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SHORT COMMUNICATION

Experimental model for local anesthetic spread in spinal anesthesia: application to medical education

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Medical education is student centered, and consolidated curricula have given way to new, more flexible and adaptive models, in which students' opinion and participation have gained importance.[1,2] The aim of the present study was to develop a low-cost experimental model (R$ 300.00) to demonstrate the spread of local anesthetics in spinal anesthesia, and to assess its impact on classroom teaching.[3]

This study was carried out at the Unicamp School of Medicine (Faculdade de Ciências Médicas/Unicamp) with approval of the Research Ethics Committee − CEP n° 3,556.842 Unicamp. The 110 3rd-year undergraduate students were invited, and 64 accepted to participate. They were separated into two groups, one control and the other intervention, with 32 students each, to evaluate the effectiveness of using the experimental teaching model. The groups were allocated based on simple randomization with sealed envelopes opened at the time of the lecture. After obtaining informed consent, the one-day study was performed by assessing one group after the other, so that the groups would not meet. The intervention was carried out in May 2019.

Both groups answered a quality-of-life questionnaire, then attended a lecture on spinal anesthesia. At the end, the control group answered a test on the topic (Table 1). In turn, the intervention group attended a demonstration on the spread of hyperbaric and isobaric bupivacaine using the experimental model, followed by an additional 15-minute period to use the model. Subsequently, they completed the test on spinal anesthesia.

The experimental model in the intervention group intended to demonstrate the anesthetic technique and the spinal spread of local anesthetics. Bupivacaine was used in two formulations: 0.5% hyperbaric and 0.5% isobaric. Dye (methylene blue) was added to bupivacaine in the proportion of 10 mL of local anesthetic to 0.5 mL of dye. Both formulations of bupivacaine differ in baricity and behavior after injection into the subarachnoid space: hyperbaric bupivacaine tends to sink and isobaric bupivacaine tends to remain static, without cranial or caudal spread in the cerebrospinal fluid. This effect results in clinical differences between the two formulations of bupivacaine.

The experimental model was placed in a wooden container with a lid, and measured 1.0 × 0.5 × 0.2 m. There was a drawing of the human spine on the back of the container, from the first cervical vertebra (C1) to the fourth sacral vertebra (S4). A hollow transparent glass cylinder with curves resembling the spine shape was developed to simulate the spinal canal. The glass structure was filled with a 0.9% saline solution and a hole was placed to inject the studied solution in the space between the third and fourth lumbar vertebra (L3−L4) (Fig. 1).

We used the Chi-Square test to compare categorical variables between groups, or when necessary, Fisher's exact test. As the numerical variables did not show normal distribution, we used the Mann-Whitney test to compare the two groups.

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Table 1 Spinal anesthesia test.

1. What is the key anatomical landmark for performing spinal anesthesia?
A) Posterosuperior iliac spine.
B) Projection of the L5 transverse process.
C) Point 3 cm lateral to the midline, at the L4 level.
D) Midpoint between the sacral hiatus and the posterosuperior iliac spine.
2. During the assessment of motor blockade in spinal anesthesia, inability to perform flexion of the hip or dorsiflexion of the foot indicates, respectively, spinal root blockade at:
A) L2 L3 and L4 L5
B) L1 L2 and L5 S1
C) L1 L2 and L4 L5
D) L3 L4 and L5 S1
3. Spinal anesthesia effect:
A) Gastric emptying time is abbreviated with T6 to L2 sympathetic blockade
B) Cardiovascular effects are independent of rostral spread of sympathetic blockade
C) Breathing is directly affected by the blockade of sympathetic autonomic fibers
D) Heating loss in every body region regardless of the level of spinal blockade
4. Main factor influencing the extent of lumbar epidural block:
A) Addition of epinephrine to the Local Anesthetic (LA)
B) Volume of the LA
C) Lower lumbar space capacity
D) Diffusion property of the LA
5. Regarding spinal anesthesia for outpatient procedures, it is correct to state:
A) When the Bromage scale decreases from 2 to 1, 90% of the patient's motor capacity is already recovered
B) Hospital discharge can be given after normalization of vital signs for at least 1-hour, postoperatively
C) The assessment of cognitive functions is the most important factor to determine hospital discharge
6. A 25-year-old patient, ASA IE, is diagnosed with appendicitis and scheduled for surgical treatment under spinal anesthesia. After thoracolumbar antisepsis, the spinal needle is inserted in the subarachnoid space and the CSF backflow stained with blood. In this scenario what is the next best recommended step?
A) Inject the local anesthetic
B) Immediately puncture another space
C) Keep the technique in case blood staining of the CSF disappears
D) Administer 10mg of vitamin K, intravenously, before repeating the puncture
7. Patient, 68 years old, 50 kg, 168 cm, has arterial hypertension and type I diabetes. He presents metastatic prostate cancer and is admitted to the intensive care unit due to bilateral pneumonia and peri malleolar abscess. He progresses with fever, tachycardia, increased insulin requirements, diabetic ketoacidosis, and respiratory failure. He has an orotracheal tube inserted, but adaptation to the mechanical ventilator is challenging, despite fentanyl sedation. Abscess drainage was performed under local anesthesia with 0.25% bupivacaine 30 mL, due to severe clinical condition of the patient. About 30 minutes after procedure onset, he showed greater ventilatory difficulty, followed by ventricular ectopias and QRS widening, which evolved to pulseless electrical activity. The most likely cause for the adverse outcome is:
A) Bupivacaine intoxication
B) Acute myocardial infarction
C) Septic shock
D) Barotrauma.
8. A 65-year-old patient, run over by a car, full stomach, with an open fracture of the proximal femur is scheduled for surgical fracture repair. On exam, patient shows anxiety and confusion, cold and sweaty skin, BP: 100 × 50 mmHg, HR: 140 bpm. Considering this hypothetical situation, which is contraindicated
A) Neuraxial block.
B) General anesthesia.
C) Use of colloids.
D) Total intravenous anesthesia.
9. The major determinant for sensory blockade duration of spinal anesthesia is:
A) Type of local anesthetic.
B) Addition of epinephrine.
C) Addition of clonidine.
D) Dose of local anesthetic
10. Regarding epidural anesthesia, it is correct to state that
A) Spinal anesthesia, unlike epidural anesthesia, can cause urinary retention.
B) Spinal anesthesia is associated with a very high risk of local anesthetic toxicity.
C) Spinal anesthesia is always a cause of arterial hypotension due to blockade of sympathetic nerves.

D) When performing spinal anesthesia for adult patients, the spinal puncture must be performed below the L1 vertebra, while for pediatric patients it must be performed below the L3 vertebra to avoid spinal cord injury.

11. The local anesthetic spread in spinal anesthesia:

A) Is inversely proportional to the injection speed.

B) Is directly proportional to the specific weight of hyperbaric solutions.

C) Is directly proportional to the pressure of the cerebrospinal fluid.

D) Is inversely proportional to the injected volume.

12. The likely diagnosis for a patient who experienced respiratory arrest after epidural anesthesia is:

A) Inadvertent intravascular injection.

B) Total spinal anesthesia

C) Acute myocardial infarction.

D) Pulmonary embolism.

13. In spinal anesthesia, the first sensation that disappears is:

A) Thermal.

B) Proprioceptive.

C) Painful.

D) Pressure.

14. In performing and evaluating spinal anesthesia, it is correct to affirm that:

A) The umbilicus corresponds to the T8 dermatome.

B) The medial malleolus and medial surface of the foot correspond to the L5 dermatome.

C) The imaginary line connecting the iliac crests corresponds to the L3—L4 interspace.

D) The xiphoid appendix corresponds to the T4 dermatome.

15. Which of the following is a delayed spinal anesthesia complication, more common in pregnant women?

A) Bradycardia.

B) Hypotension.

C) Respiratory failure.

D) Headache.

Spearman's correlation coefficient was used to verify the relationship between continuous and discrete variables. The coefficient ranges from -1 to 1. Values close to extremes indicate a negative or positive correlation, respectively, and values close to zero indicate no correlation. The significance level adopted for the statistical tests was 5%.

The groups were similar in relation to the domains and components of quality of life assessed by the SF-36 (Short Form 36), except for the functional capacity domain, in which the control group had better mean results of 95.3 (or median = 100) vs. the intervention group mean results of 91.4 (median = 95.0), $p = 0.0491$, Mann-Whitney test. In this domain, the control group showed better performance to execute physical activities. No correlation was observed between the number of correct answers in the spinal anesthesia test and the domains and components of quality of life found in the groups.

The groups presented similar performance results on the spinal anesthesia test based on the number of correct answers in each question, excluding question number 9. The percentage of correct answers for that question in the intervention group was 78.1%, significantly higher than the 37.5% found in the control group ($p = 0.0010$, Chi-Square test). No statistically significant difference between the groups was observed for the remaining questions ($p = 0.444$, Mann-Whitney test). The percentage distribution of correct answers for question 9 in the spinal anesthesia test showed a significant difference ($p = 0.0010$, Chi-Square test).

The total number of correct answers in the intervention group (median = 9.43) was higher than in the control group (median = 8.96), albeit the difference observed was not statistically significant.

A sample size calculation was performed for the study. Considering the final test score as the main variable of the study and a power of 80%, we estimated that each group would require 46 students. Given participation of students was non-mandatory, there were 32 students in each group, thus the estimated sample size was not reached, which is a limiting factor for more generalized conclusions.

The third-year students who participated in the study have access to new technologies that are intensely present in their routine. Of the total number of students, we reached 58% of voluntary participation.

Individually, the performance of both groups was similar for all test questions, except for the duration of spinal anesthesia that is associated with the dose of local anesthetic injected. Our findings suggest that using an experimental model enables visual observation of drug spreading and helps understand that drug distribution can impact spinal anesthesia, which may demonstrate the validity of the proposed model.

When correlating the quality-of-life questionnaire results with those of the spinal anesthesia questionnaire, no direct association was found between the performance in the two tests in both groups. Thus, as expected, the two samples were shown to be similar and that they would not interfere in the study. In the present study, no conflicting differences were observed between the groups.

Both groups showed a similar performance regarding the spinal anesthesia test. Only test question number 9 revealed a significant difference between the groups ($p = 0.0010$) with a higher rate of correct answers by the intervention group. Question 9 focused on the relationship between duration of spinal anesthesia and dose of local anesthetic (Question Answer D). Using the model that enabled visualization of drug dispersion allowed showing that drug spreading can affect spinal blockade duration.

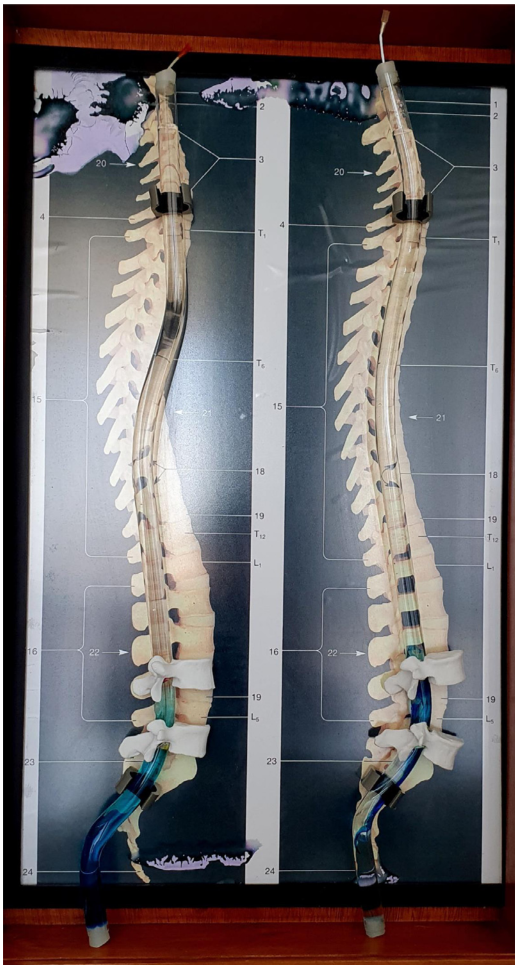

Figure 1 Experimental model.

The intervention group had a higher total number of correct answers than the control group in the spinal anesthesia test, albeit not statistically significant. Small variations in results were not sufficient to support robust conclusions. Nonetheless, our findings suggest that using the model promoted a positive impact on the understanding of the spinal anesthesia technique and on the different properties of the anesthetics used, and that assessment of a larger sample[4] could have made the difference relevant.

One of the difficulties we faced during the study was the onset of the COVID-19 pandemic. After the intervention and statistical analysis, we concluded that a larger number of students would be required.

Conflicts of interest

The authors declare no conflicts of interest.

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