

The Effect of Conventional Versus Pleth Variability Index-Guided Goal-Directed Intraoperative Fluid Management on Renal Function in Patients Undergoing Elective Total Abdominal Hysterectomy

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ABSTRACT

Introduction: Intraoperative fluid management is a critical component of anesthetic practice, aiming to maintain tissue perfusion and electrolyte balance. Inadequate or excessive fluid administration may cause complications, thereby affecting postoperative outcomes. This study aimed to assess the impact of pleth variability index (PVI)-based goal-directed fluid therapy (GDFT), compared with a conventional fluid strategy, on renal function during elective total abdominal hysterectomy (TAH).

Methods: This prospective, non-randomized, comparative study included 68 participants (American Society of Anesthesiologists I-II) who underwent TAH. Patients were followed in two parallel clinical cohorts according to the fluid management strategy applied: Group P (GDFT monitored via PVI) and Group G (conventional fluid therapy). Heart rate (HR), mean arterial pressure (MAP), urine output, blood loss, and fluid volumes were recorded every 30 minutes for up to 150 minutes post-intubation. Blood urea nitrogen (BUN), creatinine, estimated glomerular filtration rate (eGFR), urine specific gravity, and calculated osmolality were evaluated preoperatively, postoperatively, and on postoperative day 3.

Results: No statistically significant differences were observed between the groups in HR, MAP, or urine output. Group G received more fluids and experienced greater intraoperative blood loss than Group P. Postoperatively, BUN levels and calculated osmolality decreased in both groups, while eGFR and creatinine remained unchanged from baseline. Urine specific gravity increased significantly only in Group P.

Conclusion: Conventional and PVI-guided GDFT protocols exert similar effects on postoperative renal function after elective TAH. PVI-guided GDFT achieves robust hemodynamic stabilization with a significant reduction in intraoperative fluid volumes compared to conventional management, representing a reliable fluid-sparing approach for routine clinical practice.

Keywords: PVI, goal directed fluid management, renal function, traditional fluid therapy

Introduction

Intraoperative fluid therapy represents an essential component of routine anesthetic management. The main goals of fluid administration are to sustain tissue perfusion, ensure adequate oxygen delivery, preserve normal electrolyte concentrations, and achieve normoglycemia (1).

Various fluid therapy regimens are being used in the intraoperative setting, including traditional, restrictive, and goal-directed approaches. Inadequate fluid administration during the perioperative period may lead to impaired tissue perfusion and acute kidney injury (AKI), whereas excessive fluid administration may cause complications such as pulmonary edema, pneumonia, postoperative ileus, anastomotic

leakage, and impaired wound healing. Therefore, perioperative fluid replacement is of critical significance for postoperative morbidity and mortality (2,3).

Goal-directed fluid therapy (GDFT) aims to optimize intraoperative cardiac output and oxygen delivery based on individual needs, particularly in patients with limited cardiopulmonary reserve or hemodynamic instability. In patients undergoing major surgery, standard anesthetic monitoring may be insufficient to assess intraoperative hypovolemia or hypervolemia. To ensure individualized fluid therapy and optimal oxygen delivery in the perioperative period, advanced hemodynamic monitoring is recommended. Dynamic parameters such as pulse pressure variation (PPV), stroke volume variation (SVV), and pleth variability index (PVI),



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which are based on cardiopulmonary measurements, are recognized as accurate predictors of fluid responsiveness (4).

Due to its non-invasive nature and cost-effectiveness, PVI has gained prominence among dynamic hemodynamic monitoring tools, and has been shown to provide fluid optimization comparable to that of invasive monitors (5).

The primary objective of this study was to determine whether PVI-guided GDFT results in superior preservation of renal function compared with conventional fluid therapy in patients undergoing elective total abdominal hysterectomy (TAH), as assessed by perioperative changes in serum creatinine, estimated glomerular filtration rate (eGFR), blood urea nitrogen (BUN), urine specific gravity, and calculated osmolality.

Methods

This study was conducted with the approval of the University of Health Sciences Türkiye, Istanbul Training and Research Hospital Ethics Committee (decision number 257, date: October 13, 2023). The 12 months period between ethics approval and initiation of patient enrollment was attributable to institutional logistics and the procurement timeline for the specific non-invasive hemodynamic monitoring equipment (Masimo Rainbow ROOT). The study included participants aged 18 to 65 years who underwent TAH under general anesthesia between October 16, 2024, and April 16, 2025. The study was registered on the UMIN-CTR website (UMIN000058074). We acknowledge that this registration was completed retrospectively, following the conclusion of the study, due to mandatory institutional administrative workflows and formal registry approval timelines. This investigation was structured as a prospective, non-randomized, comparative study (quasi-experimental design) and reported in accordance with the STROBE guidelines. Patients were followed in a 1:1 parallel design based on the clinical fluid management approach selected by the attending anesthesia team, resulting in two distinct cohorts: Groups P and G. Because group assignments were determined by the institutional clinical pathway and the specific monitoring protocol chosen by the clinician, no randomization sequence or allocation concealment methods (such as sealed envelopes) were used. Due to the practical nature of the intraoperative interventions and the visibility of the monitoring screens, the clinical anesthesia team, the participants, and the data analysts could not be blinded to the group allocations. The flow of participants through the screening, exclusion, and final analysis stages is detailed in the provided Participant Flow Diagram. Written informed consent was obtained from each participant after they were fully briefed on the protocol and prior to their inclusion in the study.

Patients with American Society of Anesthesiologists (ASA) physical status $\geq$ III, a known history of renal failure, diabetes mellitus, diuretic use, ischemic heart disease, arrhythmias, severe peripheral arterial disease or congestive heart failure were excluded from the study. Additional exclusion criteria included patients with blood loss exceeding 20%, patients who received blood transfusions, patients who required more than 500 mL of colloid solutions, patients who required vasopressor support, and patients with psychiatric conditions impairing their ability to provide informed consent.

The required sample size was estimated through a power analysis performed with G*Power 3.1.9.4 software (Heinrich Heine University Düsseldorf, Düsseldorf, Germany). Based on a medium effect size (d : 0.5) for early postoperative fluid-driven renal variables (such as eGFR changes), a 5% significance level, and 80% statistical power, at least 63 participants were required. To account for potential dropouts, the final cohort was maintained at 68 participants and was analyzed using an independent t-test.

All patients who completed preoperative preparations and were eligible for the study were followed in one of two groups: Group P (receiving GDFT guided by PVI) and Group G (receiving conventional fluid therapy). Anesthesia was administered according to the group assignment.

Preoperative evaluation was performed for each patient included in the study, and demographic data such as age, sex, height, weight, ASA score, and comorbidities were recorded. Upon transfer to the operating room, routine monitoring, including electrocardiography, peripheral oxygen saturation, and non-invasive blood pressure, was applied, along with hemodynamic monitoring using the Masimo Rainbow ROOT device (Masimo Corp., Irvine, CA, USA) to assess PVI, perfusion index (PI), and Oxygen Reserve Index.

At induction, propofol 2 mg/kg, fentanyl 1-1.5 mcg/kg, and rocuronium 0.6-0.7 mg/kg were administered. For maintenance of anesthesia, intravenous remifentanyl and sevoflurane were administered. Ventilation parameters were adjusted to 40% FiO₂ with a flow rate of 2 L/min, tidal volume based on ideal body weight, and end-tidal CO₂ between 35-45 mmHg.

Following intubation, heart rate (HR), mean arterial pressure (MAP), peripheral oxygen saturation, urine output, blood loss, and the volume of fluids administered were recorded for all patients at 30, 60, 90, 120, and 150 minutes. The duration of surgery was also documented. Serum urea, creatinine, and eGFR levels, as well as urine specific gravity (measured using the Laboquick urine analysis strip), were assessed preoperatively, postoperatively, and on postoperative day 3. The eGFR was calculated using the 2021 Chronic Kidney Disease Epidemiology Collaboration creatinine equation, which incorporates serum creatinine, age, and sex, without race adjustment. Serum osmolality was calculated using the conventional formula: $[2 \times (\text{Na}) + (\text{Glucose}/18) + (\text{BUN}/2.8)]$, with values expressed in mOsm/L. We acknowledge that calculated osmolality is an estimate, and measured serum osmolality may differ due to an osmolar gap. In Group P, PVI values were also recorded. According to the routine preoperative protocol at our obstetrics and gynecology clinic, all patients received 2000 mL of Ringer's lactate solution, as confirmed by medical records.

Group P: Following induction, 250 mL crystalloid boluses were administered based on the PVI value, and fluid replacement was continued until the target PVI threshold of 14% was achieved. Throughout the surgical procedure, a maintenance infusion of crystalloids was administered at a rate of 2 mL/kg/h.

The intraoperative management protocol was as follows:

When PVI >14% and MAP <65 mmHg, patients were administered a 250 mL crystalloid solution as a bolus. If MAP did not increase above

65 mmHg, 5 mg IV ephedrine was administered. A total bolus dose of 15 mg of ephedrine was permitted. Patients requiring norepinephrine infusion were excluded from the study.

PVI <14% and MAP >65 mmHg: Maintenance infusion of crystalloids at 2 mL/kg/h was continued.

When PVI <14% and MAP <65 mmHg, 5 mg IV ephedrine was administered and repeated as needed, up to a total dose of 15 mg. Patients who required norepinephrine infusion were excluded from the study.

Group G: Patients received crystalloid replacement based on preoperative fasting duration, calculated basal fluid requirements (using the 4-2-1 rule), and maintenance plus insensible fluid losses (4 mL/kg/h). Of the total calculated basal fluid requirement, 50% was administered during the first hours, 25% in the second hours, and the remaining 25% in the third hours.

In cases where MAP was below 65 mmHg or decreased more than 25% from baseline, a 250 mL crystalloid solution was given as a bolus. If hypotension persisted, 5 mg IV ephedrine was administered. Patients who required norepinephrine infusion were excluded from the study.

Statistical Analysis

Descriptive statistics were expressed as mean, standard deviation, median, minimum and maximum values, and as frequencies and percentages. The distributions of the variables were assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The independent samples t-test was used for normally distributed independent quantitative data, whereas the Mann-Whitney U test was applied to non-normally distributed data. The Wilcoxon test was used to analyze dependent quantitative variables. The chi-square test was used to analyze independent categorical (qualitative) variables. All statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 70 patients were initially enrolled in the study; however, 2 were excluded because they required intraoperative blood product transfusion. Consequently, 68 patients were included in the final analysis.

The patients were assigned to two groups: Group P (n=34), who received GDFT guided by PVI, and Group G (n=34), who received conventional fluid therapy.

There were no statistically significant differences between Group P and Group G in terms of age, height, weight, body mass index (BMI), duration of surgery, baseline PVI value, ASA score, and the total of patients who needed ephedrine ($p>0.05$) (Table 1).

In both groups, postoperative and postoperative day 3 hemoglobin (HGB) and hematocrit (HCT) levels showed significant decreases compared with preoperative values ($p<0.05$), while white blood cell counts increased significantly ($p<0.05$); however, there were no significant differences between groups ($p>0.05$) (Table 2).

In both Group P and Group G, postoperative BUN and creatinine levels and those on postoperative day 3 were significantly lower than preoperative measurements ($p<0.05$), while eGFR increased significantly ($p<0.05$). The decrease in creatinine and the increase in eGFR did not differ significantly between groups ($p>0.05$). However, in Group G, both postoperative BUN levels and postoperative day 3 BUN levels were significantly lower than those in Group P ($p<0.05$) (Table 3). To evaluate the precision of the observed equivalence in primary renal outcomes, between-group mean differences with 95% confidence intervals (CIs) and observed effect sizes (Cohen's d) were calculated for overall perioperative changes on Postoperative Day 3 (Δ_{day3} : postoperative day 3-preoperative). For Δ_{day3} eGFR, the between-group mean difference was -1.20 mL/min (95% CI: -4.66 to 2.26; Cohen's d: 0.17). For Δ_{day3} creatinine, the mean difference was +0.01 mg/dL (95% CI: -0.03 to 0.05; Cohen's d: 0.11). For Δ_{day3} BUN, the mean difference was +1.50 mg/dL (95% CI: -1.62 to 4.62; Cohen's d: 0.23). These small effect sizes ($d\leq 0.23$) and narrow 95% CIs bound around zero confirm that true clinically meaningful differences in renal outcomes were not missed due to statistical power constraints.

In both groups, postoperative osmolality levels were significantly lower than preoperative levels ($p<0.05$); however, the between-group decrease in osmolality was not statistically significant ($p>0.05$). Postoperative urine specific gravity in Group G was significantly lower than that in Group P ($p<0.05$). In Group P, urine specific gravity showed a significant

Table 1. Comparison of demographic and clinical characteristics between the groups

		Group P (n=34)			Group G (n=34)				p
		Mean $\pm$ SD/n-%			Mean $\pm$ SD/n-%			Median	
Age (years)		49.1	$\pm$	5.7	48.0				0.615
Height (cm)		162.4	$\pm$	6.5	161.0				0.279
Weight (kg)		73.3	$\pm$	10.8	75.0				0.672
BMI (kg/m ²)		27.6	$\pm$	4.2	27.0				0.364
ASA score	I	14		41.2%	21			61.8%	0.089
	II	20		58.8%	13			38.2%	
Duration of operation (min)		133.2	$\pm$	28.8	120.0				0.985
Baseline PVI (%)		13.2	$\pm$	2.1	13.0				0.467
Ephedrine	(-)	31		91.2%	32			94.1%	0.642
	(+)	3		8.8%	2			5.9%	

Independent samples t-test/Mann-Whitney U test/chi-square test. BMI: Body mass index, ASA: American Society of Anesthesiologists, PVI: Pleth variability index, SD: Standard deviation

increase both immediately postoperatively and on postoperative day 3 compared with preoperative values ($p<0.05$). In Group G, there was no significant change in urine specific gravity immediately postoperative compared to preoperative values ($p>0.05$); however, a significant increase was observed on postoperative day 3 ($p<0.05$) (Table 4).

No significant differences were observed between Group P and Group G in serial measurements of MAP and HR ($p>0.05$).

The volume of fluids administered in Group G was significantly higher than that in Group P ($p<0.05$). At 30, 60, and 90 minutes, bleeding was

Table 2. Comparison of HCT, HGB and WBC levels between the groups

	Group P (n=34)				Group G (n=34)				p
	Mean ± SD			Median	Mean ± SD			Median	
HCT (%)									
Preoperative	37.2	±	5.6	37.2	37.0	±	3.5	36.8	0.868
Postoperative	34.7	±	4.4	34.9	33.4	±	3.3	32.3	0.103
Postoperative day 3	30.4	±	4.0	30.4	29.6	±	3.6	29.4	0.294
Preop/postop change	-2.5	±	4.3	-2.2	-3.7	±	2.2	-3.7	0.056
Preop/postop day 3 change	-6.7	±	3.7	-6.5	-7.4	±	3.0	-7.7	0.259
HGB (g/dL)									
Preoperative	12.2	±	1.8	12.4	12.1	±	1.3	12.1	0.778
Postoperative	11.5	±	1.6	11.5	11.0	±	1.2	10.8	0.134
Postoperative day 3	9.8	±	1.4	9.8	9.8	±	1.3	9.7	0.835
Preop/postop change	-0.8	±	0.9	-1.0	-1.1	±	0.8	-1.1	0.165
Preop/postop day 3 change	-2.4	±	1.0	-2.4	-2.3	±	1.0	-2.3	0.768
WBC (mcl)									
Preoperative	7.3	±	3.1	6.0	7.1	±	1.8	7.0	0.673
Postoperative	13.6	±	3.0	13.5	13.0	±	3.4	14.0	0.390
Postoperative day 3	8.7	±	2.2	8.5	8.2	±	2.3	8.0	0.325
Preop/Postop change	6.3	±	2.9	7.0	5.9	±	2.7	6.0	0.269
Preop/postop day 3 change	1.4	±	2.6	2.0	1.1	±	2.0	1.0	0.151
Mann-Whitney U test/Wilcoxon test. HCT: Hematocrit, HGB: Hemoglobin, WBC: White blood cell, SD: Standard deviation									

Mann-Whitney U test/Wilcoxon test. HCT: Hematocrit, HGB: Hemoglobin, WBC: White blood cell, SD: Standard deviation

Table 3. Comparison of BUN, creatinine and eGFR levels between the groups

	Group P (n=34)				Group G (n=34)				p
	Mean ± SD			Median	Mean ± SD			Median	
BUN (mg/dL)									
Preoperative	25.9	±	6.4	26.0	25.0	±	7.0	25.0	0.480
Postoperative	18.9	±	4.1	18.0	15.7	±	5.3	14.5	0.002
Postoperative day 3	17.5	±	5.3	16.0	15.2	±	5.9	14.0	0.027
Preop/postop change	-7.0	±	6.5	-5.5	-9.3	±	6.0	-9.0	0.078
Preop/postop day 3 change	-8.4	±	6.5	-8.5	-9.9	±	6.4	-9.0	0.555
Creatinine (mg/dL)									
Preoperative	0.62	±	0.09	0.60	0.60	±	0.10	0.60	0.324
Postoperative	0.57	±	0.10	0.60	0.53	±	0.09	0.50	0.151
Postoperative day 3	0.58	±	0.10	0.60	0.55	±	0.10	0.55	0.302
Preop/postop change	-0.05	±	0.08	0.00	-0.07	±	0.10	-0.10	0.506
Preop/postop day 3 change	-0.04	±	0.09	0.00	-0.05	±	0.09	-0.05	0.713
eGFR (mL/min)									
Preoperative	102.9	±	7.9	104.0	105.0	±	8.3	107.0	0.156
Postoperative	108.7	±	7.6	108.5	111.4	±	7.9	111.5	0.158
Postoperative day 3	108.0	±	8.4	109.5	111.3	±	8.6	112.0	0.206
Preop/postop change	5.8	±	6.5	5.0	6.4	±	7.6	4.5	0.966
Preop/postop day 3 change	5.1	±	7.7	5.0	6.3	±	6.6	5.0	0.649

Mann-Whitney U test/Wilcoxon test. BUN: Blood urea nitrogen, eGFR: Estimated glomerular filtration rate, SD: Standard deviation

significantly greater in Group G than in Group P ($p < 0.05$). Although the final bleeding volume was greater in Group G, the difference between the groups was not statistically significant ($p > 0.05$). There was no significant difference in urine output between Group P and Group G ($p > 0.05$) (Table 5).

Discussion

The optimal intraoperative fluid administration volume remains a topic of widespread investigation in the literature. In major surgeries, liberal fluid administration was found to be linked to an increased incidence of pulmonary complications (3).

Conversely, restrictive regimens, while not shown to increase mortality or morbidity, were associated with a greater risk of AKI (6).

In our study, we investigated the effects of conventional fluid therapy and PVI-guided GDFT on renal function. GDFT aims to optimize hemodynamic stability based on individual patient needs, and studies by Muñoz et al. (7) and Gómez-Izquierdo et al. (8) have shown that it reduces intraoperative fluid volume and shortens hospital stay; in our study, we further evaluated its effects on urine specific gravity, serum urea and creatinine levels, as well as intraoperative fluid administration and blood loss.

To maintain normovolemia, current recommendations emphasize avoiding both overly restrictive and overly liberal fluid strategies. Instead, individualized fluid therapy guided by advanced hemodynamic monitoring should be applied to optimize oxygen delivery during the perioperative period (9).

Table 4. Comparison of osmolarity and urine specific gravity levels between the groups

	Group P (n=34)				Group G (n=34)				p
	Mean ± SD			Median	Mean ± SD			Median	
Osmolarity (mOsm/L)									
Preoperative	286.0	±	3.7	286.0	285.3	±	4.4	284.5	0.153
Postoperative	283.8	±	3.9	284.0	281.7	±	5.3	283.0	0.099
Postoperative day 3	286.8	±	4.3	286.0	285.3	±	3.5	286.0	0.217
Preop/postop change	-2.2	±	5.2	-2.0	-3.6	±	5.5	-3.5	0.271
Preop/postop day 3 change	0.8	±	5.1	2.0	0.0	±	5.7	1.0	0.543
Urine specific gravity									
Preoperative	1010.9	±	4.2	1010.0	1010.4	±	4.2	1010.0	0.860
Postoperative	1015.7	±	4.1	1015.0	1011.6	±	3.6	1010.0	< 0.001
Postoperative day 3	1016.0	±	5.0	1015.0	1017.4	±	7.4	1015.0	0.659
Preop/postop change	4.9	±	3.6	5.0	1.2	±	3.9	0.0	< 0.001
Preop/postop day 3 change	5.1	±	6.7	5.0	6.9	±	8.3	5.0	0.555
Mann-Whitney U test/Wilcoxon test. SD: Standard deviation									

Mann-Whitney U test/Wilcoxon test. SD: Standard deviation

Table 5. Comparison of intraoperative fluid administration, blood loss, and urine output between the groups

	Group P (n=34)				Group G (n=34)				p
	Mean ± SD		Median	Mean ± SD		Median			
Intraoperative fluid administration volumes (mL)									
30 th minutes	244.3	±	133.5	177.5	410.3	±	100.6	400.0	< 0.001
60 th minutes	461.2	±	172.5	475.0	802.9	±	189.9	800.0	< 0.001
90 th minutes	706.8	±	228.8	700.0	1142.6	±	264.3	1200.0	< 0.001
Total	1012.1	±	319.5	1000.0	1700.0	±	409.2	1550.0	< 0.001
Intraoperative bleeding volumes (mL)									
30 th minutes	27.2	±	30.4	12.5	45.6	±	32.8	50.0	0.018
60 th minutes	78.7	±	46.9	50.0	105.9	±	48.9	100.0	0.006
90 th minutes	139.7	±	72.6	100.0	168.4	±	67.2	150.0	0.049
Total	213.8	±	97.2	200.0	253.6	±	120.9	225.0	0.250
Urine output (mL)									
30 th minutes	128.7	±	106.6	100.0	113.2	±	52.7	100.0	0.797
60 th minutes	225.7	±	162.2	200.0	207.4	±	76.0	200.0	0.570
90 th minutes	324.3	±	194.7	275.0	298.5	±	90.9	300.0	0.696
Total	465.5	±	289.4	400.0	494.6	±	172.3	475.0	0.211

Mann-Whitney U test. SD: Standard deviation

Dynamic cardiopulmonary parameters such as the PPV, PVI, and SVV are considered useful indicators for assessing fluid responsiveness, offering greater accuracy than static measures for guiding fluid management (4,10).

PVI, obtained by analyzing respiration-related changes in the PI, has been shown to correlate strongly with invasive indices such as PPV and SVV, making it an effective dynamic marker of fluid sensitivity (5,11).

Considering these advantages, we assessed intraoperative fluid responsiveness using PVI, a non-invasive measure. In a study by Çevikkalp et al. (12), PVI-based fluid therapy allowed better estimation of patients' intravascular volume than central venous pressure-based monitoring. In that protocol, patients with a PVI value above 14% received 250 mL of crystalloid replacement, and no significant changes were observed in HR or MAP (12).

Similarly, Cannesson et al. (5) and Demirel et al. (13) demonstrated that a PVI threshold of 14% could effectively distinguish fluid responders from non-responders. Based on these findings, we also adopted a PVI threshold value of 14% in our study.

To minimize the risk of postoperative AKI, intraoperative management should aim to maintain MAP above 60-65 mmHg, or above 75 mmHg in individuals with a history of hypertension (14).

In a study of 3,300 non-cardiac surgery patients, the cumulative duration of hypotension was independently associated with AKI, with MAP <55 mmHg for more than 10 minutes or <60 mmHg for more than 20 minutes significantly increasing risk (15,16).

Although tachycardia has traditionally been considered a classic sign of hypovolemia, contemporary evidence reaffirms that its clinical sensitivity and specificity remain highly limited, as compensatory mechanisms and anesthetic depth frequently confound HR variations during acute volume shifts (17).

In our study, MAP and HR measurements showed no statistically significant differences between groups P and G.

Excessive fluid administration is another well-recognized contributor to AKI in critically ill patients (18,19).

At our hospital, the obstetrics and gynecology clinic routinely administers 2000 mL of intravenous Ringer's lactate the night before surgery as part of standard preoperative hydration. Consequently, baseline PVI values in our patient population averaged around 13%. Because this standardized protocol does not account for individual characteristics, such as BMI or fasting duration, some patients may have received unnecessary or excessive fluid loading. This high-volume preoperative fluid loading represents a methodological limitation, as it likely induced a baseline volume expansion, thereby masking the potential renal-protective benefits of the PVI-guided GDFT. This ceiling effect explains why postoperative renal markers remained equivalent across the two groups.

In a study by Muñoz et al. (7) on patients undergoing laparoscopic sleeve gastrectomy, the volume of crystalloids and total fluids administered was significantly lower in the GDFT group.

Similarly, in our study, the total fluid volumes given at 30, 60, and 90 minutes, as well as overall were significantly higher in Group G than in Group P. On average, patients in Group G received 1550 mL of total fluid during the operation, while those in Group P received 1000 mL of total fluid. It was found that patients managed with the GDFT protocol required significantly less fluid infusion compared to those treated with conventional fluid therapy, consistent with findings in the literature (11,20).

Our findings regarding fluid volume reduction without compromising renal function align with the physiological frameworks highlighted in landmark multicenter trials. In the RELIEF trial by Myles et al. (21), a strictly restrictive fluid regimen was shown to significantly increase the risk of AKI compared to a liberal approach, underscoring the dangers of unguided fluid limitation. Conversely, our protocol used dynamic PVI monitoring, which allowed explicit fluid conservation (1000 mL in Group P vs. 1550 mL in Group G) without exposing patients to subclinical renal hypoperfusion. Furthermore, the contemporary OPTIMISE II trial (2024) demonstrated that structured, goal-directed fluid protocols offer a safe and reliable approach to clinical optimization without causing fluid overload (22). By implementing PVI-guided GDFT, we individualize fluid delivery to prevent both the restrictive-induced renal risks shown in the RELIEF trial (21) and the dilutional or volume-overload complications associated with conventional liberal strategies.

Rapid intravenous fluid infusion can increase atrial pressure, stimulate atrial natriuretic peptide release, and disrupt the glycocalyx, thereby promoting fluid extravasation and potentially contributing to AKI. In our study, intraoperative fluid boluses of 250 mL were administered over 10 minutes to avoid these effects. In the study of Bihari et al. (23), fluid overload may compromise endothelial integrity and dilute coagulation factors.

Group G in our study showed higher intraoperative and total bleeding volumes, which might be secondary to dilutional coagulopathy resulting from increased fluid administration. However, reverse causality cannot be ruled out, as clinical teams may have administered more fluids to Group G in response to increased bleeding, to maintain hemodynamic stability. Other factors such as individual surgeon variability or specific uterine pathologies, including fibroid size, might have influenced blood loss. Since routine perioperative coagulation profiles (prothrombin time, international normalized ratio, platelets) were not monitored as part of our study protocol, it is not possible to definitively attribute this difference to a single mechanism. In both groups, P and G, HGB and HCT values measured postoperatively and on postoperative day 3 were significantly decreased compared with preoperative values. However, there were no statistically significant differences between the two groups in the decreases in HGB and HCT values from preoperative to postoperative measurements or from preoperative to postoperative day 3 measurements.

Cannesson et al. (24) demonstrated that urine output is frequently relied upon to guide volume expansion, with 83% of ASA and 77% of ESA respondents administering fluids in response to decreased urine output.

Another study of low intraoperative urine output during laparoscopic abdominal surgery reported that patients who received 3300 mL (high-volume group) or 1325 mL (low-volume group) had nearly identical urine outputs (100 mL vs. 107 mL). The mean surgery durations were approximately 180 and 190 minutes. No significant differences were observed in preoperative or perioperative creatinine values, although HCT levels decreased significantly on postoperative days 1 and 3. The researchers concluded that oliguria was not indicative of postoperative renal function and that intraoperative fluid replacement of 4-10 mL/kg had no significant effect on urine output. Thus, intraoperative oliguria during laparoscopic abdominal surgery was neither responsive to fluid administration nor associated with postoperative renal insufficiency (25). In our study, although the fluid volume administered in Group G was higher than that in Group P, there were no significant differences in urine output between the two groups at 30, 60, and 90 minutes or at the final measurement. Intraoperative oliguria was not observed in either group. Despite significant differences in intraoperative fluid volumes, no significant effect on urine output was noted. Therefore, we consider urine output monitoring alone an insufficient indicator for guiding additional fluid administration.

Postoperative and postoperative-day-3 serum urea levels decreased significantly compared with preoperative values in both Groups P and G. However, urea levels in Group G were significantly lower than those in Group P at both postoperative measurements. We believe that the significantly lower postoperative and postoperative-day-3 urea values in Group G, compared with Group P, were due to the greater amount of intraoperative fluid replacement administered to Group G. However, both values remained entirely within the normal physiological range, indicating a lack of clinical significance. This dilutional effect might have partially masked early postoperative creatinine increases in Group G, while alternative perioperative factors such as fasting duration, tissue catabolism, and surgical stress on hepatic urea synthesis could also have influenced these levels, despite a formal BUN/creatinine ratio not being routinely tracked.

In most clinical settings, endogenous filtration markers measured in blood are routinely used to eGFR. The most common endogenous biomarker remains serum creatinine; however, contemporary consensus from the KDIGO initiative reemphasizes that serum creatinine concentrations demonstrate a significant diagnostic delay, often rising only after a substantial reduction—frequently estimated up to 50%—in functional nephron capacity or glomerular filtration (26). As detailed in recent critical evaluations of renal classification milestones, this inherent physiological limitation heavily restricts the real-time detection of the acute injury phase of perioperative renal impairment (27). This clinical “blind spot” is particularly pronounced in cohorts where healthy baseline kidneys and preserved renal functional reserve are present preoperatively, wherein minor or subclinical filtration shifts fail to trigger immediate creatinine spikes despite active physiological stress (28).

In patients with high-grade obesity scheduled for laparoscopic Roux-en-Y gastric bypass surgery, no difference was observed in preoperative and postoperative creatinine values between the group monitored with PVI and the group managed with a standard fluid regimen (13).

In our study, there were no significant differences between groups P and G in preoperative, postoperative, and postoperative day 3 eGFR values, including increases in eGFR. Similarly, comparisons of preoperative, postoperative, and postoperative day 3 serum creatinine values revealed no significant differences; according to AKI criteria, no meaningful postoperative changes were observed. Therefore, we consider that, in elective TAH surgery, although the intraoperative fluid volume was lower in the PVI-guided GDFT group, its effects on renal function were comparable to those of conventional fluid therapy.

Routinely administering excessive preoperative fluids in critically ill patients may mask postoperative increases in creatinine, leading to delayed or more difficult early detection of AKI compared to preoperative creatinine levels (15).

In our study, osmolarity values in both groups decreased significantly postoperatively compared with preoperative values; however, osmolarity on postoperative day 3 did not differ significantly from preoperative levels. The observed postoperative decrease in osmolarity in both groups may be attributable to the routine preoperative administration of 2000 mL Ringer’s lactate, according to our obstetrics and gynecology clinic’s standard preparation protocol. Similarly, the lack of significant change in osmolarity on postoperative day 3 is likely attributable to the routine use of Isolen-S as postoperative maintenance IV fluid therapy. We also consider that differences in osmolarity between preoperative, postoperative, and postoperative day 3 measurements may be related to variations in balanced crystalloid solutions administered.

The endothelial glycocalyx layer plays a key role in preventing excessive vascular fluid extravasation, thereby limiting tissue edema. Therefore, in intraoperative fluid regimens, any additional fluid should be carefully considered as it may impair glycocalyx function (29).

In a study by Hahn et al. (30), it was demonstrated that preoperative dehydration and high urine specific gravity may be strongly associated with postoperative increases in plasma creatinine.

For this reason, we measured urine specific gravity both preoperatively and postoperatively in our study. In Group P, urine specific gravity measured postoperatively and on postoperative day 3 increased significantly compared with preoperative values, with no significant difference between the postoperative and day 3 measurements. In Group G, postoperative urine specific gravity did not change significantly from preoperative values, whereas on postoperative day 3 it showed a significant increase relative to those values. Postoperative urine specific gravity in Group G was significantly lower than that in Group P. The mean preoperative urine-specific gravity in both groups was 1010, close to the lower limit of the normal range. We attribute this to the routine preoperative administration of 2000 mL of Ringer’s lactate, according to our obstetrics and gynecology clinic’s standard preparation protocol. The lower postoperative urine specific gravity in Group G, compared with that in Group P, is likely due to the higher volume of intraoperative crystalloid fluids administered to Group G. Even a 500 mL difference in intraoperative fluid administration was sufficient to affect urine-concentrating ability in ASA I-II patients assumed to have healthy kidneys.

The increase in postoperative urine specific gravity in the P group may reflect the avoidance of excessive fluid administration due to PVI-guided GDFT. In the G group, the absence of a postoperative increase in urine specific gravity and the observed lower urine specific gravity may be attributed to the higher fluid volumes administered according to the conventional fluid therapy protocol. We consider monitoring urine specific gravity a valuable parameter for assessing renal concentrating ability in the postoperative period.

Previous studies have shown that postoperative serum creatinine elevation is associated with preoperative and postoperative concentrated urine; in our study, urine specific gravity remained within normal limits, and postoperative creatinine levels were normal (30).

Study Limitations

Our study has several limitations. First, it was conducted at a single center with a relatively small sample size, which may limit the generalizability of our findings. Second, we excluded high-risk patients (ASA physical status $\geq$ III, diabetes mellitus, or pre-existing renal insufficiency) to maintain a homogeneous sample, limiting the external validity of our results to more vulnerable cohorts who might benefit most from GDFT. Therefore, future well-designed trials should focus on ASA III-IV patients or on those with pre-existing renal insufficiency, in whom GDFT is anticipated to yield a greater clinical impact. Third, intraoperative events such as major blood loss ($>20\%$) or requirement for vasopressors led to post-allocation exclusions. Although this per-protocol approach prevented confounding, it potentially introduced attrition bias. Long-term postoperative follow-up was not performed because measurements were limited to the first three postoperative days. Fourth, the routine 2000 mL preoperative hydration protocol served as a confounding factor, inducing a baseline state of volume fullness and thereby reducing the study's statistical power to detect subtle fluid-driven differences in renal outcomes. Furthermore, standard eGFR equations are validated for steady-state chronic conditions; thus, dynamic perioperative fluid shifts and subsequent hemodilution may have artificially influenced early postoperative creatinine and eGFR kinetics. Fifth, subclinical renal injury markers such as NGAL or cystatin C, which are more sensitive than serum creatinine and urea, were not evaluated due to cost constraints. Urine specific gravity was evaluated using semi-quantitative reagent strips rather than refractometry, which is a limitation in measurement precision for detecting minor between-group differences.

Conclusion

In our study comparing the effects of a traditional fluid replacement strategy and a PVI-guided fluid optimization protocol on kidney function in individuals scheduled for elective TAH, no significant differences were observed between groups in hemodynamic parameters or urine output. The total fluid volume administered and intraoperative blood loss were significantly higher in the G group. Postoperatively, both groups showed decreases in serum urea and osmolality compared to preoperative values, while eGFR and creatinine levels remained unchanged compared to preoperative values. In the P group, postoperative urine specific gravity increased significantly compared with preoperative values, whereas the G group showed no significant change.

The study reported no significant differences in postoperative renal function between conventional and PVI-guided GDFT protocols in patients undergoing elective TAH. Our findings suggest that PVI-guided GDFT achieves hemodynamic stabilization while minimizing total fluid volumes, indicating fluid conservation, in contrast to conventional fluid management. Given the equivalent postoperative renal profiles across groups, we consider it a reliable, fluid-sparing approach applicable in routine clinical practice.

Following adequate hydration, postoperative measurement of urine specific gravity, along with hourly intraoperative urine output monitoring, provides valuable information for assessing renal concentrating capacity. This postoperative increase in urine specific gravity in Group P is considered a physiological response to more tailored fluid administration. Given that serum creatinine and eGFR levels remained stable in both groups, this stability indicates that adequate renal perfusion was maintained. Consequently, this finding supports the clinical safety of the GDFT protocol in maintaining balanced renal function.

Ethics

Ethics Committee Approval: This study was conducted with the approval of the University of Health Sciences Türkiye, Istanbul Training and Research Hospital Ethics Committee (decision number 257, date: October 13, 2023).

Informed Consent: Written informed consent was obtained from each participant after they were fully briefed on the protocol and prior to their inclusion in the study.

Footnotes

Authorship Contributions: Surgical and Medical Practices - O.K.A., Y.C.A.; Concept - İ.N., Y.C.A.; Design - İ.N., Y.C.A.; Data Collection or Processing - O.K.A.; Analysis or Interpretation - Y.C.A.; Literature Search - O.K.A.; Writing - O.K.A., İ.N.

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References

1. Doherty M, Buggy DJ. Intraoperative fluids: how much is too much? *Br J Anaesth.* 2012; 109: 69-79.
2. Myles PS, McIlroy DR, Bellomo R, Wallace S. Importance of intraoperative oliguria during major abdominal surgery: findings of the Restrictive versus Liberal Fluid Therapy in Major Abdominal Surgery trial. *Br J Anaesth.* 2019; 122: 726-33.
3. Corcoran T, Rhodes JE, Clarke S, Myles PS, Ho KM. Perioperative fluid management strategies in major surgery: a stratified meta-analysis. *Anesth Analg.* 2012; 114: 640-51.
4. Xu Z, Zhang J, Xia Y, Deng X. Accuracy of pulse oximeter perfusion index in thoracic epidural anesthesia under basal general anesthesia. *Int J Clin Exp Med.* 2014; 7: 1728-34.
5. 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: 200-6.
6. Miller TE, Myles PS. Perioperative fluid therapy for major surgery. *Anesthesiology*. 2019; 130: 825-32. Erratum in: *Anesthesiology*. 2020; 132: 405.
7. Muñoz JL, Gabaldón T, Miranda E, Berrio DL, Ruiz-Tovar J, Ronda JM, et al. Goal-directed fluid therapy on laparoscopic sleeve gastrectomy in morbidly obese patients. *Obes Surg*. 2016; 26: 2648-53.
8. Gómez-Izquierdo JC, Feldman LS, Carli F, Baldini G. Meta-analysis of the effect of goal-directed therapy on bowel function after abdominal surgery. *Br J Surg*. 2015; 102: 577-89.
9. Gustafsson UO, Scott MJ, Schwenk W, Demartines N, Roulin D, Francis N, et al. Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations. *World J Surg*. 2013; 37: 259-84.
10. Cannesson M, Attouf Y, Rosamel P, Desebbe O, Joseph P, Metton O, et al. Respiratory variations in pulse oximetry plethysmographic waveform amplitude to predict fluid responsiveness in the operating room. *Anesthesiology*. 2007; 106: 1105-11.
11. Zimmermann M, Feibicke T, Keyl C, Prasser C, Moritz S, Graf BM, et al. Accuracy of stroke volume variation compared with pleth variability index to predict fluid responsiveness in mechanically ventilated patients undergoing major surgery. *Eur J Anaesthesiol*. 2010; 27: 555-61.
12. Çevikkalp E, Topçu İ, Açıkel A, Sarılar S, Keleş GT, Özyurt BC. Efficacy of pleth variability index (PVI) to evaluate intraoperative fluid management during orthopaedic spinal surgery: a randomized controlled trial. *J Anesth Reanim Spec Soc*. 2020; 28: 18-25.
13. Demirel İ, Bolat E, Altun AY, Özdemir M, Beştaş A. Efficacy of goal-directed fluid therapy via pleth variability index during laparoscopic Roux-en-Y gastric bypass surgery in morbidly obese patients. *Obes Surg*. 2018; 28: 358-63.
14. Leone M, Asfar P, Radermacher P, Vincent JL, Martin C. Optimizing mean arterial pressure in septic shock: a critical reappraisal of the literature. *Crit Care*. 2015; 19: 101.
15. Goren O, Matot I. Perioperative acute kidney injury. *Br J Anaesth*. 2015; 115 Suppl 2: ii3-14.
16. Walsh M, Devereaux PJ, Garg AX, Kurz A, Turan A, Rodseth RN, et al. Relationship between intraoperative mean arterial pressure and clinical outcomes after noncardiac surgery: toward an empirical definition of hypotension. *Anesthesiology*. 2013; 119: 507-15.
17. Chaves RCF, Corrêa TD, Neto AS, Bravim BA, Cordioli RL, Moreira FT, et al. Assessment of fluid responsiveness in spontaneously breathing patients: a systematic review of literature. *Ann Intensive Care*. 2018; 8: 21.
18. Grams ME, Estrella MM, Coresh J, Brower RG, Liu KD; National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome Network. Fluid balance, diuretic use, and mortality in acute kidney injury. *Clin J Am Soc Nephrol*. 2011; 6: 966-73.
19. Fülöp T, Pathak MB, Schmidt DW, Lengvárszky Z, Juncos JP, Lebrun CJ, et al. Volume-related weight gain and subsequent mortality in acute renal failure patients treated with continuous renal replacement therapy. *ASAIO J*. 2010; 56: 333-7.
20. Abbas SM, Hill AG. Systematic review of the literature for the use of oesophageal Doppler monitor for fluid replacement in major abdominal surgery. *Anaesthesia*. 2008; 63: 44-51.
21. Myles PS, Bellomo R, Corcoran T, Forbes A, Peyton P, Story D, et al. Restrictive versus liberal fluid therapy for major abdominal surgery. *N Engl J Med*. 2018; 378: 2263-74.
22. OPTIMISE II Trial Group. Cardiac output-guided haemodynamic therapy for patients undergoing major gastrointestinal surgery: OPTIMISE II randomised clinical trial. *BMJ*. 2024; 387: e080439.
23. Bihari S, Dixon DL, Painter T, Myles P, Bersten AD. Understanding restrictive versus liberal fluid therapy for major abdominal surgery trial results: did liberal fluids associate with increased endothelial injury markers? *Crit Care Explor*. 2021; 3: e0316.
24. Cannesson M, Pestel G, Ricks C, Hoeft A, Perel A. Hemodynamic monitoring and management in patients undergoing high risk surgery: a survey among North American and European anesthesiologists. *Crit Care*. 2011; 15: R197.
25. Matot I, Dery E, Bulgov Y, Cohen B, Paz J, Neshet N. Fluid management during video-assisted thoracoscopic surgery for lung resection: a randomized, controlled trial of effects on urinary output and postoperative renal function. *J Thorac Cardiovasc Surg*. 2013; 146: 461-6.
26. Ostermann M, Bellomo R, Burdmann EA, Doi K, Endre ZH, Goldstein SL, et al. Controversies in acute kidney injury: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Conference. *Kidney Int*. 2020; 98: 294-309.
27. Goyal A, Daneshpajouhnejad P, Bashir K. Acute kidney injury. 2026 Aug 17. In: *StatPearls [Internet]*. Treasure Island (FL): StatPearls Publishing; 2026. Jan-.
28. Engel D, Löffel LM, Wuethrich PY, Hahn RG. Preoperative concentrated urine increases the incidence of plasma creatinine elevation after major surgery. *Front Med (Lausanne)*. 2021; 8: 699969.
29. Ding X, Cheng Z, Qian Q. Intravenous fluids and acute kidney injury. *Blood Purif*. 2017; 43: 163-72.
30. Hahn RG, Weinberg L, Li Y, Bahlmann H, Bellomo R, Wuethrich PY. Concentrated urine, low urine flow, and postoperative elevation of plasma creatinine: a retrospective analysis of pooled data. *PLoS One*. 2023; 18: e0290071.