered at a dose of 4 mL kg^{-1} h^{-1} to patients with a PVI <14%. Intraoperative blood loss was calculated by adding the amount of blood in the aspirator, and weighing the surgical compress and, sponge, etc., and the blood loss was replaced.

All patients were evaluated intraoperatively at 0, 5, 10, 30, 60, 90, and 120 minutes, as well as at the end of surgery. Specifically, heart rate, mean arterial pressure (MAP), peripheral oxygen saturation, and CVP were measured. Furthermore, lactate, hemoglobin (Hb), and hematocrit levels were recorded at the beginning, middle, and end of surgery. In the PVI group, total Hb levels and PVI values were also recorded at 5-minute intervals.

The data were compared both within and between the groups, and the correlation between PVI and CVP changes due to fluid management during the operation was assessed.

Statistical analysis

For statistical analyses, IBM SPSS version 21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) was used. Shapiro- Wilks test was used to analyze normality of the distribution of variables. Descriptive statistics were given as mean ± standard deviation or median (min-max) for continuous variables. Group comparisons were performed using the Mann-Whitney U test and t test, intragroup comparisons were performed using the paired t test and Wilcoxon test. In order to compare repeated measures the changes from the baseline, and percentage change [= (last-baseline)/baseline] values were calculated from the baseline. Pearson chi-square test or Fisher's Exact test was used to compare categorical data. Categorical data were given as n and %. Statistical significance was accepted at p<0.05.

RESULTS

No differences were found between the groups in terms of demographic data, comorbidities, surgical indications, or surgical levels (p>0.05). There were statistically significant differences in the distribution of the diagnoses, and surgical indications (p=0.004). Trauma patients were more numerous in Group C while greater number of spinal stenosis patients were found in Group PVI (Table I).

Table I. Demographic data

	Group C (n=50)	Group PVI (n=50)	P value
Sex (female)	33 (66%)	36 (72%)	0.665
Age (year)	57.38±11.1	54.4±11.71	0.208
BMI	27.25±4.64	27.52±4.57	0.775
Weight (kg)	77.66±12.61	77.2±14.03	0.881
Surgical indications			
Spinal Stenosis	31 (62%)[a]	45 (90%)[b]	
Spondylolisthesis	9 (18%)[a]	3 (6%)[a]	0.004*
Trauma	10 (20%)[a]	2 (4%)[b]	
Operative level			
2 levels	18 (36%)	11 (22%)	
3 levels	1 (2%)	3 (6%)	0.373
4 levels	28 (56%)	32 (64%)	
5 levels	3 (6%)	4 (8%)	
Comorbidities			
COPD	1 (2)	1 (2)	1.000
DM	13 (26)	13 (26)	1.000
HT	19 (38)	11 (22)	0.081
CAD	4 (8)	1 (2)	1.000
CVD	0 (0)	1 (2)	1.000

** Surgical indications was statistically significant between groups. Trauma patient was higher in Group C while Spinal stenosis patient was higher group PVI.*
Data were expressed as mean ± SD, frequency (n) and percentage (%) BMI: Body Mass İndex, COPD: Chronic Obstructive Pulmonary disease, DM: diabetes mellitus, HT: hypertension, CAD: coronary artery disease, CVD: Cerebrovasculer disease, PVI: Pleth Variability Index

When the changes from baseline in CVP values were compared between groups, there were no statistically significant difference in the changes of CVP values at 5, 10, 90, 120, 150 minutes and final values from baseline. However, there were statistically significant differences in the changes of CVP values at 30 and 60 minutes from baseline (p<0.05) (Table II).

Table II. CVP percentage value changes

	Group C (n=50)	Group PVI (n=50)	P value
CVP 0	10.02±3.68	10.88±3.75	0.251
CVP 5	0.00 (0.00:0.07)	0.00 (0.00:0.06)	0.576
CVP 10	0.00 (0.00:0.07)	0.00 (0.00:0.17)	0.092
CVP 30	0.00 (-0.81:1.00)	0.00 (-0.82:2.40)	0.028*
CVP 60	-0.13 (-0.81:3.00)	0.00 (-0.67:2.20)	0.018*
CVP 90	-0.08 (-1.00:4.33)	0.00 (-0.67:2.17)	0.069
CVP 120	-0.13 (-1.00:3.33)	0.05 (-0.64:2.80)	0.157
CVP 150	-0.13 (-1.00:3.33)	0.03 (-0.64:2.80)	0.191
CVP END	0.00 (-1.00:4.00)	-0.04 (-0.73:2.00)	0.525

CVP: Central Venous Pressure, PVI: Pleth Variability İndex
Data were expressed as mean±SD, frequency (n) and percentage (%)

When the alteration from baseline at the 30th minute were examined, the alteration in both groups did not change on average from baseline. However, higher increases were observed in the PVI group (p=0.028) (Table II).

When the changes in CVP values at 60 minutes from baseline were examined, there was a 13% decrease in Group C, whereas there was no change in the PVI group (0.00%). The changes were statistically significant (p=0.018) (Table II).

When the changes from baseline in HR values were compared between groups, there are no statistically significant difference in the changes of any HR value from baseline (Table III).

No significant differences were found between the groups in terms of MAP measurements at 5,10 and 60 minutes relative to baseline (Table III). The measurements in Group PVI were lower than Group C. (Table IV).

The mean volume of intraoperative fluid replacement was 3522±1098.1 mL in Group C and 1914±542.86 mL in Group PVI (p<0.05). The mean unit of intraoperative red blood cell transfusion was 0.42±0.57 unit in Group C and 0.08±0.27 unit in Group PVI (p<0.05). The mean unit of fresh-frozen plasma transfused was 0.06±0.23 unit in Group C, whereas in Group PVI fresh-frozen plasma transfusion was not performed (p>0.05; Table IV). The mean intraoperative urine volume was 475.2±278.29 mL in Group C and 521±309.88 in Group PVI (p>0.05; Table IV). The mean amount of intraoperative bleeding was 286±88.08 mL in Group C and 286±70.73 in Group PVI (p>0.05; Table V). The mean volume of postoperative red blood cell transfusion was 0.44±0.57 unit in Group C and 0.66±0.82 unit in Group PVI (p>0.05; Table V).

Table III. Comparison of heart rate (beat/minute) percentage value changes between groups

	Group C (n=50)	Group PVI (n=50)	P value
HR 0	77.5 (53:112)	83.5 (57:160)	0.106
HR 5	0.00 (-0.23:0,25)	-0.04 (-0.51:0.50)	0.170
HR 10	-0.03 (-0.35:0,42)	-0.04 (-0.90:0.34)	0.909
HR 30	-0.15 (-0.35:0.23)	-0.18 (-0.53:0.42)	0.072
HR 60	-0.17 (-0.37:0.32)	-0.21 (-0.51:0.19)	0.102
HR 90	-0.18 (-0.41:0.37)	-0.19 (-0.54:0.27)	0.513
HR 120	-0.14±0.16	-0.18±0.15	0.205
HR150	-0.11±0.16	-0.15±0.16	0.173
HR END	-0.09 (-0.42:0.40)	-0.06 (-0.48:0.81)	0.477

MAP: Mean Arterial Pressure, HR: Heart Rate, PVI: Pleth Variability Index
Data were expressed as mean±SD, frequency (n) and percentage (%)

Table IV. Comparison of mean arterial pressure (mmHg) percentage value changes between groups

	Group C (n=50)	Group PVI (n=50)	P value
MAP 0	101.62±20.43	109.48±14.64	0.030
MAP 5	-0.08 (-0.46:0.31)	-0.08 (-0.49:0.17)	0.301
MAP 10	-0.08 (-0.46:0.29)	-0.22 (-0.50:0.30)	0.347
MAP 30	-0.23 (-0.57:0.41)	-0.32 (-0.48:-0.10)	0.009*
MAP 60	-0.26 (-0.53:0.25)	-0.32 (-0.54:0.01)	0.087
MAP 90	-0.24 (-0.55:0.46)	-0.31 (-0.48:0.01)	0.014*
MAP 120	-0.24 (-0.52:0.31)	-0.35 (-0.51:0.00)	0.012*
MAP 150	-0.22 (-0.50:0.34)	-0.32 (-0.50:-0.06)	0.007*
MAP END	-0.06±0.24	-0.14±0.17	0.044*

MAP: Mean Arterial Pressure, HR: Heart Rate, PVI: Pleth Variability Index
Data were expressed as mean ± SD, frequency (n) and percentage (%)

Table V. Comparison of intraoperative fluid management variables

	Group C (n=50)	Group PVI (n=50)	P value
Intraoperative fluid management			
Total fluid (mL)	3522±1098.1	1914±542.86	0.0001
Given ES (pack)	0.42±0.57	0.08±0.27	0.000
Given FFP (pack)	0.06±0.23	0.00±0.00	0.080
Total urine output	475.20±278.29	521.00±309.88	0.439
Bleeding amount	286.00±88.08	286.00±70.73	1.000
Postoperative blood transfusion			
ES	0.44±0.57	0.66±0.82	0.125
Intraoperative lactate values			
Lactate 2 PC	0.04 (-0.78:1.60)	0.21 (-0.40:1.33)	0.071
Lactate 3 PC	0.05 (-0.38:2.40)	0.43 (-0.38:3.43)	0.005*

ES: Eritrocyte Suspension, FFP: Fresh Frozen Plasma, PVI: Pleth Variability Index, PC: percentage changes
Data were expressed as mean ± SD, median(min:max).

Table VI. Comparison of intraoperative and postoperative hemoglobin and hematocrit percentage changes

	Group C (n=50)	Group PVI (n=50)	P value
Hb 0			
Hb 1 PC	12.68±1.69	12.65±1.57	0.908
Hb 2 PC	-0.11 (-0.23:0.19)	-0.04 (-0.23:0.02)	0.003*
Htc 0	-0.12±0.09	-0.09±0.06	0.081
Htc 1 PC	39.14±5.51	39.07±4.93	0.951
Htc 2 PC	-0.10 (-0.22:0.13)	-0.05 (-0.19:1.83)	0.002*
Postop Hb PC	-0.12 (-0.28:1.88)	-0.09 (-0.22:0.11)	0.013*
Postop Htc PC	-0.03 (-0.30:0.21)	-0.06 (-0.27:0.30)	0.434
	-0.03 (-0.30:0.23)	-0.07 (-0.29:2.13)	0.288

Hb: Hemoglobin Htc: Hematocrit, PVI: Pleth Variability Index, PC: Percentage changes
Data were expressed as mean ± SD, median(min:max).

No significant difference was found between the groups as for lactate 2 measurements when compared from baseline (p=0.081) (Table V). There were statistically significant increases between groups in lactate 3 measurements when compared from baseline. The increases were 5% in Group C and 43% in Group PVI (p=0.005) (Table V).

There were statistically significant decreases between groups in Hb1 measurements when compared from baseline. The decreases was 11% in Group C and 4% in Group PVI (p=0.003). No difference were found between the groups in terms of Hb 2 measurements. (p=0.081) (Table VI). There were statistically significant decreases in Group C than Group PVI group in terms of Htc 1 and Htc 2 measurements when compared from baseline (p<0.05). In Hb 1 measurements the decreases were 11% in Group C and 4% in Group PVI. The decreases in Hb 2 measurements in Group C and PVI were 12, and 9, respectively (Table VI).

There were no statistically significant difference between groups in terms of postoperative Hb and Htc measurements when compared from baseline (p>0.05) (Table VI).

DISCUSSION

In the present prospective, randomized clinical trial involving patients who had received intraoperative fluid replacement under the guidance of either PVI or CVP monitoring, the amounts of intraoperative red blood cell transfusion and fluid replacement were significantly lower in Group PVI, whereas there was no significant difference between the groups in terms of postoperative red blood cell transfusion or perioperative Hb and hematocrit values.

Mortality and morbidity can be reduced by proper fluid management in patients undergoing major surgical interventions [9]. Therefore, noninvasive monitors, which can measure parameters continuously and in a dynamic manner, are becoming increasingly important [10]. In patients undergoing major surgery, fluid management is routinely monitored by measuring static preload parameters (heart rate, MAP and CVP). However, these parameters fail to track the patient's response to fluid loading. Stanislav et al. followed up patients monitored using CVP, and the bolus administration of fluids caused elevations in CVP values [11]. In the present study, the baseline CVP values were comparable between groups. However, from the 30th and 60th minutes onwards, the CVP values were significantly higher in Group PVI than in Group CVP. This difference was not observed at the end of the operation, when the CVP measurements were once again comparable between the groups. We posit that this difference in CVP values during follow-up was related to bolus fluid administration in Group PVI. Indeed, a meta-analysis by Marik et al. [12] showed that there is not always a relationship between circulating blood volume and CVP. In the present study, there were higher CVP values in Group PVI, even though the intra-group comparison showed no significant differences. This suggests that PVI measurement reveals the circulating blood volume may be more effective than CVP measurement, which can be affected by bolus administrations.

Bouchard et al. [13] reported that high-volume fluid replacement in patients with renal failure in intensive care units negatively affects mortality and morbidity, and a perioperative fluid follow-up study by Renata et al. [14] indicated that perioperative fluid replacement has similar consequences in high-risk surgeries. In the present study, in both groups the intra-group comparisons showed a significant difference in terms of changes in heart rates, which are eamong the indicators of fluid deficit. However, there was no difference between the groups in this regard. Furthermore, while there was a clinically insignificant difference in initial MAPs between the groups against the favor of CVP group, there was no difference in MAP during the follow-up period. Nonetheless, the cardiac effects of anesthetics may also have caused the intra-group differences in heart rate and MAP [15,16].

Recent studies have suggested that dynamic markers, such as PVI, SVV, and PPV, are more successful and reliable in evaluating response to fluid management [5-7,17,18]. However, SVV and PPV are invasive measurement methods. Automatic and continuous PVI monitoring is a noninvasive technique that measures the effects of changes in ventilation on the wavelength of the pulse oximetry [10]. In patients undergoing major spinal surgery, intraoperative fluid management is a controversial issue. In such cases,

rather than liberal fluid management, restrictive fluid management is reported to have positive effects on early postoperative prognosis, length of hospital stay, wound healing, and pulmonary rehabilitation [19]. In a meta-analysis of randomized controlled trials comparing perioperative targeted fluid therapy with standard fluid therapy, the American Society of Anesthesia (ASA) reported that targeted fluid therapy decreases postoperative complications and length of hospital stay [20].

In another study, Carson et al. [21] separated patients into two groups, implementing a liberal blood transfusion strategy in one group (intraoperative Hb > 10 mg dL^{-1}) and a restrictive transfusion strategy in the other group (intraoperative Hb 7-8 mg dL^{-1}). In addition, more blood transfusions were performed in the liberal group, whereas more fluid replacements were performed in the restrictive group. The need for postoperative transfusion was greater in the restrictive group than in the liberal group due to heart failure, hypotension, and tachycardia. In the present study, the amount of intraoperative red blood cell transfusion was significantly lower in the PVI group. However, there was no difference in the amount of blood loss between the groups. In the present study the frequency of transfusions was lower in the PVI group of than in the literature. In the present study, intraoperative Hb levels were above 10 mg dL^{-1} in both groups, and neither group saw any hemodynamic change during follow-up that may have caused Hb deterioration. PVI monitoring is thought to reflect the blood volume status more accurately than CVP monitoring, and it may be more useful in major surgeries, especially when volume changes occur that may affect the hemodynamics. PVI monitoring may also be a useful guide for accurate blood transfusion strategies.

Poorly managed, restrictive fluid therapy can ultimately lead to multiple organ failure or even death through hypovolemia and organ dysfunction, whereas exaggeration of liberal fluid management can lead to edema, resulting in reduced cardiac function, pulmonary edema, coagulation and bleeding disorders, and renal insufficiency [22]. In a meta-analysis by Feng Ju Jia et al. [23] cardiopulmonary complications were more frequent in patients undergoing major abdominal surgery who under liberal fluid management. In another meta-analysis by Corcoran et al. [24] where fluid regimens during major surgical interventions were investigated, liberal fluid management was associated with increased pulmonary complications, pulmonary edema, and pneumonia.) In their study about intraoperative PVI-based fluid management in patients undergoing major abdominal surgery, Yinan et al. [25] found that fluid replacement was lower in the PVI group than in the CVP group. Moreover, Forget et al. [26] in their study on intraoperative PVI-based fluid management in patients undergoing major abdominal surgery also found that fluid replacement was smaller in the PVI group. In the present study, the amount of fluid replacement was higher in Group CVP than in Group PVI. Thus, our findings are comparable with those in the literature. In addition, in the correlation analysis, we found a significant correlation between PVI and CVP. Thus, the reason may be that less fluid was used in the PVI group because intravascular fluid status can be better determined using PVI monitoring. In the present study there were no differences between the groups in terms of postoperative blood transfusion.

In reconstructive and multi-level spinal surgeries, severe intraoperative bleeding and blood loss can occur, thus increasing the need for blood transfusion [27]. In the present study, although the Hb and hematocrit levels were lower than baseline in the blood gas analysis, the difference was thought to be clinically insignificant, because the Hb levels were above 10 mg dL^{-1} in both cases.

Lactate is an important parameter indicating tissue perfusion and volume status [25,26]. In the present study, the increase in final intraoperative lactate levels in both groups was statistically significant against the favor of PVI group. However, this result may not be clinically significant because the lactate levels were below the limit value of 2 mmol L^{-1} in both groups.

In conclusion, the present study has indicated that PVI monitoring is more valuable than CVP monitoring because it is noninvasive, provides better cardiac stabilization with less fluid replacement, and more accurate results in the evaluation of intravascular volume status. Failure to follow up the duration of surgery and postoperative complications are the most important limitations in our study.

Ethics Committee Approval: Celal Bayar University Faculty of Medicine Hospital Ethics Committee for Non-Interventional Clinical Studies was approved (2015/20478486-404).

Conflict of Interest: None

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Informed Consent: The patients' consent were obtained

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