Distribution of Hypobaric Tetracaine within Cerebrospinal Fluid in a Spinal Canal Model

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We studied the distribution of hypobaric tetracaine within cerebrospinal fluid (CSF) using a spinal canal model to examine the spread of a hypobaric anesthetic solution during spinal anesthesia. In our study, 0.2% tetracaine colored with methylene blue was observed to migrate upwards rapidly and spread horizontally in the upper portion of the model placed horizontally and filled with CSF which was collected from several neurosurgical patients. The boundary between the hypobaric solution and CSF could be clearly identified. These results suggest that the hypobaric tetracaine will distribute in the upper portion of the spinal canal during spinal anesthesia. It can be used to produce unilateral spinal blockade in the lateral decubitus position despite a small difference in specific gravity between the hypobaric anesthetic and CSF. In addition, the fact that the hypobaric solution showed a rapid horizontal spread suggests that correct positioning both during and following administration of the anesthetic is important to control the level of anesthesia. (Key words: hypobaric tetracaine, spinal anesthesia, spinal canal model)

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Hypobaric spinal anesthesia is reported useful for unilateral blockade[1]. We have already reported the usefulness of unilateral blockade using 0.2% hypobaric tetracaine[2]. The distribution of a hypobaric solution can be affected by the patients' position during and after intrathecal injection of the anesthetic[1]. However, hypobaric anesthetics are also considered little affected by gravitation because of a small difference in specific gravity between hypobaric anesthetics and CSF[3]. We, therefore, designed our current study to observe the distribution of the hypobaric solution within CSF in a spinal canal model and to compare it with that of the hyperbaric solution.

Two types of transparent polyvinyl tubes were prepared as a spinal canal model for this study. Tube 1 was 8 mm

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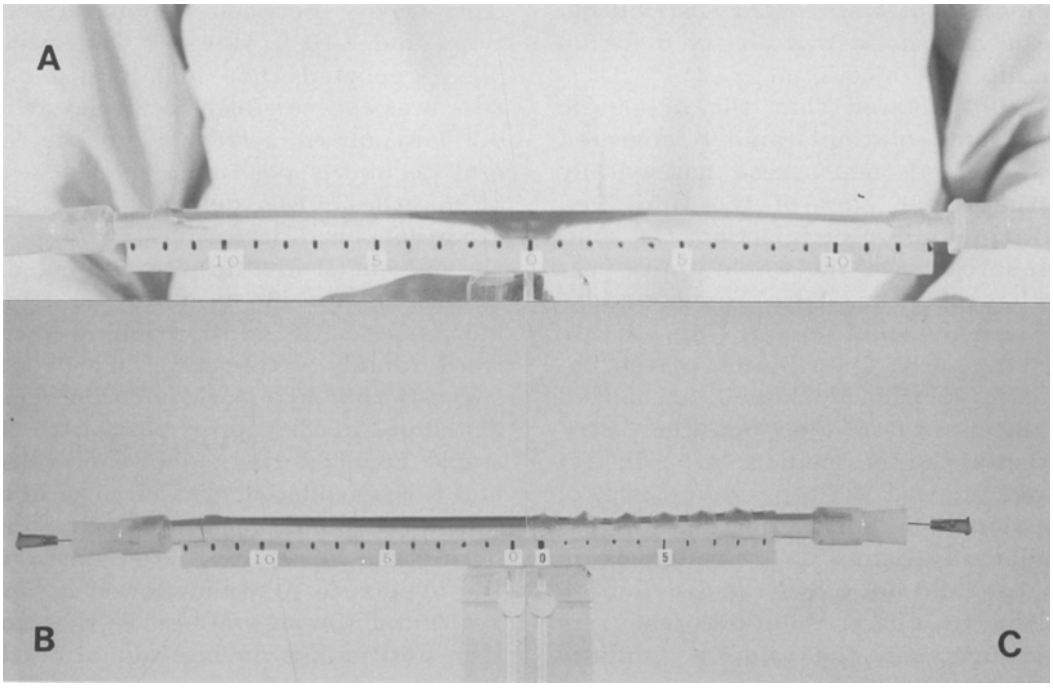

Fig. 1. Distribution of 0.2% hypobaric tetracaine within CSF in a spinal canal model. A shows during injection. B and C show 1 min after injection into tube 1 (B) and tube 2 (C). The half portion of each tube is shown. Hypobaric solutions are colored with methylene blue. Needles at the end of tubes are for removal of the equivalent amount of CSF to the solution injected.

in internal diameter (I.D.), 240 mm in length and about 15 ml in volume with smooth inner surface, while tube 2 was 8 mm in I.D., 200 mm in length and about 12 ml in volume with rough inner surface simulated the dural sheath along the nerve roots. The longitudinal axis of the tube was horizontal with the floor. Each tube was filled with CSF collected from several neurosurgical patients. The composition of CSF was within a normal value except for the alkaline pH (specific gravity; 1.007, pH; 8.0, protein; 8 $mg \cdot dl^{-1}$, glucose; 67 $mg \cdot dl^{-1}$, Cl; 114 $mEq \cdot l^{-1}$ and no blood cells). Tetracaine was prepared as a hypobaric solution after diluted to 0.2% with distilled water and colored with a small amount of methylene blue. The specific gravity of the solution measured with a pycnometer was 1.001 at 37°C and did not change after colored. As a hyperbaric solution, we used 0.2% tetracaine in 5% dextrose colored with methylene blue. The specific gravity of the hyperbaric solution was 1.021. All materials including those described above had been kept at 37°C and the specific gravity was measured with a pycnometer at 37°C.

Test 1; Three ml of the prepared tetracaine solution were injected into the tube 1 using a 23-gauge spinal needle. The needle inserted into the tube horizontally at the middle of both the tube's length and the diameter, and the tip of the needle was located at the center of the tube's cross-section. The rate of injection was 0.05 $ml \cdot sec^{-1}$. Test 2; The 0.2% tetracaine solution was injected into the tube 2 by the same way as in test 1. Test 3; The hyperbaric tetracaine solution was injected into the tube 1 in the same

manner as in test 1. The distribution of the anesthetic was observed for 20 min after its injection.

Test 1 showed that the hypobaric tetracaine solution rapidly migrated upwards and then spread horizontally in the upper part of the tube (fig. 1A). One min after injection, the solution spread over the whole upper part of the tube (fig. 1B). The boundary between the solution and CSF was observed clearly. Distribution of the hypobaric solution remained unchanged for 20 min after injection. The distribution of the tetracaine solution in test 2 was limited to the upper part of the model and spread horizontally in a similar way as test 1. The roughness of our tube did not affect the distribution of the hypobaric solution. One min after injection, the solution similarly spread all over the upper portion of the tube 2 (fig. 1C). In test 3, the hyperbaric anesthetic solution introduced into CSF moved downward quickly and spread horizontally in the lower portion of the tube 1. The boundary between hyperbaric solution and CSF was also clearly identified as in test 1. Distribution of the hyperbaric anesthetic also remained unchanged for 20 min.

Hypobaric spinal anesthesia is reported to have many advantages[4,5]. For instance, blood pressure changes are minimized, lumber puncture can be performed with the operative side up, and it is unnecessary to change the position of the patient when surgery is performed in the lateral decubitus position. Hypobaric techniques are also useful for unilateral blockade, especially for anesthesia of the only one lower extremity[1]. In hypobaric spinal anesthesia, it is demonstrated that the volume of anesthetics rather than the position would have more influence on the distribution of the anesthetics within the spinal canal because of a relatively small difference in specific gravity between hypobaric solutions and CSF[3]. However, we previously reported that unilateral blockade was successfully achieved with 0.2% hypobaric tetracaine in the lateral decubitus position, and the level of anesthesia was determined by the grade of head-down positioning[2]. In the current study, despite a small difference in specific gravity, the hypobaric anesthetic solution migrated upward rapidly within CSF. The result suggests that hypobaric solution would distribute in the upper portion of the spinal canal during spinal anesthesia and it is considered suitable to produce unilateral spinal blockade in the lateral decubitus. In addition, the fact that the hypobaric solution showed a rapid horizontal spread emphasizes that correct positioning during and after the administration of anesthetic is important to control the level of anesthesia. Although this model was not exactly the same as the human spinal canal, these results appear to be in accordance with our clinical findings.

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