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Clinical Observation of the Effect of Sodium Ion Concentration on the Test Dose of Lidocaine in Patients Undergoing Epidural Block Cesarean Section

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Abstract: Objective: To investigate the effect of changes in sodium ion concentration on the onset time of lidocaine in obstetric epidural block test doses. Methods: Eighty pregnant women scheduled for elective cesarean section, with no age or weight restrictions and ASA grade I or II, were selected. Lidocaine was diluted to two concentrations of 1% and 1.5% using normal saline (NS) and sterile water for injection (SW). The patients were randomly divided into four groups (n = 20): Group A (1% SW), Group B (1% NS), Group C (1.5% SW), and Group D (1.5% NS). A 3 mL test dose of epidural block was administered. The onset time, sensory and motor block levels, and adverse reactions were observed in each group. Results: The onset time was slowest in Group A (mean onset time 4.79 ± 0.65 minutes) and fastest in Group D (mean onset time 3.59 ± 0.61 minutes). Comparison between groups showed that the onset time was significantly shorter in Group B compared to Group A ($P < 0.05$), but there was no significant difference compared to Group C ($P > 0.05$). Group C had a faster onset time compared to Group A ($P < 0.05$), but a slower onset time compared to Group D, with a statistically significant difference. Group D had the fastest onset time, which was statistically significant compared to the other three groups. There were no significant differences in sensory and motor block levels or adverse reaction rates between the four groups ($P > 0.05$). Conclusion: Compared to sterile water for injection, diluting lidocaine with normal saline can shorten the onset time of the test dose. The 1.5% normal saline group had the shortest onset time, which is related to the increased sodium ion concentration in the solution, thereby reducing the onset time of lidocaine.

Keywords: Lidocaine; Normal saline; Sterile water for injection; Test dose

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1. Introduction

Epidural block is widely used in obstetric surgical anesthesia, and lidocaine is commonly used as a test dose

medication. Its role is to verify the success rate of epidural space block and reduce the serious consequences of total spinal anesthesia caused by a large amount of liquid entering the subarachnoid space. Although increasing the drug dose will obviously accelerate the onset time, the toxicity will also increase accordingly. Therefore, it is particularly important to adjust its physicochemical properties without increasing the drug dose, so as to change its onset time. In this study, lidocaine was diluted to different concentrations with normal saline and sterile water for injection, respectively, to find the most suitable combination and concentration of test dose for obstetric epidural anesthesia.

2. Materials and methods

2.1. Patient selection and grouping

The study protocol has been reviewed and approved by the hospital's medical ethics committee for compliance, and all subjects participating in the study have signed informed consent documents by themselves or their families. A total of 80 parturients who planned to undergo elective cesarean section were included in this study. The inclusion criteria were set as ASA anesthesia grade I to II, and there were no serious systemic diseases, pregnancy comorbidities, fetal abnormalities, or contraindications to intravertebral anesthesia. There were no restrictive requirements for the age, height, and weight of the parturients. They were randomly divided into 4 groups (n = 20) using a random number table method: 1% lidocaine SW group (Group A), 1% lidocaine NS group (Group B), 1.5% lidocaine SW group (Group C), and 1.5% lidocaine NS group (Group D). Anesthesia Method: Patients were fasting for 6–8 hours before surgery without premedication. After entering the operating room, routine monitoring of ECG, BP, HR, and SpO2 was performed. A venous access was opened, and 500 mL of hydroxyethyl starch 130/0.4 sodium chloride injection was infused. Mask oxygen inhalation was administered at a flow rate of 3 L/min. In the left lateral position, a puncture was performed at the L1-2 intervertebral space. After successful puncture and aspiration to confirm no blood or cerebrospinal fluid, a 3.5 cm [1] epidural catheter was placed cephalad and secured. A test dose of 3 mL was administered, and the patient was instructed to lie in the supine position. After observing for 10 minutes without adverse reactions and recording all data, additional doses were administered by the anesthesiologist until the anesthesia level reached T6 [2].

2.2. Preparation of medicinal solution

A designated person used 2% lidocaine hydrochloride (Shanghai Hefeng Pharmaceutical Co., Ltd.) mixed with normal saline (NS) and sterile water for injection (SW) to prepare two concentrations of 1% and 1.5%. 3ml was taken as the test dose.

2.3. Observation indicators

After administering the test dose, the patient's block effect was evaluated every 1.5 minutes until anesthesia took effect. The sign of anesthesia taking effect is the weakening of the patient's pain or cold sensation (the order of nerve block: pain sensation → cold sensation → warmth sensation → touch and deep pressure sensation → loss of motor function). Record the time when anesthesia starts to take effect for each group of patients, as well as the level of sensory block and motor block, 10 minutes after administration. Also, record the incidence of adverse reactions (hypotension, excessively high anesthesia level, local anesthetic poisoning, nausea, and vomiting) in patients. The evaluation time was 10 minutes.

2.3.1. Evaluation method of sensory block

The patient's subjective feelings: feeling of heat, heaviness, or numbness in the lower limbs; Objective evidence: skin sensitivity to pain and cold is reduced. Either situation can be regarded as the anesthesia taking effect. The Von Frey Filaments were used to test pain sensation before and after drug administration by selecting the appropriate strength based on actual conditions. Changes in cold sensation were tested with alcohol cotton balls of the same size.

2.3.2. Evaluation method of motor block

The modified Bromage grading method was used for evaluation, including 0, I, 2, and 3 points, representing complete movement ability of both lower limbs, inability to lift lower limbs but able to bend knees, inability to bend knees but able to bend ankles, and complete inability to move both lower limbs, respectively.

2.4. Statistical processing

In the study, mean ± standard deviation (SD) and (*n*, %) were used to represent measurement data and counting data, respectively. Both *t* and χ^2 tests were performed using statistical software (SPSS 19.0) for analysis. $P < 0.05$ was considered statistically significant.

3. Results

There were no statistically significant differences in age, height, and weight among the four groups of pregnant women ($P > 0.05$), as shown in **Table 1**.

Table 1. Comparison of general indicators among the four groups of pregnant women. ($n = 20$, mean ± SD)

Group	Height (cm)	Weight (kg)	Age (years)	*P*-value
Group A	164 ± 5	76 ± 8	28 ± 6	> 0.05
Group B	162 ± 6	74 ± 7	27 ± 5	> 0.05
Group C	163 ± 7	73 ± 7	28 ± 4	> 0.05
Group D	162 ± 4	74 ± 5	26 ± 4	> 0.05

The onset time of block in Group A was slower than that in the other groups ($P < 0.05$). Group D had the fastest onset time among all groups ($P < 0.05$). Compared with Group C, Group B had a slightly faster onset time, but the difference was not statistically significant ($P > 0.05$). When comparing groups with the same concentration of test dose, the onset time in the normal saline group was faster than that in the sterile water for injection group ($P < 0.05$). There was no statistically significant difference in the highest sensory block level at 10 minutes among all groups, which was T10. None of the patients in the four groups experienced motor block, high epidural block, subarachnoid block, or severe local anesthetic poisoning after receiving the test dose. No adverse reactions such as nausea, vomiting, or blood pressure reduction were observed. The observation indicators recorded within 10 minutes for each group are shown in **Table 2**.

Table 2. Observation indicators recorded within 10 minutes for each group. (n = 20, mean ± SD)

Group	n	Onset time (min)	Sensory block level	Bromage score	Adverse reaction rate
Group A	20	4.79 ± 0.65	T10	0	0
Group B	20	4.19 ± 0.48[a]	T10	0	0
Group C	20	4.20 ± 0.63[a]	T10	0	0
Group D	20	3.59 ± 0.61[abc]	T10	0	0

Note: Compared with Group A, [a]$P < 0.05$; Compared with Group B, [b]$P < 0.05$; Compared with Group C, [c]$P < 0.05$.

4. Discussion

Lidocaine has been reported in the literature to have a UV/M ratio close to 0.4–0.6 [3]. Due to its relatively low toxicity and fast onset time, it is commonly used as a test dose medication. The significance of the test dose includes improving the detection rate of epidural catheters misplaced into the sheath or blood vessels [4] and guiding the initial dose of epidural medication. The incidence of local anesthetics accidentally entering the blood vessels during epidural block is significantly higher than that of other regional blocks, usually at 2% [5]. During full-term pregnancy, due to the obvious enlargement of the uterus compressing the inferior vena cava, compensatory dilation and filling of the epidural vascular plexus may occur. When performing an epidural puncture under this physiological state, the puncture needle or indwelling catheter may directly cause mechanical damage to the epidural blood vessels. Relevant clinical research data show that during epidural catheter placement in patients undergoing cesarean section surgery, the incidence of blood vessel injury or accidental insertion of the catheter into a vein ranges from 1.3% to 15.7%. When sitting for a puncture, the risk of such complications may further increase, making the test dose particularly important [6–9]. The faster the test dose takes effect, the shorter the waiting time for the patient and the surgeon, which is more significant for women with active uterine contractions. Although increasing the drug dose can achieve a faster onset, it also increases the potential risks for patients. It is worth exploring how to shorten the onset time of smaller doses of local anesthetics through reasonable solution compatibility.

The physicochemical properties and onset time of local anesthetics are influenced by the pH value and [Na^+] concentration of the local anesthetic solution. When the pH value increases, the proportion of non-ionized base components in local anesthetics increases accordingly. This molecular form change can accelerate the diffusion rate of local anesthetics through the nerve sheath and nerve cell membrane, thereby significantly reducing the onset time of local anesthetics [10]. There are certain differences in the pH value and osmotic concentration between normal saline (pH 6.88) and sterile water for injection (pH 5.5) [11]. Diluting local anesthetics with these solutions can also produce changes in the physicochemical properties of the medication, which can have a certain impact on the onset time of local anesthetics. The voltage-gated sodium channels on the nerve cell membrane are the targets of local anesthetics.

Current research indicates that the potential mechanisms of local anesthetics' blocking effect on sodium channels in cell membranes and the resulting inactivation of sodium channels can be summarized into three aspects:

(1) Local anesthetics can reduce the proportion of activated channels and correspondingly increase the proportion of inactivated channels;

(2) Local anesthetics may partially or completely block the process of conformational transitions, directly

interfering with the activation process of the channels, which is to inhibit the transition of channels from a resting state to an open state;

(3) Local anesthetics may reduce the amount of ion flow through each open channel [12]. In clinical practice, the onset and recovery speed of the blocking effect are mainly determined by the relatively slow diffusion and clearance processes of local anesthetic molecules within neural tissue, rather than relying on rapid binding and dissociation reactions between the molecules and ion channels [13]. The onset time depends on the drug concentration, degree of ionization, hydrophobicity, and physical properties of the surrounding neural tissue. When the pH value of the local anesthetic solution increases, the proportion of uncharged base-form local anesthetic components will increase accordingly. Changes in the composition of such components can accelerate the diffusion rate of the drug through the nerve sheath and nerve cell membrane, thereby significantly reducing the onset time of the local anesthetic.

In this experiment, with the same dose and concentration, the onset time of the normal saline group (C, D) was significantly faster than that of the sterile water for injection group (A, B), suggesting that changes in sodium ion concentration in local anesthetics can affect the onset time of nerve block; motor block and local anesthetic toxicity did not occur, possibly due to the small dose of lidocaine, which would not produce significant symptoms even if this dose entered the bloodstream. However, through careful clinical manipulation, the situation of local anesthetics accidentally entering blood vessels can be avoided to the maximum extent. Great caution is required when administering drugs intrathecally. Currently, only normal saline and sterile water for injection are used to dilute the drug solution in clinical practice, and they have different pH values and significant differences in sodium ion concentration. Through this experiment, we can see that normal saline is more suitable for diluting local anesthetics, providing a certain reference for our future selection of obstetric anesthesia drug combinations.

5. Conclusion

Based on the findings, diluting lidocaine with normal saline, particularly at a 1.5% concentration, significantly reduces the onset time of the test dose compared to using sterile water for injection. This acceleration in onset is attributed to the increased sodium ion concentration in the solution, which enhances the efficacy of lidocaine.

Disclosure statement

The author declares no conflict of interest.

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