Brief Report

Viscosity of diluent and sensory level of subarachnoid anaesthesia achieved with tetracaine

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Purpose: Our objective was to evaluate the effect of viscosity in determining the cephalad spread of tetracaine administered by the subarachnoid route.

Methods: We studied 42 patients that were randomly assigned to receive subarachnoid anaesthesia for arthroscopy of the knee. They received 8 mg tetracaine dissolved in either glucose 10%, sodium chloride (NaCl) 5%, glucose 5%, or NaCl 2.5%. The specific gravity and viscosity of each solvent was also measured. Cephalad spread was defined as the level of sensory block achieved.

Results: The specific gravity of the glucose 5% and the NaCl 2.5% solutions were similar (1.0197 ± 0.0001 vs 1.0177 ± 0.0001 (mean $\pm$ SD)). That was also true for the more concentrated pair of solutions (1.0385 ± 0.0001 for glucose 10% vs 1.0353 ± 0.0003 in NaCl 5%). However, the viscosities of the 10% and 5% solutions of glucose (0.01178 ± 0.0002 and 0.01020 ± 0.0002 (g·cm⁻¹·sec⁻¹)) were higher ($P < 0.05$) than that of the other two solutions, being 0.00955 ± 0.0001 for NaCl 5% and 0.00934 ± 0.0002 for NaCl 2.5%. The median maximal extent of sensory block achieved was significantly higher ($P < 0.05$) with a solution of tetracaine in glucose 10% injected into the subarachnoid space at the L₃₋₄ interspace than that observed in the two groups administered tetracaine in NaCl. The level of sensory block 30 min after the injection of anaesthetic was: T₃ [T₁₋₆] (median [range]) with glucose 10%, T₆ [T₄₋₁₀] with NaCl 5%, T₅ [T₂₋₁₁] with glucose 5%, and T_{5,5} [T₂₋₁₁] with NaCl 2.5%.

Conclusion: Viscosity was shown to be one of determinants of the clinical extent of spread of a subarachnoid anaesthetic such as tetracaine.

Objectif : Évaluer l'influence de la viscosité sur la diffusion céphalique de la tétracaïne sous-arachnoïdienne.

Méthodes : Cette étude aléatoire portait sur 42 patients devant recevoir une rachianesthésie pour une arthroscopie du genou. Ils ont reçu 8 mg de tétracaïne dissoute soit dans du glucose 10%, du chlorure de sodium (NaCl) 5%, du glucose 5% ou du NaCl 2,5%. La densité et la viscosité de chaque solvant étaient aussi calculées. Le niveau du bloc sensitif définissait l'extension céphalique.

Résultats : La densité du glucose 5% et du NaCl 2,5% était identique ($1,0197 \pm 0,0001$ vs $1,0177 \pm 0,0001$, moyenne $\pm$ ET). Ceci était aussi vrai pour les solutions plus concentrées ($1,0385 \pm 0,0001$ pour le glucose 10% vs $1,0353 \pm 0,0003$ pour le NaCl 5%). Cependant la viscosité des solutions de glucose à 10% et à 5% ($0,01178 \pm 0,0002$ et $0,01020 \pm 0,0002$ (g·cm⁻¹·s⁻¹)) était plus élevée ($P < 0,05$) que celle des deux autres solutions, ($0,00955 \pm 0,0001$ pour NaCl 5% et $0,00934 \pm 0,0002$ pour NaCl 2,5%). L'extension maximale médiane du bloc sensoriel était significativement plus élevée ($P < 0,05$) avec la solution de tétracaïne dans le glucose 10% injectée dans l'espace sous-arachnoïdien L₃₋₄ que celle qu'on a observée dans les deux groupes de tétracaïne NaCl. Le niveau du bloc sensoriel 30 min après l'injection de l'anesthésique était : T₃[T₁₋₆] (médiane)[écart] avec glucose 10%, T₆[T₄₋₁₀] avec NaCl 5%, T₅[T₂₋₁₁] avec glucose 5% et T_{5,5}[T₂₋₁₁] avec NaCl 2,5%.

Conclusion : La viscosité constitue un des facteurs cliniques déterminants de l'extension d'un anesthésique sous-arachnoïdien comme la tétracaïne.

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THE specific gravity of a solution influences the extent of the cephalad spread of subarachnoid anaesthesia. Although several reports indicate that solutions of differing specific gravity differ in their extent of cephalad spread,¹⁻⁴ other reports have not demonstrated such a difference.^{5,6} This indicates that numerous factors affect the spread of local anaesthetic.

However, viscosity has not been studied for its independent effect on the cephalad spread of a subarachnoid injection of an anaesthetic solution. The present study compared the cephalad spread of four different solutions of tetracaine administered via the subarachnoid route. The viscosity of these solutions differed, but their specific gravity was similar.

Patients and methods

Subjects and experimental design

Forty-two patients (25 men and 17 women aged 17 to 57 yr) who were undergoing arthroscopy of the knee participated in this study after giving informed consent. They were classified as ASA risk class I or II. This study protocol was approved by our hospital's committee on ethics.

Lumbar puncture was performed aseptically at the level of L₃₋₄ intervertebral space using 22 gauge "pencil-point" type of needle (PAJUNK®, Atraumatic standard Sprotte needle, Germany) by a median approach with the hole of the needle directed caudally. Crystalline tetracaine (Tetocaine® for injection, 20 mg; Kyorin Pharmaceutical, Tokyo, Japan) was dissolved in 5 ml of each of the four solutions. A volume of 2 ml of the resulting solution (8 mg tetracaine solution) was injected into the subarachnoid space over 24 sec by means of an infusion pump (Atom Syringe Infusion Pump 235, Atom Co., Tokyo, Japan).

Patients were assigned to receive the anaesthetic in one of four solutions: glucose 10% (10G group, n = 9); NaCl 5% (5Na group, n = 9); glucose 5% (5G group, n = 12), and NaCl 2.5% (2.5 Na group, n = 12) by randomly selecting one of four cards on which a group name was written.

To determine sensory blockade, the anaesthetist assessed the spread of loss of cold sensation of the patient's body according to a dermatomal chart, using cotton soaked in rubbing alcohol every five minutes for 30 min after the spinal injection.

Measurement of the specific gravity and viscosity of solvents

To measure the specific gravity of each solvent a 25 ml pycnometer bottle with a thermometer (Gay-Lussac type, Shibata-Kagakukougyou Co, Ltd, Tokyo, Japan) was used at 25°C. The specific gravity was determined

as the ratio of the weight of the solvent to the weight of distilled water at the same temperature.

To determine the viscosity of each solvent, an Ostwald viscometer (Shibata-Kagakukougyou Co, Ltd, Tokyo, Japan) was used in a 25°C bath. The viscosity of each solvent was calculated from the formula.

$$\eta_s/\eta_w = d \cdot t / dw \cdot tw$$

where η_s = viscosity of solvent, η_w = viscosity of distilled water, d = specific gravity of solvent, t = time for the solvent to travel a fixed distance, dw = specific gravity of distilled water, and tw = time for distilled water to travel a fixed distance.

Statistical method

Variables related to specific gravity or viscosity, and the level of anaesthesia obtained at the same time points in the four groups were compared by a Kruskal-Wallis test, followed by Mann-Whitney U-tests. Variables within groups were evaluated by the Friedman tests, followed by Wilcoxon tests. A level of $P < 0.05$ was accepted as statistically significant.

Results

There were no differences between the four patient groups in terms of age, sex, weight, and height.

The difference in specific gravity between glucose 10% (1.0385 ± 0.0001 (mean $\pm$ SD)) and NaCl 5% (1.0353 ± 0.0003) and between glucose 5% (1.0197 ± 0.0001) and NaCl 2.5% (1.0177 ± 0.0001) were only 0.0032 and 0.0020, respectively. However, their viscosities showed greater differences. The viscosity of glucose 10% (0.01178 ± 0.0002 (g·cm⁻¹·sec⁻¹)) was the highest among the four solutions tested, being 123% of the viscosity of the NaCl 5% solution (0.00955 ± 0.0001). That of glucose 5% (0.01020 ± 0.0002) was the second highest, being 109% of the viscosity of NaCl 2.5% solution (0.00934 ± 0.0002). The difference in viscosity between these two glucose solutions was 0.00158. The viscosities of NaCl 5% and NaCl 2.5% were lower than those of the two glucose solutions.

Data on the distribution of peak sensory blockade are shown in Figure 1. The upper sensory levels in the 10G, 5G and 2.5Na groups at each time point observed were higher in order of their viscosity, not their specific gravity. Differences in the upper sensory level were seen between the 10G group and both NaCl groups at all points in time ($P < 0.05$).

In all patients, anaesthesia was adequate for arthroscopy of the knee without pain. There were no complications such as neuronal problems or post-spinal headache.

FIGURE 1 Median cephalad sensory level with range bars achieved following subarachnoid administration of 8 mg tetracaine in glucose 10% (●-●), NaCl 5% (■-■), glucose 5% (○-○), and NaCl 2.5% (□-□) solutions.

* $P < 0.05$ vs. 10% glucose group.

Discussion

The main finding of this study was that the maximal extent of blockade in the group receiving glucose 10% as the solvent in the anaesthetic solution exceeded that in the group receiving NaCl 5% as a solvent. In contrast, the clinical spread of anaesthetic solution in the group administered glucose 5% did not differ from that in the group administered NaCl 2.5%. Therefore, our results could not be explained by differences in specific gravity; one must thus consider other factors.

Solutions that are made hypobaric or isobaric by the addition of distilled water or saline are considerably less viscous than are hyperbaric solutions that contain dextrose. Such differences in viscosity may affect the diffusibility of hypobaric or isobaric anaesthetics.^{7,8} However, specific gravity or baricity is not always correlated with viscosity. Our findings can be explained by the differences in viscosity among the four solutions tested. The present study did not clarify the reason behind the relatively more extensive spread of the more viscous solution. We suggest that a high viscosity may indicate poor diffusibility, so that its viscous gradient in the CSF may induce a more extensive spread of the anaesthetic. In contrast, a solution of low viscosity may diffuse into the CSF in a few minutes, being in equilibrium with the CSF, and thus leading to a less extensive spread of the anaesthetic.

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