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ORIGINAL RESEARCH

Intraoperative fluids and postoperative renal function in major gyneco-oncologic surgery: a retrospective study

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Abstract

Background: Acute kidney injury (AKI) is a common postoperative complication in major surgeries, including gynecologic cancer surgeries, but the relationship between intraoperative fluid management and postoperative AKI remains unclear. This study aims to evaluate the effect of perioperative fluid management strategies on postoperative renal function in patients undergoing major gynecologic cancer surgeries. **Methods**: This retrospective study analyzed data from 164 patients aged 18 years and older who underwent gynecologic cancer surgery. Patients were classified into three groups based on fluid management strategy: noninvasive goal-directed fluid therapy (NI-GDFT), minimally invasive goal-directed fluid therapy (MI-GDFT), and conventional fluid therapy (CFT). The primary objective was to evaluate the effect of fluid management on the development of postoperative AKI, as defined by the Acute Kidney Injury Network (AKIN) criteria. Secondary objective was to assess the intraoperative fluid volumes and postoperative non-renal complications. **Results**: When fluid management strategies were evaluated, it was observed that the amount of intraoperative fluid used in goal-directed fluid therapy regimens was lower than that used in conventional fluid regimens ($p < 0.05$). There were more postoperative complications in the CFT group compared to the NI-GDFT and MI-GDFT groups, including a higher incidence of AKI on postoperative day 1 ($p < 0.05$). The duration of hospitalization and the length of intensive care unit (ICU) stays were similar across all groups. **Conclusions**: Our retrospective data suggest that goal-directed fluid management, supported by advanced hemodynamic monitoring, might help reduce the incidence of postoperative AKI in patients undergoing major gynecologic cancer surgery. **Clinical Trial Registration**: NCT06101498.

Keywords

Advanced hemodynamic monitoring; Acute kidney injury; Conventional fluid therapy; Goal-directed fluid therapy; Intraoperative fluid management

1. Introduction

Acute kidney injury (AKI) is a common and significant complication after non-cardiac major abdominal surgery and can significantly increase the risk of morbidity and mortality [1]. The kidney, being an encapsulated organ, is susceptible to damage from both fluid overload and hypovolemia. For instance, fluid overload can lead to edema within the renal tissue, whereas a lack of sufficient blood volume (hypovolemia) can impair renal function. In addition, positive fluid balance has been associated with a higher incidence of postoperative AKI [2], and conversely, fluid deficits resulting from conditions such as an open abdomen during surgery, bleeding or acid drainage can also impair renal function. As a result, numerous fluid management strategies have been explored in studies of major abdominal surgeries [3, 4].

In gyneco-oncologic surgeries, fluid management is particularly challenging due to the physiological changes associated with the female reproductive system, such as significant fluid shifts during cytoreductive surgery, and gender-specific differences in the metabolism and elimination of drugs [5]. Additionally, noninvasive methods such as heart rate (HR) and blood pressure monitoring may not provide reliable assessments of intravascular volume or tissue perfusion, which limits their effectiveness in guiding fluid management [6]. Moreover, advanced hemodynamic monitoring techniques, including the measurement of cardiac output, have been shown to improve fluid management accuracy and reduce postoperative complications [7, 8]. Therefore, perioperative optimization of fluid status and blood pressure is crucial for reducing the risk of postoperative AKI [9].

This study aimed to evaluate the effects of various fluid

management strategies on renal function in the postoperative period, specifically in a patient cohort where intraoperative fluid management was complicated by advanced age and comorbidities, and also assessed the perioperative fluid volumes, the use of vasopressors and inotropes, and the duration of hospitalization and intensive care unit (ICU) stay.

2. Materials and methods

2.1 Study protocol and eligibility criteria

This study was designed as a retrospective analysis, conducted in accordance with the Helsinki Declaration and approved by the Ethics Committee of Başakşehir Çam and Sakura City Hospital (protocol no: 2023-478, date: 11 October 2023). The study was also registered in clinical trials (NCT06101498).

We reviewed the data of 164 patients who underwent laparotomy for gynecologic cancer between January 2023 and August 2023. Since the study was retrospective, the requirement for informed consent was waived by the ethics committee. Patient data were obtained from the hospital's electronic database and anesthesia follow-up records. Inclusion criteria encompassed patients older than 18 years with American Society of Anesthesiologists (ASA) risk scores of II and III who underwent major open surgery for endometrial, cervical or ovarian malignancy, with or without lymph node dissection, omentectomy or bowel resection.

2.2 Anesthesia management

The HR, mean arterial pressure (MAP), peripheral oxygen saturation (SpO_2), and temperature of the patients were routinely monitored according to the standards set by ASA. Additionally, we used noninvasive monitoring of the Patient State Index (PSI) (Masimo Corporation, Radikal 7, USA) to assess the depth of anesthesia. After establishing the necessary monitoring, we placed an epidural catheter for multimodal analgesia or performed peripheral trunk blocks under ultrasonographic guidance. Standard induction agents included fentanyl (2–4 mcg/kg), propofol (1–2 mg/kg) and rocuronium (0.6 mg/kg). Anesthesia was maintained with remifentanil infusion (0.05–0.2 mcg/kg/min) and sevoflurane (minimum alveolar concentration 0.8–1). Orotracheally intubated patients were ventilated using volume-controlled mode tidal volume 6–8 mL/kg, frequency 12–14/min, positive end-expiratory pressure (PEEP) 5–7 mmHg. Invasive arterial pressure monitoring was routinely performed via radial artery cannulation.

2.3 Intraoperative fluid management

In our clinic, intraoperative fluid management is determined by the anesthesiologist, who selects the appropriate strategy based on the hemodynamic monitoring method chosen and the patient's comorbidities.

The patients in this study received a fluid management strategy using a goal-directed fluid management (GDFT) using two different advanced hemodynamic monitoring techniques or conventional fluid management, which *involved* basic hemodynamic monitoring. Specifically, Group NI-GDFT comprised patients who received GDFT using the Pleth Variability Index (PVI), a noninvasive method that continuously measures dynamic changes in blood volume and predicts fluid volume status. Group MI-GDFT consisted of patients who received GDFT using the Pressure Regulating Analytical Method (PRAM), a minimally invasive approach. A diagram of the study groups is presented in Fig. 1.

The patients were informed to fast for six hours preoperatively, and exenteration was not performed. All patients received an initial preoperative infusion of 2 mL/kg/h of Isolyte solution.

For those receiving conventional fluid management, fluid deficit was determined based on several parameters: a 20% increase in peak HR, a 25% decrease in MAP, urine output below 0.5 mL/kg/h, and estimated intravascular loss calculations.

For patients undergoing noninvasive GDFT, fluid management was guided by targeting specific hemodynamic parameters: the PVI and MAP. The target values were PVI below 14 and MAP above 65 mmHg. Routine crystalloid infusion of 2 mL/kg/h (Isolyte solution) was administered. If PVI exceeded 14 or MAP exceeded 65 mmHg, a mini fluid challenge (100 mL crystalloid in 10 minutes) was given intravenously, with repetition of the mini fluid challenge every 5 minutes if the PVI trend decreased.

If MAP fell below 65 mmHg, a mini fluid challenge was applied in addition to the ongoing infusion and repeated every 5 minutes until the PVI reached 14. If hypotension persisted, noradrenaline infusion was administered. If MAP remained below 65 mmHg, and the PVI was below 14 with a HR of less than 60 beats per minute, dopamine infusion was administered. If HR exceeded 60 beats per minute, noradrenaline infusion was used (Fig. 2).

In the minimally invasive goal-directed fluid management group, fluid management was guided based on the patients' cardiac output measurements using the PRAM for hemodynamic monitoring. Key parameters such as cardiac index (CI), fluid responsiveness (pulse pressure variation (PPV), stroke volume variation (SVV)) and MAP were continuously monitored. The target values for fluid management were MAP >65 mmHg, CI >2.5 L/min/m^2 and PPV & SVV $<14\%$. The patients routinely received 2 mL/kg/h of crystalloid infusion (Isolyte solution). If PPV & SVV exceeded 14%, fluid responsiveness was reassessed every 5 minutes by administering a mini fluid challenge (100 mL crystalloid (Isolyte) over 10 minutes) until the values fell below 14%. If CI dropped below 2.5 L/min/m^2, MAP remained above 65 mmHg, and PPV & SVV were $<14\%$, a 100 mL bolus of crystalloid (Isolyte) was administered over 10 minutes, followed by dobutamine infusion if CI remained below 2.5 L/min/m^2. If PPV & SVV was $<14\%$, CI was <2.5 L/min/m^2 and MAP was <65 mmHg, noradrenaline infusion was administered (Fig. 3).

At the end of the operation, the extubated patients were transferred to the postoperative recovery unit and subsequently moved to the ward when the modified Aldrete score reached ≥ 9. For postoperative analgesia, patients routinely received 3 $\times$ 1 g of paracetamol and 2 $\times$ 75 mg of diclofenac sodium, in addition to patient-controlled epidural or intravenous analgesia.

Data collected included the amount of crystalloid used during the perioperative period, the volume of bleeding, the num-

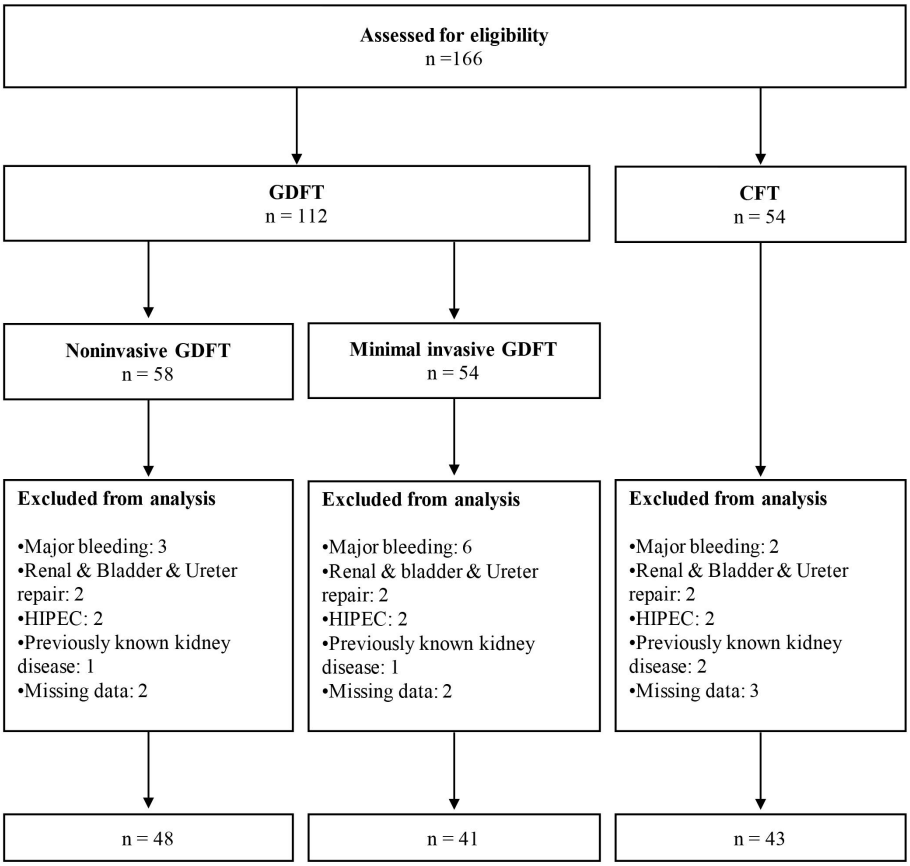


FIGURE 1. Flow chart of patient management. GDFT: goal-directed fluid management; CFT: conventional fluid therapy; HIPEC: hyperthermic intraperitoneal chemotherapy.

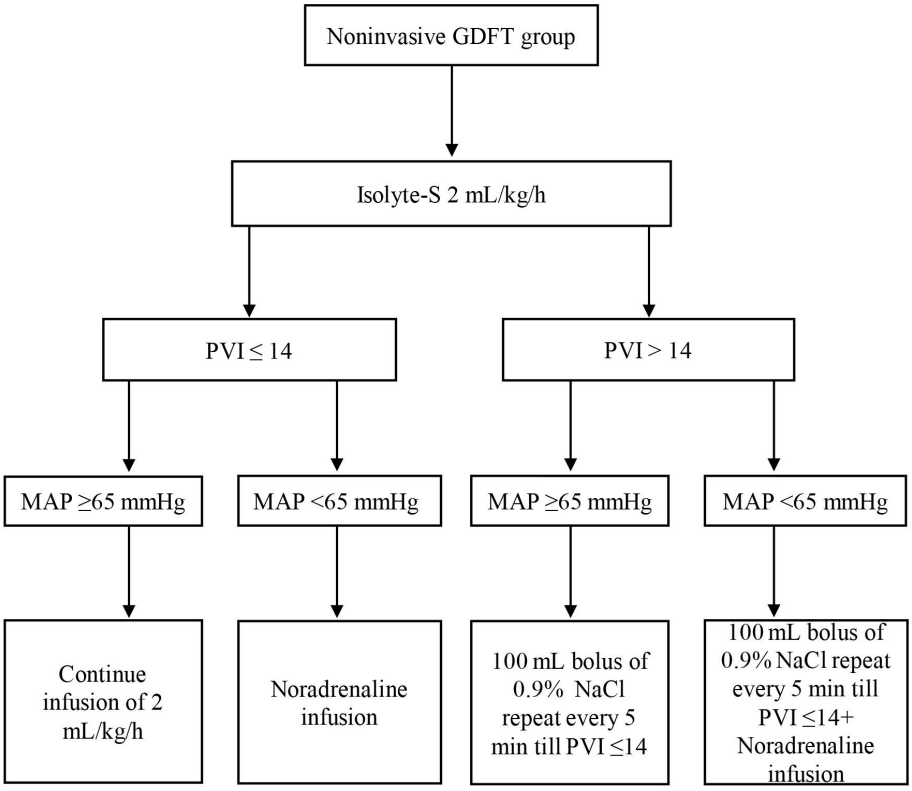
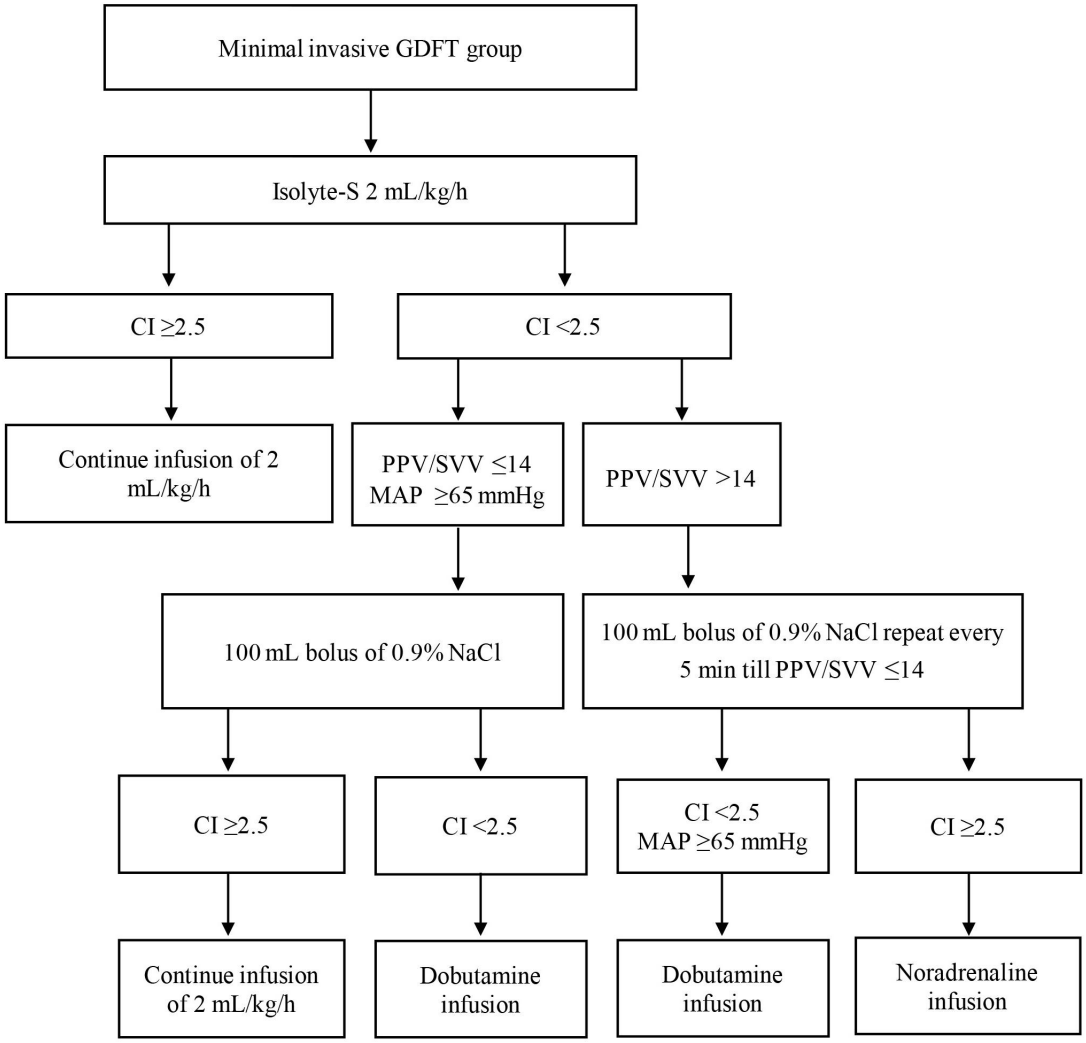


FIGURE 2. Noninvasive GDFT group fluid management. GDFT: goal-directed fluid management; PVI: Pleth Variability Index; MAP: mean arterial pressure; Isolyte-S: Isolyte solution.



F I G U R E 3. Minimally invasive GDFT group fluid management. GDFT: goal-directed fluid management; CI: cardiac index; PPV: pulse pressure variation; SVV: stroke volume variation; MAP: mean arterial pressure; Isolyte-S: Isolyte solution.

ber of patients requiring blood and blood product transfusions, urine output, presence of acidity and use of vasopressors or inotropes. Additionally, information on the duration of the operation, demographic characteristics (age, body mass index (BMI), comorbidities), ASA scores, postoperative intensive care needs, length of hospitalization, and the presence of infectious complications (wound site infection, urinary tract infection, pneumonia) was recorded. Renal complications, such as AKI, as well as gastrointestinal complications (*e.g.*, anastomotic leakage), were also documented.

Renal function was evaluated by comparing preoperative and postoperative day 1 levels of urea, creatinine, glomerular filtration rate (GFR), hemoglobin (Hb), hematocrit (Hct) and lactate. AKI was assessed according to the Acute Kidney Injury Network (AKIN) classification, which defines AKI based on blood urea nitrogen (BUN), serum creatinine levels and urine output [9, 10]. The severity of postoperative complications was assessed using the Clavien-Dindo classification, which categorizes complications into five grades, where Grade 1 refers to non-surgical interventions such as endoscopic or radiological imaging, and Grade 5 represents death [11].

2.4 Statistical analyses

Statistical analyses were performed using Number Cruncher Statistical System (NCSS) 11 (450MHz Alliance, Kaysville, Utah, 2017). Frequency and percentage values were reported for categorical variables. For continuous variables, the mean ± standard deviation or median (interquartile range (IQR)) was presented, as appropriate. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test.

Chi-square analysis was employed to examine the relationships between categorical variables. When necessary, Fisher's exact test or Fisher-Freeman-Halton test was used. For continuous variables with normal distribution, an independent sample *t*-test was used to compare two groups. One-way analysis of variance (ANOVA) was used for comparing three groups of normally distributed continuous variables. For continuous variables that did not meet the assumption of normal distribution, the Mann-Whitney U test was applied to compare two independent groups.

For group comparisons of normally distributed variables, ANOVA with *post hoc* Bonferroni correction was applied, while for non-normally distributed variables, the Kruskal-Wallis H test with *post hoc* Dunn's correction was used.

Chi-square and Fisher exact tests were also employed for the intergroup comparison of categorical variables. A p-value of < 0.05 was considered statistically significant.

3. Results

Of the 164 patients initially assessed, 34 were excluded due to preoperative use of antihypertensive drugs Angiotensin converting enzyme (ACE) inhibitors or antidiabetic drugs (metformin), an estimated glomerular filtration rate (eGFR) <15 mL/min/1.73 m^2, major bleeding (>1000 mL), tumor invasion requiring repair of the kidney, bladder or ureter, administration of hyperthermic intraperitoneal chemotherapy (HIPEC), a history of renal disease, or missing data, leading to a final cohort of 130 patients for data analysis. All the included patients underwent laparotomy via a longitudinal incision for suspected malignancy of the cervix, ovary or endometrium. Based on the fluid management strategy employed, the patients were categorized into three groups according to the preference of the anesthesiologist: the noninvasive goal-directed fluid therapy group (NI-GDFT, n = 48) utilizing PVI, the minimally invasive goal-directed fluid therapy group (MI-GDFT, n = 41) employing PRAM, and the conventional fluid therapy group (CFT, n = 43) (Fig. 1).

Data analysis showed that demographic characteristics, including age, BMI and comorbidities, were comparable among the three groups. Cancer type (benign, malignant or borderline) and operative duration did not differ significantly between the assessed groups ($p > 0.05$). However, the MI-GDFT group had a significantly higher proportion of patients classified as ASA III (46.3%) compared to the other groups ($p < 0.05$) (Table 1).

Assessments of intraoperative fluid administration revealed that the mean crystalloid and total fluid volumes were significantly lower in the NI-GDFT (1650 mL) and MI-GDFT (1500 mL) groups compared to the CFT group (4000 mL) ($p < 0.05$). Similarly, the median colloid volume was reduced in the NI-GDFT and MI-GDFT groups. The amount of intraoperative blood loss, the proportion of patients requiring blood transfusion, and urine output were comparable across all groups. However, intraoperative vasopressor and inotrope requirements were significantly higher in the NI-GDFT and MI-GDFT groups than in the CFT group ($p < 0.05$) (Table 2).

The preoperative and postoperative day 1 arterial blood gas lactate levels and laboratory parameters are presented in Table 3. The results showed that Hb, Hct, urea, creatinine and GFR levels did not differ significantly among the three groups at either time point ($p > 0.05$).

Preoperative lactate values were similar across groups, whereas postoperative day 1 lactate levels were significantly higher in the CFT group than in the NI-GDFT and MI-GDFT groups ($p < 0.05$) (Table 3).

The postoperative morbidity differed significantly between the groups. We found that complications occurred in four patients (8.3%) in the NI-GDFT group, three patients (7.3%) in the MI-GDFT group and 16 patients (37.2%) in the CFT group ($p < 0.05$). The incidence of postoperative grade 1 AKI, as defined by the AKIN classification, was 4.2% in the NI-GDFT group, 4.9% in the MI-GDFT group and 25.6% in the

TABLE 1. Demographic data, ASA scores, cancer types and operation times of the patients.

Variables	Group NI-GDFT (n = 48)	Group MI-GDFT (n = 41)	Group CFT (n = 43)	p
Age (yr)	55.8 ± 12.1	59.1 ± 11.6	53.1 ± 13.4	0.09
BMI, kg/m^2	29.8 ± 6.3	31.3 ± 7.5	31.4 ± 6.9	0.40
ASA				
II	35 (72.9)	22 (53.7)	37 (86.0)	0.04*
III	13 (27.1)	19 (46.3)	6 (14.0)	
Comorbidity				
No	32	11	27	
Cardiac	12	25	14	
Respiratory	4	5	2	0.11
Endocrine	10	14	7	
Others	0	3	0	
Cancer type				
Benign	12 (25.0)	7 (17.1)	11 (25.6)	
Malign	33 (68.8)	33 (80.5)	30 (69.8)	0.80
Borderline	3 (6.3)	1 (2.4)	2 (4.7)	
Operation time (min)	170 (150–240)	200 (150–245)	225 (187–285)	0.06

*$p < 0.05$. *Categorical variables are presented as numbers (%). Continuous variables are expressed as mean ± standard deviation (SD), number of patients (proportion) or median (interquartile range, IQR), as appropriate.*
Abbreviations: BMI: body mass index; ASA: American Society of Anesthesiologists; NI-GDFT: noninvasive goal-directed fluid therapy; MI-GDFT: minimally invasive goal-directed fluid therapy; CFT: conventional fluid therapy.

TABLE 2. Intraoperative fluid administration, blood loss, transfusion requirements, urine output, presence of ascites and use of vasopressors and inotropes.

Variables	Group NI-GDFT (n = 48)	Group MI-GDFT (n = 41)	Group CFT (n = 43)	*p*
Amount of crystalloid (mL)	1650 (1200–2200)	1500 (1200–2500)	4000 (3200–4600)	<0.001*
Amount of colloid (mL)	0 (0–0)	0 (0–0)	0 (0–500)	<0.001*
Total amount of fluid (mL)	1650 (1200–2200)	1500 (1200–2500)	4000 (3200–4600)	<0.001*
Amount of bleeding (mL)	200 (100–250)	200 (100–450)	150 (100–600)	0.190
Total number of patients transfused with blood and/or blood products	6 (12.5)	9 (21.9)	13 (30.2)	0.110
Intraoperative urine (mL)	250 (150–500)	300 (150–425)	300 (200–500)	0.900
Presence of intra-abdominal acid fluid discharge, n (%)	7 (14.6)	7 (17.1)	3 (6.9)	0.200
Vasopressor and inotropes, n (%)	7 (14.6)	23 (56.1)	6 (13.9)	<0.001*

**p < 0.05. Data are expressed as the number of patients (proportion) or median (interquartile range, IQR). NI-GDFT: noninvasive goal-directed fluid therapy; MI-GDFT: minimally invasive goal-directed fluid therapy; CFT: conventional fluid therapy.*

TABLE 3. Preoperative and postoperative day 1 blood gas and laboratory values.

Variables	Group NI-GDFT (n = 48)	Group MI-GDFT (n = 41)	Group CFT (n = 43)	*p*
Hemoglobin (g/dL)				
Preoperative	12.2 (11.3–13.5)	11.9 ± 1.5	11.9 (9.7–13.4)	0.3
Postoperative day 1	10.5 ± 1.07	10.2 ± 1.1	10.1 ± 1.6	0.3
Hemotocrit (%)				
Preoperative	37.1 ± 4.5	36.4 ± 4.4	37.1 (31.6–40.4)	0.6
Postoperative day 1	31.4 ± 2.9	31.2 ± 3.0	30.8 ± 4.5	0.6
Urea (mg/dL)				
Preoperative	24.4 (20.5–35)	31.4 (24–38.5)	27.1 (23.1–39.5)	0.3
Postoperative day 1	20.5 (15–27)	22.5 (17.1–30.5)	22.9 (14.7–27.8)	0.4
Creatinine (mg/dL)				
Preoperative	0.7 ± 0.1	0.7 (0.5–0.8)	0.7 (0.6–0.8)	0.5
Postoperative day 1	0.9 (0.5–0.8)	0.7 (0.6–0.8)	0.7 (0.6–0.9)	0.3
GFR				
Preoperative	90.1 ± 17.7	89 (68.5–101)	91.5 ± 23.5	0.2
Postoperative day 1	90.8 ± 20	85.3 ± 21.7	94 (72–113)	0.5
Lactate (mmol/L)				
Preoperative	0.8 ± 0.3	0.7 (0.5–1)	0.9 (0.5–1.2)	0.4
Postoperative day 1	1 (0.7–1.2)	0.8 (0.6–1)	1.3 (1–1.8)	<0.001*

**p < 0.05. Categorical variables are presented as numbers (%). Numerical variables that do not follow a normal distribution are expressed as median (interquartile range, IQR). NI-GDFT: noninvasive goal-directed fluid therapy; MI-GDFT: minimally invasive goal-directed fluid therapy; CFT: conventional fluid therapy; GFR: glomerular filtration rate.*

CFT group, with a significantly higher incidence observed in the CFT group ($p < 0.05$). The frequency of infectious and gastrointestinal complications did not differ among the groups. According to the Clavien-Dindo classification, complications were graded as follows: in the NI-GDFT group, two patients had grade 1 complications and two had grade 2; in the MI-GDFT group, 66.6% had grade 1 complications and 33.3% had grade 2; and in the CFT group, five patients (38.4%) had grade 1, six (46.1%) had grade 2 and two (15.3%) had grade 3 complications. However, the hospital length of stay and intensive care unit admission rates were comparable among the three groups ($p > 0.05$) (Table 4).

4. Discussion

The findings of this study indicate that patients who received conventional fluid therapy during major gynecologic-

TABLE 4. Postoperative complications, length of hospitalization and intensive care unit stay.

Variables	Group NI-GDFT (n = 48)	Group MI-GDFT (n = 41)	Group CFT (n = 43)	*p*
Number of patients with at least one complication	4 (8.3)	3 (7.3)	16 (37.2)	0.020*
Renal complications				
AKIN 1	2 (4.2)	2 (4.9)	11 (25.6)	0.013*
Infections-related complications				
Wound site infection	1 (2.1)	0	1	0.900
Urinary tract infection	1	1	0	0.400
Pneumonia	0	0	2 (4.7)	0.120
Gastrointestinal complications				
Anastomotic leakage	0	0	2 (4.7)	0.120
Length of hospital stay (d)	6 (4–8)	6 (5–8)	6 (5–8)	0.800
Intensive care admission n (%)	8 (16.7)	9 (22)	13 (30.2)	0.300

**p < 0.05. Categorical variables are presented as numbers (%). Numerical variables that do not follow a normal distribution are expressed as median (interquartile range, IQR). NI-GDFT: noninvasive goal-directed fluid therapy; MI-GDFT: minimally invasive goal-directed fluid therapy; CFT: conventional fluid therapy; AKIN: Acute Kidney Injury Network.*

oncologic surgeries had a higher incidence of grade 1 AKI, classified using the AKIN criteria. This outcome highlights the importance of perioperative fluid management, which is a key component of enhanced recovery after surgery (ERAS) protocols in major abdominal procedures [12]. Since AKI is a leading cause of increased postoperative mortality and prolonged hospitalization [13, 14], early identification of its underlying cause is essential to enable timely intervention and potential reversibility. In the group with a higher incidence of grade 1 AKI, the intraoperative fluid volume administered was 4000 mL, nearly three times the amount given to patients in the other groups, suggesting that excessive fluid resuscitation may have contributed to renal dysfunction.

Effective fluid resuscitation aims to optimize left ventricular end-diastolic volume and stroke volume to maintain adequate tissue perfusion. However, renal function is particularly sensitive to acute fluctuations in volume status, with both hypovolemia and hypervolemia posing risks of renal injury [3, 15]. While hypovolemia can lead to inadequate organ perfusion, hypervolemia may cause tissue edema, impairing microcirculation and reducing oxygen delivery. This paradoxical effect of fluid overload has been linked to increased morbidity, prolonged intensive care unit (ICU) stays, and higher mortality rates [16]. Conversely, excessive fluid restriction may also increase the risk of postoperative kidney injury, further complicating perioperative management [17]. Therefore, maintaining normovolemia and euvolemia throughout the perioperative period is critical.

Intraoperative fluid management in major abdominal surgeries is highly complex, as fluid requirements vary depending on the extent of the surgical field, intraoperative blood loss, surgical complications and individual patient factors [18]. The severity of the surgical stress response, the underlying surgical pathology, and the patient's overall medical condition all determine the optimal fluid volume. Previous studies evaluating perioperative fluid administration have shown that both restrictive (<900 mL; 500–1191 mL) and liberal (>2700 mL; 3216–7932 mL) fluid regimens are associated with unfavorable postoperative outcomes, underscoring the need for an individualized, balanced approach [17, 19].

In this study, patients in the noninvasive and minimally invasive GDFT groups received median intraoperative fluid volumes of 1650 mL (1100–2275 mL) and 1500 mL (1200–2500 mL), respectively. For minimally or moderately invasive procedures, 1–2 L of a balanced electrolyte solution is typically administered, whereas major invasive surgeries often require a more restrictive or goal-directed fluid management strategy. Given the high morbidity and mortality associated with gynecologic cancer surgeries, precise intraoperative fluid management is particularly important, as excessive bleeding can complicate hemodynamic stability [20]. To address these challenges, invasive, minimally invasive, and noninvasive dynamic monitoring methods can be employed to guide fluid administration. A meta-analysis of 32 studies demonstrated that GDFT provides the greatest benefit in procedures with high surgical mortality, yet its advantages in gynecologic-oncologic surgeries remain unclear [21]. In this study, the CFT group, which received the largest volume of fluid, had a higher incidence of pneumonia and anastomotic leakage, likely due to excessive volume administration and associated renal complications. These findings align with previous evidence suggesting that fluid overload may contribute to increased postoperative morbidity. Thus, achieving an optimal balance between adequate perfusion and fluid restriction remains essential to improving postoperative outcomes.

AKI can be readily diagnosed in hospitalized patients based on an increase in serum creatinine levels and/or a decrease in urine output. Although several biomarkers are being investigated for early detection of renal dysfunction, serum creatinine remains the primary laboratory marker used in the official definition of AKI and is the most widely utilized biomarker in clinical practice. Once AKI is diagnosed, further assessments are necessary to determine its underlying cause [13, 19]. In this study, the incidence of AKI was significantly higher in

the CFT group compared to the other groups ($p = 0.013$). A previous study evaluating five fluid management strategies in non-cardiac surgeries demonstrated that the incidence of postoperative AKI increased in both the excessively restrictive (<900 mL) and excessively liberal (>2700 mL) fluid therapy groups [17]. Similarly, Yu J *et al.* [8] reported that goal-directed fluid therapy based on stroke volume changes reduced postoperative complications in gynecologic cancer surgeries; however, no significant difference in AKI incidence was observed between the goal-directed and conventional fluid therapy groups. Another study also found no association between GDFT and postoperative AKI [22]. Nevertheless, evidence suggests that early administration of vasopressors and inotropes as part of a goal-directed fluid therapy approach may reduce the risk of postoperative AKI by preventing both fluid overload and hypotension [9, 23]. Our findings support this hypothesis, as the earlier initiation of vasopressor and inotropic support in the GDFT groups may have facilitated optimal hemodynamic stability while minimizing excessive fluid administration.

Hypovolemia or hypervolemia that disrupts end-organ perfusion triggers anaerobic metabolism, leading to the production of lactic acid. Serum lactate levels serve as a marker of anaerobic metabolism and indicate tissue hypoxia, often increasing in response to latent hypoperfusion [23]. Previous studies in gynecologic oncology surgeries have demonstrated that a GDFT strategy using noninvasive hemodynamic monitoring is associated with lower postoperative lactate levels and fewer complications compared to liberal fluid therapy [24]. In particular, hypervolemia can impair tissue perfusion by promoting interstitial edema, ultimately resulting in organ dysfunction [25]. Consistent with these findings, our study demonstrated significantly higher postoperative day 1 lactate values in the CFT group, which received a considerably larger volume of fluid than the other two groups. Despite similar operative durations across all groups (170–225 min), the administration of 4000 mL of fluid in the CFT group likely contributed to renal perfusion impairment. These findings suggest that GDFT may protect organs vulnerable to perioperative hypoperfusion and contribute to improved morbidity and mortality outcomes [7, 8]. Given the dynamic nature of tissue perfusion requirements during high-risk surgeries, GDFT strategies remain the preferred approach [26].

Although this study provides valuable insights into fluid management in major gynecologic-oncologic surgeries, this study had several limitations. First, its retrospective design restricts the ability to establish causal relationships. Second, because serum creatinine was measured only at 24 hours postoperatively, AKI incidence may have been underestimated, as longer-term renal function changes were not assessed. Third, the lack of postoperative urine output monitoring and albumin level measurements, due to unavailable laboratory data, limits a comprehensive evaluation of fluid balance and renal function. Lastly, since the study was conducted at a single center and included only patients undergoing open surgery, the findings may not be generalizable to those undergoing laparoscopic procedures or broader patient populations.

5. Conclusions

AKI remains a significant contributor to postoperative morbidity and mortality. While various fluid management strategies are employed, their effects on early and long-term postoperative renal outcomes remain uncertain. In this study, patients who received GDFT had a lower incidence of AKI; however, further research is necessary to identify optimal strategies for preventing and minimizing the risk of AKI in surgical patients.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

DA, NA, NAV and FGÖ—designed the study. DA, NA, NAV, ASB, NSE and FGÖ—conducted the research. DA, NAV and ASB—analyzed the data. DA, ASB, NSE and FGÖ—drafted the manuscript. All authors contributed to revisions and approved the final version.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Basaksehir Cam and Sakura City Hospital (protocol no: 2023-478, date: 11 October 2023). Since the study was retrospective, the requirement for informed consent was waived by the ethics committee.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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