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Efficacy of Goal-Directed Fluid Therapy Guided by Pleth Variability Index in Patients Undergoing Large Volume Liposuction Under General Anesthesia

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ABSTRACT

Background: Liposuction, which was introduced in the early 1980s, has undergone major developments and is now the most widely done aesthetic surgery.

Aim of the work: This study aimed to assess efficiency of pleth variability index [PVI] obtained from Massimo pulse oximeter to anticipate intraoperative responsiveness of fluid in large volume liposuction under general anesthesia.

Patients and methods: This prospective comparative randomized controlled trial, 60 females undergoing liposuction 5 liters or more, aged range 21-40 years, patients grouped according to fluid management strategy, thirty cases were managed by Rohrich formula [control group] and thirty were managed by PVI [study group].

Results: There was statistically significant difference as regards total IV fluid with mean 2790 [SD = 443] in control versus 3155 [SD = 452] in PVI group as well as urinary output mean 1410 [SD = 382] in control versus 2019 [SD = 449] in PVI group. Significant postoperative lactate [mean 2.5 [SD = 1.1] in control versus 0.9 [SD = 1] in PVI group]. No significant difference in hypotensive episodes [mean 0.77 [SD = 1.01] recorded from 11/30 patients developed hypotension in control versus 1.07 [SD = 1.20] from 12/30 patients in PVI group]. Insignificant postoperative readiness for discharge [mean 3.9 [SD = 0.8] in control versus 4.07 [SD = 0.87] in PVI group].

Conclusion: Fluid administration guided by PVI resulted in increased intraoperative fluid with better peripheral tissue perfusion compared to Rohrich formula. But Rohrich is still valid and can be used safely with caution as a patient might be under-hydrated.

Keywords: Pleth Variability Index; Massimo Pulse Oximeter; Large Volume Liposuction; Rohrich Formula.

INTRODUCTION

The liposuction technique includes use of wetting solutions" containing lidocaine and epinephrine", major fluid shift, prolonged operative time and electrolyte disturbances. Fluid therapy plays a crucial part in the management of these individuals [1]. Nevertheless, DeltaPP monitoring [respiratory variations in arterial pulse pressure] is an intrusive procedure and lacks reliability in routine clinical settings. The Pleth Variability Index [PVI] is capable of continuously and automatically calculating the respiratory variances in the photoplethysmogram. This is done using data obtained non-invasively through a pulse oximetry sensor. PVi, which stands for pleth variability index, is a parameter that can be used to forecast fluid responsiveness in patients receiving mechanical ventilation under general anaesthesia. It is closely related to DeltaPOP [respiratory variations in the pulse oximeter plethysmographic waveform amplitude] and can provide non-invasive predictions. Additionally, PI [perfusion index] and PVI are novel variables that are produced automatically and constantly by plethysmographic waveform analysis. The PI value is derived from pulse oximetry, which measures how much is absorbed of infrared and red light [2-4].

The advances in liposuction technology have enabled the treatment of larger body areas in one session, according to the patients' preferences. This leads to significant fluid shifts during these procedures [5]. Therefore, many formulas have been proposed to estimate the intraoperative intravenous fluid requirements in liposuction [5-7]. Nevertheless, no consensus on the optimal fluid management strategy existed for liposuction [8].

THE AIM OF THE WORK

This study aimed to evaluate the impacts of administering fluid intraoperatively via PVI in large volume liposuction under general anesthesia, we compared this method to providing fluid at a ratio of 1.2 between the fluids provided [via IV plus infiltration] and the total suction [fats, fluids and blood], as recommended by Rohrich.

PATIENTS AND METHODS

This work was performed following the permission of the Ethics Council of Azhar university at February 2018, faculty of medicine, Medical research and it needed to be updated every 6 years according to Ethics council rules with new registration number [0423/2024]. Each participant submitted a well-informed written consent before commencing the work. The processes conducted on human subjects adhered to the ethical principles set by the institutional research committee and comparable ethical standards.

Study participants: This work was a prospective comparative randomized controlled trial that involved 60 female patients; their age range was 21-40 years [mean 32.9 years [+/- 5.73 SD]. They came for liposuction operation at Azhar university hospital, Cairo. Fluid management in half of the cases [30] is managed by Rohrich formula, and the other half [30] were managed by goal directed therapy GDT via numeric value obtained from pleth variability index [PVI]. The study was conducted from June 2018 to May 2022.

Inclusion criteria: Female patients ranging in age from 21 to 40 years old scheduled for liposuction of total aspirate more than 5000 cc [mean 5500.8 cc [± 489.6 SD] under general anesthesia.

Exclusion criteria: Patient undergoing concomitant procedures, patients with concomitant illness, patients discharged to ICU following surgeries, individuals with less than 12 mg/dl hemoglobin or needed blood transfusion during surgery and patients with BMI above 40.

Management of anesthesia: All patients were 8 hours fasting time, premedicated with risek [40 mg] and ondansetron [4 mg], monitoring was done by noninvasive measures [noninvasive blood pressure NIBP, electrocardiography ECG, end-tidal carbon dioxide tension, beside Massimo pulse oximetry], thermal pad was used with patient intraoperative and warm fluids were used throughout the operation to decrease risk of hypothermia and minimize probability of misreading.

Anesthesia was inducted utilizing Propofol 2 mg/kg, fentanyl 2ug/Kg, and atracurium 0.5 mg/Kg, and maintained by isoflurane [1-1.5%]. Mechanical ventilation was modified to sustain end tidal CO_2 [35-40 mmHg]. Urinary catheter inserted for monitoring. Maintenance doses of atracurium were given on time and additional doses of fentanyl titrated keeping MAP within 25% of the baseline readings. At the end of the procedure, the use of isoflurane was stopped, and any remaining neuromuscular blocking agent counteracted by administering neostigmine at a dose of 0.05 mg/Kg and atropine at a dose of 0.02 mg/Kg and patient was extubated and admitted to recovery room.

Fluid therapy: The initial 5 litres of infiltration involved the implementation of a super-wet method, which included 1 cc of 1:1000 epinephrine, 15 cc of 2% lidocaine, and 1 litre of normal saline crystalloid. For infiltration amounts over 5 litres, the infiltration solution was prepared without lidocaine. Participants were obtained a fluid bolus of 5 ml/kg crystalloid before induction of anesthesia, then fluid management was as follows:

Group C: we gave maintenance fluids at 4-2-1 rule with keeping Intraoperative fluid ratio at [1.2]

Group S: we target PVI 14% or less by giving maintenance fluids of ringer lactate at 4-2-1 rule and fluid boluses as needed till reach target, after reaching target we decreased infusion rate to maintenance.

In both groups rescue fluid bolus of 100 ml Ringer solution in 3 mins was given if mean arterial pressure decreased from 20% to 30% and repeated as needed. The same fluid bolus was given plus ephedrine bolus of 6 mg if mean blood pressure decreased more than 30% for 5 mins and repeated as needed. if blood pressure still less than 20% for 15 mins we gave 250 ml colloid [voluven].

Outcome parameters

Primary: Readiness of patient to be discharged from hospital "assessed by modified PADSS score every 2 hours after surgery"

Others: Postoperative lactate; Total intraoperative fluid requirements; Total urine output in ml/kg/hr; Number of episodes of hypotension more than 5 mins.

Statistical analysis and sample size calculation

Given a two-sided α risk of 5% and a power of 80%, we have determined that the minimum required sample size is 59 participants. We intended to enroll 60 individuals utilizing MedCalc Software version 14.10.2 [MedCalc Software, Ostend, Belgium] [29]. The study aims to include thirty individuals in each group to identify a difference of 1 hour in the length of postoperative hospitalization, which is the primary outcome. We conducted an experiment to examine the hypothesis that the PVI would result in a shorter duration of hospitalization contrasted to the normal medical treatment. Despite our one-sided hypothesis, we employed two-sided tests for all comparisons.

The data analysis was conducted employing the Statistical Package for Social Science [SPSS] software, version 15 for Microsoft Windows, [SPSS Inc. in Chicago, IL, USA]. The normality of continuous data was assessed employing the Shapiro-Wilk test and reported as either the mean and standard deviation or the median and interquartile range, depending on the data distribution. The analysis of continuous data was conducted using either an unpaired t-test or a Mann Whitney test, as appropriate. The categorical data was shown as frequency and evaluated using a chi-square test. The data obtained from repeated measures were analyzed utilizing a repeated measure analysis of variance [ANOVA], followed by post-hoc pairwise comparisons employing the Bonferroni test. A P value below 0.05 was deemed to be statistically significant.

RESULTS

Between June 2018 to May 2022, a total of sixty participants were randomly assigned to two groups: thirty participants were assigned to the PVI group, while the remaining 30 participants were assigned to the control group. The baseline characteristics of patients, as determined by demographic data, were comparable among the groups, demonstrated that a statistically insignificant difference existed among both studied groups regarding age and weight **[table 1].** It had been demonstrated that a statistically insignificant difference existed among both studied groups regarding the site of liposuction **[Table 2].**

There was a statistically insignificant differences among both studied groups regarding total infiltration and total suction **[Table 3].**

A statistically substantial variation existed among the two groups under the study regarding total IV fluid and urinary output, and a STATISTICALLY insignificant variation existed among the two groups under study regarding a number of intraoperative hypotensive episodes. As well as similar numbers of patients had hypotension in each group, and there was statistically significant variation regarding postoperative lactate among the two groups under the study. This was predicted as the study group guided by PVI receiving more fluids, so perfusion was better. However, this study did not take in consideration basal preoperative lactate but we hypothesize that we worked at females only with statistically indifference between their age and weight with no serious medical conditions with the same fasting hours so we did not think preoperative lactate will be significant **[Table 4]. Table [5]** demonstrated that there was statistically insignificant difference among the two studied groups as regard readiness to be discharged [assessed by modified PADS score]"

Table [1]: Demographic data among the groups

	Age [years]		Weight [kg]	
Group	**Control**	**Study**	**Control**	**Study**
Min	22	21	70	70
Max	40	42	88	88
Mean	33.03	32.8	79.97	80.47
SD	5.08	6.5	5.24	5.45
Median	34	35	80	80
Test of sig.[P]	**U=445.5 [0.935]**		**U=427 [0.732]**	

SD: Standard deviation, U: Mann Whitney test, p: p value for contrasting two groups under the study

Table [2]: Site of liposuction among study and control groups

	Site of liposuction	
Group	**Control**	**Study**
Abdomen and back	23 [76.7%]	20 [66.7%]
Abdomen and thigh	5 [16.7%]	7 [23.3%]
Abdomen, thigh and arms	2 [6.7%]	3 [10%]
X^2 [MC] :p	**0.823: 0.693**	

X^2: Chi squared test, MC: Monte Carlo, P: p value for comparing two studied groups

Table [3]: Total infiltration and total suction among study and control groups

	Total infiltration [ml]		Total suction [ml]	
Group	Control	Study	Control	Study
Min	5000	5000	5000	5000
Max	6000	6300	7000	6500
Mean	5183.3	5260	5513.33	5385
SD	382.5	432	561.2	473.5
Median	5000	5000	5400	5200
Test of sig.[P]	**U=407 [0.401]**		**U=394 [0.393]**	

SD: Standard deviation, U: Mann Whitney test, p: p value for comparing two studied groups.

Table [4]: Intraoperative fluid management, intraoperative hypotensive episodes, and Postoperative lactate presented as mean and [standard deviation]

	Control group "mean-[SD]"	Study group "mean-[SD]"	P value
Total fluids	2790[443]	3155[452]	0.002
Crystalloids	2408[418]	2755[423]	0.01
Colloids	318[61]	380[51]	0.85
Urine output	1410[382]	2019[449]	<0.001
Number of patients had hypotension	11/30	12/30	
Hypotensive episodes presented as mean and [standard deviation]	0.77[1.01]	1.07[1.20]	0.319
Postoperative lactate	2,5[1.1]	0.9[1]	0.03

Data are presented as mean-[SD], SD: stander deviation

Table [5]: Postoperative readiness to be discharged assessed by modified PADS score per hours.

	Postoperative hours for discharge [hours]	
Group	Control	Study
Min	3	2
Max	6	6
Mean	3.9	4.07
SD	0.80	0.87
Median	4	4
U [p]	**390.5 [0.3843]**	

SD: Standard deviation, U: Mann Whitney test, p: p value for comparing two studied groups

DISCUSSION

In this study, we used hot air mattress in all cases beside giving warm IV fluid, If the patient experiences shivering, we adjust the temperature in the operating room accordingly. In liposuction, standard noninvasive monitoring is usually used including pulse oximeter, blood pressure, ECG, capnography and urinary catheter. Some studies explored more indicators to guide fluid administration in large volume liposuction.

Jain *et al.* [9] used stroke volume variation as an indicator for intraoperative fluid administration in patients who underwent large-volume liposuction. They found that pulse pressure variation and stroke volume, as dynamic parameters, could help determine the suitable amount of IV fluid for patients who had extensive liposuction.

Many studies also agreed that dynamic indicators were more accurate and preferable than static indicators [9-12]. Therefore, we also chose a dynamic indicator, which is PVI, to evaluate fluid responsiveness in patients undergoing mechanical ventilation.

PVI is a measure of how the PI changes over time due to the impact of mechanical ventilation on blood flow. PI shows the pulse oximeter waveform's amplitude is primarily determined by two factors: stroke volume and vasomotor tone. PVI is an indication that accurately measures the ability of the body to respond to fluid administration, which means it is based on the principles of how the heart and lungs interact and affect each other during mechanical ventilation. For example, the tidal volume used can affect the ability of PVI to estimate fluid responsiveness [13]. To enable precise prediction, adults must have a tidal volume of no less than 8 mL.kg-1 [14].

PVI was less reliable in predicting fluid responsiveness in individuals that breath spontaneously than in mechanically ventilated ones [15], but it still seemed to perform better contrasted to central venous pressure as some studies indicated [16]. The validity of PVI measurement was compromised during spontaneous ventilation because each spontaneous breath could not achieve a standard tidal volume of **Keller *et al.*** [13].

Also, PVI was a parameter that was indirectly associated with the pulsus paradoxus, and it was also proposed that tachypnea could interfere with the measurement. Additionally, it was observed that hypercapnia led to inaccuracy in PVI, so respiratory rate was deemed to be crucial for the precision of PVI measurement [15].

In this work, all individuals were mechanically ventilated and tidal volume was 8 ml/kg, monitored by capnography preventing hypercapnia, no patients with arrhythmias nor any cardiac problems that can affect usefulness of PVI. The current data only came from the Massimo finger pulse oximetry probe. However, one study reported that the Massimo forehead probe has higher predictive accuracy [17]. The authors stated that PVI relies on the variation between the minimum and maximum perfusion index, which can affect its accuracy in individuals with poor peripheral perfusion. **Broch *et al.*** [2] showed that restricting their analysis to individuals with adequate peripheral perfusion [e.g. PI > 4%] enhanced the accuracy of PVI.

Some researchers have reported that PVI is a poor predictor of fluid responsiveness in major surgeries such as liver transplantation [18] and colorectal surgery [19]. They attributed this to the influence of unstable intraoperative condition, low perfusion, and high-risk patients.

Another factor that could reduce the PVI accuracy values is the variability of PI due to various reasons. The manufacturer recommended that the PI value ought to be higher than 1 for the PVI measurement [20].

Previous studies have shown that PVI and PI might be influenced by conditions including hypothermia, vascular disease, low cardiac output, and vasoconstrictor use [17].

Le Guen *et al.* [21] who worked in patients undergoing kidney transplantation reported that PVI was an inaccurate predictor of responsiveness to fluid measured by esophageal Doppler and recommended against using it for fluid management. They attributed this to the alterations of vascular and endothelial function that could affect capillary distribution and distal outflow in patients with chronic renal failure.

Cannesson *et al.* [22] claimed that a PVI value greater than 14 was shown to suggest responsiveness to fluid with a sensitivity of 81% and a specificity of 100% in a study of 25 individuals who underwent coronary bypass surgery. This study was significant because it showed the low predictive value of static parameters including cardiac index and CVP under the same clinical conditions where PVI performed well.

Another study involving patients who had major surgery found that a PVI value > 9.5 was a reliable indicator of fluid responsiveness with 93% sensitivity and 100% specificity [23].

Renner *et al.* [24] demonstrated that a PVI ≥13% could detect fluid responsiveness with 84% sensitivity and 64% specificity, while CVP failed to do so in 27 infants with an average age of 17 months.

We compared PVI-guided fluid approach to Rohrich fluid approach [4] in mechanically ventilated patients undergoing large volume liposuction [5L and more]. In PVI group we target PVI 14% or less by giving maintenance fluids at 4-2-1 rule and fluid boluses as needed till reach target. In Rohrich approach, we gave maintenance fluids at 4-2-1 rule with keeping Intraoperative fluid ratio at [1.2].

We found a higher volume of infused fluids in the PVI group [mean = 3155ml - SD = 452]. Showing that fluid management guided by Rohrich formula [mean = 2790ml - SD = 443] is not providing excessive fluids compared to PVI. That was statistically significant with a P value of 0.02.

Also, we calculated mean intraoperative fluid ratio in the PVI group and it was "1.345", and that was near to **Trott *et al.*** [25] that we mentioned before who worked with intraoperative fluid ratio at 1.4 in liposuctions more than 4 L. This finding showed that Rohrich fluid management might be too conservative in large volume liposuction.

We also think Rohrich was conservative as we found better peripheral perfusion in the PVI group. This was represented by the lower serum lactate level by the end of the operation and higher intraoperative urinary output. We found no substantial variation among both groups with an average of 4 hours postoperative in both groups, minimum was 2 hours in PVI group and 3 hours in control group, whereas maximum was 6 hours reported in both groups. No other studies used PVI for intraoperative fluid management in large volume liposuction before, but many studies used PVI intraoperatively to predict responsiveness to fluid in other types of surgeries in addition to in ICU.

In 2019, a systematic review and meta-analysis predicting preload responsiveness using PVI under various conditions showed that PVI's reliability is restricted, although it can have a significant impact on bedside monitoring for those with mechanical ventilation who aren't undergoing surgery. This meta-analysis had reported PVI sensitivity 76% and specificity 76% when using PVI in operating room compared to sensitivity 85% and specificity 80% when using PVI without surgery as a bedside monitor in mechanically ventilated patients [26].

PVI value is influenced by several variables: preload and afterload of both ventricles, cardiac contractility, local vasomotor tone and pleural and trans-pulmonary pressures, at the site of measurement [14].

Vasomotor tone and cardiopulmonary interactions can be affected by various factors in everyday clinical settings, various factors are taken into consideration, including regional sympathetic blocks, surgical stress, nociceptive stimulation, sedative depth, temperature of the body, settings of ventilation, and vasoactive medications [12]. Therefore, these conditions are potentially confounding factors that may impact the accuracy and utility of PVI. Hence, patient and surgery characteristics should be considered when applying PVI.

Forget P *et al.* [27] conducted a multi-center study with 88 patients and found that fluid management strategies did not change significantly before and after using PVI. They performed different types of surgeries, including orthopedic and colonic surgeries. This also confirmed that PVI interpretation should consider the clinical context.

Also, **Fischer *et al.*** [28] studied 447 patients mechanically ventilated under general anesthesia undergoing intermediate risk orthopedic surgeries, they showed that fluid administration guided by PVI didn't shorten the duration of hospital stays or fitness for discharge. And that was like our conclusion regarding readiness of patients to be discharged after liposuction.

This study shows the ability of PVI as noninvasive dynamic indicator for responsiveness to fluid in liposuction. Recent research has confirmed that using dynamic measurements based on the interactions between the heart and lungs among individuals on mechanical ventilation is the most accurate way to predict responsiveness to fluids. Therefore, it is necessary to have an automatic and ongoing calculation of these dynamic measures. This study is considered a step towards using noninvasive dynamic indicators intraoperatively to reach the optimum number of fluids required.

However, various limitations in our study need to be considered when evaluating the clinical significance of our findings. This study is limited by its single-center design and the relatively small number of patients involved, which reduces the statistical power and precision of our findings. Furthermore, confirming the accuracy of PVI in this population remains challenging, as previously indicated. Furthermore, as an intrinsic limitation, PVI which measures changes in peripheral pulse volume, is not a valid indicator for individuals with atrial fibrillation or numerous ectopics due to the impact of arrhythmias, which are more prone to volume overload and need precise monitoring, so our study was limited to patients with sinus rhythm.

Although there are some limitations, the existing research indicates that using a non-invasive Massimo finger pulse oximeter to measure PVI has a reasonable capacity for predicting fluid or preload responsiveness in adult patients receiving mechanical ventilation.

Conclusion: The study showed that non-invasive PVI can anticipate fluid responsiveness in large volume liposuctions for patients mechanically ventilated under general anesthesia. Also, fluid administration guided by PVI resulted in increased intraoperative fluid with slight improvement in peripheral tissue perfusion compared to Rohrich formula.

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Conflict of interests: None to be declared.

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