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# Heavy gravity combined with light gravity local anesthetic in subarachnoid anesthesia for cesarean section did not reduce the incidence of intraoperative hypotension in maternal women: a prospective cohort study

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## Abstract

**Background** Subarachnoid anesthesia is the primary anesthetic method for elective cesarean section surgery, characterized by rapidly taking effect and reliable analgesia. However, subarachnoid anesthesia is prone to cause a high block level, resulting in a high incidence of maternal hypotension. How to reduce the incidence of maternal hypotension under subarachnoid anesthesia is a practical problem that needs to be solved urgently in clinical practice.

**Methods** This prospective cohort study was performed at Nantong Maternal and Child Health Care Hospital in China between January and July 2023. This study compared the incidence of hypotension in pregnant women undergoing subarachnoid anesthesia during elective cesarean section in four groups, including group A (control group) with 10 mg of 10% glucose solution; Group B with 5 mg 10% glucose solution group; Group C with 4 mg 10% glucose solution group; Group D with 2 mg 10% glucose solution group. Each group was given a dose of 10 mg Ropivacaine with a concentration of 0.5% and a volume of 2 ml. The primary outcome was the incidence of maternal hypotension. The secondary outcomes were the plane of anesthesia, abdominal wall muscle relaxation degree and the incidence of adverse events.

**Results** Data from 74 (18, A group; 26, B group; 15, C group; 15, D group) participants were analyzed. Hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section did not reduce the incidence of intraoperative hypotension in pregnant women ($P=0.152$). The plane of anesthesia gradually shifted from T4 to T10 as the specific gravity of ropivacaine decreased ($P<0.01$). Satisfaction about abdominal wall muscle

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relaxation degree gradually decreased with the decrease of the specific gravity of ropivacaine ($P=0.04$). And the incidence of adverse events gradually increased with the decrease of the specific gravity of ropivacaine ($P=0.027$).

**Conclusions** Hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section did not reduce the incidence of intraoperative hypotension in pregnant women.

**Keywords** Hyperbaric local anesthetic, Hypobaric local anesthetic, Subarachnoid anesthesia, Cesarean section, Hypotension

## Background

Caesarean section (CS) is one of the most frequently performed operations worldwide, with 1 in 5 women (21.1%) currently giving birth through this route [1]. Centroneuraxial anesthesia is currently the best anesthesia method for elective cesarean section, which can significantly reduce the risk of aspiration and intubation failure, and maternal mortality compared with general anesthesia [2]. It is undeniable that adequate preoperative assessment to choose the best anesthesia strategy is very important [3].

Centroneuraxial anesthesia can be divided into subarachnoid anesthesia and epidural anesthesia, between which subarachnoid anesthesia has become the mainstream anesthesia for elective cesarean section because of its rapid onset and exact analgesic efficacy [4]. However, the upper plane of anesthesia is not easy to control during subarachnoid anesthesia (often leads to too high block plane), and the incidence of maternal hypotension is high, which can easily lead to insufficient blood supply to the placenta, cause fetal distress and even increase neonatal mortality [5]. How to reduce the incidence of maternal hypotension in subarachnoid anesthesia is a practical problem that needs to be solved urgently in clinical practice, and it is also the largest research hotspot in obstetric anesthesia at present.

Previous studies have shown vasoactive drugs and repositioning to be the most effective methods for treating and preventing hypotension, but both approaches have significant drawbacks [6, 7]. Some results have shown that vasoactive drugs predispose to transient hypertension and cause fetal lactic acidosis [8, 9]. There are not many well conducted positioning studies. A recent study showed that sitting for 5 min after spinal anesthesia and then lying flat reduced the incidence of maternal hypotension, but this requires more health care workers and patients are at risk of falling out of bed [10].

In addition to the two recognized measures mentioned above, we sometimes use fluid therapy and reducing the dose of local anesthetic drugs to prevent or treat maternal hypotension in our clinical work. However, there are many controversies about these methods. Therefore, how to control and adjust the anesthesia level and reduce the incidence of maternal hypotension has become a new research direction.

There are two important factors in adjusting the anesthetic level: patient position and anesthetic specific gravity [11]. Centroneuraxial anesthesia drugs can be divided into isobaric, hypobaric and hyperbaric according to different specific gravity [12]. Among them, 10% glucose is added to the hyperbaric spinal anesthesia fluid, which is easier to combine with the spinal nerve, reach the required anesthesia level faster, and obtain a satisfactory muscle relaxation effect [13]. In clinical work, we have found that the weight of gravity is often caused by the high level of anesthesia, which leads to maternal hypotension.

Theoretically, the method of combining hyperbaric with hypobaric, under the premise that the total dose of subarachnoid anesthesia drug remains unchanged, can improve the cephalad movement of local anesthetic drugs, thereby reducing the occurrence of maternal hypotension during surgery. This technique has never been tried before. Therefore, this study aimed to explore whether hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section could reduce the incidence of intraoperative hypotension in pregnant women.

## Methods

### Study design

This prospective cohort study was performed at Nantong Maternal and Child Health Care Hospital in China between January and July 2023. This study compared the incidence of hypotension in pregnant women undergoing subarachnoid anesthesia during elective cesarean section in different gravity of ropivacaine.

### Participants

Pregnant women who visited to Nantong Maternal and Child Health Care Hospital for elective cesarean section were enrolled. Inclusion and exclusion criteria were evaluated by means of in-person interviews and medical record review. According to the research objectives, subject characteristics, ethical principles, safety and statistical requirements, and aims to ensure the scientific, effectiveness and ethics of clinical trials, we developed inclusion and exclusion criteria.

The inclusion criteria included pregnant women meeting criteria for cesarean section and anesthesia, those

aged between 20 and 37 years, those with gestational ages ranging from 31 to 41 weeks, those exhibiting normal mental state and cognitive function; and those with American Society of Anesthesiologists classification I or II. The exclusion criteria included pregnant women with peripheral neurological diseases, those vital organ dysfunction or injury, those reproductive organ malformations, those severe pregnancy complications, or those lacking clinical data due to various reasons.

### Trial design

Pregnant women were randomly assigned to four groups: group A (control group) with 10 mg of 10% glucose solution; Group B with 5 mg 10% glucose solution group; Group C with 4 mg 10% glucose solution group; Group D with 2 mg 10% glucose solution group. Each group was given a dose of 10 mg Ropivacaine with a concentration of 0.5% and a volume of 2 ml.

All patients underwent anesthesia administered by the same anesthesiologist at our hospital. Upon arrival in the operating room, pregnant women received oxygen inhalation at a rate of 3 L/min and underwent continuous monitoring of electrocardiogram, blood pressure, and arterial oxygen saturation. Lactated Ringer's solution was rapidly administered via upper-limb venous access. The next step involved positioning the patient in the left lateral position with their head horizontal neither up nor down and hold this position until the subarachnoid anesthesia was done for lumbar puncture at the L3-4 level, and then lying flat. Administration of anesthesia followed once cerebrospinal fluid outflow became visibly apparent to the naked eye, and according to the result of randomization, different gravity of ropivacaine were given. Monitor pregnant women's vital signs closely, including blood pressure, plane of anesthesia, degree of abdominal wall muscle relaxation, other adverse events, and providing corresponding clinical management promptly. The timing of measurements is from the time when the participant or her trustee or guardian sign the completed informed consent form to the end of the operation.

### Outcomes

The primary outcome was the incidence of maternal hypotension, defined as systolic blood pressure less than 90 mmHg, and/or diastolic blood pressure less than 60 mmHg. The secondary outcomes were the plane of anesthesia, abdominal wall muscle relaxation degree and the incidence of adverse events. Monitored variables and adverse events were collected by observers during the procedure.

**Table 1** Baseline characteristics of pregnant women

| | Group A ($n=18$) | Group B ($n=26$) | Group C ($n=15$) | Group D ($n=15$) | *P* value |
|---|---|---|---|---|---|
| Age (y) | 31.28 | 29.73 | 31.07 | 28.67 | 0.262 |
| Weight (Kg) | 74.36 | 75.25 | 75.02 | 76.37 | 0.959 |
| Height (cm) | 160.92 | 161.54 | 160.80 | 163.93 | 0.282 |
| Plane of Anesthesia (T4/6/8/10) | 1/17/0/0 | 8/12/6/0 | 0/3/12/0 | 1/1/11/2 | < 0.01 |

### Sample size estimation

The sample size was calculated using PASS 11.0 statistical software. In our preliminary clinical trial, the incidence of maternal hypotension in group A (control group) with 10 mg of 10% glucose solution was approximately 18%. According to our previous clinical experience, we assumed that the intervention group will have a reduce the incidence of maternal hypotension from 18 to 9%. The sample size was calculated assuming a power of 1-$\beta$ of 0.80, α level of 5%, and a dropout of 5%. Thus, the required sample size was determined to be 74 in total.

### Statistical analysis

All statistical analyses were performed using SPSS software version 26 (IBM SPSS Statistics, Armonk, NY, USA) [14]. Categorical variables were expressed as frequencies and percentages [n (%)], while continuous variables were presented as mean ± standard deviation ($\bar{x} \pm s$). Group comparisons for categorical variables were conducted using the chi-square test ($\chi^2$), while variance analysis supplemented with the LSD intra- group test was employed for continuous variables, with significance determined at a $P<0.05$. This careful statistical approach facilitated a robust evaluation of the data and provided meaningful insights into the outcomes of the study. The adverse events were compared between the two groups using the chi-square or Fisher's exact probability test. The adverse events and adverse reactions were expressed as frequency and percentage.

## Results

A total of 74 pregnant women were enrolled. Among them, 18 in the group A (control group), 26 in the group B, 15 in the group C, 15 in the group D. They were included in the intention-to-treat analysis.

### General characteristics

Table 1 shows the pregnant women's baseline characteristics. The pregnant women's characteristics for four groups, including age, weight, height and the plane of anesthesia (Table 1).

### Primary study outcome

Hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section did not reduce the incidence of intraoperative hypotension in pregnant women. The incidence rates of hypotension

were 16.7% (3/18),15.4% (4/26), 0% (0/15) and 0% (0/15) in the four groups, respectively ($P = 0.152$, Fig. 1), and the confidence intervals were 95%.

### Secondary study outcomes

The plane of anesthesia gradually shifted from T4 to T10 as the specific gravity of ropivacaine decreased ($P < 0.01$, Table 1). Satisfaction about abdominal wall muscle relaxation degree gradually decreased with the decrease of the specific gravity of ropivacaine ($P = 0.04$, Table 2). And the incidence of adverse events gradually increased with the decrease of the specific gravity of ropivacaine ($P = 0.027$, Table 3). Analysis of the usage of additional anesthetics among the four groups revealed that the dosage administered in group A was the lowest, while that in group D was the highest ($P < 0.01$, Table 3). In groups B, C, and D, there was a significant decrease in the rate of vasopressor utilization, indicating that reducing the proportion of Ropivacaine is more favorable for maintaining the blood pressure stability of pregnant women during cesarean section ($P < 0.01$, Table 3).

## Discussion

To the best of our knowledge, this is the first clinical trial exploring that if hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section could reduce the incidence of intraoperative hypotension in pregnant women.

Cesarean section is becoming more prevalent in clinical practice, particularly with the implementation of the third-child policy in China [15]. Cesarean section procedures demand detailed attention to anesthesia and analgesia protocols. Determining the most precise and effective dosage of different specific gravity of Ropivacaine holds significant implications for ensuring the safety of both pregnant women and newborns. In this study, the efficacy of four different specific gravity of Ropivacaine in cesarean section was analyzed, providing valuable insights for future clinical medication guidance. The aim was to evaluate the outcomes resulting from the application of these doses. The objective was to furnish clinicians with a dependable reference to enhance anesthesia protocols for Cesarean section procedures.

Subarachnoid anesthesia drugs can be divided into isobaric, hypobaric and hyperbaric according to different specific gravity. If the same anesthetic is used, the dose is week, the same part is punctured, the injection speed is constant, the needle tip is oblique and the direction is facing the same side, the hyperbaric fluid flows to the low level, and the hypobaric fluid flows to the high flow, and the body position is adjusted within 10 min after injection, and a satisfactory anesthesia plane can generally be obtained. However, the isobaric is easily affected by the volume, density, and temperature of the cerebrospinal

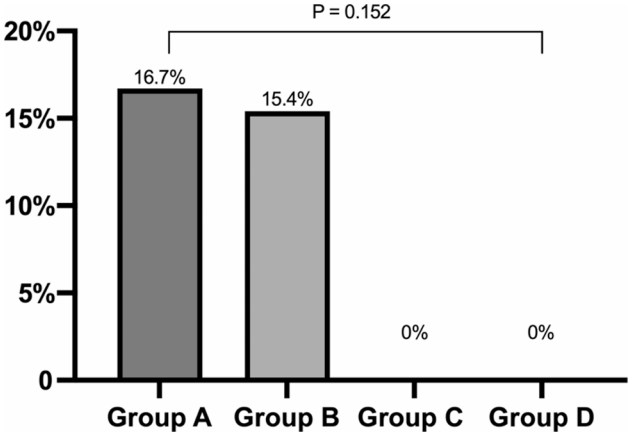


**Fig. 1** Rates of hypotension in four groups

**Table 2** Abdominal wall muscle relaxation degree of four groups

| | Group A ($n = 18$) | Group B ($n = 26$) | Group C ($n = 15$) | Group D ($n = 15$) | *P* value |
|---|---|---|---|---|---|
| Satisfied | 16 (88.89) | 22 (84.67) | 12 (80.00) | 6 (40.00) | 0.04 |
| Fair | 1 (5.56) | 2 (7.69) | 2 (13.33) | 4 (26.67) | 0.241 |
| Dissatisfied | 1 (5.56) | 2 (7.69) | 1 (6.67) | 5 (33.33) | 0.047 |

**Table 3** Adverse events in four groups

| | Group A ($n = 18$) | Group B ($n = 26$) | Group C ($n = 15$) | Group D ($n = 15$) | *P* value |
|---|---|---|---|---|---|
| Additional Anesthetics | 1 (5.56) | 11 (42.31) | 1 (6.67) | 12 (80.00) | < 0.01 |
| Rate of Vasoactive Drugs Use | 12 (66.67) | 7 (26.92) | 2 (13.33) | 4 (26.67) | < 0.01 |
| Adverse Reaction | 0 (0.00) | 3 (11.54) | 1 (6.67) | 5 (33.33) | 0.027 |

fluid, and the sensory impediment boiling plane is unpredictable [16, 17]. Compared with hyperbaric, the hypobaric has a wide range of diffusion and poor controllability [18]. Compared with the addition of 10% sugar to the hyperbaric spinal anesthesia solution, it is easier to bind to the spinal nerve, reach the required anesthesia level faster, and obtain satisfactory muscle relaxation effect, so the hyperbaric spinal anesthesia solution has become the most used spinal anesthesia drug in clinical. However, in clinical work, we have found that the weight of gravity is often caused by the high level of anesthesia, which leads to maternal hypotension [13].

Theoretically, the method of combining hyperbaric with hypobaric, under the premise that the total dose of spinal anesthesia drug remains unchanged, can improve the cephalad movement of local anesthetic drugs, thereby reducing the occurrence of maternal hypotension during surgery. However, our results suggested that hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section did not reduce the incidence of intraoperative hypotension in pregnant

women. We consider that this may have something to do with the fact that our sample size was too small, as the number of hypotensive women during caesarean section was none in both group C and group D.

However, large doses of Ropivacaine have the potential to induce surgical anesthetic effects, whereas smaller doses may result in a sensory block accompanied by localized, non-progressive motor nerve block [19]. Consequently, an increase in the proportion of Ropivacaine naturally enhances its anesthetic efficacy. Analysis of the usage of additional anesthetics among the four groups revealed that the dosage administered in group A was the lowest, while that in group D was the highest, thereby reinforcing the above-mentioned observation.

In groups B, C, and D, there was a significant decrease in the rate of vasopressor utilization, indicating that reducing the proportion of Ropivacaine is more favorable for maintaining the blood pressure stability of pregnant women during caesarean section. Besides, α2-agonists seem to increase the time to first rescue analgesia and to prolong the duration of sensory block when used as adjuvants to local anesthetic in cesarean section patients. Also, α2-agonists may reduce the incidence of shivering and nausea or vomiting [20].

Tang et al. [21] also observed a lower incidence of hypotension in pregnant women following a reduction in the proportion of Ropivacaine, which aligns with our findings. We consider that this phenomenon occurs because Ropivacaine initially moves from the puncture site towards the cephalad side (from L3 to T6) when the hyperbaric anesthetic solution is administered. Subsequently, the hypobaric Ropivacaine moves from the puncture site towards the caudal side, thereby reducing the dose of local anesthetic shifting towards the cephalad side. This reduction in anesthesia level ultimately contributes to the decrease in the incidence of perioperative hypotension [22].

The increase in adverse reactions observed in group D is attributed to the low proportion of Ropivacaine, resulting in a higher concentration of anesthetic drugs migrating towards the caudal side post-injection, thus failing to achieve the desired nerve block. This hypothesis is supported by the lower satisfaction rate of abdominal wall muscle relaxation in group D compared to the other three groups.

This study also has certain limitations. First, this was a prospective cohort study and has a small sample size and the groups contribution was uneven, which night cause potential bias. Second, the trial is not international, and the participating institution of our experiment only has Nantong Maternal and Child Health Care Hospital in China. Third, only pregnant women with American Society of Anesthesiologists grades I–II were included in this trial, and those with American Society of Anesthesiologists grades III–IV were excluded. Thus, further studies including maternal women with larger sample size and randomized controlled multicenter and higher American Society of Anesthesiologists classifications are needed [23]. Improving these limitations in future research will enhance the understanding of optimal anesthesia protocols and their implications for pregnant health.

## Conclusions

Hyperbaric combined with hypobaric local anesthetic in subarachnoid anesthesia for cesarean section did not reduce the incidence of intraoperative hypotension in pregnant women.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-02895-5.

Supplementary Material 1

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Not applicable.

### Author contributions

LZW: study design and data interpretation. WQ: study conduct, data analysis, manuscript preparation and editing. LLL, XXZ and KRL: study conduct and data analysis. All authors: manuscript revision. All authors have reviewed the final manuscript.

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### Data availability

The study number, participant number, date of participant information, and informed consent will be appropriately documented in the participant case report form. The data manager was responsible for data processing and conducted regular monitoring according to the sponsor's standard operating procedures to ensure that the dates are adequate, accurate, and complete. The source data was locked after the completion of the quality assurance procedures. Data is provided within supplementary information files.

## Declarations

### Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of Maternity and Child Health Care Hospital of Nantong University (approval NO. Y2022035).

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

In the study, we obtained informed consent form from all participants. Trained anesthesiologists will explain this trial to the potential participants in detail, and the informed consent form will be provided. Participants can decide whether they wish to participate in the trial after sufficient time to deliberate. Subsequently, the participant or her trustee or guardian can sign the informed consent form, and they can withdraw at any time during the trial.

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