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Research Article

The Correlation between Corrected Flow Time (FTc) Based on Esophageal Doppler Monitoring and Pleth Variability Index (PVI) in the Fluid Therapy in Patients Undergoing Total Abdominal Hysterectomy

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ABSTRACT

Background: The occurrence of bleeding during major surgeries is common and requires timely and accurate management in the prevention and treatment of hypovolemia and hemodynamic instability during and after surgery. This study evaluated the correlation and agreement between the two protocols determining the status of the hypovolemia during hysterectomy.

Methods: This study was a randomized single-blinded clinical trial. The study population included 30 patients undergoing Total Abdominal Hysterectomy in Shariati Hospital in Tehran between 2015 and 2016. The patients were randomly assigned to two groups using a randomized table of numbers, so that in the FTc group, fluid therapy was performed based on the FTc index and in the PVI group based on the PVI index. The changes in FTc and PVI values were recorded every 5 minutes and the changes in the two indicators from the beginning to the end of the treatment were evaluated. At the beginning and end of the surgery, an arterial blood gas analysis (ABG) was also performed. The amount of bleeding during operation and urinary output were recorded in two groups.

Results: There was no significant difference across the two groups in total fluid intake during surgery, mean volume of blood loss, mean urine output, and duration of surgery. The arterial blood gas status was also similar in both groups at the beginning and the end of the operation. We found a strong adverse correlation between FTC and PVI indices at the different time points evaluated within the surgery. In total, there was a strong correlation between the mean FTC and the mean PVI during the first hour (r=-0.765, P < 0.001) and the second hour (r=-0.941, -P < 0.001) of operation. Considering the cut-off point of 350msec for the FTC and 13% for the PVI in predicting hypovolemia, the agreement between the two protocols in fluid therapy during the first hour after surgery was 79.8% and 76.6%.

Conclusion: There is a strong and significant correlation between the two FTC (with a cut off of 350) and PVI (with a cut point of 13%) to predict need for fluid therapy.

The ability to evaluate intravascular volume is an important part of intraoperative care as well as hemodynamic stability during operation. Inadequate intravascular volume leads to a reduction in the supply of tissue oxygenation and therefore a dysfunction of tissue oxygenation, while preload fluid conditions can lead to increased edema and organ dysfunction, such as respiratory failure [1-2]. The use of vasopressors and inotropes in patients with hypovolemia is dangerous and leads to adverse outcomes during and after surgery [3]. In the supply of necessary fluid and intravascular volume, attention has to be paid to two

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concepts, namely, Euvolemia, and the response to fluid responsiveness, both of which are the concept of Frank-Starling's equation that describes the changes in the stroke volume in response to changes in the heart's preload [4-5]. In evaluating a variety of techniques for assessing the status of fluid in circulation, the effectiveness of these methods should always be assessed on the basis of predicting the response to fluid therapy against the body's euvolemic state and thus the best way to evaluate the condition of fluid therapy is to provide the best prediction of this balance. In addition to this, non-invasive or minimal invasive evaluation methods should be prioritized.

The use of Doppler principles in computing velocity of blood flow in the arteries through the Esophageal Doppler Monitoring (EDM) technique allows for the minimal invasive evaluation and monitoring of cardiac output and vascular flow rate [6-7]. In this technique, Doppler waves reflected from red blood cells are recorded and analyzed and, accordingly, the velocities of the arteries can be evaluated. In this regard, an index called "flow time" is calculated which is defined as "the time needed for pumping blood from the left ventricle through stroke volume" [8]. Given the fact that the amount of this flow time is directly related to the heart rate, the corrected flow time (FTc) indicator is used. Recently, EDM technique indicators such as FTc have been especially considered in the evaluation of prognosis after surgery [9].

Scientists have found that blood pressure changes in response to respiratory cycles, and this variation in blood pressure is far higher in patients with hypovolemia [10]. In patients who lose fluid volume, intravenous pressure is lower and therefore changes in systemic blood pressure during the respiratory cycle will be higher [11]. In this regard, indicators such as systolic pressure variation (SPV) and pulse pressure variation (PPV) during the respiratory cycle will be better indicators for responding to fluid therapy [12]. Viewing pulse pressure changes from the arterial pressure waveform is an important indicator in evaluating the response to treatment. However, the change in plethysmographic waveform of pulse oximetry (ΔPOP) is a more sensitive indicator for evaluating response to treatment [13-15]. Due to the non-invasive nature of the ΔPOP measurement as well as the availability of pulse oximetry, this method is preferred to many static and dynamic indices. In this regard, the Pleth Variability Index (PVI) was the first available plethysmography Index (PI), which was directly related to the ΔPOP value. The PVI index is an indicator of the dynamic variation in the PI that occurs during the normal respiratory cycle. In fact, the PI itself represents the pulse oximetry wave amplitude by recording the device's infrared signals.

Both groups of static and dynamic parameters are able to evaluate and estimate the volume of intravascular fluid, as well as the response rate to fluid therapy in patients undergoing surgery or under intensive care. In this regard, dynamic parameters are far more efficient and more sensitive to evaluate the response to fluid therapy. Some of these parameters can be evaluated invasively and some by minimal invasive techniques. What of particular interest in recent years has been the remarkable precision and usefulness of the two FTc indicators (evaluated by EDM) as well as the PVI parameter (evaluated by plethysmography). However, the degree of correlation and overlap between the two indicators has not been evaluated so far. What was studied in this study was to determine the correlation between two FTc and PVI indices in evaluating fluid therapy in patients undergoing hemorrhagic surgeries.

Methods

This study was a randomized single-blinded clinical trial. The study population included patients undergoing Total Abdominal Hysterectomy in Shariati Hospital in Tehran between 2015 and 2016. Inclusion criteria were age below 70 years, ASA class I-II. The exclusion criteria were 1) history of hemorrhagic diseases; 2) previous history of major surgery; 3) history of hematopoietic or cancerous diseases; 4) lack of written consent of the study, 5) presence of any cardiac arrhythmia; and 6) presence of abnormalities of the esophagus such as esophagitis or Mallory-Weiss syndrome. Initially, all patients were monitored by ECG monitoring and pulse oximetry, and SBP, DBP, HR and O2 sat were determined. After receiving the initial serum, patients underwent general anesthesia. All patients were monitored simultaneously with EDM as well as plethysmography, and the initial measures of FTc and PVI were determined. The patients were randomly assigned to two groups using a randomized table of numbers, so that in the FTc group, fluid therapy was performed based on the FTc index and in the PVI group based on the PVI index. In the FTc group, if the FTc was less than 350, the patient was considered hypovolemic. In this group, patients were treated with bolus crystalloid (7 cc/kg) and then, if the treatment was not effective, subsequent boluses were repeated to reach the FTc equal to 350. In the PVI group, patients with PVI greater than 13% were treated with bolus crystalloid fluid (100 to 200 cc) and treatment was continued until the PVI reached 13%. In both groups, changes in FTc and PVI values were recorded every 5 minutes and the changes in the two indicators from the beginning to the end of the treatment were evaluated. At the beginning and end of the surgery, an arterial blood gas analysis (ABG) was also performed.

The amount of bleeding during operation and urinary output were recorded in two groups.

Descriptive analysis was used to describe the data, including mean ± standard deviation (SD) for quantitative variables and frequency (percentage) for categorical variables. Chi square test, t test, or Mann-Whitney U test were used for comparison of variables. The association between the quantitative variables was assessed using the Pearson's or Spearman's correlation coefficient tests. To assess the value of each index to predict response to fluid therapy, the area under the ROC analysis was assessed. The trend of the change in quantitative variables was assessed using the Repeated Measure ANOVA test. For the statistical analysis, the statistical software IBM SPSS Statistics for Windows version 22.0 (IBM Corp. Released 2013, Armonk, New York) was used. P values <0.05 were considered statistically significant.

Results

A total of 15 subjects in the FTC group and 15 subjects in the PVI group were enrolled. As shown in Table 1, there was no significant difference across the two groups in, age, ASA class, average total fluid intake during surgery, mean volume of blood loss, mean urine output, and duration of surgery. The arterial blood gas status was also similar in both groups at the beginning and the end of the operation. We found a strong adverse correlation between FTC and PVI indices at the different time points evaluated within the surgery (Table 2). In total, there was a strong correlation between the mean FTC and the mean PVI during the first hour (correlation coefficient of -0.765, -P < 0.001) and the second hour (correlation coefficient of -0.941, -P < 0.001) of operation (Figures 1 and 2). In general, considering the cut-off point of 350msec for the FTC and 13% for the PVI in predicting hypovolemia, the agreement between the two protocols in fluid therapy was 79.8% and 76.6% respectively during the first and second hours of operation.

Table 1- Baseline characteristics in both protocols

Item	FTC protocol (n = 15)	PVI protocol (n = 15)	P value
ASA class			0.121
I	8 (53.3)	12 (80.0)	
II	7 (46.7)	3 (20.0)	
Mean age, year	54.93 ± 21.96	54.00 ±15.78	0.893
Fluid transfused, cc	843.33 ± 334.27	690.00 ± 132.56	0.110
Volume of bleeding, cc	260.00 ± 103.85	240.00 ± 82.81	0.564
Urine output, cc	216.67 ± 119.02	180.00 ± 41.40	0.269
Duration of surgery, hr	1.83 ± 0.58	1.70 ± 0.25	0.426

Table 2- The correlation between FTC and PVI measures in both protocols within surgery

Item	Correlation coefficient	P value
First hour of operation		
Min 5	-0.561	0.001
Min 10	-0.516	0.004
Min 15	-0.867	< 0.001
Min 20	-0.858	< 0.001
Min 25	-0.652	0.001
Min 30	-0.617	0.001
Min 35	-0.561	0.001
Min 40	-0.678	< 0.001
Min 45	-0.548	0.008
Min 50	-0.525	0.012
Min 55	-0.557	0.007
Min 60	-0.657	0.001
Second hour of operation		
Min 5	-0.856	< 0.001
Min 10	-0.824	< 0.001
Min 15	-0.834	< 0.001
Min 20	-0.781	< 0.001
Min 25	-0.598	0.011
Min 30	-0.578	0.039
Min 35	-0.742	0.004
Min 40	-0.603	0.013

Min 45	-0.926	< 0.001
Min 50	-0.703	0.035
Min 55	-0.798	0.010
Min 60	-0.954	< 0.001

Figure 1- Linear correlation between FTC and PVI indicators during the first hour of surgery

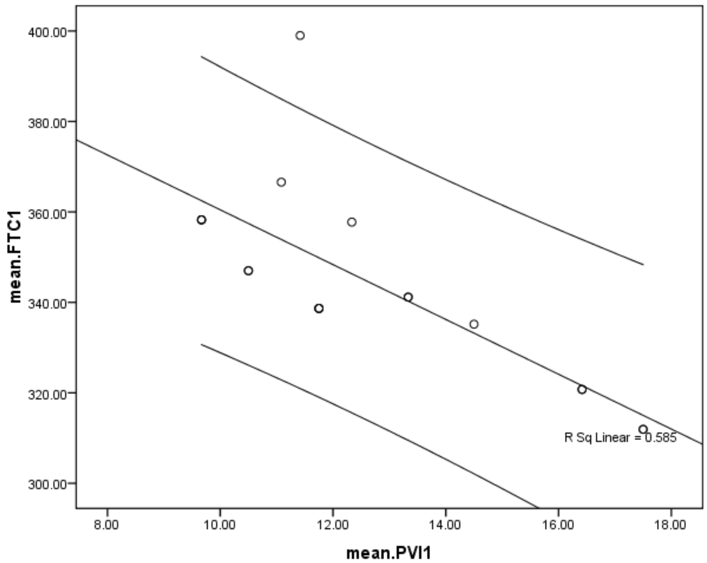
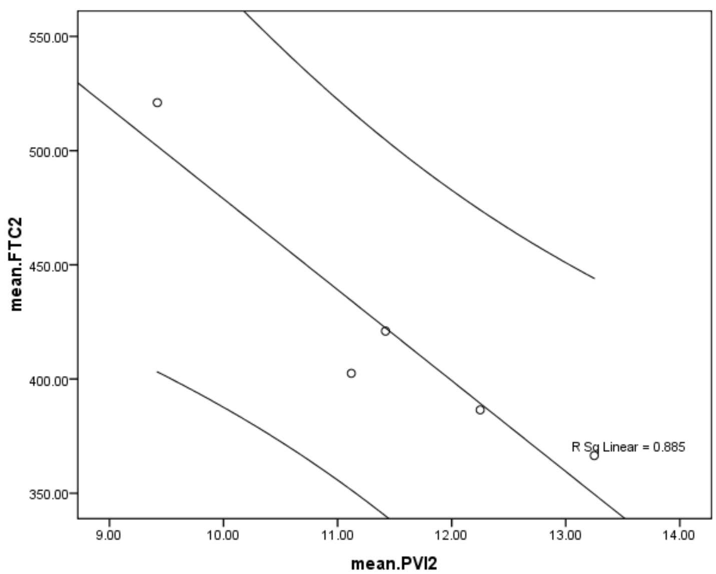


Figure 2- Linear correlation between FTC and PVI indicators during the second hour of surgery



Discussion

The occurrence of bleeding during Hysterectomy is common and requires timely and accurate management of the prevention and treatment of hypovolemia and hemodynamic instability during and after surgery. In this regard, there are certain criteria to diagnose hypovolemia and also response to fluid therapy, some of which are invasive and some can be evaluated by minimal invasive methods. Accordingly, the determination of the FTC (using the EDM technique) and the PVI index (based on pulse oximetry) are two valid indicators in this assessment, which the values less than 350 and more than 13%, respectively, indicating the status of the hypovolemia and the need for fluid therapy. In this study, we evaluate the correlation and agreement between the two protocols determining the status of the hypovolemia during hemorrhagic Surgery. Therefore, the values of both indicators were evaluated at intervals of five minutes during the first and second hours of surgery and a quantitative correlation coefficient between the measured values was determined. The volume of surgical bleeding, volume of fluid intake, volume of urine output and arterial blood gas analysis status were also evaluated in two protocols to evaluate the quality of fluid therapy. Our findings suggest that, firstly, there was a high correlation between the two protocols in assessing and determining the conditions for hypovolemia during surgery, to the extent that the agreement rate between the two protocols was estimated to be 76% to 80%. In fact, both protocols are highly effective in determining the state of hypovolemia and the need for fluid therapy during surgery. Our study also illuminated that the indicators of fluid therapy such as favorable urine output and the status of ABG during transport in the two protocols were quite similar, and both protocols were effective in predicting the occurrence of hypovolemia and the need for a successful fluid therapy. What has been studied in most of the previous researches is the evaluation of the two protocols in predicting the response rate to fluid therapy, and in this regard, our study is the first study to evaluate the agreement and correlation of the two protocols in the treatment of patients. Overall, it seems that considering the establishment of a stable hemodynamic status, controlling the amount of hemorrhage during operation, stable status in ABG, and the establishment of favorable urine output among our patients in both groups, both the FTC and PVI protocols are predicted to be successful in diagnosing hypovolemia and also in assessing response to treatment and there is no difference between the two methods. Given that each of the protocols has its own potential limitations; it is possible to use any of the protocols in the specific circumstances during hemorrhagic surgeries.

What considered in the present study as a measure of hypovolemia was FTC values less than 350 and PVI higher than 13%, which seems to be the preferred cutoff points to predict the need for fluid therapy. However, various studies have found different cutting points in this regard. In a study by Kim et al, the cut-off point for PVI was 8% in supine condition and 8% in prone state [16-17]. In the study by Yang et al, the FTC cutoff point in supine and prone states was 358 and 331 respectively [17]. In the study by Siswojo et al., the cut-off points for the PVI index in predicting the response to fluid therapy was 10.5% [16-18]. In the study by Fu et al, the best predicting cutoff point for PVI was 13.5% [19]. Therefore, different cutoff points have been introduced for FTC and PVI to evaluate the need for fluid therapy and the response to this treatment with a variety of sensitivities and specificities, which might be due to many factors, such as the condition of the patient during operation, the care and preparation before operation, the severity of hemodynamic instability during the operation, as well as the technique for evaluation of the parameters.

Conclusion

It can be concluded that there is a strong and significant correlation between FTC (with a cutoff of 350) and PVI (with a cut point of 13%) to predict need for fluid therapy undergoing hemorrhagic surgeries. Therefore, both protocols will be useful in determining the hypovolemic status during surgery and management of the patient's fluid therapy.

References

[1] Boldt J, Lenz M, Kumle B, Papsdorf M. Volume replacement strategies on intensive care units: results from a postal survey. Intensive Care Med. 1998; 24(2):147-51.

[2] Marik PE, Monnet X, Teboul JL. Hemodynamic parameters to guide fluid therapy. Ann Intensive Care. 2011; 1(1):1.

[3] Marx G, Schindler AW, Mosch C, Albers J, Bauer M, Gnass I, et al. Intravascular volume therapy in adults: Guidelines from the Association of the Scientific Medical Societies in Germany. Eur J Anaesthesiol. 2016; 33(7):488-521.

[4] Chaui-Berlinck JG, Monteiro LHA. Frank-Starling mechanism and short-term adjustment of cardiac flow. J Exp Biol. 2017; 220(Pt 23):4391-4398.

[5] Sequeira V, van der Velden J. The Frank-Starling Law: a jigsaw of titin proportions. Biophys Rev. 2017; 9(3):259-267.

[6] Monnet X, Rienzo M, Osman D, Anguel N, Richard C, Pinsky MR, et al. Esophageal Doppler monitoring predicts fluid responsiveness in critically ill ventilated patients. Intensive Care Med. 2005;31(9):1195-201.

[7] Singer M. Esophageal Doppler monitoring of aortic blood flow: beat-by-beat cardiac output monitoring. Int Anesthesiol Clin. 1993; 31(3):99-125.

[8] Marquez J, McCurry K, Severyn DA, Pinsky MR. Ability of pulse power, esophageal Doppler, and arterial pulsepressure to estimate rapid changes in stroke volume in humans. Crit Care Med. 2008; 36(11):3001-7.

[9] Lee JH, Kim JT, Yoon SZ, Lim YJ, Jeon Y, Bahk JH, et al. Evaluation of corrected flow time in oesophageal Doppler as a predictor of fluid responsiveness. Br J Anaesth. 2007; 99(3):343-8.

[10] Linsenbardt ST, Thomas TR, Madsen RW. Effect of breathing techniques on blood pressure response to resistance exercise. Br J Sports Med. 1992; 26(2):97-100.

[11] Herakova N, Nwobodo NHN, Wang Y, Chen F, Zheng D. Effect of respiratory pattern on automated clinical blood pressure measurement: an observational study with normotensive subjects. Clin Hypertens. 2017; 23:15.
[12] Kubitz JC, Forkl S, Annecke T, Kronas N, Goetz AE, Reuter DA. Systolic pressure variation and pulse pressure variation during modifications of arterial pressure. Intensive Care Med. 2008; 34(8):1520-4.
[13] Cannesson M, Desebbe O, Rosamel P, Delannoy B, Robin J, Bastien O, et al. Pleth variability index to monitor the respiratory variations in the pulse oximeter plethysmographic waveform amplitude and predict fluid responsiveness in the operating theatre. Br J Anaesth. 2008; 101(2):200-6.
[14] Napoli AM. Physiologic and clinical principles behind noninvasive resuscitation techniques and cardiac output monitoring. Cardiol Res Pract. 2012; 2012:531908.
[15] Rick JJ, Burke SS. Respirator paradox. South Med J. 1978; 71(11):1376-8.
[16] Kim DH, Shin S, Kim JY, Kim SH, Jo M, Choi YS. Pulse pressure variation and pleth variability index as predictors of fluid responsiveness in patients undergoing spinal surgery in the prone position. Ther Clin Risk Manag. 2018; 14:1175-1183.
[17] Yang SY, Shim JK, Song Y, Seo SJ, Kwak YL. Validation of pulse pressure variation and corrected flow time as predictors of fluid responsiveness in patients in the prone position. Br J Anaesth. 2013; 110(5):713-20.
[18] Siswojo AS, Wong DM, Phan TD, Kluger R. Pleth variability index predicts fluid responsiveness in mechanically ventilated adults during general anesthesia for noncardiac surgery. J Cardiothorac Vasc Anesth. 2014; 28(6):1505-9.
[19] Fu Q, Mi WD, Zhang H. Stroke volume variation and pleth variability index to predict fluid responsiveness during resection of primary retroperitoneal tumors in Hans Chinese. Biosci Trends. 2012; 6(1):38-43.