# A teaching tool in spinal anesthesia

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*The purpose of the present study was to develop and evaluate a new model for teaching spinal anesthesia to nurse anesthesia students. The new teaching tool was evaluated to determine if the use of a spinal model allowing visual combined with the haptic sense was more effective than the traditional spinal model using primarily the haptic sense. Specifically, was there a difference in the number of successful passes, the amount of time taken for each spinal attempt, and the number of participants who reached 90% proficiency when comparing the use of both spinal models?*

*Data analysis using a paired* t *test and Wilcoxon signed rank test revealed that the number of successes, amount of time needed to complete 1 needle pass, and point at which 90% proficiency was reached with the newly designed model were significantly greater than with the traditional model. The present study demonstrated that significant differences exist between participants who used both visual and haptic sense and participants who used primarily the haptic sense when performing spinal anesthesia.*

*Findings of this study will be used to provide information that may be used to change the current curriculum for the training of nurse anesthesia students in spinal anesthetic procedures.*

**Key words:** Haptic sense, simulator, spinal anesthesia, teaching tool, virtual reality.

Regional anesthetic procedures are significantly more difficult to learn than basic manual skills that are necessary for a general anesthetic.[1] Currently, no studies have been done to determine whether there is enhanced learning by measuring the difference in the number of successful spinal placement attempts, the time it takes to place the spinal needle, and the time when proficiency is reached when comparing the use of the newly designed spinal model vs the traditional spinal model. In addition, no studies have been done that examine nurse anesthetists' or nurse anesthesia participants' learning process for spinal needle placement. A new teaching tool was evaluated to determine if the use of a spinal model allowing visual combined with haptic (sense of touch) sense was more effective than the traditional spinal model using primarily the haptic sense.

## Specific aims

The specific aim of this study was to determine whether the use of a spinal model allowing visual combined with haptic sense is more effective than the traditional spinal model using primarily the haptic sense. Specifically, is there is a difference in the number of success rates, the amount of time taken for the spinal attempts, and the number of participants who reached 90% proficiency when comparing the use of both spinal models? We tested the following hypotheses:

1. Participants will exhibit a greater number of successful needle placements on the newly designed spinal model compared to the number of successful needle placements on the traditional spinal model. Using the traditional model, success will be defined as visualization of Betadine solution in the needle hub. Using the newly designed model, success will be defined as the investigators visually confirm correct placement of the spinal needle. Participants will not view the needle trajectory until the needle pass is reported as "complete" by the investigators.

2. Time required to complete 1 needle pass on the newly designed spinal model will be less than the time required to complete 1 needle pass on the traditional spinal model. Time will be measured in hundredths of a second from the point at which the participant touches the model until the point at which the forward trajectory of the spinal needle stops (newly designed model) or Betadine solution is seen in the spinal needle hub (traditional model).

3. The point at which 90% proficiency is reached by participants on the newly designed model will be achieved in fewer needle passes than the point at which 90% proficiency is reached by participants on the traditional model. The participant will be consid-

ered 90% proficient when 9 out of 10 consecutive passes are successful. The needle pass number at which the participant begins 90% proficiency will be recorded.

## Background and significance

After examining the learning process of first-year anesthesia residents, Konrad et al reported spinal anesthesia placement as being one of the most difficult procedures with a significantly slower rise in the learning curve.[1] Proper placement of spinal anesthetic requires manipulation of a needle around bony prominences in the vertebral column and into the subarachnoid space of the spinal cord.[2] Success rates are closely associated with the number of attempts that anesthetists are exposed to during training.[1,3-6] At least 20 attempts at spinal needle placement are necessary to achieve an improvement from baseline.[1]

Models have been traditionally used as a supplement to spinal anesthesia training. They allow the trainee to "feel" the technique and provide a way for the trainee to feel the different levels of resistance and "popping" as the needle passes through the various layers of tissue.

It is assumed that by providing training in a nonthreatening environment, participants will learn spinal anesthetic techniques more quickly and safely. In addition, increasing confidence and decreasing anxiety in the learner, the preceptor, and the patient will augment their real-world performance.

Loacker et al[7] discuss the development of an assessment tool to evaluate the learning process of beginning participants. Elements involved include (1) determining a specific ability or expected outcome, (2) identifying component abilities, (3) selecting or designing a stimulus or context, (4) developing criteria, (5) providing for self-assessment, and (6) judging the performance and giving feedback.

Our objective was to determine whether there was enhanced learning by measuring the difference in the number of successful spinal placement attempts, the time it takes to place the spinal needle, and the time when proficiency is reached when comparing the use of the newly designed spinal model vs the traditional spinal model.

## Materials and methods

This research incorporated the previous 6 educational elements discussed by Loacker et al[7] in the following manner:

1. The specific ability desired by the development of this teaching tool was successful demonstration of spinal anesthesia using 2 different spinal models. A successful "pass" referred to the continual advance of the needle (with or without pauses) until the dura was entered. This was determined by the return of a Betadine solution representing cerebrospinal fluid on the traditional spinal model and by visualization of correct needle placement by the investigators into the subarachnoid space on the newly designed spinal model. If Betadine solution was not seen in the hub of the needle using the traditional model, the pass was not considered successful. Participants were not allowed to view the needle trajectory until the needle pass was reported as "complete" by the investigators.

2. Component abilities needed were basic knowledge of lumbar anatomy, common approaches used in spinal anesthesia, and appropriate techniques used during placement of a spinal anesthetic. These were taught to each participant during the didactic portion of his or her training.

3. Development of the newly designed model allowed for the participant to incorporate both visual and haptic senses. Selection of the traditional model required the participant to rely primarily upon the haptic sense.

4. The criterion for successful spinal technique was determined by several methods. The methods included recording the number of successful needle passes, the length of time needed to complete each pass, and the point at which participants reached 90% proficiency with both the traditional and newly designed models.

5. Self-assessment was ongoing. Using the traditional model, participants felt the trajectory of the needle as it passed through the various structures. Using the newly designed model, participants were able to feel the trajectory of the needle through the various structures and visualize needle trajectory after the pass. The visualization allowed feedback for future attempts.

6. With the traditional model, participants were able to judge their performance as successful by return of the Betadine solution. With the newly designed model, participants were able to judge their performance as successful by visual confirmation of needle placement in the subarachnoid space. Verbal comments and suggestions were allowed throughout the spinal laboratory session. No physical assistance or prompting was allowed from the staff present.

The sample group consisted of 26 nurse anesthesia students from the Mayo School of Health Science Master of Nurse Anesthesia Program class of 2002. The participants were from various demographic areas and had various nursing experiences and skills. The sample group had no prior regional anesthesia

experience or contact with either of the 2 models used. In addition, all participants had been in the Mayo School of Health Science Master of Nurse Anesthesia Program for 15 months.

Training prior to the use of the spinal models consisted of traditional teaching methods, which included lecture and atlas. The laboratory portion consisted of randomly dividing the 26 participants into 6 groups. All 26 of the participants' names were placed into a container, randomly drawn, and assigned to a group labeled 1 through 6. Groups 1, 2, 5, and 6 consisted of 4 members per group, and groups 3 and 4 consisted of 5 members per group.

The laboratory portion consisted of 6 stations with 1 group at each station. The 6 stations were comprised of 2 landmark identification stations, 2 preparation and draping stations, 1 traditional spinal model station, and 1 newly designed spinal model station. Groups 1, 3, and 6 attempted 20 spinal placements per participant on the traditional model, followed by 20 subsequent attempts per participant on the newly designed model. Groups 2, 4, and 5 attempted 20 spinal placements per participant on the newly designed model, followed by 20 subsequent attempts per participant on the traditional model.

Several steps were taken in an attempt to minimize repetitious learning. Participants rotated in an assigned order within their group to allow for maximum time between each needle pass. A interval of 5 to 10 minutes occurred between each participant's needle pass. Between each pass, participants were engaged in activities that were unrelated to spinal needle placement.

Each participant received the same instructions on how to identify landmarks on the 2 models, the criteria for a successful spinal placement, and the definition of 1 needle pass. The following explanation was given:

> The time begins when you first touch the model. The landmarks are the iliac crest, which is in vertical alignment with the lumbar vertebra spinous process number 4 (L4) or the L4 to L5 interspace. Find the iliac crest, make a vertical line down to the spinous process of L4, palpate the interspace, and begin the needle pass. One needle pass per sitting will be allowed. With the traditional model, 1 needle pass is defined as a forward motion until resistance is met or until Betadine solution is visualized in the needle hub. With the newly designed model, 1 needle pass is defined as a forward motion until resistance is met. The time will stop when forward motion of the needle ceases. After 1 pass is completed, you must allow complete rotation of the group members before attempting your next pass. You will have a total of 20 attempts on each spinal model.

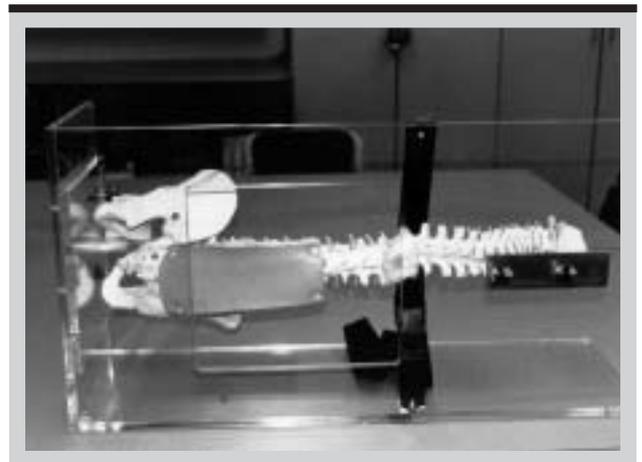Visualization of Betadine solution in the needle hub with the traditional model or the investigators visually confirming correct placement of the spinal needle with the newly designed spinal model signified 1 successful needle pass. Participants attempting passes on the newly designed model were allowed to visualize the trajectory of the spinal needle once the pass was complete. The participant could use this information in subsequent attempts to adjust his or her trajectory. The traditional model did not allow for this additional feedback.

The same room and equipment was used for all groups. A 22-gauge, 3 $\frac{1}{2}$-inch Whitacre spinal needle was used. The materials, which simulated the various layers of tissue in both models, were identical and were provided by the same manufacturer. The spinal column for the newly designed model was a simulation of a life-sized spinal column and pelvis. The Mayo Mechanical Engineering Department mounted the spinal column in clear plexiglass so that it could be placed in positions comparable to those of the traditional model. The newly designed spinal model was made of a full spinal column (Figure 1).

The traditional spinal model was designed by Nasco Life/Form Spinal Injection Simulator #LF01036U (Fort Atkinson, Wis) to simulate the lower back area, specifically, T10 through S5 (Figure 2).

With both models placed in the lateral position, the participant visualized the epidermis and was able to palpate the iliac process and the spinous processes of the vertebrae. If the trajectory of the needle was correct, the needle passed through the various layers representing simulated skin, subcutaneous fat, supraspinous ligament, ligamentum flavum, dura, and into the subarachnoid space. The participant was able to feel varying degrees of resistance as the needle passes through these structures. With the blind model, a "pop" was felt as the needle entered the subarachnoid space. A wire-reinforced latex rubber column created

**Figure 1. Newly designed model**

**Figure 2.** Traditional model



**Figure 3.** Student performing spinal placement on traditional model



**Figure 4.** Student performing spinal placement on newly designed model



the popping sensation. Correct placement of the needle was confirmed by return of a Betadine solution, which was representative of cerebrospinal fluid.

Two investigators were present at the traditional model station, and 2 investigators were present at the newly designed model station. Prior to starting the testing sessions, all investigators participated in 5 trial sessions to verify interrater reliability. One investigator measured the time taken in hundredths of a second using stopwatches manufactured by the same company for each needle pass per participant, while the other investigator observed and recorded the data on the data sheet (Figures 3 and 4). Data recorded included the name of the participant, the group number, the time taken for each needle pass, and whether it was successful or unsuccessful (Figure 5). The participant was considered 90% proficient when 9 out of 10 consecutive passes were successful. The needle pass number at which the participant began 90% proficiency was recorded. For example, if a participant was 90% proficient for passes 2 through 11, a "2" was recorded. If a participant was 90% proficient for passes 5 through 14, a "5" was recorded. Therefore, a score of 1 to 11 had the potential to be recorded. Participants who never reached 90% received a score of "12" for statistical purposes.

Since each student practiced on both the traditional and the newly designed models, comparisons between the models of each outcome measure were analyzed in a paired manner by comparing each student against themselves. The time needed to complete 1 needle pass was averaged across the 20 attempts for each student, and the paired *t* test was used to compare the overall mean time across all students between the traditional and newly designed models. The number of successful attempts and the point at which 90%

proficiency was reached were each compared between the 2 models using the Wilcoxon signed rank test. This statistical method was used since it focuses on the ranks of the outcomes rather than the actual values that were ordinal in nature. All calculated *P* values were 2-sided, and *P* values less than .05 were considered statistically significant.

## Results

Data for the study (n = 26) is summarized in the Table. The differences in number of successes, time, and point at which 90% proficiency was reached were analyzed using a paired *t* test and a nonparametric test (the Wilcoxon signed rank test).

For each of the 26 participants, the average number of successes with the traditional model was 13. The average number of successes with the newly designed

**Figure 5.** Data collection sheet

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**Please fill in the following information:**                    **Traditional Model**
                                                                 **Newly Designed Model**

Name: _____

Length of time in nurse anesthesia program: 15 months

| Spinal attempt # | Time | Pass successful | Pass unsuccessful |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |

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**Table.** Data summary

| | Time* | No. of successful needle passes | No. at which 90% reached |
|---|---|---|---|
| Traditional | 13.14 | 13 | 3 |
| Newly designed model | 8.74 | 17 | 9 |
| *P* values | <.001 | <.001 | <.001 |

\* Hundredths of a second

model was 17. The number of successes with the newly designed model was significantly greater than the number of successes with the traditional model ($P < .001$). The Wilcoxon signed rank test also showed significance ($P < .05$, Figure 6).

For each of the 26 participants, the average time needed to complete 1 needle pass on the traditional model was 13.14 seconds. The average time needed to complete 1 needle pass on the newly designed model was 8.74 seconds. The amount of time needed to complete the needle pass on the newly designed model was significantly less than the amount of time needed

**Figure 6.** Average number of successful needle passes for newly designed model vs traditional model
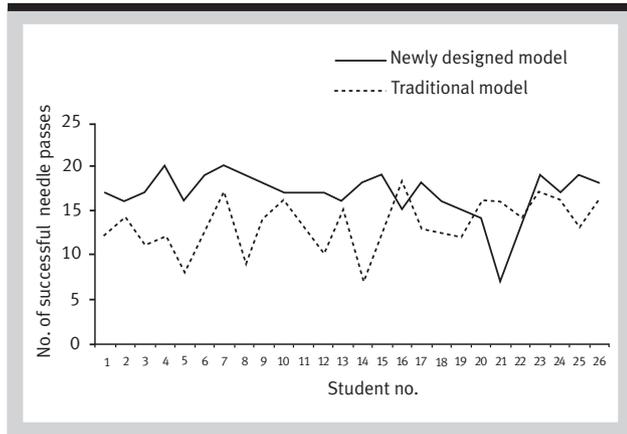


**Figure 7.** Average time of needle passes for newly designed model vs traditional model



**Figure 8.** Number of needle pass at which 90% proficiency reached for newly designed model vs traditional model



to complete 1 needle pass on the traditional model ($P < .001$). The Wilcoxon signed rank test also showed significance ($P < .01$, Figure 7).

For each of the 26 participants, the average point at which 90% proficiency was reached with the newly designed model was 3. The average point at which 90% proficiency was reached with the traditional model was 9. The point at which 90% proficiency was reached with the newly designed model was achieved with significantly fewer needle passes than with the traditional spinal model ($P < .001$). The Wilcoxon signed rank test also showed significance ($P < .001$, Figure 8).
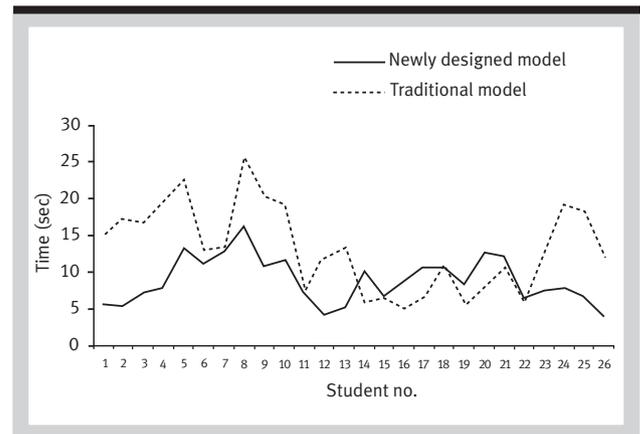
## Discussion

Although the results show statistical significance favoring the newly designed model, there were several factors that need to be considered.

One factor was that the data collected were nonindependent observations. For example, participants were aware that they were being timed, which led some participants to compete against their own times and other participants' times. This may have caused a false decrease in time needed to achieve a successful needle pass or an increase in the failure rate.

A second factor was that 2 participants did not proceed in the order assigned. Therefore, there was a shorter interval between needle passes for these 2 participants. This may have caused a decrease in time, an increase in number of successes, and a decrease in the number of needle passes needed to achieve 90% proficiency. This may be attributed to enhanced learning among those participants.

A third factor was that some participants attempted needle passes at different vertebral interspaces other than the specified interspaces of L3 to L4. This may have caused an increase in time, a decrease in the
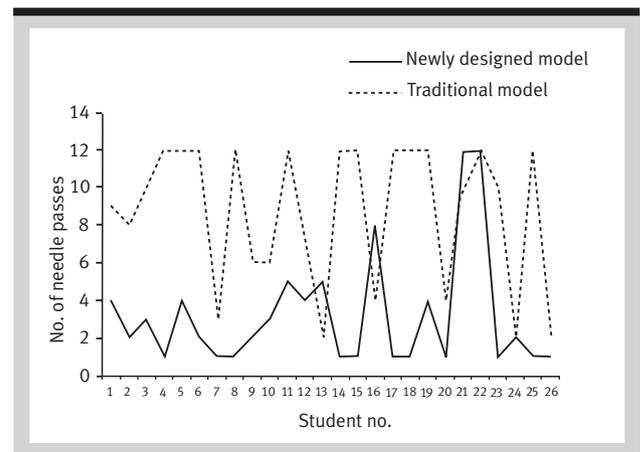
number of successes, and an increase in the time that 90% proficiency was reached.

A fourth factor to consider was that the investigators' definition of 90% proficiency was reached secondary to the participant's memorization of needle placement and angle of trajectory of previous attempts.

A fifth factor to consider is the fact that there was a time difference between the traditional and newly designed model when a successful needle pass was determined. In the traditional model, there was a short lag time between the time when the participant's needle entered the subarachnoid space and the time when Betadine solution was visualized. This may have biased results toward the newly designed model.

A sixth factor to be considered is the fact that when using the traditional model there may have been the chance that the needle penetrated the subarachnoid space without the return of Betadine solution in the needle hub. This would be impossible for the investi-

gators to know, as the spaces could not be visualized. Throughout the testing period, none of the participants questioned whether they had entered the subarachnoid space without visualizing the return of Betadine solution.

Identical analyses were performed to look at whether the above factors affected the statistical significance by excluding those participants. A total of 9 participants were excluded. Statistical significance was still achieved with an increase in success ($P <$ .01), a decrease in time ($P < .05$), and a decrease in the number of needle passes required to achieve 90% proficiency ($P < .0001$).

An additional factor was the potential for a learning or carryover effect introduced by having each student practice on both models. To address this issue, an additional analysis was conducted focusing on just the data obtained from the first model per student (groups 1, 3, and 6 [n = 13]) on the traditional model and groups 2, 4, and 5 [n = 13] on the newly designed model). Upon comparing these 2 independent groups of subjects, statistical significance was still attained. The newly designed model had a higher number of successful needle passes (Wilcoxon rank sum test, $P =$ .0264) a shorter completion time (2-sample $t$ test, $P =$ .0009), and fewer number of needle passes to achieve 90% proficiency (Wilcoxon rank sum test, $P = .0133$), compared to the traditional model.

Other variables that may have affected the results of this study include:

1. The positioning of the models
2. Differences in ease of identifying landmarks
3. Changes in the materials of both models after repetitive use
4. Inconsistencies in the timing of each needle pass
5. Differences of group sizes

Positioning of the traditional model was left lateral, whereas positioning of the newly designed model was right lateral. Participants expressed that transition between the models was difficult because of this difference in positioning. The newly designed model was constructed for right lateral positioning but in the future could be modified to accommodate both right and left lateral positions. Participants also stated that the bony landmarks of the newly designed model were more prominent than the bony landmarks of the traditional model. Participants noted preexisting holes in the skin of both of the models due to repetitive needle punctures, which may have aided in identifying the appropriate interspace. Time measurement of needle passes may have been inconsistent between the 2 models due to 2 different investigators measuring time for each model. Although stopwatches made by the same

manufacturer were used and interrater reliability was verified, no effort was made to time an identical period with each stopwatch to determine if they agreed. Due to small group sizes, attempts at inhibiting repetitive learning may have been limited since a participants' subsequent attempt would take place sooner than a subsequent attempt in a larger group.

## Conclusions

The findings of our study indicate that the ability to visualize the trajectory of the spinal needle may enhance learning of spinal needle placement. This was shown by participants achieving an increase in number of successful spinal needle placements, a decrease in the amount of time required for placement of spinal needles, and a decrease in the number of passes required to achieve 90% proficiency.

## Suggestions for further research

Although this study demonstrates that the ability to visualize the spinal needle trajectory may enhance the learning of spinal needle placement, the use of nonhuman models does not offer a high degree of realism. Mannequins do not provide a good representation of human tissue, and they are prone to wear out with repeated use and do not allow for variation in patient anatomy. Cadaveric specimens have been used in the past but offer limited opportunity. They are difficult to obtain and lack human patient variability.[8]

Current literature suggests that virtual reality (VR) is a useful and effective technique for a wide variety of applications and has a positive effect on the learning process.[9-11] VR is a relatively new science that is finding its way into a wide scope of educational programs including architectural design, flight and driving simulation, and military and police training.[10,12,13]

VR has enormous potential in medical training as well, and specifically in the placement of spinal needles for the training anesthetist.[8-10,12,14,15] Ideally, development of VR software may offer a more realistic human model by allowing the user to perform spinal needle placement using a variety of approaches and multiple simulated patients, along with the ability to visualize needle trajectory. VR also has the potential to allow for precise timing of correct needle placement and the ability to allow for transparency through all skin layers into the actual subarachnoid space.

VR may offer an exciting opportunity for further research in the development of a teaching tool for spinal anesthesia.

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