scientific reports

Check for updates

OPEN

Exploring the effect of fluid management guided by optic nerve sheath diameter on postoperative headache in women with cesarean section

Qiao Yang[1], Ruiming Deng[2], Qiaoling Weng[4], Tingyu He[2], Ziqiang Dong[2], Xianwei Jin[3]✉ & Weibo Zhong[2]✉

In cesarean section surgery, spinal anesthesia can lead to a reduction in intracranial pressure (ICP), which may result in headaches. Adequate fluid replacement is generally required postoperatively to prevent low ICP. However, excessive empirical fluid replacement can increase the circulatory burden on the patient and potentially elevate ICP, thereby contributing to the occurrence of headaches. This trial aims to investigate whether fluid management guided by ultrasound measurement of the optic nerve sheath diameter can reduce the incidence of postoperative headaches in patients. This single-center randomized controlled clinical trial was conducted at Ganzhou People's Hospital in China from December 2022 to July 2023. A total of 138 ASA II and III patients aged 18 years and older, scheduled for cesarean section under spinal anesthesia, were randomly assigned to either a restricted infusion group (Group E, *n* = 71), which underwent restrictive infusion adjustments to maintain the optic nerve sheath diameter within the normal range (2.2–5 mm), or an empirical infusion group (Group C, *n* = 67), where the optic nerve sheath diameter was solely monitored, and empirical infusion treatment was employed. Within 72 h post-operation, all patients were monitored every 12 h for ultrasound-measured optic nerve sheath diameter (ONSD) and the occurrence of postoperative headaches. The primary outcome was the incidence of postoperative headaches. Secondary outcomes included ONSD assessed by ultrasound, pain scores using the visual analog scale (VAS), postoperative fluid supplementation, nausea and vomiting, back pain, mean arterial pressure (MAP), heart rate (HR), length of hospital stay, and patient satisfaction. The incidence of postoperative headache in Group E was lower than that in Group C, however, this difference was not statistically significant (*P* = 0.094). There was no difference in the volume of fluid replacement between the two groups within the first 0–12 h post-surgery, but significant difference was observed between 12 and 24 h (*P* = 0.002). Additionally, there was no significant reduction in discharge time between two groups (*P* = 0.309). Under ultrasound guidance, maintaining a normal diameter of the optic nerve sheath does not decrease the incidence of postoperative headaches in women with cesarean section receiving a spinal anesthesia. However, it may offer patients a more effective approach to fluid replacement.

Trial registration: ChiCTR.org.cn (ChiCTR2400089214). Date of registration: 4/9/2024.

Keywords Optic nerve sheath diameter, Cesarean section, Postoperative headache, Spinal anesthesia

Abbreviations

ASA	American Society of Anaesthesiologists
MAP	Mean arterial pressure

[1]Department of Anesthesiology, Ganzhou Maternal and Child Health Care Hospital, No. 25, Nankang Road, Ganzhou 341000, Jiangxi Province, China. [2]Department of Anesthesiology, Ganzhou People's Hospital, Ganzhou, Jiangxi Province, China. [3]Department of Medicine, Graduate School, Nanchang University, Nanchang, Jiangxi Province, China. [4]Nanchang University Second Affiliated Hospital, Nanchang, Jiangxi Province, China. ✉email: 363006220069@email.ncu.edu.cn; zhongweibo@mail.gzsrmyy.com

HR	Heart rate
PLT	Platelet
SpO2	Pulse Oxygen Saturation
Hb	Hemoglobin
VAS	Visual Analogue Scale
ONSD	Optic nerve sheath diameter
ICP	Intracranial pressure
PDPH	Post-Dural Puncture Headache
CSF	Cerebrospinal fluid
SBP	Systolic Blood Pressure
ICHD-3	International Classification of Headache Disorders, 3rd Edition
M	Median
P25	First quartile
P75	Third quartile
SD	Standard deviation
PONV	Postoperative nausea and vomiting

Spinal anesthesia is one of the most commonly utilized techniques for cesarean Sect. [1], owing to its rapid onset, reliable efficacy, and minimal impact on both the mother and the infant[2,3]. However, this method can result in post-dural puncture headache (PDPH)[4,5]. Research indicates that the incidence of PDPH following simple spinal anesthesia is greater than that observed after epidural block anesthesia, with Flaatten et al. reporting an incidence rate as high as 15.5%[6]. Although combined spinal-epidural anesthesia merges the advantages of the rapid onset of spinal anesthesia with the prolonged duration of epidural anesthesia, it may present a higher risk of PDPH compared to spinal anesthesia alone, due to the necessity of dural puncture following epidural anesthesia.

Currently, various treatment methods for postoperative headaches induced by spinal anesthesia have been employed both domestically and internationally. Conservative approaches are primarily categorized into two types: supplementation of cerebrospinal fluid (CSF) and reduction of CSF outflow[7,8]. For mild symptoms, it is generally advised that patients maintain a supine position or adopt a low head and high foot posture to mitigate CSF outflow. However, relevant studies indicate that prophylactic bed rest following spinal anesthesia may not confer any significant benefits[9]. In more severe cases, small doses of sedatives are administered alongside substantial empirical fluid supplementation[10]. It is crucial to consider a potentially overlooked aspect of high-dose empirical fluid replacement therapy for postoperative headaches: whether excessive fluid replacement could lead to complications such as hypertension, heart failure, and ICP, particularly in patients with pre-existing conditions that may be exacerbated by volume overload. Furthermore, unmonitored infusion methods may also result in headaches due to intracranial hypertension.

The regulation of cerebrospinal fluid volumes is crucial for the safe treatment of postoperative headaches. However, there are currently no corresponding monitoring indicators to guide this regulation. Subtle changes in cerebrospinal fluid volumes can directly affect intracranial pressure, with excessive cerebrospinal fluid leading to increased intracranial pressure and resulting in symptoms such as headache, vomiting, and other reactions[11,12]. Conversely, insufficient cerebrospinal fluid can result in low intracranial pressure, leading to a series of complications, including postoperative headache[13]. With the advancement of ultrasound technology[14], real-time and non-invasive measurement of the optic nerve sheath diameter in patients can be achieved, thus avoiding invasive and complication-prone intracranial pressure monitoring methods[15]. This advancement may assist in the treatment of postoperative headaches resulting from spinal anesthesia. Recent studies have indicated that ultrasound measurement of ONSD is beneficial for evaluating intracranial pressure, and early measurement may help patients avoid serious complications[16]. Furthermore, it can also be utilized for the diagnosis and management of postoperative headaches caused by intracranial low pressure[17], serving as an effective predictive tool for postoperative headaches[18].

The experiment conducted by Marca et al. further substantiates the correlation between ONSD and infusion volume[19]. This finding indicates that excessive blind fluid replacement may significantly elevate ICP, with ONSD being closely associated with headaches resulting from elevated ICP[20]. Consequently, it is plausible that regulating fluid intake to maintain normal ONSD can diminish the occurrence of postoperative headaches. Based on this premise, we hypothesize that ultrasound-guided fluid management aimed at sustaining normal ONSD can reduce the incidence of postoperative headaches in patients undergoing cesarean sections under spinal anesthesia, thereby facilitating patient recovery.

Methods

Study design

This Randomized controlled trial was approved by the Ethics Committee of Ganzhou People's Hospital, with the consent letter No. TY-ZKY2022-90-01. Following the principles of the Declaration of Helsinki, Clinical trial registration (Registration No.: ChiCTR2400089214) was completed. The protocol was explained to the patients prior to the commencement of the experiment, and all participants voluntarily signed the informed consent form. We adhered to the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines.

A total of 152 patients aged 18 years and older, scheduled to undergo spinal anesthesia for cesarean section surgery classified as American Society of Anesthesiologists (ASA) II-III (where II indicates a patient with mild systemic disease and III indicates a patient with severe systemic disease), were selected from Ganzhou People's Hospital between December 2022 and July 2023. The inclusion criteria mandated that all patients exhibit normal coagulation, cardiovascular, and pulmonary function. The exclusion criteria were as follows: ① a history of

mental illness or headache, ② patients who had previously undergone painless delivery, ③ those with pregnancy-induced hypertension, ④ diabetic patients, and ⑤ patients with inadequate anesthesia results necessitating a change in anesthesia method (failed spinal anesthesia). Furthermore, any patient who did not cooperate or chose to withdraw during the process was classified as a dropout.

Using a computer-generated randomization table, patients were randomly assigned to either the restricted infusion group or the empirical infusion group in a 1:1 ratio for monitoring the ONSD (Fig. 1). To conceal group allocation, the assignments were placed in sealed envelopes, which were sequentially handed to the non-blinded

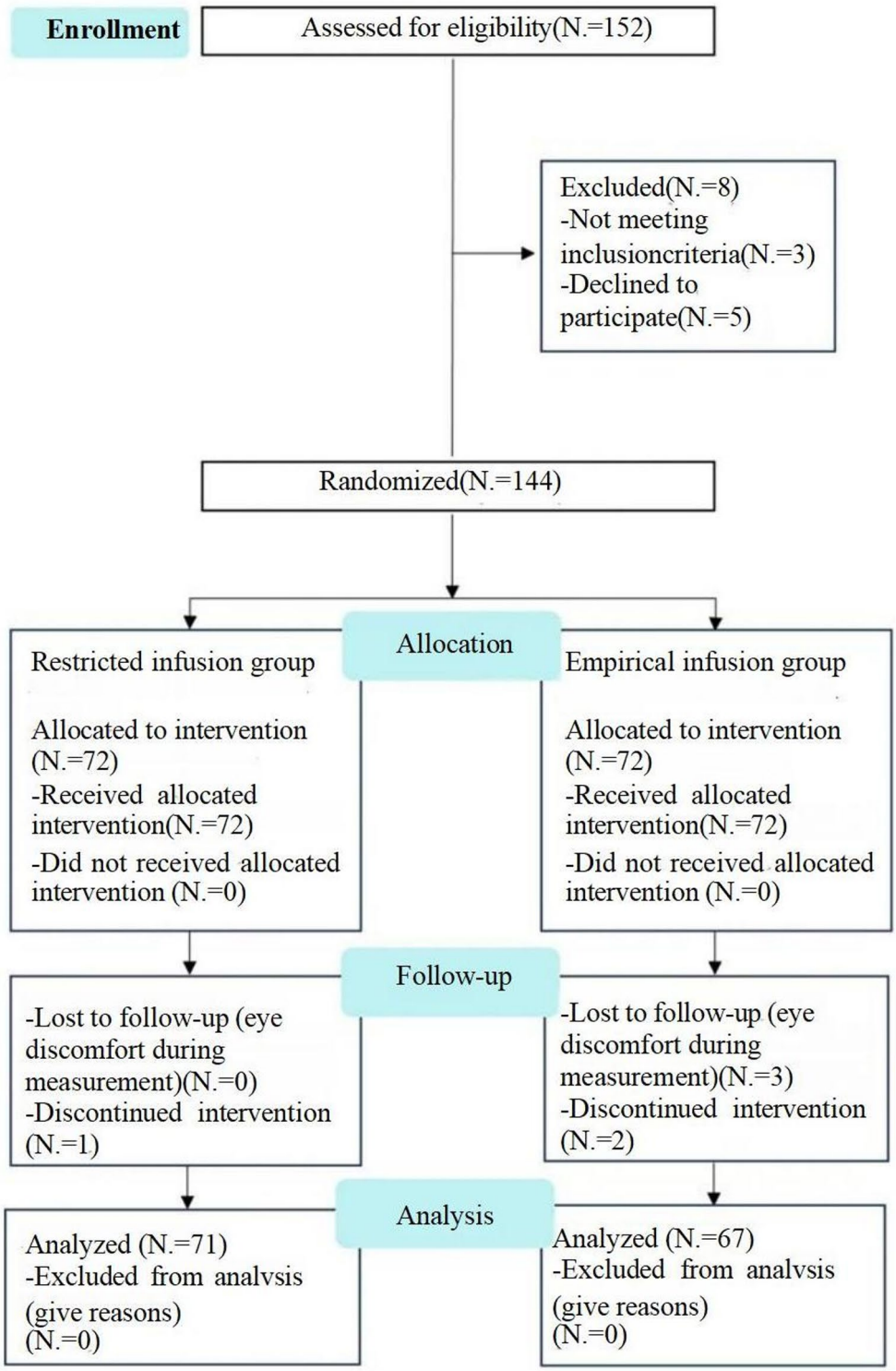

Fig. 1. Flow diagram.

members involved in liquid adjustment (Tingyu He). Anesthesiologists responsible for patient management and postoperative follow-up (Weibo Zhong, Ruiming Deng) remained blinded to group assignments until the conclusion of the experiment.

The following items are required for Preparation

An ultrasound device (Mindray TE7 color Doppler ultrasound system, Shenzhen Mindray Biomedical Electronics Co., Ltd.), sterile gauze, a sterile drape, iodophor, lidocaine, bupivacaine, 5% glucose injection, ephedrine hydrochloride injection, oxytocin injection, sufentanil injection, a transparent application, sterile gloves, a disposable sterile protective sleeve for the ultrasound probe, medical ultrasound probe disinfection gel, and disposable spinal anesthesia puncture kits.

Anesthesia and postoperative monitoring

Upon entering the room, two groups of patients were monitored for vital signs, including heart rate, intermittent non-invasive blood pressure and blood oxygen saturation. Patients were instructed to lie supine, close their eyes, and cover their eyelids with transparent patches to prevent coupling agents from entering their eyes during the examination. All monitoring and procedures were conducted by the same experienced senior anesthesiologist. Prior to anesthesia (T1), a 7.5-13 MHz high-frequency linear array probe was utilized. The probe was gently positioned on the upper eyelid in a transverse section, with the marker facing the right side of the patient (Fig. 2). It was then moved from the forehead to the nose to identify the optimal imaging plane until a clearly defined low echo linear structure, Specifically, the ONSD was visualized behind the eyeball. ONSD measurements for both eyes were taken three times at a distance of 3.0 mm behind the retina, resulting in a total of six measurements. The average of these measurements was then calculated.

During the anesthesia process, both groups of patients received spinal anesthesia. All patients were positioned in a left lateral orientation, with their backs perpendicular to the surgical table, heads bent forward, and hands clasped around their knees as closely as possible. The lumbar space was maximized, and the puncture site was identified at the L2-L3 lumbar space. The skin at the puncture site was disinfected with iodophor, extending from the scapular angle to the coccyx, with disinfection performed on both sides to the posterior axillary line. Following disinfection, a sterile drape was placed, and the puncture point was determined. Lidocaine was applied in layers to the skin, spinous, and interspinous ligaments for local infiltration. Use 25G sprotte spinal anesthesia puncture needles for direct insertion technique puncture, and after successful puncture, a prepared heavy-density local anesthetic (2 ml of 0.5% bupivacaine combined with 1 ml of 10% glucose injection) was slowly injected. After 50–60 s of injection, the needle was withdrawn, and the puncture site was covered with sterile gauze and secured with adhesive tape. The patient was then assisted in gradually changing to a supine position. Before making the surgical skin incision, the level of spinal anesthesia blockade is assessed. An 18-gauge needle is utilized to prick the skin, allowing for the evaluation of cephalad spread. The assessment is

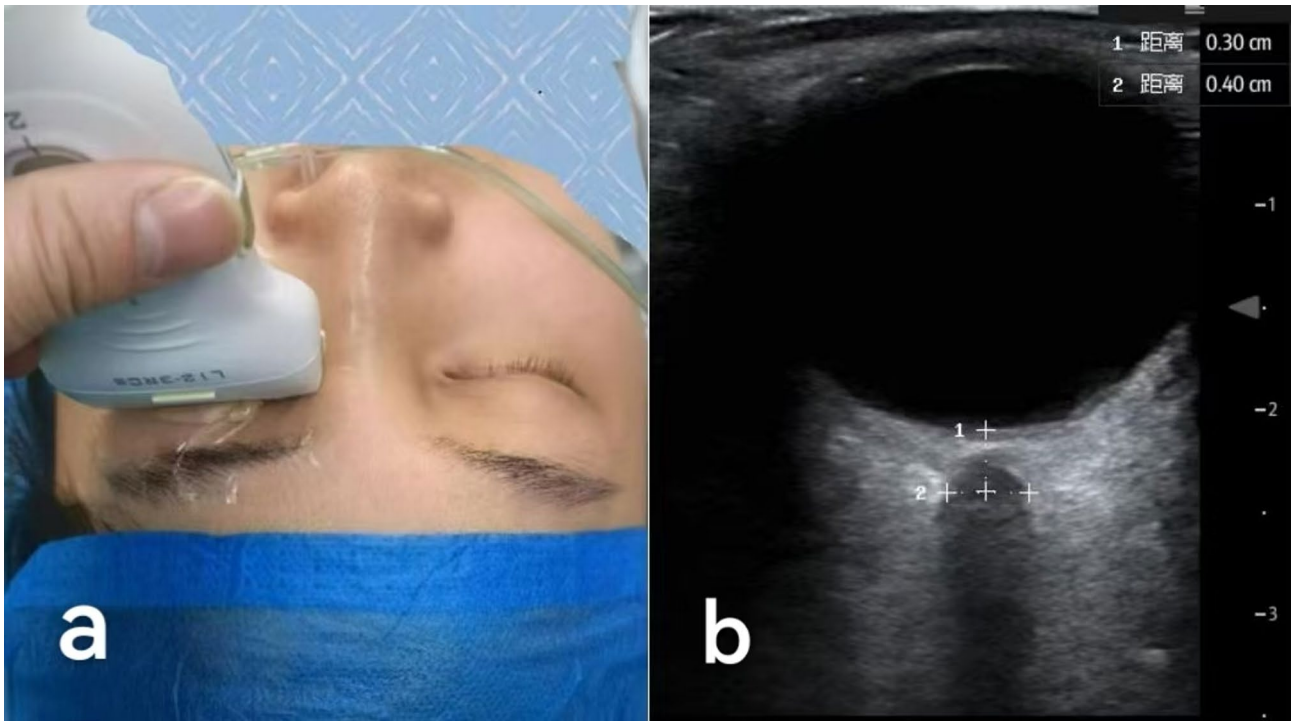

Fig. 2. Schematic diagram of optic nerve sheath measurement under ultrasound. (**a**) Place the ultrasound probe vertically on the patient's right eye. (**b**) Measure the horizontal distance between the inner walls of the optic nerve sheath at a distance of 3 mm behind the retina.

conducted from the anesthetized area to the non-anesthetized area, with three skin pricks performed at each level to ensure the validity of the assessments[21]. In the event of hypotension (defined as Systolic Blood Pressure (SBP) < 90 mmHg or MAP less than 20% of the pre-anesthetic baseline value) or bradycardia (heart rate < 50 beats per minute) during the operation, treatment should be promptly initiated by increasing fluid infusion and administering 6 mg of ephedrine hydrochloride intravenously until the values return to within the normal range. Fluid replacement during the procedure adheres to the 4-2-1 rule, utilizing Compound Sodium Chloride Injection to meet physiological requirements. The volume of blood loss is compensated with an equivalent volume of colloidal solution. During the surgery, use oxytocin as per the surgeon's instructions. Should the patient experience insufficient anesthesia block levels during the operation and find it intolerable, this is recorded as a failure of spinal anesthesia. Additional intravenous doses of propofol, remifentanil, and rocuronium are administered for general anesthesia to facilitate the continuation of surgery. An intravenous analgesia pump is connected at the conclusion of the surgery, employing the same formula (sufentanil 2 μg/kg + 0.9% normal saline diluted to 100 ml). The background dose is set at 2 ml/h, with a PCA (patient-controlled analgesia) dose of 2 ml, a locking interval of 20 min, allowing patients to self-administer analgesia based on their individual needs. Postoperatively, the patient is transferred to the obstetric ward for monitoring of vital signs. After surgery, it is essential to maintain a VAS score of ≤ 3. If PCA intravenous analgesia proves ineffective, an indomethacin 50 mg anal suppository may be administered as a remedial treatment, with additional pain management options available every 4–6 h if necessary. In the event of vomiting, 10 mg of metoclopramide should be administered intravenously for treatment.

Within three days after surgery, ultrasound was used to monitor the ONSD in two groups of patients every 12 h. The normal diameter range for adult ONSD is 2.2–5 mm, with a diameter exceeding 5 mm indicating an increase in ICP[22]. Patients in group E receive infusion adjustments to maintain the ONSD within the normal range, which is a restrictive fluid replacement therapy. If the ONSD exceeds the normal value, intravenous fluid replacement should be discontinued within the next 12 h. Conversely, if the ONSD is below the normal threshold, an additional 500 ml of compound sodium chloride injection should be administered within the same timeframe. In contrast, group C received empirical fluid replacement based solely on clinical experience, with their measurements recorded but without any adjustments to their infusion.

Observation indexes

We recorded the ONSD of two patient groups at several time points: before anesthesia (T1), upon completion of surgery (T2), and at 12 (T3), 24 (T4), 36 (T5), 48 (T6), and 72 h after surgery (T7). Patients were assessed for headaches based on the International Classification of Headache Disorders, 3rd Edition (ICHD-3)[23]. Postoperative pain was evaluated using the VAS, and patient satisfaction was measured through a questionnaire administered at the T7 time point.

General information

The study recorded various parameters, including age, gender, height, weight, preoperative platelet count, preoperative hemoglobin value, pulse oxygen saturation (SpO2), intraoperative fluid replacement volume, blood loss, urine output, length of hospital stay, number of cesarean sections, number of attempts required (total number of intervertebral foramen punctures during spinal anesthesia), puncture time (duration from initial skin penetration with the spinal needle to the first clear observation of cerebrospinal fluid (CSF) free flow), and first puncture success rate (proportion of successful punctures on the first attempt during spinal anesthesia). Additionally, the use of ephedrine, oxytocin, indomethacin suppository, and metoclopramide injection in both groups was documented.

Main research indicators

The primary outcome was the incidence of postoperative headache in the two groups, evaluated using the ICHD-3, within three days following the operation. A postoperative headache is defined by the simultaneous fulfillment of the following five criteria: (1) Headache onset within five days after lumbar puncture; (2) Location: primarily in the frontal and occipital regions; (3) Postural exacerbation (worsening in the upright position within 15 min and improvement in the supine position); (4) Remission factors: headache alleviates or resolves within 15 min in the supine position; (5) Accompanied by at least one related symptom (e.g., neck stiffness, tinnitus, photophobia, nausea/vomiting). The VAS score ranged from 0 (no pain) to 10 (unbearable pain). The criteria for the satisfaction survey included: very satisfied (comfortable, without postoperative complications), relatively satisfied (mild nausea and back pain, etc.), neutral (significant nausea and other discomfort), and dissatisfied (headache and other discomfort following the operation).

Secondary research indicators

The postoperative complications of both groups were documented, including nausea, vomiting, and postoperative back pain, along with the corresponding treatments administered. Additionally, the infusion volume for both groups of patients was recorded three days post-surgery. MAP, HR, and patient satisfaction were also measured for both groups.

Sample size and statistical analysis

Preliminary experiments revealed that the incidence of postoperative headache in Group E was 4%, compared to 20% in Group C. Assuming a Type I error rate of 0.05 and an efficacy of 0.80, the calculated minimum sample size for the study was determined to be at least 122 participants. To account for potential patient dropouts due to changes in clinical conditions, a total of 152 patients were initially recruited for the study. Since the preliminary experiment was conducted prior to the formal clinical trial, the data from the preliminary experiment were

excluded from the final analysis. Categorical data are presented as counts or percentages, while quantitative data that exhibit a normal distribution are expressed as means and standard deviations. Parametric testing is employed for data with a normal distribution, whereas non-parametric testing is utilized for data lacking a normal distribution. The Chi-square test and Fisher's exact test are applied for the analysis of categorical data. A p-value of less than 0.05 is considered the threshold for statistical significance. All data analyses were conducted using the Statistical Product and Service Solutions 23.0.

Results

Out of the 152 initially selected patients, only 138 met the inclusion criteria. These 138 patients were randomly assigned to two groups: a restricted infusion group (Group E, $n=71$) and an empirical infusion group (Group C, $n=67$).

Comparison of general information between two groups of patients

There were no statistically significant differences in baseline data such as age, gender, height, weight, platelets, albumin, hemoglobin, preoperative mean arterial pressure, and heart rate ($P>0.05$). Additionally, there were no significant differences in preoperative nerve sheath diameter, oxygen saturation, and intraoperative fluid replacement ($P>0.05$). The comparison of the number of attempts required, puncture time, and first puncture success rate between two groups of patients showed no statistically significant difference ($P>0.05$). In addition, the usage of ephedrine, oxytocin, indomethacin suppositories, and metoclopramide injection in two groups of patients were also have no significant differences. (Table 1)

Comparison of postoperative headache incidence between two groups of patients

There was no statistically significant difference in the incidence of postoperative headache between the two groups of patients ($P=0.094$). (Fig. 3; Table 2)

Comparison of MAP and HR between two groups of patients at different time points

There was no statistically significant difference in MAP and HR between the two groups of patients at different time points ($P>0.05$). (Table 3)

Variables	Patients, mean ± SD		*P*
	Group C ($n=67$)	Group E ($n=71$)	
Age, M (P25, P75), [range], y	29 (27, 32), [20–33]	29 (27, 32), [34 – 33]	0.930
Height, cm	157.94 ± 4.67	158.72 ± 4.57	0.325
Weight, M (P25, P75), kg	65 (60, 70)	68 (61, 74)	0.651
BMI, M (P25, P75)	26.04 (24.61, 28.04)	27.18 (24.22, 29.37)	0.203
Hb, g/L	119.37 ± 10.60	118.63 ± 13.16	0.718
PLT, 10^9/L	224.22 ± 57.42	219.14 ± 48.72	0.577
Albumin, g/L	35.00 ± 2.11	34.27 ± 3.33	0.129
WBC, 10*9/L	8.70 ± 1.89	9.10 ± 1.99	0.224
Hospital stay, d	4.55 ± 1.18	4.76 ± 1.21	0.309
SPO_2, M (P25, P75), %	98 (97, 98)	98 (98, 98)	0.925
Infusion volume, M (P25, P75), ml	1000 (800, 1000)	1000 (840, 1000)	0.925
Blood loss, M (P25, P75), ml	400 (300, 400)	400 (400, 400)	0.158
Urine volume, M (P25, P75), ml	200 (150, 250)	200 (150, 200)	0.812
Number of punctures M (P25, P75)	1 (1, 2)	1 (1, 2)	0.883
Puncture time, M (P25, P75), min	4 (4, 5)	4 (4, 6)	0.763
first puncture success rate, No. (%)	50 (74.63)	51 (71.83)	0.711
Use of ephedrine, No. (%)	24 (35.82)	27 (38.03)	0.788
Use of oxytocin, No. (%)	67 (100.0)	71 (100.0)	1
Use of indomethacin, No. (%)	43 (64.18)	41 (57.75)	0.439
Use of metoclopramide, No. (%)	9 (14.43)	8 (11.27)	0.699
Number of previous cesarean section			
First cesarean section, No. (%)	35 (52.24)	39 (54.93)	0.567
≥ 2, No. (%)	32 (47.76)	32 (45.07)	

Table 1. Comparison of baseline data between two groups of patients. Group C: empirical infusion group, Group E: restricted infusion group. *PLT* platelet, *Hb* hemoglobin, *MAP* mean arterial pressure, *HR* heart rate, *WBC* white blood cells, *BMI* body mass index, *SPO2* Pulse Oxygen Saturation, *M* Median, *P25* first quartile, *P75* third quartile, *SD* standard deviation.

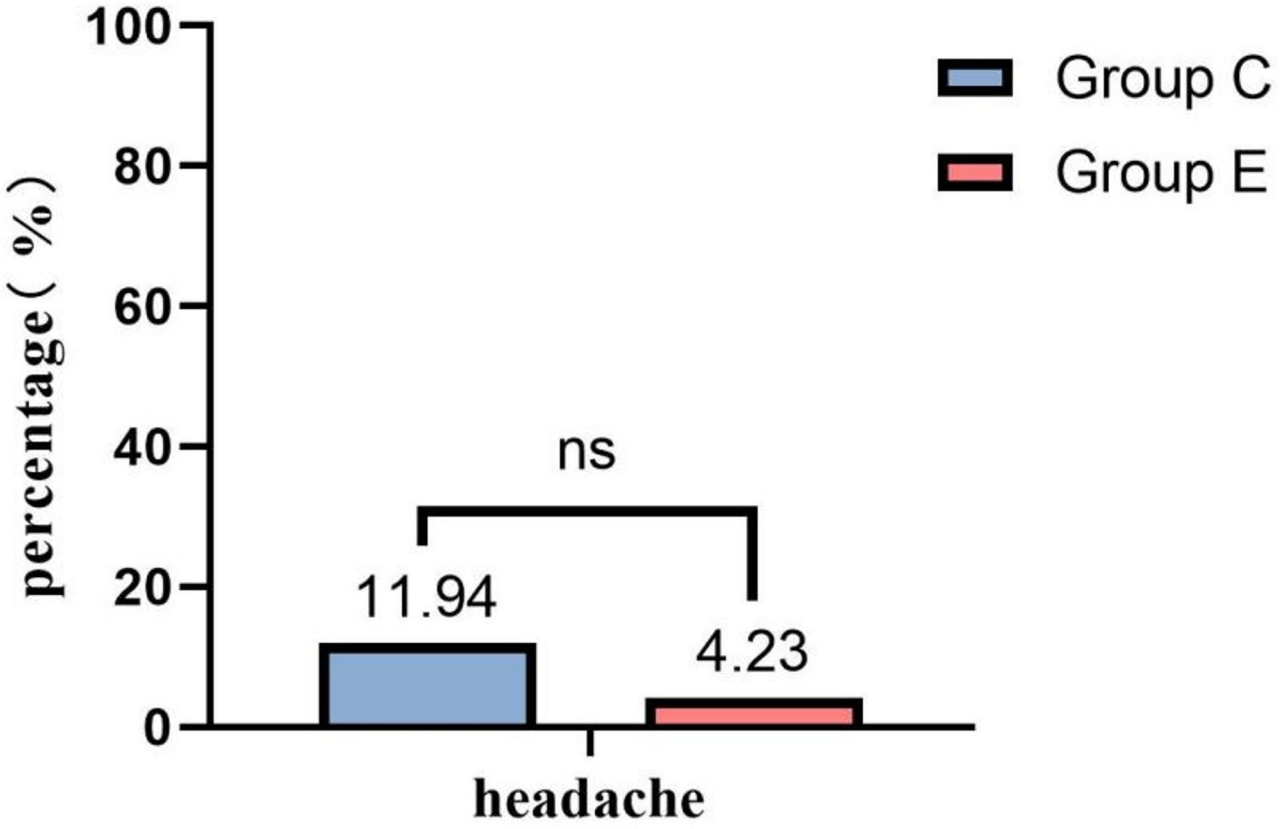

Fig. 3. Comparison of headache occurrence between two groups. Group C: empirical infusion group, Group E: restricted infusion group. Comparison of headache occurrence between two groups.

Group	Adverse reactions, No. (%)			
	Headache incidence rate	PONV	Lower back pain	Satisfaction(%)
C($n=34$)	8 (11.94)	21 (31.34)	11 (16.42)	43 (64.18)
E($n=36$)	3 (4.23)	18 (25.35)	8 (11.27)	57 (80.28)*
$\chi 2$	2.797	0.610	0.770	4.479
P	0.094	0.435	0.380	0.034

Table 2. Comparison of adverse reactions and patient satisfaction between two groups. Group C: empirical infusion group, Group E: restricted infusion group. *PONV* postoperative nausea and vomiting. Compared with group C, $^{*}P<0.05$, $^{**}P<0.001$.

Comparison of ONSD, fluid replacement and VAS scores between two groups at different time points

There was no statistically significant difference in the diameter of the optic nerve sheath between the two groups of patients at time points T1, T2, T3, T6, and T7 ($P>0.05$). Compared with group C, group E had significantly lower diameters of the optic nerve sheath at time points T4 ($P=0.024$) and T5 ($P=0.032$). There was no statistically significant difference in the amount of fluid replacement between the two groups during the 0–12 h, 24–36 h, 36–48 h, and 48–72 h time periods after surgery ($P>0.05$). Compared with group C, group E had significantly lower fluid replacement during the 12–24 h time period ($P=0.002$). There was no statistically significant difference in VAS scores at different time points between the two groups ($P>0.05$). (Fig. 4; Table 4)

Comparison of postoperative nausea and vomiting (PONV), lower back pain between two groups of patients

There was no statistically significant difference in PONV and lower back pain between the two groups ($P>0.05$). (Table 2)

Comparison of patient satisfaction between two groups

Compared with group C, group E had significantly higher satisfaction ($P=0.034$). (Table 2)

	T1	T2	T3	T4	T6
Comparison of MAP scores at different time points between two groups, mean ± SD					
C($n=67$)	89.43 ± 8.41	83.75 ± 6.89	82.85 ± 5.73	84.03 ± 5.40	85.54 ± 5.79
E($n=71$)	90.59 ± 7.24	84.31 ± 6.08	83.93 ± 6.79	83.75 ± 6.66	85.00 ± 6.88
F	0.755	0.260	1.011	0.075	0.245
P	0.387	0.611	0.316	0.785	0.622
P-group	0.690				
P-time	< 0.001				
P-group×time	0.172				
Comparison of HR scores at different time points between two groups, mean ± SD					
C($n=67$)	85.15 ± 11.21	83.42 ± 9.07	78.58 ± 9.80	75.34 ± 9.82	74.51 ± 9.50
E($n=71$)	87.56 ± 11.00	85.85 ± 10.02	79.59 ± 9.71	77.08 ± 10.37	76.77 ± 10.11
F	1.603	2.217	0.369	1.024	2.070
P	0.204	0.139	0.544	0.313	0.153
P-group	0.218				
P-time	< 0.001				
P-group×time	0.482				

Table 3. Comparison of hemodynamics at different time points between two groups of patients. Group C: empirical infusion group, Group E: restricted infusion group. *MAP* mean arterial pressure, *HR* heart rate, *M* median, *P25* first quartile, *P75* third quartile, *SD* standard deviation. Compared with group C, $^{*}P<0.05$, $^{**}P<0.001$.

Discussion

In this study, we aimed to investigate whether ultrasound-guided fluid replacement to control the diameter of the optic nerve sheath in patients would reduce the incidence of postoperative headaches in women with cesarean section. The results indicated that the group E, which underwent infusion adjustments, experienced a lower incidence of postoperative headaches compared to the group C, which received fluid replacement after surgery, but this difference was not statistically significant ($P=0.094$). On the other hand, satisfaction surveys conducted on two groups of patients showed that group E, which adjusted for infusion based on the ONSD, significantly improved patients' satisfaction ($P=0.034$). Although there was no statistically significant difference in the diameter of the optic nerve sheath between the two groups of patients at time points T1, T2, T3, T6, and T7 ($P>0.05$). However, compared with group C, group E had significantly lower diameters of the optic nerve sheath at time points T4 ($P=0.024$) and T5 ($P=0.032$). Additionally, there was no significant difference in fluid replacement volume between the two groups within the first 0–12 h post-surgery($P=0.458$). A significant difference in fluid replacement volume was observed between the two groups during the 12–24 h period post-surgery ($P=0.002$). No differences in fluid replacement volume were noted during the 24–36 h, 36–48 h, and 48–72 h intervals following surgery ($P>0.05$).

The results of this study indicate that there is no significant difference in the incidence of postoperative headache between the two groups. This finding is consistent with the results reported by Huang et al.[24], which may be attributed to the continuous improvements in the size and quality of puncture needles. Relevant studies[25,26] have indicated that puncture needle size is associated with postoperative headaches; however, thinner spinal anesthesia puncture needles may decrease the incidence of postoperative headaches while potentially affecting the success rate of the first puncture. Additionally, repeated punctures and changes in puncture angle may increase the incidence of postoperative headaches. Studies[27] have demonstrated that even 26G spinal anesthesia puncture needles, when used in various puncture directions, can lead to a higher incidence of postoperative headaches. Consequently, the treatment and prevention of postoperative headaches in women with cesarean section should adopt a multifaceted approach, emphasizing the maintenance of an appropriate volume of CSF. Moreover, adequate postoperative fluid replacement and supine rest can significantly alleviate postoperative headaches in women with cesarean section, and these measures have been incorporated as routine procedures following cesarean sections, resulting in a continuous decrease in the incidence of postoperative headaches in this patient population. In this study, we did not observe any significant effect of controlling infusion based on the diameter of the optic nerve sheath on the incidence of postoperative headache in patients. However, compared to excessive fluid replacement administered without guidance, the incidence of postoperative headache was lower when infusion was controlled according to the diameter of the optic nerve sheath. Furthermore, the volume of fluid replacement in group E was significantly less than that in group C during the 12–24 h postoperative period, suggesting that ultrasound-guided fluid replacement can enhance postoperative infusion management in women with cesarean section. When comparing the diameter of the optic nerve sheath between the two groups of patients at 24 and 36 h post-surgery, we found that the average diameter in group C was significantly greater than that in group E; however, this did not correlate with an increased incidence of postoperative headache. No differences in the diameter of the optic nerve sheath were observed between the two groups at 12 and 48 h after surgery. This phenomenon may be attributed to the prohibition of eating or drinking during the perioperative period of cesarean sections, which is implemented to avoid reflux and aspiration. Additionally, a significant volume of

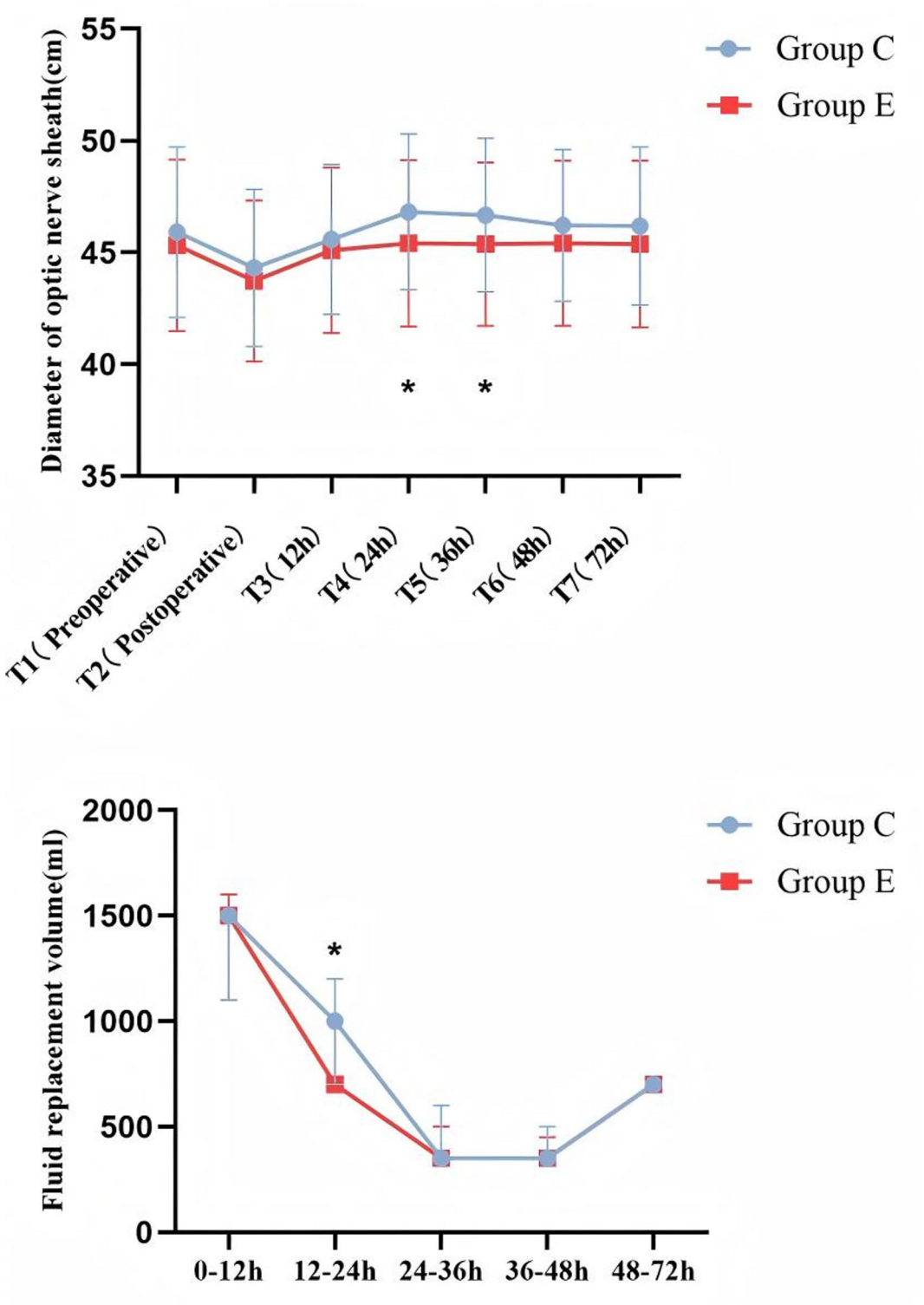

Fig. 4. Comparison of ONSD and fluid replacement between two groups of women at different time points. Group C: empirical infusion group, Group E: restricted infusion group. Comparison of optic nerve sheath diameter and fluid replacement between two groups at different time points.

fluid is lost during the operation, necessitating adequate intravenous infusion. Consequently, the diameter of the optic nerve sheath may remain close to or slightly exceed the normal range, and the self-regulatory function of cerebral blood vessels[28] may prevent an immediate increase ICP and headache. The observed differences in optic nerve sheath diameter between the 48-hour and 72-hour groups may stem from the lack of variation in

	T1	T2	T3	T4	T5	T6	T7
Comparison of ONSD between two groups, mean ± SD							
C($n=67$)	45.91 ± 3.81	44.31 ± 3.52	45.58 ± 3.35	46.81 ± 3.48	46.67 ± 3.43	46.21 ± 3.40	46.18 ± 3.53
E($n=71$)	45.31 ± 3.83	43.73 ± 3.60	45.10 ± 3.70	45.41 ± 3.72*	45.37 ± 3.65*	45.41 ± 3.69	45.38 ± 3.72
F	0.853	0.918	0.644	5.186	4.680	1.746	1.667
P	0.357	0.340	0.424	0.024	0.032	0.189	0.199
P-group	0.161						
P-time	< 0.001						
P-group×time	< 0.001						
Comparison of VAS scores at different time points between two groups, M (P25, P75)							
C($n=67$)	1 (0, 3)	1 (0, 2)	3 (2, 3)	3 (3, 3)	3 (3, 4)	3 (3, 3)	3 (2, 3)
E($n=71$)	0 (0, 2)	0 (0, 1)	3 (2, 3)	3 (3, 3)	3 (3, 4)	3 (3, 3)	3 (2, 3)
Z	-1.376	-1.191	−0.015	−0.535	−0.363	−0.291	−0.374
P	0.169	0.234	0.988	0.593	0.717	0.771	0.709

Table 4. Comparison of ONSD and VAS scores at different time points between two groups. Group C: empirical infusion group, Group E: restricted infusion group. *VAS* visual analogue scale, *ONSD* optic nerve sheath diameter, *M* median, *P25* first quartile, *P75* third quartile, *SD* standard deviation. Compared with group C, *$P<0.05$, **$P<0.001$.

diameter from 24 h post-surgery. The indiscriminate fluid replacement initiated after several hours could also be a contributing factor to the absence of differences in postoperative headache incidence between the two groups.

Currently, headaches resulting from insufficient CSF are becoming increasingly rare[29]. However, adequate postoperative fluid replacement for women with cesarean section has become a standard procedure for preventing postoperative headaches following spinal anesthesia. Simultaneously, the CSF loss associated with simple spinal anesthesia is relatively minimal. Therefore, the necessity for adequate postoperative fluid replacement in women with cesarean section appears less justified. By adjusting the body fluid volume through the ONSD strategy, it is possible to specifically correct the state of low ICP[30], with its core mechanism being the restoration of the balance between cerebral blood flow and CSF dynamics. Clinically, it is essential to assess the volume status on an individual basis, balancing the benefits of volume expansion against the circulatory risks, thereby optimizing the management of postoperative headaches.Additionally, pregnant women during the perioperative period often experience complications such as gestational hypertension and edema[31]. Thus, indiscriminately replenishing fluids to mitigate postoperative headaches lacks a scientific basis. Although high-dose empirical fluid replacement has yielded certain results in clinical practice, the absence of volume monitoring methods in women with cesarean section complicates this approach. With the advancement of volume monitoring technology through peri-implantation ultrasound, it is now possible to assess postoperative volume changes in women with cesarean section from multiple perspectives, including inferior vena cava filling degree and collapse index[32,33]. This method is well-suited for monitoring postoperative volume in women with cesarean section. The present study also demonstrates the safety and effectiveness of ultrasound technology in this context. Moreover, bedside monitoring is straightforward and efficient, allowing for rapid assessment of changes in the patient's ICP. It also helps prevent complications such as heart failure and cerebral edema that may arise from excessive fluid infusion. Therefore, with scientifically guided fluid replacement, it is possible to achieve outcomes comparable to those of empirical fluid replacement, including a lower incidence of postoperative headaches, expedited patient recovery, and enhanced satisfaction.

Limitations

This study has several limitations. Firstly, it only addressed the effects of fluid infusion on postoperative headaches, without considering the impact of spinal anesthesia puncture methods and adjuvant drugs on these headaches[34,35]. Secondly, the monitoring period for postoperative headaches may have been insufficient, potentially affecting the reported incidence. Consequently, the generalizability of our findings warrants further investigation. Lastly, as this study was conducted at a single center, a larger sample size may be necessary to validate our results.

Conclusions

Under ultrasound guidance, maintaining the normal range of optic nerve sheath diameter does not reduce the incidence of postoperative headaches in women with cesarean section undergoing spinal anesthesia. However, it can facilitate more effective volume management, potentially aiding in early recovery.

Data availability

The data sets used and/or analyzed during the present study are available from the corresponding author on reasonable request. The email of corresponding author is zhongweibo@mail.gzsrmyy.com.Data is provided within the manuscript, if more detailed data is needed, it can be supplemented again.

Received: 15 January 2025; Accepted: 18 May 2025

Published online: 04 June 2025

References

1. Bucklin, B. A., Hawkins, J. L., Anderson, J. R. & Ullrich, F. A. Obstetric anesthesia workforce survey: twenty-year update. *Anesthesiology* **8**, 103 (2005).
2. Hutton, M., Brull, R. & Macfarlane, A. J. R. Regional anaesthesia and outcomes. *BJA Educ.* **18**(2), 52–56 (2018).
3. Klimek, M., Rossaint, R., van de Velde, M. & Heesen, M. Combined spinal-epidural vs. spinal anaesthesia for caesarean section: meta-analysis and trial-sequential analysis. *Anaesthesia* **73**(7), 875–888 (2018).
4. Lomax, S. & Qureshi, A. Unusually early onset of post-dural puncture headache after spinal anaesthesia using a 27G Whittacre needle. *Br. J. Anaesth.* **100**(5), 707–708 (2008).
5. Maranhao, B., Liu, M., Palanisamy, A., Monks, D. T. & Singh, P. M. The association between post-dural puncture headache and needle type during spinal anaesthesia: a systematic review and network meta-analysis. *Anaesthesia* **7**, 76 (2021).
6. Flaatten, H., Felthaus, J., Larsen, R., Bernhardsen, S. & Klausen, H. Postural post-dural puncture headache after spinal and epidural anaesthesia. A randomised, double-blind study. *Acta Anaesthesiol. Scand.* **42**(7), 759–764 (1998).
7. Lee, H. J., Lee, Y. H., Park, J. H. & Hong, J. Comparison of efficacy of an epidural blood patch in patients with spinal leakage of cerebrospinal fluid. *Pain Physician*. **24**(8), 571–576 (2021).
8. Uppal, V. et al. Evidence-based clinical practice guidelines on postdural puncture headache: a consensus report from a multisociety international working group. *Reg. Anesth. Pain Med.* **49**(7), 471–501 (2024).
9. K C HB, Pahari, T. Effect of posture on post lumbar puncture headache after spinal anesthesia: A prospective randomized study. *Kathmandu Univ. Med. J. (KUMJ)* **15**(60), 324–328 (2017).
10. Mowafy, S. M. S. & Ellatif, S. E. A. Effectiveness of nebulized Dexmedetomidine for treatment of post-dural puncture headache in parturients undergoing elective Cesarean section under spinal anesthesia: a randomized controlled study. *J. Anesth.* **35**(4), 515–524 (2021).
11. Hayreh, S. S. Pathogenesis of optic disc edema in Raised intracranial pressure. *Prog Retin Eye Res.* **50**, 108–144 (2016).
12. Olatosi, J. O., Kushimo, O. T., Okeke, C. I. & Oriyomi, O. O. Post operative nausea and vomiting in adult Nigerians. *Nig Q. J. Hosp. Med.* **18**(4), 227–230 (2008).
13. Wang, L. J. et al. Ultrasonographic optic nerve sheath diameter as a noninvasive marker for intracranial hypotension. *Ther. Adv. Neurol. Disord.* **15**, 17562864211069744 (2022).
14. Raval, R. et al. Comparison of three Point-of-Care ultrasound views and MRI measurements for optic nerve sheath diameter: A prospective validity study. *Neurocrit Care*. **33**(1), 173–181 (2020).
15. Tavakoli, S., Peitz, G., Ares, W., Hafeez, S. & Grandhi, R. Complications of invasive intracranial pressure monitoring devices in neurocritical care. *Neurosurg. Focus*. **43**(5), E6 (2017).
16. Pei Wang, X., Zhou, F. & Sheng Xiaolong Wang.Ultrasonic optic nerve sheath diameter can be used as a diagnostic measure after accidental dural puncture during Cesarean section: a case report. *BMC Anesthesiol.* **24**, 35 (2024).
17. Fernando, S. M. et al. Diagnosis of elevated intracranial pressure in critically ill adults: systematic review and meta-analysis. *BMJ* **366**, l4225 (2019).
18. Peng, Q. et al. The value of the optic nerve sheath diameter (ONSD) in predicting postdural puncture headache (PDPH): A prospective observational study. *Pain Physician*. **26**(1), 45–52 (2023).
19. Marca, A., Luca, M. & Biondino, D. The effect of fluid challenge test on optic nerve sheath diameter. *JCPSP-J. Coll. Physici.* **3**, 33 (2023).
20. Yilmaz, G., Akca, A., Kiyak, H. & Salihoglu, Z. Elevation in optic nerve sheath diameter due to the Pneumoperitoneum and Trendelenburg is associated to postoperative nausea, vomiting and headache in patients undergoing laparoscopic hysterectomy. *Minerva Anestesiol.* **2**, 86 (2020).
21. Zhou, Q. H., Xiao, W. P. & Shen, Y. Y. Abdominal girth, vertebral column length, and spread of spinal anesthesia in 30 minutes after plain bupivacaine 5 mg/ml. Anesth. *Analg* **6**, 119. https://doi.org/10.1213/ANE.0000000000000199 (2014).
22. Koziarz, A. et al. Bedside optic nerve ultrasonography for diagnosing increased intracranial pressure: A systematic review and Meta-analysis. *Ann. Intern. Med.* **171**(12), 896–905 (2019).
23. Smith, J. H. et al. Volume, and Post-Dural puncture headache: A Case-Control study and systematic review. *Headache* 8. https://doi.org/10.1111/head.13602 (2019).
24. Huang, Y., Cai, Y., Peng, M. Q. & Yi, T. T. 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. *BMC Anesthesiol.* **24**(1), 319 (2024).
25. Pan, P. H., Fragneto, R., Moore, C. & Ross, V. Incidence of postdural puncture headache and backache, and success rate of dural puncture: comparison of two spinal needle designs. *South. Med. J.* **97**(4), 359–363 (2004).
26. Naulty, J. S. et al. Influence of local anesthetic solution on postdural puncture headache. *Anesthesiology* **72**(3), 450–454 (1990).
27. Bıçak, M., Salık, F. & Akelma, H. Is there an effect on the development of postdural puncture headache of dural punction made with the spinal needle in three different orientations during spinal anaesthesia applied to pregnant patients?? *J. Pain Res.* **12**, 3167–3174 (2019).
28. Favre, M. E., Lim, V., Falvo, M. J. & Serrador, J. M. Cerebrovascular reactivity and cerebral autoregulation are improved in the supine posture compared to upright in healthy men and women. *PLoS One*. **15**(3), e0229049 (2020).
29. Ferede, Y. A., Nigatu, Y. A., Agegnehu, A. F. & Mustofa, S. Y. Incidence and associated factors of post dural puncture headache after Cesarean section delivery under spinal anesthesia in university of Gondar comprehensive specialized hospital, 2019, cross sectional study. *Int. J. Surg. Open.* **33**, 100348 (2021).
30. Wang, L. J. et al. Ultrasonographic optic nerve sheath diameter as a noninvasive marker for intracranial hypotension. *Ther. Adv. Neurol. Discov* (2022).
31. Kuller, L. H. & Catov, J. Invited commentary: gestational hypertension and Diabetes-A major public health concern. *Am. J. Epidemiol.* **186**(10), 1125–1128 (2017).
32. Chong, Y., Yu, Y., Zhao, Y. & Zhang, Y. Value of inferior Vena Cava diameter and inferior Vena Cava collapse index in the evaluation of peripartum volume: A prospective cohort study. *Eur. J. Obstet. Gynecol. Reprod. Biol.* **285**, 69–73 (2023).
33. Prekker, M. E., Scott, N. L., Hart, D., Sprenkle, M. D. & Leatherman, J. W. Point-of-care ultrasound to estimate central venous pressure: a comparison of three techniques. *Crit. Care Med.* **41**(3), 833–841 (2013).
34. Coviello, A. et al. Sufentanil vs. Dexmedetomidine as neuraxial adjuvants in Cesarean section: A Mono-Centric retrospective comparative study. *J. Clin. Med.* **11**(22), 6868 (2022).
35. Coviello, A. et al. Impact of Ultrasound-Assisted method on success rate of spinal anesthesia performed by novice trainees: A retrospective comparative study. *J. Pers. Med.* **13**(10), 1515 (2023).

Acknowledgements

The authors would like to thank all the reviewers who participated in the review. All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

Author contributions

All authors contributed to the study conception and design. Writing - original draft preparation: Q.Y.; Writing - review and editing: Q.Y., Q.W., X.J., W. Z.; Conceptualization: R.D., X.J., W.Z.; Methodology: X.J., W.Z.; Formal analysis and investigation: Q.Y., Q.W., T.H., Z.D., X.J., W.Z.; Resources: X.J., W.Z.; Supervision: X.J., W.Z.;Draw figures and tables to present the results: W.Z.,and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

This Randomized controlled trial was approved by the Ethics Committee of Ganzhou People's Hospital, with the consent letter No. TY-ZKY2022-90-01. Following the principles of the Declaration of Helsinki, Clinical trial registration (Registration No.: ChiCTR2400089214) was completed. All patients voluntarily signed the informed consent.

Additional information

Correspondence and requests for materials should be addressed to X.J. or W.Z.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.