ABSTRACT

Introduction: Ultrasound can increase accuracy in identifying intervertebral levels, leading to safer and more effective delivery of spinal anaesthesia. This pilot study reports on the implementation and evaluation of a training module designed to teach residents lumbar ultrasound for facilitated neuraxial block administration.

Materials and methods: The module encompassed three methods of training: (1) verbal instruction; (2) unlimited access to an interactive laptop-based training application; and (3) instructor-guided lumbar ultrasound performed on a model for 1 hour per week for 4 weeks. Five residents were assessed following module training and after 6 months. Residents were assessed for the quality of their ultrasound scan and their ability to estimate the depth of the dura/ligamentum flavum in both transverse and paramedian views. In addition, an eight question survey was used to assess resident confidence before and after training.

Results: Image quality and dura resolution showed no statistically significant changes immediately after training and at 6 months follow-up. Residents demonstrated an acceptable ability to estimate dura depth immediately after training; however ability decreased at 6 months follow-up, indicating a low retention of skill. Resident confidence in lumbar ultrasound for neuraxial technique increased remarkably after training and remained high at 6 months follow-up.

Conclusion: Long-term practice in ultrasound for neuraxial technique is required to reinforce and retain skill. Results from this pilot study can be used to design a multicenter, full-powered investigation to better determine the impact of training in lumbar ultrasound for improved neuraxial block delivery.

Keywords: Neuraxial block, Sonoanatomy training, Spinal anaesthesia.


Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

Neuraxial regional analgesia traditionally relies on the palpation of landmarks that may not be accurate or evident, especially in cases of obesity and scoliosis. By palpation, even the most experienced anaesthesiologists incorrectly estimate the interspace level in up to 71% of cases.1,2 Anatomical uncertainty can result in numerous puncture attempts, trauma to neurovascular structures, and unintentional dura puncture. Ultrasound can increase accuracy in identifying intervertebral levels to 70 to 76%, compared to 29 to 30% using palpation and Tuffier’s line alone.2,3 Studies on obstetric patients indicate ultrasound can significantly reduce puncture attempts and result in more successful blocks, fewer complications and increased overall patient satisfaction.4 Anaesthesia residents had a significantly higher initial success rate of 86% using ultrasound as a visual aid, versus 60% success with conventional palpation and loss of resistance technique in their first 10 epidurals.5 With further experience, performance rose to 94% success in the ultrasound group and 84% success in the control group.5 However, in spite of promising results from pilot studies, the use of ultrasound as a visual aid in neuraxial regional blocks is still typically reserved for the most difficult patients and is not part of a standardized training curriculum.

This study aimed to implement and assess a lumbar ultrasound training module to improve resident skill and confidence with the use of ultrasound in the identification of lumbar anatomy for the optimal needle insertion points for a neuraxial block. In the training module, normal models (BMI < 25 and nonparturient) were used for teaching so that residents could master the basic principles and skills before attempting to use the techniques on difficult patients. A survey was used at two time points to investigate resident confidence with the techniques, prior to and 6 months after the training model. The survey was also used to determine whether residents had integrated ultrasound into their neuraxial technique, and if not, to identify and discuss barriers to use.

MATERIALS AND METHODS

Ethical approval for the study was obtained from the local research ethics committee of Queen’s University.

This pilot observational study involved five anaesthesia residents and encompassed three levels of training:

1. Verbal instruction covering lumbar anatomy, the details of lumbar ultrasound and the practice of neuraxial blocks.
2. Unlimited access to an interactive online training application.
3. Hands-on instructor-guided ultrasound practice on a model. After verbal instruction, residents had unlimited access to an online instructional module, which describes the role of ultrasound for spine demarcation before placement of a neuraxial block, and familiarizes residents with ultrasound technology and techniques. Residents then attended up to four, one hour, weekly sessions with an
instructor to learn lumbar ultrasound and perform the technique on a model. Two models were employed by the study (one female and one male) both with a BMI <25 and the female was nonparturient. One model was used with all five residents for the first assessment, and the second model was used with all residents for the 6-month follow-up.

Ultrasound imaging was performed using a Zonare ultrasound machine (CA, USA) equipped with a curvilinear C5-2 low frequency probe. Residents acquired ultrasound images of the lumbar spine in both paramedian and transverse views and were instructed on the measurement of dura depth from the ultrasound images.

Residents were assessed for the image quality of their ultrasound scan and their ability to measure the depth of the dura/ligamentum flavum in both the transverse and paramedian views. Two experts in lumbar sonoanatomy and neuraxial blocks (Dr V Shyam and Dr J Murdoch) also performed ultrasound scans and made dura depth estimates on the same models. For each model and view, an average of the two expert dura depth estimates was taken as the ideal dura depth measure. The dura depth estimate from each resident was compared against the average dura depth measure of the experts. A deviation equal to or less than ± 0.5 cm from the expert dura depth measure was taken as the acceptable limit for variation in resident estimates.

Image quality of resident ultrasound scans and dura resolution were graded by an expert (Dr MC McMullen) on a scale from 1 to 5, with 5 representing ideal quality/resolution and 1 indicating poorest quality/resolution. The expert was blinded to the identity of resident/expert scans. Image quality and dura resolution scores of the resident group were compared at initial and 6-month follow-up for paramedian and transverse views using a t-test with p < 0.05 taken to be statistically significant.

The five residents were assessed in ultrasound image quality and dura depth estimate accuracy following their training and again 6 months later to evaluate retention of skill.

An eight question survey (Appendix) was administered immediately and at 6 months after training, to gauge resident familiarity and confidence with ultrasound and epidural technique, integration of the techniques into resident practice, and to identify barriers to use. Survey questions allowed for answers on a scale of 1-7, with 1 being ‘strongly disagree’ and 7 representing ‘strongly agree’.

RESULTS

The overall image quality and dura resolution scores for the group of five residents in paramedian and transverse views, initially and at 6 months follow-up, are summarized in Table 1. For paramedian views, overall quality and dura resolution averaged 2.8 and 3.2, respectively, and did not vary between initial and 6 months follow-up. In the transverse view, overall image quality decreased from 3.0 to 2.6 and dura resolution decreased from 3.0 to 2.0 between initial and 6-month follow-up (see Table 1); however, the differences were not statistically significant (p > 0.05).

Dura depth estimates from lumbar ultrasound scans of expert and resident groups are summarized in Table 2. At initial assessment, 80% (4/5) of residents were able to estimate dura depth in both paramedian and transverse views to within 0.5 cm of the average expert measurement. Immediately after training, the average difference between a resident dura depth measure (± standard error of the mean) was 0.34 ± 0.2 for the paramedian view and 0.48 ± 0.2 for the transverse view. However, at 6 months follow-up only 20% (1/5) of residents in the paramedian view and 40% (2/5) of residents in the transverse view were able to provide a dura depth estimate within 0.5 cm of the expert measure. After 6 months, the average difference between a resident’s dura depth measure had increased to 1.2 ± 0.3 for the paramedian view and 0.9 ± 0.4 for the transverse view.

Survey results showed the average number of structured training sessions attended by the group of five residents was 2.2. The average number of lumbar ultrasounds

| Table 1: Resident lumbar scan overall image quality grades and dura resolution grade in paramedian and transverse views initially and at 6 months follow-up. Grades were assigned from 1 to 5, with 1 indicating poor quality/resolution and 5 indicating optimal. Results are stated as the mean of resident scores ± the standard error of the mean (N = 5) |
|---|---|---|
| **Overall quality** | **Dura resolution** |
| **Paramedian view** | | |
| Initial assessment | 2.8 ± 0.4 | 3.2 ± 0.2 |
| 6 months follow-up | 2.8 ± 0.4 | 3.2 ± 0.8 |
| **Transverse view** | | |
| Initial assessment | 3.0 ± 0.3 | 3.0 ± 0.5 |
| 6 months follow-up | 2.6 ± 0.5 | 2.0 ± 0.5 |

| Table 2: Dura depth estimates from lumbar ultrasound scans comparing expert and resident values for paramedian and transverse views immediately and 6-months after completion of the training module. Estimates for the N = 5 groups are reported as the mean ± the standard error of the mean with 95% confidence intervals in brackets |
|---|---|
| **Expert (cm)** | **Resident (cm)** |
| **Paramedian view** | | |
| Initial assessment | 3.8 ± 0.1 (3.3 to 4.3) | 4.1 ± 0.3 (3.0 to 5.2) |
| 6 months follow-up | 5.9 ± 0.2 (5.2 to 6.6) | 6.7 ± 0.5 (4.3 to 9.0) |
| **Transverse view** | | |
| Initial assessment | 3.8 ± 0.2 (3.0 to 4.6) | 3.8 ± 0.3 (2.4 to 5.2) |
| 6 months follow-up | 5.4 ± 0.1 (5.1 to 5.7) | 5.4 ± 0.6 (2.8 to 8.1) |
observed prior to the instructional module was 1.6 and the average number of lumbar ultrasounds performed prior to the module was 1.0. On a scale of 1 to 7, with 1 being strongly disagree and 7 being strongly agree, prior to the ultrasound module, the average score for confidence in their ability to image the lumbar spine was 1.7. After the module, confidence rose to 5.0, and 6 months later the average was 5.6. Confidence in identifying lumbar interspace level, optimal needle insertion point, and to identify the dura in paramedian and transverse views was reported to rise remarkably after the training module, and to remain fairly high at 6 months follow-up (Table 3). Eighty percent of residents found the hands on teaching the most valuable part of the module. The average number of times trainees utilized spinal ultrasound in their clinical practice in the 6 months following completing the training module was 1.2. In addition comments from the survey question eight, residents report the training module to have been a very good experience. Requests were made for training with more difficult models (e.g. BMI >25 and challenging lumbar anatomy due to age related changes). Requests were made for a larger variety of spine images to work through in the online training module.

**DISCUSSION**

The initial assessment indicated the educational module successfully taught 80% (4 out of 5) of residents the skill of identifying dura depth from ultrasound with a discrepancy of 0.5 cm or less with respect to the expert’s depth estimate. However, our study showed that over time, residents did not retain the level of skill acquired following their training module, as evidenced by a marked increase in deviation between resident dura depth estimates in comparison to the expert control group. At 6 months follow-up only 20% of residents were able to match the expert dura depth measure to within 0.5 cm in paramedian and transverse views, respectively. The low retention of skill for depth estimation and degradation in ultrasound image quality 6 months after training illustrates the importance of regular reinforcement of technical skills through long-term practice.

Survey results indicated that resident confidence in the performance of lumbar ultrasounds and in identifying lumbar interspace level, optimal needle insertion point, and the identity and measurement of dura depth in paramedian and transverse views rose remarkably immediately and remained high at 6 months after the training module, in comparison to confidence before training. However, given the decreased ability to accurately estimate dura depth at 6 months follow-up, it is clear that resident confidence is not necessarily equivalent to their competence. The average number of times trainees utilized spinal ultrasound in their clinical practice in the 6 months following completing the training module was 1.2, and it is hypothesized that retention of skill would be enhanced by increasing the frequency of spinal ultrasound in clinical practice to reinforce skills.

Barriers to the clinical use of ultrasound as a visual aid for spinal anaesthesia were identified to be a lack of equipment availability (reported by 4/5 residents), a lack of time (reported by 3/5 residents), a deficiency of personal experience in acquiring images (2/5 residents), a deficiency of personal experience in the interpretation of images (2/5 residents), and a lack of availability of experienced instructors (1/5 residents). The major barriers to use (equipment availability, lack of training, and lack of instructors) can likely be mitigated through the further development of a training module and the incorporation of such a module into a core training curriculum. Such a step would make available instructors well-versed with the technique and allocate the necessary equipment, which would allow residents to practice and reinforce their use of ultrasound-guidance in regional spinal anaesthesia.

Some limitations of our study include the small study group of residents, which arose due to difficulties in pulling residents from busy schedules involving clinical duties. Due to the small study size, the performance of a single resident greatly swayed the outcome measures. Furthermore, this study did not control for previous ultrasound experience, especially in neuraxial techniques. Also, the study did not control for a variety of stages of training in the residents. Finally, we did not investigate whether

<table>
<thead>
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<th>Survey question</th>
<th>Prior to module</th>
<th>Immediately after</th>
<th>Six months after</th>
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<td>Confidence in ability to image lumbar spine by ultrasound</td>
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<td>5.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Confidence in identification of lumbar interspace level</td>
<td>2.1</td>
<td>4.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Confidence in identification of optimal insertion site</td>
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<td>4.8</td>
<td>5.0</td>
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<tr>
<td>Confidence in identification and measure of dura depth from paramedian view</td>
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<td>4.9</td>
<td>4.4</td>
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<tr>
<td>Confidence in identification and measure of dura depth from trans view</td>
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<td>4.8</td>
<td>4.2</td>
</tr>
</tbody>
</table>
ability to correctly identify the depth to dura correlates with better clinical outcomes.

CONCLUSION

This study implemented and assessed a lumbar ultrasound training module designed to improve resident skill and confidence with the use of ultrasound as a visual aid in regional spinal anaesthesia techniques. We found the module to raise confidence and to temporarily teach residents an acceptable level of skill in identifying lumbar anatomy through ultrasound. However, longer-term practice is required to reinforce skills for incorporation into clinical practice. Future work would explore extended training to ready residents for use of the techniques on challenging patients, such as those with obesity or scoliosis. Results from this pilot study can be used to design a multicenter, full-powered investigation to better determine the impact of our training module in teaching lumbar ultrasound for improved neuraxial block delivery.

APPENDIX: SURVEY QUESTIONS

1. (a) Average number of lumbar ultrasounds observed prior to the module?
   (b) Average number of lumbar ultrasounds performed prior to the module?
2. Average number of training sessions attended?
3. Prior to the spinal ultrasound module I felt confident in my ability to image the lumbar spine on ultrasound? (Answer between 1 to 7 with 1 being strongly disagree and 7 being strongly agree).
4. Prior to the lumbar spinal ultrasound module, using ultrasound imaging, I felt confident in my ability to: (Answers between 1-7 with 1 being strongly disagree and 7 being strongly agree).
   (a) Identify lumbar interspace level?
   (b) Identify my optimal insertion site?
   (c) Identify and measure ligamentum flavum/dura complex on longitudinal paramedian view?
   (d) Identify and measure ligamentum flavum/dura complex on transverse ultrasound view?
5. After the module I felt confident in my ability to image the lumbar spine on ultrasound. (Answer between 1-7 with 1 being strongly disagree and 7 being strongly agree)
6. After the lumbar spinal ultrasound module, using ultrasound imaging, I feel confident in my ability to: (Answers between 1-7 with 1 being strongly disagree and 7 being strongly agree).
   (a) Identify lumbar interspace level?
   (b) Identify my optimal insertion site?
   (c) Identify and measure depth of ligamentum flavum/dura complex on longitudinal paramedian view?
   (d) Identify and measure depth of ligamentum flavum/dura complex on transverse ultrasound view?
   (e) Adopt the technique into my clinical practice?
7. What was the most valuable part of the module? Please circle letter:
   (a) Online slide show/video
   (b) Online quiz
   (c) Hands-on teaching
   (d) Other
8. Additional comments.

REFERENCES


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