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Evaluation of the effect of fluid management on intracranial pressure in patients undergoing laparoscopic gynaecological surgery based on the ratio of the optic nerve sheath diameter to the eyeball transverse diameter as measured by ultrasound: a randomised controlled trial

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Abstract

Background During gynecological laparoscopic surgery, pneumoperitoneum and the Trendelenburg position (TP) can lead to increased intracranial pressure (ICP). However, it remains unclear whether perioperative fluid therapy impacts ICP. The purpose of this research was to evaluate the impact of restrictive fluid (RF) therapy versus conventional fluid (CF) therapy on ICP in gynecological laparoscopic surgery patients by measuring the ratio of the optic nerve sheath diameter (ONSD) to the eyeball transverse diameter (ETD) using ultrasound.

Methods Sixty-four patients who were scheduled for laparoscopic gynecological surgery were randomly assigned to the CF group or the RF group. The main outcomes were differences in the ONSD/ETD ratios between the groups at predetermined time points. The secondary outcomes were intraoperative circulatory parameters (including mean arterial pressure, heart rate, and urine volume changes) and postoperative recovery indicators (including extubation time, length of post-anaesthesia care unit stay, postoperative complications, and length of hospital stay).

Results There were no statistically significant differences in the ONSD/ETD ratio and the ONSD over time between the two groups (all $p > 0.05$). From T2 to T4, the ONSD/ETD ratio and the ONSD in both groups were higher than T1 (all $p < 0.001$). From T1 to T2, the ONSD/ETD ratio in both groups increased by 14.3%. However, the extubation time in the

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RF group was shorter than in the CF group [median difference (95% CI) -11(-21 to -2) min, $p=0.027$]. There were no differences in the other secondary outcomes.

Conclusion In patients undergoing laparoscopic gynecological surgery, RF did not significantly lower the ONSD/ETD ratio but did shorten the tracheal extubation time, when compared to CF.

Trial registration ChiCTR2300079284. Registered on December 29, 2023.

Keywords Optic nerve sheath diameter, Eyeball transverse diameter, Laparoscopic, Gynecology, Intracranial pressure, Fluid strategy

Background

Laparoscopic surgery has become the first choice for most gynecological surgeries due to its various advantages, including less trauma, rapid healing, and fewer postoperative complications [1]. However, during laparoscopic gynecological surgeries, the Trendelenburg position (TP) and carbon dioxide(CO2) pneumoperitoneum are often required, which can increase the patient's intracranial pressure (ICP) [2]. Intracranial persistent hypertension may result in severe neurological complications [3]. Some studies demonstrate that ICP is related to internal jugular vein function, end-tidal carbon dioxide (ETCO2), anesthetic drugs, pneumoperitoneum pressure, and other factors [4–7]. Some preventive measures have achieved clinical results but changes in ICP cannot be entirely avoided. Therefore, other influencing factors warrant exploration.

In recent years, ultrasound real-time monitoring of the optic nerve sheath diameter (ONSD) has been recognised as a reliable evaluation method to judge ICP [8]. However, due to substantial errors in its measurement, its clinical application is limited [9]. Some studies have found that the ONSD is closely related to the eyeball transverse diameter (ETD) [10]. It has also been shown that the standard deviation of the ONSD/ETD index is smaller and more accurate than the ONSD measurement [11]. Therefore, the ratio of the ONSD to the ETD is considered to be a more appropriate indicator for evaluating increases in ICP.

The increase of ICP and cerebral edema caused by gynecological laparoscopic surgery are mainly caused by the increase of cerebral hydrostatic pressure [12], and therefore reasonable fluid management plays an important role. If perioperative hemodynamics can be achieved, the probability of a delayed recovery of brain function and mortality will be reduced [13, 14]. Anaesthesiologists usually administer an adequate quantity of fluids during surgery to correct preoperative fasting and other fluid deficiencies, anaesthesia-induced vasodilation, bleeding, and extravascular space effusion [15]. However, active or free fluid resuscitation strategies can lead to complications such as pneumonia and prolonged hospital stays [16]. Restrictive fluid management as part of rapid surgical rehabilitation has been shown to promote early recovery and reduce postoperative complications in patients undergoing major surgery [17]. In addition, restrictive fluid (RF) management can improve the prognosis of patients with traumatic brain injury [18]. However, it is not clear whether the fluid infusion strategy will affect ICP during surgery.

We hypothesized that RF management would delay increases in ICP. To test our hypothesis, we compared differences in the ONSD/ETD ratios between RF and conventional fluid (CF) management in patients undergoing laparoscopic gynaecological surgery. Circulatory indicators such as mean arterial pressure (MAP), urine volume, and heart rate (HR) have been the focus of attention in liquid management research, where MAP is closely related to ICP [19]. In addition, recovery indicators such as extubation time, length of post-anaesthesia care unit (PACU) stay, postoperative complications, and length of hospital stay are important indicators to evaluate general anesthesia and postoperative recovery. Therefore, the key secondary outcomes in this study included intraoperative circulatory parameters and postoperative recovery indicators.

Methods

Study design

This prospective, single-centre, randomised, controlled clinical trial was meticulously reviewed and granted approval by the Institutional Ethics Committee of the Affiliated Yongchuan Hospital of Chongqing Medical University (NO.2023LLS037). This trial was registered with the Chinese Clinical Trial Registration Centre prior to the enrolment of patients (ChiCTR2300079284). Patients were recruited from January 3rd, 2024 to March 20th, 2024. Patients were included in the study after obtaining written informed consent. This manuscript strictly follows the applicable CONSORT guidelines [20].

Inclusion criteria: (1) female patients undergoing elective laparoscopic gynaecologic surgery, (2) patients aged 19–70 years, (3) estimated operation time > 1 h, and (4) American Society of Anaesthesiologists (ASA) grade I–II. Exclusion criteria: (1) patients with liver or kidney dysfunction or severe cardiopulmonary disease, (2) patients with pre-existing ophthalmic or neurological disease, (3) patients with a history of ophthalmic surgery

or neurosurgery [21], (4) body weight (BW) > 150% of the ideal body weight (IBW), (5) patients receiving drugs that may affect intraocular pressure, (6) patients where the boundary of the optic nerve sheath and the boundary of the transverse diameter of the eyeball cannot be clearly visualized during ultrasound measurement, (7) patients with subcutaneous emphysema during the operation, and (8) patients who refused to participate.

Patients were randomly assigned to the RF group or the CF group at a 1:1 ratio using a computer-generated randomisation table. Randomly generated study numbers were concealed in black opaque envelopes. The anaesthetist opened each envelope before anaesthesia was administered to determine the patient's assigned group. The anaesthesiologist was not blinded to group allocations because they were responsible for the interventions. The surveyors and the surgical team could not be completely blinded. Blinded researchers performed statistical analyses and evaluated the results. Both the patients and outcome assessors were blinded to the allocation status of the study participants.

Management of general anaesthesia and analgesia

All patients underwent standardised anaesthesia procedures according to institutional protocols. Patients were fasted for at least 8 h and were not allowed to drink water for at least 2 h before anaesthesia. Before the induction of anaesthesia, the patients were not given any sedatives, fluid infusions, or analgesic medications. A peripheral infusion pipeline was established after entering the operating room. A multifunctional monitor (model: Benvision N12, China, Shenzhen Mindray Biomedical Electronics Co., Ltd) was utilised for continuous monitoring of MAP, HR, and oxygen saturation (SpO_2). For bispectral index (BIS) monitoring, a disposable BIS sensor (SWT-S002; China, Chengdu Sweet Medical Device Co., Ltd) was affixed to the patient's forehead after thoroughly cleaning the skin with alcohol swabs. For regional cerebral oxygen saturation (rSO2) monitoring, a near-infrared spectrum sensor (MNIR-P100, China, Chongqing Mingxi Medical Device Co., Ltd) was applied to the right side of the patient's forehead.

Anaesthetic management was executed in the following manner. Midazolam 0.03 mg·kg−1, Sufentanil 0.4 μg·kg−1, Etomidate 0.2 mg·kg−1, and Rocuronium 0.6 mg·kg−1 were used for anaesthesia induction. After endotracheal intubation was performed, all patients were provided with volume-controlled mechanical ventilation at a tidal volume of 8–10 mL·kg−1 and an inhalation-to-exhalation ratio of 1:2. The respiratory parameters were adjusted to maintain an ETCO2 value between 35 and 45 mmHg. Positive end-expiratory pressure (PEEP) was not given to all patients. Subsequently, a 20-gauge radial artery catheter was inserted, and a pressure sensor (model FT-A001, manufactured by Guangdong Baihe Medical Technology Co., Ltd., located in China) was employed to monitor the arterial blood gas level and arterial blood pressure. Combined intravenous inhalation anesthesia was administered and maintained with propofol (1–4 mg·kg-1·h-1), sufentanil (0.3–0.5 μg·kg−1·h−1), and inhaled sevoflurane (1–2%) in 2 L of 50% oxygen/air mixtures. BIS values were used to monitor the depth of anesthesia and were maintained between 40 and 60. Patients were treated with 12 mmHg pneumoperitoneum pressure and 30°TP. A temperature probe was placed into the nasopharynx through the nose, and temperature was maintained above 36℃ using an inflatable heating device (wu-505, China, Jiangmen Dacheng Medical Instruments Co., Ltd). Sufentanil and Propofol were discontinued before skin suturing commenced, and Sevoflurane was discontinued after the operation was completed. Patients were sent to the PACU after surgery. Patients with Steward resuscitation scores above four were returned to the ward [22]. Patient-controlled intravenous analgesia (PCIA) pumps were used in both groups after the procedure, with a drug formulation of 2 μg/kg Sufentanil (not more than 200 ug) diluted with normal saline to 100 mL. The background dose was 2 mL/h, the PCIA dose was 0.5 mL, the locking time was 15 min, and the maximum dose was 4 mL per hour [23].

Intraoperative fluid and haemodynamic management

Patients in both groups were maintained with Ringer's solution (Gyzz H50021207, 500 ml, Southwest Pharmaceutical Co., Ltd) throughout the operation period. The RF group was given a 5 mL/kg infusion during anaesthesia induction (from the beginning of anaesthesia induction until skin incision) [24] and then maintained at 5 mL/kg/h until the end of surgery. The CF group was given a 10 mL/kg infusion during anaesthesia induction and then maintained at 8 mL/kg/h until the end of surgery. The fluid regimen was selected according to previous studies [25]. This study only evaluated intraoperative fluid infusion. PACU and postoperative fluid were not studied or analysed.

Blood pressure remained within ±20% of the awake value, and systolic blood pressure remained above 90 mmHg. Hypotension was corrected with dopamine and/or ephedrine/phenylephrine. If the HR was below 50 beats/minute, atropine was administered in a dose of 0.5 mg. Blood transfusions were started when haemoglobin levels were below 70 g.L-1.

Optic nerve sheath diameter and eyeball transverse diameter measurement

Ultrasound (SonoScape E2, CHINA) was used for ONSD measurements. A transparent disposable patch was used to protect the patient's eye after anaesthesia induction.

An ultrasonic coupling agent was evenly applied to the ultrasonic probe. The 6–15 hz high-frequency ultrasound probe was gently placed laterally above the eyeball without pressure. The hypoechoic region of the vertical eyeball was visualized after adjusting the probe angle. The ONSD was measured at 3 mm behind the optic papilla. To improve the accuracy of ultrasonic detection and control for differences between researchers, the ONSD measurement was carried out according to a closed standard procedure [26]. Images of the left and right eyes were captured separately on three occasions at a single time point. The maximum ETD [27] in the visual field was measured at the ONSD measurement section at the same time (Fig. 1). The accuracy of the ONSD and ETD measurements was 0.01 mm. The ONSD and ETD was measured 10 min after induction of anaesthesia in the supine position (T1), 10 min after CO2 pneumoperitoneum in the TP (T2), 60 min after CO2 pneumoperitoneum in the TP (T3), and 10 min after close of the pneumoperitoneum in the supine position (T4).

Outcome measures

The primary outcomes were the differences in the ONSD/ETD ratio between the groups at predetermined time points. The key secondary outcomes included intraoperative circulatory parameters and postoperative recovery indicators. Intraoperative circulatory parameters included MAP, HR, and urine volume changes. Postoperative recovery indicators included time to extubation, length of PACU stay, postoperative complications, and length of hospital stay.

The MAP, HR, rSO2, ETCO2, peak inspiratory pressure (Ppeak) and BIS at T1, T2, T3, and T4 were recorded. The arterial partial pressures of carbon dioxide ($PaCO_2$) and lactic acid (Lac) were measured at T1, T3, and T4 using a blood gas analyser (GEM Premier5000, America, Instrumentation Laboratory) [28]. The amount of bleeding, total intraoperative fluid volume, vasoactive drugs, and urine volume were documented at the end of the operation. Bulbar conjunctival oedema immediately after surgery, extubation time, operation time, anaesthesia time, pneumoperitoneum time, length of hospital stay, and length of PACU stay were recorded. Postoperative complications such as PONV, headache, and dizziness were recorded (during 12 h of follow-up). The length of hospital stay was determined as the time from the day of surgery to the day of discharge.

Sample size and statistical analyses

The sample size of the clinical trial was calculated using the non-inferiority test for differences between the average values of two independent samples. According to pre-experimental results, the standard deviation of the conventional infusion group was 0.5 mm, and the standard deviation of the restrictive infusion group was 0.6 mm. Based on a previous study [29], using 0.5 mm as the non-inferiority value and assuming a test level $a=0.025$ (one side) and $\beta=0.1$, according to PASS (version 15.0.3, NCSS, LLC, Kaysville, UT, USA), 27 subjects were needed in each group. Assuming a loss to follow-up rate of 15%, a total of 64 subjects were required in the two groups.

Statistical analyses were conducted using the SPSS software version 27.0 (IBM Corp., Armonk, N.Y., USA). Normally distributed data are expressed as the mean±standard deviation, whereas non-normal distributions are presented as the median (interquartile range IQR). Categorical variables are denoted by numbers (proportion). The Kolmogorov-Smirnov test and the Levene test were used to evaluate the normality and homogeneity

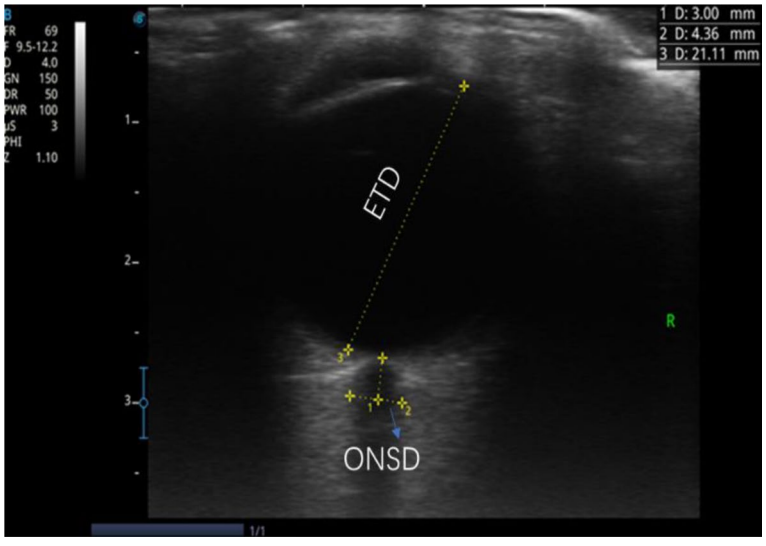

Fig. 1 Measurement of the ONSD and the ETD. ONSD: optic nerve sheath diameter; ETD: eyeball transverse diameter

Table 1 Patient characteristics

	Conventional fluid infusion group (*n* = 32)	Restrictive fluid infusion group (*n* = 32)	*P* Value
Age(year)	46 ± 11	50 ± 12	0.280
Height(cm)	157.1 ± 4.2	155.3 ± 4.6	0.099
Weight(kg)	57.7 ± 5.5	58.5 ± 6.8	0.600
Body mass index (BMI) ($kg•m^{-2}$)	23.4 ± 1.9	24.3 ± 2.5	0.114
ASA physical status (n)			
I	19 (0.59)	12 (0.38)	0.080
II	13 (0.41)	20 (0.62)	0.080
Comorbidity (n)			
Hypertension	4 (0.13)	7 (0.22)	0.320
Diabetes mellitus	0 (0)	3 (0.09)	0.238
Anemia	2 (0.06)	5 (0.16)	0.426

Data are presented as the mean ± standard deviation or n (proportion)

of variance of the data, respectively. For data with normal distribution and equal variances, the Student 's t test was performed for comparisons between groups. If the data did not conform to a normal distribution, non-parametric tests were performed. Between-groups analysis of categorical data was performed using the $\chi 2$ test or the Fisher exact test. For the analysis of two groups at multiple time points, repeated measures analysis of variance or generalised estimation equations were used. A *p*-value less than 0.05 was considered statistically significant.

Results

A total of 64 patients were enrolled in this trial and completed the study at the affiliated Yongchuan Hospital, Chongqing Medical University, between January and March 2024. The baseline characteristics of the two groups were comparable (Table 1). The study workflow is shown in Fig. 2.

Changes in the ONSD/ETD ratios and ONSD at different time points for the two groups are shown in Table 2. There were significant increases in the ONSD/ETD ratios in both groups at T2, T3, and T4 when compared to T1 ($P<0.001$). From T1 to T2, the ONSD/ETD ratios of the two groups increased from (0.21 ± 0.02) mm to (0.24 ± 0.02) mm, an increase of 14.3%. In addition, there were significant increases in the ONSD in both groups at T2, T3, and T4 when compared to T1 ($P<0.001$). However, no significant differences in the ONSD/ETD ratios

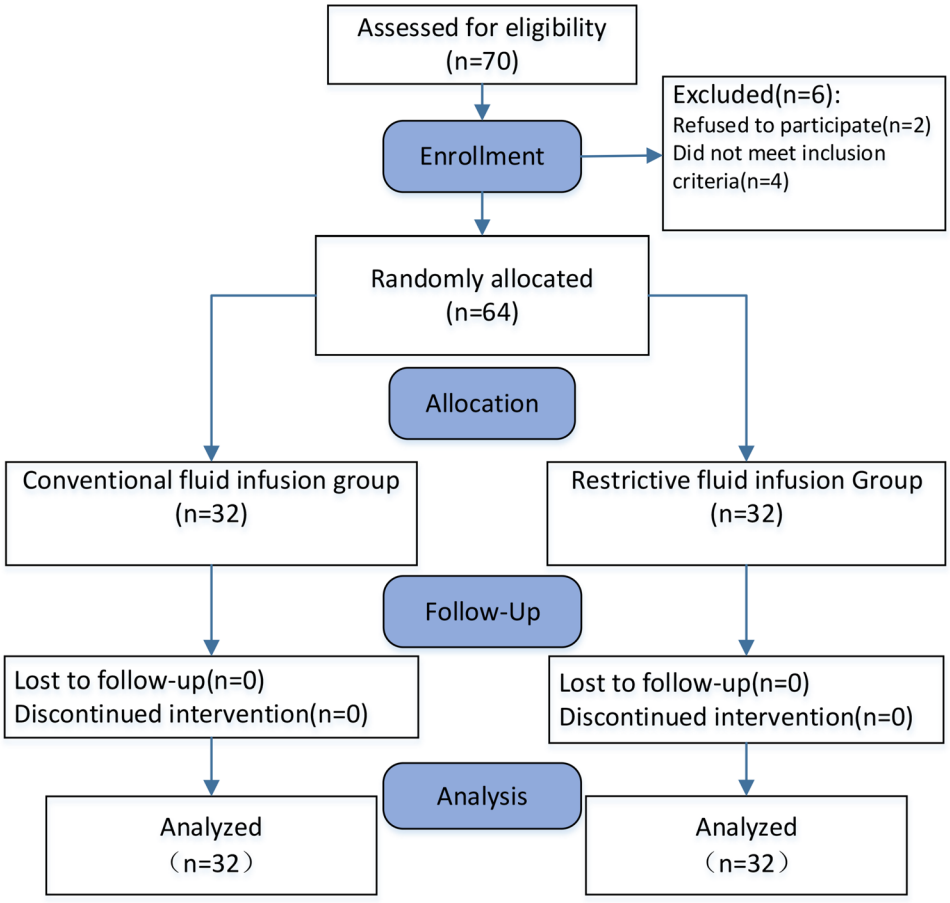

Fig. 2 Study workflow

Table 2 Comparison of the ONSD, ETD, and ONSD/ETD ratio between the two groups

	Group	T1	T2	T3	T4
ONSD	R	4.79 ± 0.46	5.58 ± 0.42[b]	5.69 ± 0.39[b]	5.13 ± 0.42[b]
	C	4.83 ± 0.41	5.68 ± 0.46[b]	5.82 ± 0.42[b]	5.27 ± 0.46[b]
ETD	R	22.97 ± 1.11	22.91 ± 1.00	22.83 ± 1.04	23.04 ± 0.98
	C	23.24 ± 1.13	23.25 ± 1.22	23.25 ± 1.17	23.20 ± 1.13
ONSD/ETD	R	0.21 ± 0.02	0.24 ± 0.02[b]	0.25 ± 0.02[b]	0.22 ± 0.02[b]
	C	0.21 ± 0.02	0.24 ± 0.02[b]	0.25 ± 0.02[b]	0.23 ± 0.02[b]

R restrictive fluid infusion group, C conventional fluid infusion group, ONSD optic nerve sheath diameter, ETD eyeball transverse diameter. [b]$p<0.001$ compared to T1

of the RF and CF groups were seen over time (p_{T1}=0.612, P_{T2}=0.950, P_{T3}=0.829, P_{T4}=0.374). There were also no significant differences in the ONSD of the RF and CF groups over time (P_{T1}=0.718, P_{T2}=0.454, P_{T3}=0.187, P_{T4}=0.213).

Relevant intraoperative parameters are shown in Table 3. The total intraoperative fluid volume of the RF group was lower than the CF group [median difference (95% CI) -504.69(-666.68 to -342.7) mL, $p<0.001$)], but there was no difference in urine volume and the amount of bleeding between the two groups. In addition, Lac was decreased at T3 in both groups when compared to T1 (CF: P=0.033; RF: P=0.015), but no significant difference was seen between the two groups over time. At T2, the MAP was higher in the RF group than at T1 ($p_{T2\ vs.\ T1}<0.001$). From T2 to T4, the MAP was higher in the CF group than at T1 ($P_{T2\ vs.\ T1}<0.001$, $P_{T3\ vs.\ T1}<0.001$, $P_{T4\ vs.\ T1}$=0.02). However, there were no significant differences in the MAP of both groups over time (p_{T1}=0.182, P_{T2}=0.697, P_{T3}=0.064, P_{T4}=0.191) (Fig. 3).

The extubation time of the RF group was shorter than the CF group [median difference (95% CI) -11(-21 to -2) min, p=0.027], but there were no differences in lengths of PACU stay and length of hospital stay between the two groups (Table 3).

For the rSO2, there were no significant differences between the CF group and the RF group over time (P_{T1} = 0.413, P_{T2} = 0.563, P_{T3} = 0.217, P_{T4} = 0.764). In addition, there were no significant differences in $ETCO_2$, Ppeak, and HR between the two groups (Fig. 3).

There were no significant differences in the incidence of bulbar conjunctival oedema, PONV, headache, dizziness, or complications between the two groups (Table 4). The complications of the two groups were as follows: two cases of intermuscular venous thrombosis (improved after anticoagulant therapy) and one case of

Table 3 Intraoperative profiles

	Conventional fluid infusion group n = 32	Restrictive fluid infusion group n = 32	P value	Absolute effect size* (95%CI)
Anaesthesia time (min)	203.5(170.5-233.8)	216.5(171.3–260.0)	0.432	11.5(-15 to 40)
Operation time (min)	141.5(111.3-179.8)	163.5(118.5-212.5)	0.286	16(-13 to 45)
Extubation time (min)	47.5(35.5–59.0)	34.0(20.3–52.3) [a]	0.027	-11(-21 to -2)
Length of PACU stay (min)	75.0(65.0–90.0)	70.0(60.0-82.5)	0.203	-5(-15 to 5)
Pneumoperitoneum time(min)	119.5(93.3-171.5)	138.0(102.8-195.8)	0.327	14(-13 to 43)
Amount of bleeding (ml)	90(50–200)	80(50–100)	0.485	0(-50 to 20)
Length of hospital stay (days)	5.5(5.0-6.8)	6.0(5.0–7.0)	0.225	1(0 to 1)
Total intraoperative fluid volume (ml)	1725.0 ± 337.0	1220.3 ± 310.8[a]	<0.001	-504.69(-666.68 to -342.7)
Patients receiving packed RBCs, n(%)	1 (0.03)	2 (0.06)	1	0.03(-0.13 to 0.19)
Urine volume (ml)	300.0(300.0-400.0)	300.0(200.0-387.5)	0.074	-50(-100 to 0)
PaCO2 (mmHg)				
T1	33.0(31.0-35.8)	34.0 (32.0-36.8)	0.508	1(-1 to 2)
T3	40.0 (38.0–42.0) [b]	41.0 (38.0–43.0) [b]	0.627	1(-2 to 2)
T4	40.0 (37.0-42.8) [b]	39.0 (37.0-44.8) [b]	0.909	0(-2 to 2)
Lac (mmol/L)				
T1	0.8(0.6–0.9)	0.7(0.6-1.0)	0.739	0(-0.1 to 0.1)
T3	0.7 (0.6–0.8) [b]	0.7 (0.6–0.9) [b]	0.583	0(-0.1 to 0.1)
T4	0.7(0.6–0.9)	0.7(0.6–0.9)	0.967	0(-0.1 to 0.1)
Use of narcotic drugs				
Sufentanil (ug)	98(80–100)	97(80–110)	0.698	0(-6 to 13)
Rocuronium (mg)	90.0(80.0-100.0)	90.0(72.5–100.0)	0.722	0(-10 to 10)
Propofol (mg)	400.0(352.5–465.0)	400.0(327.5-487.5)	0.913	0(-50 to 40)
Atropine, n(%)	7 (0.22)	9 (0.28)	0.564	0.06(-0.15 to 0.27)
Vasoactive drugs, n(%)	6 (0.19)	8 (0.25)	0.545	0.06(-0.14 to 0.26)

Data are presented as the mean ± standard deviation or n (proportion) or median (interquartile range IQR). [a]$p<0.05$ compared to the conventional fluid infusion group, [b]$p<0.05$ compared to T1

*indicates mean difference in proportion to median difference between the two groups

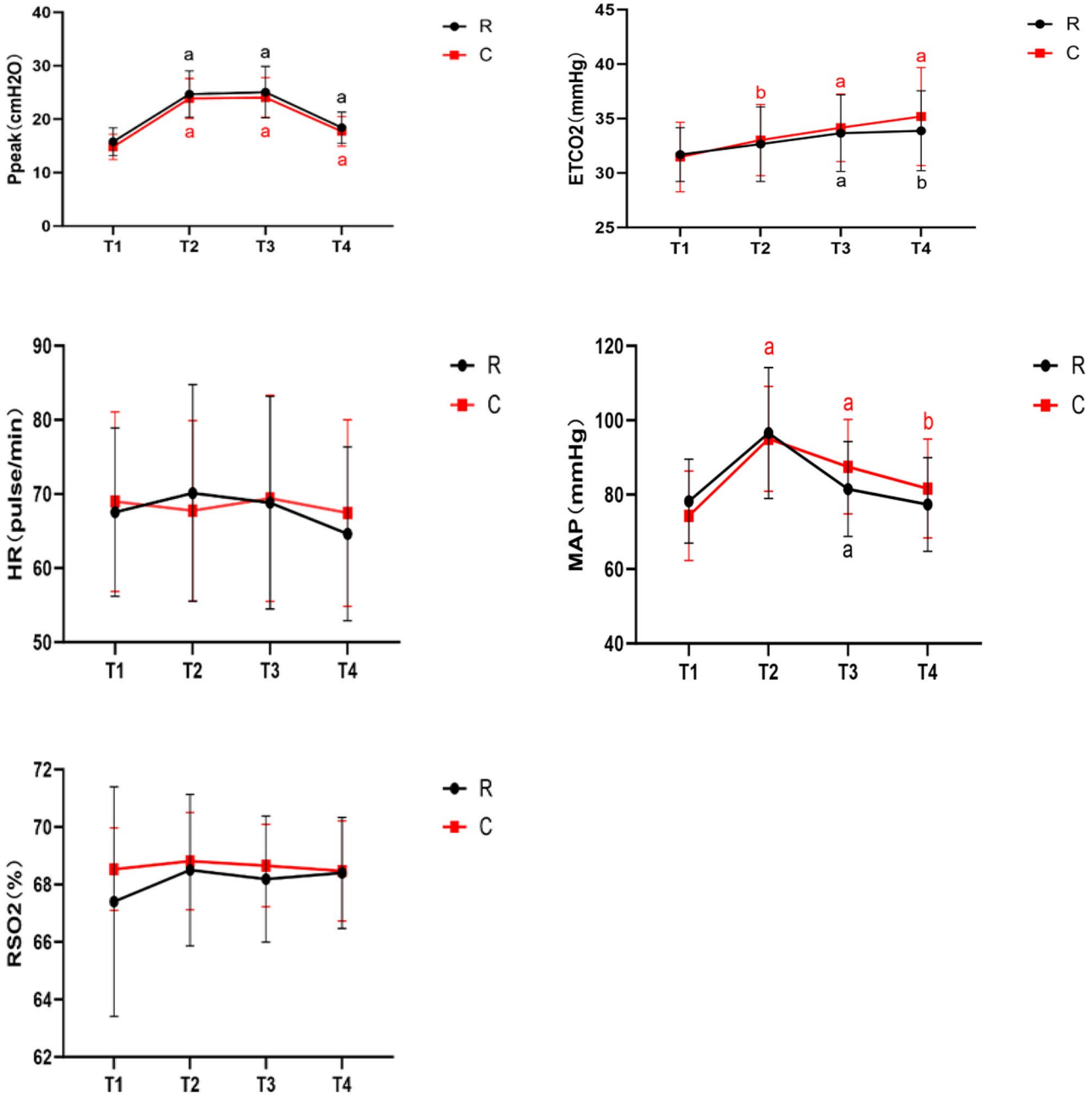

Fig. 3 Red represents the CF group and black represents the RF group; [a]$p<0.001$ compared to T1; [bp]<0.05 compared to T1. R restrictive fluid infusion group, C conventional fluid infusion group, Ppeak peak inspiratory pressure, ETCO2 end-tidal carbon dioxide, HR heart rate, MAP mean arterial pressure, RSO2 regional cerebral oxygen saturation T1: 10 min after induction of anaesthesia in the supine position; T2: 10 min after CO2 pneumoperitoneum in the TP; T3: 60 min after CO2 pneumoperitoneum in the TP; T4: 10 min after close of the pneumoperitoneum in the supine position

postoperative fever (>38 °C) in the RF group; one case of upper respiratory tract infection and two cases of postoperative fever in the CF group. No severe neurological complications were reported in either group during hospitalization.

Discussion

Our study revealed that RF therapy did not further decrease the ONSD/ETD ratio but resulted in an earlier extubation time when compared to CF therapy in patients undergoing laparoscopic gynaecological surgery.

CO_2 pneumoperitoneum and the TP are both risk factors for ICP increases in laparoscopic surgery [2]. Pneumoperitoneum and TP lead to increased intra-abdominal and intra-thoracic pressures, and compression of the

Table 4 Postoperative parameters

	Conventional fluid infusion group (*n* = 32)	Restrictive fluid infusion group (*n* = 32)	*P* value
Bulbar conjunctival oedema (n) mild/moderate	16/5	20/1	0.228
PONV (n)	9 (0.28)	11 (0.34)	0.590
Headache and dizziness (n) complication (n)	2 (0.06)	1 (0.03)	0.613
Thrombotic events (n)	0 (0)	2 (0.06)	0.492
Upper respiratory tract infection (n)	1 (0.03)	0 (0)	1
Postoperative fever (n)	2 (0.06)	1 (0.03)	1

Data are presented as n (proportion)

inferior vena cava leads to increased central venous pressure (CVP), thereby reducing venous drainage of the central nervous system and lumbar plexus and increasing cerebrospinal fluid pressure [12]. In addition, chemical reactions mediated by CO_2 must be considered. CO_2 is a powerful vasoactive factor that can rapidly increase cerebral blood volume and lead to an increase in ICP. The ONSD is reported to increase after acute hypercapnia in awake and spontaneously breathing patients [30]. In the current study, the ONSD was significantly increased after pneumoperitoneum and posture changes, consistent with previous findings [2]. However, unlike previous studies, the ONSD did not return to the baseline range after the end of surgery. This may be due to the effect of Sevoflurane as, in this study, Sevoflurane was discontinued after the operation. A previous study reported that Propofol anaesthesia induced a lower increase in the ONSD than Sevoflurane anaesthesia [31]. This may explain why the ONSD decreased relatively slowly.

The main challenge for the protection of brain function is to effectively balance cerebral blood flow and ICP to prevent hypoxic-ischemic injury [32]. In this process, it is essential to monitor and maintain adequate cerebral perfusion pressure (CPP) [33, 34], which involves precise fluid management. Therefore, management goals are to maintain hemodynamic stability without causing fluid overloads [35]. Goal-directed fluid therapy (GDFT) is effective in maintaining stable haemodynamics, optimising the balance between tissue perfusion and volume load, and ultimately, enhancing postoperative outcomes [36]. However, it is difficult to use this approach in all patients due to the invasive and advanced nature of the required technology. In addition, there remains controversy as to whether restrictive infusion is inferior to GDFT [37]. RF therapy has many advantages in the perioperative period. It is reported that RF therapy is associated with faster recovery, lower incidence rates of postoperative complications, lower 30-day readmission rates, and shorter hospital stays in laparoscopic colorectal cancer surgery, as compared to excessive fluid therapy [38]. However, to date, relatively few studies have evaluated the impact of fluid strategies on ICP during the perioperative period due to confusion regarding the definition of fluid strategies and the limited monitoring of ICP in non-craniocerebral surgery patients. Additionally, due to the prolonged retention of colloids in circulation after administration [39], and to account for risk in this study, only Ringer's solution was used to compensate for fluid loss. The results from the current study revealed no significant differences in the ONSD/ETD ratio and ONSD changes between the RF group and the CF group. However, the analysis indicated that the operation time of the two groups was less than three hours. Therefore, we hypothesise that the short-term impacts of different fluid strategies on ICP may be small in laparoscopic gynaecologic surgery. However, the effects on patients undergoing longer surgeries need to be investigated further.

There is increasing evidence that rSO_2 reflects the overall brain tissue oxygen supply and demand [40]. However, rSO_2 is affected by various factors, such as skin pigment, age, vasoactive drugs, and $PaCO_2$ [41–43]. There were no differences in age, use of vasoactive drugs, and $PaCO_2$ between the two groups in this study. The results of the current study indicated that changes in rSO_2 at each stage of the perioperative period were small, and there were no differences in these changes between the two groups. This finding is consistent with previous research findings [44]. Regarding complications, elevated ICP usually leads to PONV and postoperative headaches. It is reported that the degree of ONSD increase during laparoscopic surgery is significantly correlated with the occurrence of PONV and headaches within the first three hours of recovery [5]. In this study, since there was no difference in the degree of ONSD increase under the two fluid management regimens, it was expected that there was no noticeable difference in postoperative complications.

The current study found that the extubation time of the RF group was significantly shorter than the CF group [34.0 (20.3,52.3) ml versus 47.5 (35.5,59.0) min, $P=0.027$], similar to the results of prior studies [45]. The RF management strategy has advantages in shortening the duration of mechanical ventilation. However, there was no significant difference in the length of hospital stay and PACU stay between the two groups in this study. This is at odds with previous studies [46–48]. This may be because the operation time in this study was relatively short, and the surgery was minimally invasive. Thus, the surgery had little impact on the patient's body. Accordingly, the patients did not show significant differences in the late recovery period. In the current study, the MAP was increased in both groups at T2 after pneumoperitoneum, which is consistent with previous studies [49]. We also found that the MAP of the CF group was slightly

higher than that of the RF group at T3 and T4, albeit not statistically significant. In addition, there was no difference in urine volume and lactic acid between the two groups. This shows that the restrictive infusion regimen does not affect tissue perfusion, and has no obvious disadvantage in maintaining the MAP when compared to the conventional infusion regimen. Therefore, the restrictive infusion strategy can be safely used in laparoscopic gynaecological surgery.

There are several limitations to consider with the current study. Firstly, the ONSD/ETD ratio was not measured before anesthesia was administered. This may affect the balance of the baseline data. Awake measurements lead to patient discomfort, and eye rotations during these may also lead to measurement errors. Therefore, strategically, these data were excluded from the current study. Secondly, the operation type meant that the operation time was relatively short, and no longer-term monitoring and follow-up were performed. Therefore, we cannot make inferences about the long-term impacts on ICP and the differences in complications between the two fluid strategies.

Therefore, further prospective studies with longer tracking times, and optimised experimental designs are required to compare the effects of RF and CF on the ONSD/ETD ratio.

Conclusions

The current study revealed that RF does not significantly reduce the ONSD/ETD ratio in patients undergoing gynecological endoscopic surgery in the short term, as compared with CF. It also has no significant effects on circulation maintenance or tissue perfusion. However, it can shorten the extubation time. These results indicate that the RF management strategy is safe for use in gynecological laparoscopic surgery and can promote improved postoperative recovery.

Abbreviations

RF	Restrictive fluid
CF	Conventional fluid
ICP	Intracranial pressure
ONSD	Optic nerve sheath diameter
ETD	Eyeball transverse diameter
TP	Trendelenburg position
rSO_2	Regional cerebral oxygen saturation
PONV	Postoperative nausea and vomiting
MAP	Mean arterial pressure
ASA	American Society of Anaesthesiologists
ETCO2	End-tidal carbon dioxide
BW	Body weight
IBW	Ideal body weight
HR	Heart rate
SpO_2	Oxygen saturation
BIS	Bispectral index
PEEP	Positive end-expiratory pressure
PACU	Post-anaesthesia care unit
PCIA	Patient-controlled intravenous analgesia
Ppeak	Peak inspiratory pressure
PaCO2	Partial pressures of carbon dioxide
Lac	Lactic acid
GDFT	Goal-directed fluid therapy

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Author contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis: YH, YC, TTY. Data interpretation: all authors. Writing the first draft of the paper: YH, TTY. All authors were involved in critical revision of the paper for important intellectual content and approved the final version.

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Data availability

The datasets utilised and/or analysed throughout this study are accessible from the corresponding author upon legitimate request.

Declarations

Ethics approval and consent to participate

This study was reviewed and approved by the Institutional Ethics Committee of Yongchuan Hospital, affiliated with Chongqing Medical University (2023LLS037). Patients were enrolled in the study after written informed consent was obtained.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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