Background and Objectives: Success in performing ultrasound-guided peripheral nerve blockade (PNB) demands sound knowledge of sonoanatomy, good scanning techniques, and proper hand-eye coordination. The objectives of our study were to evaluate whether simulator training aids success of novice operators in ultrasound-guided PNB and to determine what number of procedures is required to attain proficiency.

Methods: Twenty Postgraduate Year 2 anesthesiology residents with no previous experience in ultrasound-guided PNB were randomly assigned into 2 groups. Both groups received conventional teaching comprising of 4 didactic lectures on PNBs with ultrasound guidance. Using a low-fidelity simulation model, 1 group further received an hourlong training session on needling and proper hand-eye coordination. Once the training was over, the residents started their rotation through our block room. Using a logbook, each resident recorded the number of successful and failed ultrasound-guided regional anesthesia blocks performed over a 3-week period. A successful block was defined as one that was effective for surgical anesthesia and performed within 15 mins, with only verbal guidance from a staff anesthesiologist. Cumulative summation charts were created to track progress using a predetermined acceptable failure rate of 30%.

Results: The conventional training group had 98 successful blocks, and the simulation group had 144 (51.3% vs 64%; \( P = 0.016 \)). In the conventional training group, 4 of 10 residents achieved proficiency, and in the simulation training group, 8 of 10 residents achieved proficiency (80% vs 40%; \( P = 0.0849 \)).


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The application of ultrasound for the performance of peripheral nerve blocks (PNBs) is evolving to become a common practice in regional anesthesia. Ultrasound-guided PNB facilitates direct visualization of nerves, needle placement, and distribution of local anesthetic. Its use has become popular in regional anesthesia because it frees the operator from using the classically described landmarks. However, for residents or novice anesthesiologists, learning this new technology poses a challenge. There are 2 aspects to learning how to perform an ultrasound-guided PNB: (1) interpretation of sonoanatomy, which involves identification of anatomic structures as seen on the ultrasound images, and (2) needling technique, which involves learning to manipulate the ultrasound transducer and needle to direct the needle to the target under direct vision. This second aspect requires knowledge of sonoanatomy as well as hand-eye coordination.

The concept of “see one, do one” has proven to be an expensive, time-consuming, and inconsistent model for teaching health professionals to perform complex procedures. It has been recommended that 3 major components of technical skills be taught before application of the new skill within a clinical setting. These include the following:

- acquiring cognitive knowledge about the specific procedure, including the steps of the procedure, the function, and operation of the equipment;
- receiving instruction on basic, generic enabling skills required for the procedure; and
- opportunities to perform the procedure in a variety of platforms, such as virtual reality, bench model simulators, cadaver, and live animal models.

The use of simulation training in regional anesthesia may help in the third component by facilitating target localization and improving performance of needling techniques. However, the transfer of this skill to clinical practice has not been evaluated as to whether it aids achievement of proficiency in clinical performance of ultrasound-guided PNB.

The objective of our study was to evaluate whether the inclusion of a teaching session on a low-fidelity phantom simulator aids achievement of proficiency in clinical performance of ultrasound-guided PNB in novice operators. A secondary objective was to determine the number of ultrasound-guided PNB procedures required to attain proficiency using the cumulative summation (CUSUM) analysis.

MATERIALS AND METHODS

The study commenced following University Health Network Research Ethics Board approval and after each resident had provided a signed informed consent for participation in the study. Thirty anesthesia residents in their second year of training were recruited into the study between 2008 and 2010 at Toronto Western Hospital, University of Toronto. Residents with previous experience in ultrasound-guided peripheral nerve blockade or neuraxial blockade were excluded from the study. The residents were recruited by our institute’s research coordinator to avoid any undue influence to participate. All residents received conventional teaching, which included 4 half-hour didactic lectures on basic upper- and lower-limb ultrasound-guided PNBs: interscalene, supraclavicular, infracavicular, axillary, femoral, sciatic, and ankle blocks. Continuous catheter and neuraxial blocks, considered to be advanced blocks, were excluded from the assessment. The residents were also encouraged to educate themselves on the above ultrasound-guided PNBs from our institute’s Web site (www.usra.ca) at the discretion of the residents.
Residents were randomized by computer-generated numbers into 2 groups: a simulation group and a conventional group. All residents assigned to the simulation group received an hour-long teaching session on a commercially available, low-fidelity simulation model, in addition to conventional training. This simulation session included hands-on practice on a Minismus Trainer prototype (Life-Tech Inc, Stafford, Tex), using a high-definition ultrasound machine (M-Turbo; SonoSite Inc, Bothell, Wash). Residents practiced scanning methods, using a linear transducer, for 1 hr. This included repeating needle-tipping techniques and practicing visualizing the needle by ultrasound and then guiding it to a target location. Residents in the conventional group, after completing their didactic teaching, did not receive simulation training. Residents from both groups then started their rotation within the block room. Residents in the conventional group and the simulation group were allowed to observe ultrasound-guided nerve blocks being performed and could commence performing supervised blocks when they felt comfortable with the procedure.

Using a logbook, each resident recorded the number of successful and failed ultrasound-guided PNB blocks performed over their 3-week rotation. This was accepted on an honor system, and each resident was responsible for correctly following up his/her blocks and entering the data into his/her logbook. All blocks were performed under the supervision of a staff anesthesiologist trained in ultrasound-guided PNBs who was blinded to the group to which the resident was assigned. A research assistant was present during all blocks to make sure the block was performed within 15 mins. A successful block was defined as one effective for surgical anesthesia without any supplemental nerve blocks, performed within 15-min duration with or without verbal guidance from the supervising staff anesthesiologist. If the block needed supplemental nerve block for surgical anesthesia or the time required to perform exceeded 15 mins or was taken over by the staff anesthesiologist because of technical difficulties, the resident was considered to be unsuccessful at the procedure. If the block required supplementation in the operating room or was converted to a general anesthetic for patient comfort, it was also considered to be unsuccessful for the resident.

Ultrasound imaging was performed using a high-definition ultrasound machine (M-Turbo; SonoSite Inc). Residents were given a choice of using a high- or low-frequency transducer probe, depending on the type and depth of the block performed. Each block was assessed by pinprick sensation and motor weakness to ascertain loss of sensation in the distribution of the targeted nerves. Once in the operating room, each patient received standard treatments, which included supplemental oxygen via face mask and propofol sedation. The sedation was maintained at a level where the patient was able to respond to any verbal query.

Following completion of their rotation, each resident returned his/her completed logbook to the research coordinator.

**Statistical and CUSUM Analysis**

The number of successful blocks in each group was compared by \( \chi^2 \) test, and the number of successful upper- and lower-limb blocks was also compared using the \( \chi^2 \) test.

For each resident, the CUSUM technique was applied to consistently monitor block success. The acceptable failure rate, \( f_0 \), in performing ultrasound-guided PNBs was determined by staff anesthesiologists to be 30%. This was chosen based on past resident performance at our institution. The unacceptable failure rate, \( f_1 \), was set at twice the value of \( f_0 \) at 60% \( \cdot \). The type I and type II error rates (\( a \) and \( \beta \), respectively) were set to 0.1 to produce equidistant horizontal boundary lines, \( h_0 \) and \( h_1 \) (Table 1).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptable failure rate, ( f_0 )</td>
<td>0.30</td>
</tr>
<tr>
<td>Unacceptable failure rate, ( f_1 )</td>
<td>0.60</td>
</tr>
<tr>
<td>( P; \ln \left( f_1 / f_0 \right) )</td>
<td>0.69</td>
</tr>
<tr>
<td>( Q; \ln \left( \left( 1 - f_0 \right) / \left( 1 - f_1 \right) \right) )</td>
<td>0.56</td>
</tr>
<tr>
<td>Probability of type I error, ( a )</td>
<td>0.10</td>
</tr>
<tr>
<td>Probability of type II error, ( \beta )</td>
<td>0.10</td>
</tr>
<tr>
<td>( a; \ln \left( \left( 1 - \beta \right) / \alpha \right) )</td>
<td>2.20</td>
</tr>
<tr>
<td>( b; \ln \left( \left( 1 - \alpha \right) / \beta \right) )</td>
<td>2.20</td>
</tr>
<tr>
<td>( h_0; b / (P + Q) )</td>
<td>1.76</td>
</tr>
<tr>
<td>( h_1; a / (P + Q) )</td>
<td>1.76</td>
</tr>
<tr>
<td>( s; Q / (P + Q) )</td>
<td>-0.45</td>
</tr>
<tr>
<td>( f; 1 - s )</td>
<td>+0.55</td>
</tr>
</tbody>
</table>

A positive value for a successful block, \( s \), and a negative value for a failed block, \( f \), were added sequentially to a cumulative score to result in a CUSUM curve that shows a downward trend for success and an upward trend for failure (Appendix 1). Cumulative summation charts were generated to measure competency levels of the residents with increasing numbers of procedures performed. Residents were considered proficient if the graph crossed the lower decision line. Success and failure rates in performing the PNBs were tracked to visualize trends. Residents able to achieve proficiency, defined as traversing both lines, were compared using the Fisher exact test.

**RESULTS**

Of 30 Postgraduate Year 2 residents who were recruited and completed a 3-week regional anesthesia rotation, 10 residents did not return their logbooks at the end of rotation. The remaining 20 residents with completed logbooks constituted 10 each in the simulation and the conventional groups. The total number of attempted blocks by any resident ranged from 9 to 41. In the conventional training group, the residents performed 191 total upper- and lower-limb blocks. In the simulation group, the residents performed a total of 225 blocks (Fig. 1). Of these, the conventional training group had 98 successful blocks, and the simulation group had 144 (51% vs 64%; \( P = 0.016 \)). The main reason for failure in both groups was the inability to complete the block within the 15-min limit. Four of 10 residents achieved proficiency in the conventional training group, and 8 of 10 residents achieved proficiency in the simulation training group (80% vs 40%; \( P = 0.0849 \)). In the conventional training group, the number of blocks that required reaching proficiency ranged from 4 to 13.

![Comparison of the percentage of successful nerve blocks in the simulation and conventional training group.](image-url)
blocks, and in the simulation group, the number ranged between 4 and 20 blocks. In the conventional training group, 19 blocks, on average, were performed, and a trend of success was seen after an average of 7 block attempts. In contrast, in the simulation training group, an average of 22 blocks was performed, and a trend of success was seen after performing an average of 5 block attempts (Fig. 2).

**DISCUSSION**

The results of our study show that a 1-hr practice session on a low-fidelity simulation model, in addition to conventional teaching, improved the overall success rate of ultrasound-guided regional anesthesia (UGRA) in novice Postgraduate Year 2 anesthesia residents. Similarly, simulation seemed to have helped more residents attain proficiency than residents in the conventional training group based on CUSUM analysis, but the difference was not statistically significant.

Simulation has gained popularity in the medical education because of changes in the concepts of teaching technical skills. Grantcharov and Reznick \(^5\) stated that rather than having the “see one, do one” method, teaching should include an opportunity to perform the procedure on different platforms before carrying out the procedure on a patient. A systematic review by Issenberg et al. \(^6\) identified simulation as a key feature for effective learning. Some benefits of simulation technology include improvements in technical and examination skills and acquisition and retention of knowledge compared with traditional lectures. \(^7\)

This was seen in our study, where the residents who had 1-hr training on a simulation model, had higher block success compared with the conventional training group. In simulation, quality of performance corresponds to deliberate practice with informative feedback and opportunities for repetition and correction of errors. \(^8\)

During our 1-hr simulation training, our residents were given both feedback and supervision. Ultrasound-guided PNB blocks require both knowledge of sonoanatomy and hand-eye coordination to direct the needle to the nerve target under real-time ultrasound guidance. Sites and colleagues, \(^9\) when looking at novice behavior associated with learning ultrasound-guided peripheral regional anesthesia, found that the 2 main mistakes were failure to visualize the needle before advancement and unintentional probe movement. They concluded that this technical component of the block can be improved with preclinical simulation training. Although we did not look for these mistakes in our subjects, we did show a higher success rate in the simulation-trained group than in the group that received conventional training. This meant that more blocks were performed within a 15-min period and provided surgical anesthesia to the patient without supplementation. This illustrates that simulation may improve hand-eye coordination and help a novice operator overcome the major pitfalls of ultrasound-guided PNB blocks.

Some authors have suggested that only a minimal number of supervised procedures (<20) are required to subsequently perform successful blocks. \(^10\) This has been supported by Sites et al, \(^11\) who found that inexperienced residents performing a simulated breast cyst aspiration under ultrasound guidance improved accuracy and success after only 6 task repetitions. Conversely, it has been shown by de Oliveira Filho et al \(^12\) that it can take approximately 37 to 109 repetitions to acquire 2 basic interventional ultrasound skills: maintaining needle visibility and injecting fluid around a simulated target. Our study showed similar results, as our residents performed a wide number of blocks after which they achieved the skill proficiency. Some residents were able to show proficiency on the CUSUM graph after only 4 blocks, whereas others did not show proficiency after 41 blocks. This may, in part, be attributed to the fact that the residents did not perform 1 standardized block and may have practiced different blocks in different orders. Although each block was supervised and verbal feedback was provided throughout the block, we were unable to determine how many blocks are required to attain proficiency in UGRA. We, however, did see that more residents attained proficiency in the simulation training group compared with the conventional training group. Although our results did not show statistical significance, a clear trend favoring simulation training was observed.

We used a commercially available, low-fidelity simulator Minisim Trainer prototype (Life-Tech Inc) \(^13\) because very few high-fidelity simulators are available for UGRA. If they are available, they are very expensive. It can be argued that a high-fidelity model would have been more advanced and provided the trainees with an experience that is more true to life; however, it has been shown that there is no difference in learning when a high-fidelity model is compared with low-fidelity model. \(^14\)

In our study, the CUSUM analysis was applied as both a graphical and quantitative means to illustrate performance in the early learning phase. The CUSUM is a control chart on which the cumulative differences of the quality characteristic from a target level are plotted in sequence, leading to tighter control of a given process and allowing detection of deviations from pre-established standards. The CUSUM method has been applied previously to objectively assess competency in technical procedures, such as epidural anesthesia, \(^15\) fetal biometry assessment, and \(^16\) paraesophageal hernia repair. \(^17\) These studies have substantiated the use of the CUSUM tool to recognize periods of competency and highlight trends in successes and failures.

Our study has some important limitations. The types of blocks performed by our residents were not standardized in either order or type. This may have affected the number required to attain proficiency or even the overall success rate, as not all residents were equally competent in all blocks. However, this was intentional to preserve the learning opportunities for the resident. Each resident spent only 3 weeks in regional anesthesia during their 4-month posting at our hospital. They were allowed to perform all blocks, which ranged from the simple to intermediate category of PNBs. Nonetheless, the principle of simulation would still be applicable to all PNBs with respect to localization of target and placement of needle to the target.
In conclusion, simulation training improves the success rate of ultrasound-guided performance of regional anesthesia. We recommend further studies at each specific block to assess the number of blocks required to attain proficiency.

REFERENCES

APPENDIX 1

\[ a = \ln \left\{ \left(1 - \beta \right)/\alpha \right\} \quad b = \ln \left\{ \left(1 - \alpha \right)/\beta \right\} \]
\[ a = \ln \left\{ \left(1 - 0.1 \right)/0.1 \right\} \quad b = \ln \left\{ \left(1 - 0.1 \right)/0.1 \right\} \]
\[ a = \ln \left(0.9 / 0.1\right) \quad b = \ln \left(0.9 / 0.1\right) \]
\[ a = \ln 9 \quad b = \ln 9 \]
\[ a = 2.2 \quad b = 2.2 \]

An error of 0.1 (constant) was selected for type I (\( \alpha \)) and type II (\( \beta \)) failure rates. Acceptable and unacceptable failure rates were determined by staff anesthesiologists. The acceptable failure rate (\( f_0 \)) was set at 30%. The unacceptable failure rate (\( f_1 \)) was set at 60%.

\[ P = \ln \left( f_1 / f_0 \right) \quad Q = \ln \left( \left(1 - f_0 \right)/\left(1 - f_1 \right) \right) \]
\[ P = \ln \left(0.6 / 0.3\right) \quad Q = \ln \left(1 - 0.3\right)/\left(1 - 0.6\right) \]
\[ P = \ln 2 \quad Q = \ln \left(0.7 / 0.4\right) \]
\[ P = 0.693 \quad Q = 1.75 \]
\[ Q = 0.559 \]

The decrement (success) with each success on the CUSUM plot(s) is calculated as follows:
\[ s = Q / \left( P + Q \right) \]
\[ s = 0.559 / \left(0.693 + 0.559 \right) \]
\[ s = 0.559 / 1.252 \]
\[ s = 0.45 \]

The increment for each failure (\(1 - s\)) = 1 - 0.45 = 0.55. Thus, for each failure, the line will go up by +0.55. And for each success, it will go down by −0.45.

To determine the boundary lines, the spacing between the unacceptable (\( b_0 \)) and the acceptable (\( h_1 \)) boundaries is then calculated as follows:

\[ h_0 = b / \left( P + Q \right) \quad h_1 = a / \left( P + Q \right) \]
\[ h_0 = 2.2 / \left(0.693 + 0.559 \right) \quad h_1 = 2.2 / \left(0.693 + 0.559 \right) \]
\[ h_0 = 1.76 \quad h_1 = 1.76 \]

Subsequent boundary lines can be constructed as multiples of \( h_0 \).