Beyond selective spinal anesthesia: A flow pattern analysis of a hyperbaric dye solution injected in a lower-density fluid

ABSTRACT

Introduction: Spinal anesthesia is a technique performed since more than a century and the introduction of hyperbaric anesthetics allowed the anesthesiologists to be more selective when using this technique. The aim of this study is to show the in vitro flow patterns of a hyperbaric dye solution through 27 G Quincke and Sprotte spinal needles, injected at different speeds, in a lower-density fluid.

Methods: A simulator was made using a gummy-like sponge and a disposable plastic urine glass, filled with saline solution, which has a similar density to cerebrospinal fluid (CSF). A hyperbaric dye solution was composed by mixing 3 ml of plain methylene blue with 1 ml of glucose 33%. We used both 27 G Quincke and Sprotte spinal needles to perform a bevel up and a bevel down injection with both slow (15 s) and fast (4 s) injection speed of 0.5 mL hyperbaric dye solution. All the injections were performed using a preset syringe pump and recorded by a camera.

Results: The least selectivity was observed after a bevel up-fast injection through the 27 G Sprotte needle, followed by both bevel up and down fast injections through the 27 G Quincke needle. On the contrary, the best selectivity was observed after a bevel down-slow injection through the 27 G Sprotte needle, followed by both bevel up and down slow injections through the 27 G Quincke needle.

Conclusion: When a 27 G Sprotte needle is used to inject a hyperbaric solution in a lower-density fluid-like CSF, the spread depends on both the bevel direction and the injection speed.

Key words: Cerebrospinal fluid; local anesthetics; needles; spinal anesthesia

Introduction

Spinal anesthesia is a technique performed since more than a century. The introduction of hyperbaric anesthetics allowed the anesthesiologists to be more selective when using this technique.

In the literature, there are studies that tried to correlate the injection speed and the local anesthetic spread along the spinal canal. In a study performed on 20 patients using Whitacre needles, Anderson et al. reported a faster onset...
and offset if an injection of plain bupivacaine was performed slowly (3 ml over 3 min).[1]

This result was not reported in all the studies involving hyperbaric anesthetics. In the work by Holman et al., involving an in vitro hyperbaric dye injection, a higher peak dye concentration was recorded when a slow injection was performed.[2] Furthermore, the literature gives controversial results about the correlation between the speed of injection and unilateral spinal anesthesia when hyperbaric local anesthetics are used. In the work by Casati et al., it was stated that slow injection speeds had no clinical advantages in obtaining unilateral spinal anesthesia.[3] However, other works suggested instead that a slower injection speed is responsible for a more selective spinal anesthesia.[4,5]

Only one study showed the flow dynamics of a plain dye solution through different spinal needles and using different speeds in an in vitro model,[6] but there is none concerning a hyperbaric dye solution.

The aim of this study is to show the in vitro flow patterns of a hyperbaric dye solution through 27 G Quincke and Sprotte spinal needles, injected at different speeds, in a lower-density fluid by using an easy “do-it-yourself” cerebrospinal fluid (CSF) simulator.

Methods

A simple “do-it-yourself” simulator was made using a disposable plastic urine glass (Vacuette®). A square hole of about 1 × 1 cm was pierced in the glass lid [Figure 1]. A square portion of about 1.2 × 1.2 cm was cut from a gummy-like sponge (package of the Echelon Flex 45, Ethicon Endo-Surgery LLC, Somerville, New Jersey). The square sponge was then fitted inside the hole, the glass filled with saline solution, which has a similar density to CSF, and the lid closed. The slightly bigger dimension of the square sponge and its hermetic properties did not allow fluid losses.

We used a 27 G Quincke (Spinocan®, B. Braun Medical, Melsungen, Germany) and a 27 G Sprotte (Pencan®, B. Braun Medical, Melsungen, Germany) spinal needles.

All the injections were performed using a preset syringe pump (Perfusor® Space Infusion Pump, B. Braun Medical, Melsungen, Germany).

The hyperbaric dye solution was composed by mixing 3 ml of plain methylene blue with 1 ml of glucose 33%, that is close to the 8% dextrose concentration of the common hyperbaric anesthetics.

Moreover, the effective hyperbaric nature was confirmed by the fact that, when immersed in the saline solution, the dye solution precipitated anyhow on the bottom.

For each needle, a bevel up and a bevel down injection with both slow (15 s) and fast (4 s) injection speed of 0.5 ml hyperbaric dye solution were performed, for a total amount of four different injections per needle (bevel up-fast, bevel up-slow, bevel down-fast, and bevel down-slow).

All injections were recorded by a camera.

The objective was to analyze the in vitro spread characteristics of the hyperbaric solution in relationship with different infusion rates and bevel orientation, and then define the key-points for a successful selective spinal anesthesia.

During the observations, we considered the “selectivity” as the less presence of turbulences during injection and the predominant presence of dye on the bottom of the glass after injection. This could be compared to a selective spinal anesthesia performed on a patient laying on the lateral decubitus, with a successful unilateral motor and sensitive block.

The screenshots of the recordings were taken after half of the injection (2 s for the fast injections; 7.5 s for the slow injections) and at the end of injection (4 s for the fast injections; 15 s for the slow injections).

Results

By analyzing the recorded images, we found several differences among needle tip shapes, injection speeds, and bevel directions.

For the Quincke needle, there was no significant difference between the bevel up and bevel down injections. In both cases, the injected dye had almost the same unselective flow pattern. It appears to be a difference instead between the slow and fast injection speeds [Figure 2].
The best selectivity for the Quincke needle was achieved after a slow injection of the hyperbaric dye, independently from the bevel direction.

Regarding the Sprotte needle, both bevel direction and injection speed were relevant to the flow pattern and selectivity [Figure 3]. Bevel direction was the most determinant factor for the initial spread pattern of the dye. Injection speed instead was relevant both in the bevel up and bevel down injections, being the slow speed the best factor for selectivity. Therefore, for the Sprotte needle, the best selectivity was achieved by performing a slow injection with a bevel down position.

**Discussion**

Performing a successful selective spinal anesthesia does not rely on the administration of hyperbaric anesthetic only. Studies about this issue are few and are focused mainly on injection speed or anesthetic characteristics, leaving out needle considerations.

This study aimed to analyze through a simulated scenario what might happen when a hyperbaric anesthetic is injected in the spinal canal using different needles and injection patterns.

In details, the least selectivity was observed after a bevel up-fast injection through the 27 G Sprotte needle [Figure 3], followed by both bevel up and down fast injections through the 27 G Quincke needle [Figure 2].

On the contrary, the best selectivity was observed after a bevel down-slow injection through the 27 G Sprotte needle [Figure 3], followed by both bevel up and down slow injections through the 27 G Quincke needle [Figure 2].

However, this study has a limitation: the simulator has a wider diameter than a spinal canal and has a different morphology. Nevertheless, the fluid physical dynamics is objective and makes it suitable to be interpreted in our qualitative analysis, whose main outcome was to analyze the flow patterns of a hyperbaric dye solution through different spinal needles injected in a lower-density fluid.

In conclusion, if a selective spinal anesthesia needs to be achieved with a hyperbaric anesthetic, considerations about spinal needle tip shape, injection speed, and bevel orientation should be made. When a 27 G Sprotte needle is used to inject a hyperbaric solution in a lower-density fluid-like CSF, the spread depends on both the bevel direction and the injection speed. If a 27 G Quincke needle is used instead, the anesthetic spread depends on the injection speed only.

These easy tips should be considered when a selective spinal anesthesia needs to be performed.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.
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