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ORIGINAL ARTICLE

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A model for training ultrasound-guided fine-needle punctures

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SUMMARY

OBJECTIVE: To evaluate the efficacy of a training program in ultrasound-guided fine needle puncture using a cost-effective model.

METHODS: We evaluated the training of 20 resident radiology physicians, based on a theoretical course and a practical simulation part with models that focused on the puncture technique of thyroid nodules. The total time to perform the procedure, the number of punctures on the model surface, and the application of a questionnaire were used to assess the performance and confidence of the resident physicians in performing the procedure.

RESULTS: The training model used was easy to reproduce, inexpensive, versatile, and capable of simulating the echotexture of thyroid tissue. There was a significant reduction in the total time needed to perform the procedure with a mean of 173.7 s±91.28 s from R1 and 112.8 s±17.66 s from R2 before the course vs. 19.2 s±112.8 s and 14.3 s±9.36 s, respectively, after the course ($p<0.0001$); as well as the number of superficial punctures, with a mean of 2.2 punctures±0.92 from R1 and 1.5 punctures±0.32 from R2 before the course vs 1.1 punctures±0.71 and 1.0 puncture±0.0, respectively, after the course ($p<0.0001$). There was also a subjective improvement in the performance and confidence in performing this procedure.

CONCLUSIONS: An inexpensive and easy-to-reproduce gelatin-based model enabled adequate training of resident physicians and proved capable of improving their skills and confidence in simulating the procedure, even with a short period of training.

KEYWORDS: Thyroid gland. Biopsy, fine-needle. Ultrasonography. Education, Medical. Simulation Training.

INTRODUCTION

Ultrasound-guided fine-needle aspiration biopsy (FNAB) is a widely available, safe, and accurate procedure, but the effectiveness of the procedure depends on the skill and experience of the professional and requires adequate training[1-3]. FNAB is a technically challenging procedure for inexperienced clinicians with sensitive nearby structures such as the jugular veins, carotid arteries, and trachea.

Practical simulation-based training with models and virtual environments is useful for step-by-step training in a variety of procedures, in addition to improving coarse skills and learning how to handle materials in a controlled environment where specific flaws can be identified and addressed[4-6]. An objective measurement of performance, associated with an analysis of the tests done by the students, allows the assessment of effectiveness of the model and progress of resident physicians[1,4,5].

In this study, we evaluated the training of 20 medical residents in radiology, 10 from the first year and 10 from the second year of residency, based on theoretical classes and practical simulations with a gelatin-based model, focusing on FNAB of thyroid nodules.

The main aim of this study was to create a feasible and inexpensive model for training in ultrasound-guided procedures, with special emphasis on FNAB. The final goal was to determine whether this training could increase the resident doctors' confidence and performance in conducting an FNAB.

METHODS

Subjects

Twenty radiology resident doctors from the Department of Radiology of the University Teaching Hospital at Campinas (UNICAMP) participated in the study after signing an informed consent form. The subjects were divided into 2 groups, one of which consisted of 10 resident physicians from the first year of the course (R1), whereas the other consisted of 10 residents from the second year of the course (R2). None of the participants had any previous experience in ultrasound-guided punctures or training models, although the second-year residents (R2) had more training in nonprocedural diagnostic ultrasound.

Device

The matrix consisted of a reproducible combination of gelatin, Metamucil, *maisena* (cornstarch), and water (Figure 1)[7]. This mixture provided a homogeneous matrix for elastography, with adequate rigidity for puncturing. Additional elements can be added

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to this matrix, depending on the aim of the training. The gelatin is opaque, so the target is not visible through the matrix. The major advantage of this model is its very low final cost (~US$1).

We used a grape as a target because it has the following characteristics:

1. a morphology, echotexture, and dimensions similar to those of a thyroid nodule,
2. a composition that consisted of puncturable material with good resistance, and
3. material that was easy to obtain and inexpensive.

The target was glued to the bottom of the container to prevent it from moving, thus eliminating the need for several phases of matrix layering (Figure 2).

Figure 1. Close-up external view of the model. The target, which consisted of a grape embedded in the red elastic matrix, is not visible in this view.

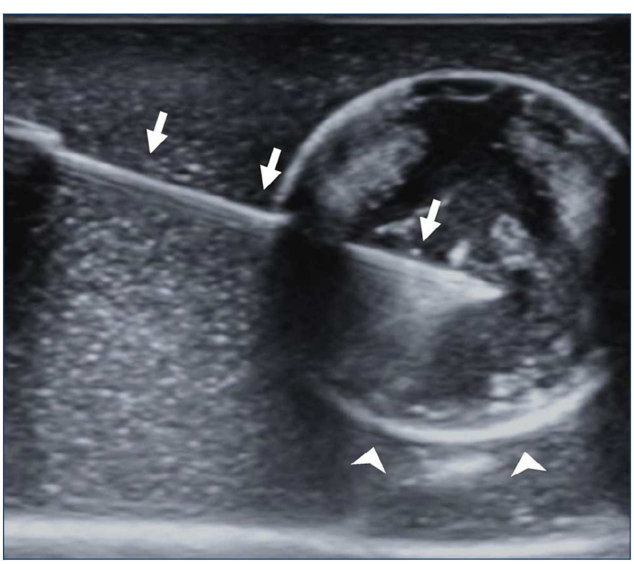


Figure 2. A target (a grape; arrowheads) embedded in the elastic matrix of the model. Note the good contrast between the surrounding "tissue" (matrix) and the target, and the clear visualization of the needle (arrows).

The perishable nature of the grapes meant that the model had a maximum shelf-life of 20 days when stored at ~4°C (39.2°F). In general, the model retained its durability and intactness for up to ~10 punctures.

Recipe for the matrix

Notably, 100 mL of natural spring water, 150 mL of boiling water, 20 g of gelatin, 10 g of Metamucil, and 2 g of cornstarch were mixed, thoroughly stirred for 2 min, and then added to the mold (container) to which the target had already been glued. The mold and its contents were then placed in a refrigerator to cool for 30–60 min. This cooling step is necessary for proper matrix solidification.

Training program

A theoretical and practical course (3 h duration) was offered, with an emphasis on thyroid nodules and FNAB. Theoretical classes were taught by specialist doctors, through an online platform, with each class lasting for 30 min. The classes included the ultrasonographic diagnosis of thyroid nodules, the clinical relevance of thyroid nodules, FNAB technique, and pathological analysis. The practical class was done face-to-face, lasted for 1 h, and was taught by a radiologist; this class provided an opportunity for the resident doctors to review the FNAB technique and train their puncture technique in the model. Each resident received one copy of the model with which to train.

Data acquisition

The resident physicians performed an ultrasound-guided biopsy of a target (grape) embedded in the polymeric matrix, before and after the course. Targets were at the same depth for all residents. For this, a 25-gauge needle was used, without the puncture guide. The time required to initiate puncturing of the matrix surface, the time until ultrasound identification of the needle within the target, and the total time required for the complete procedure were recorded. The training was considered complete when the needle was identified within the target. The number of punctures on the matrix surface (simulating the patient's skin) was also quantified. These data (keeping time and number of punctures) were recorded by a third-year resident physician. After the course, the participants completed a questionnaire that sought to evaluate the usefulness of the model and the course. The replies were scored using Likert's 10-point psychometric response scale (see Appendix).

Statistical methods

A descriptive statistical analysis was applied to the data and involved measures of central tendency (median and mean) and dispersion (standard deviation) for numerical variables. The Mann-Whitney nonparametric test was used to compare the numerical variables evaluated before the course, and to compare the answers to the questionnaire applied to the two groups (R1 and R2) after the course. Comparisons between intervals (before and after the course) and groups (R1 vs, R2) were done using the analysis of variance (ANOVA) test for repeated measures. A value of p<0.05 indicated significance.

This study was conducted after the approval of the local ethics committee of our institution.

RESULTS

Time to perform the procedure

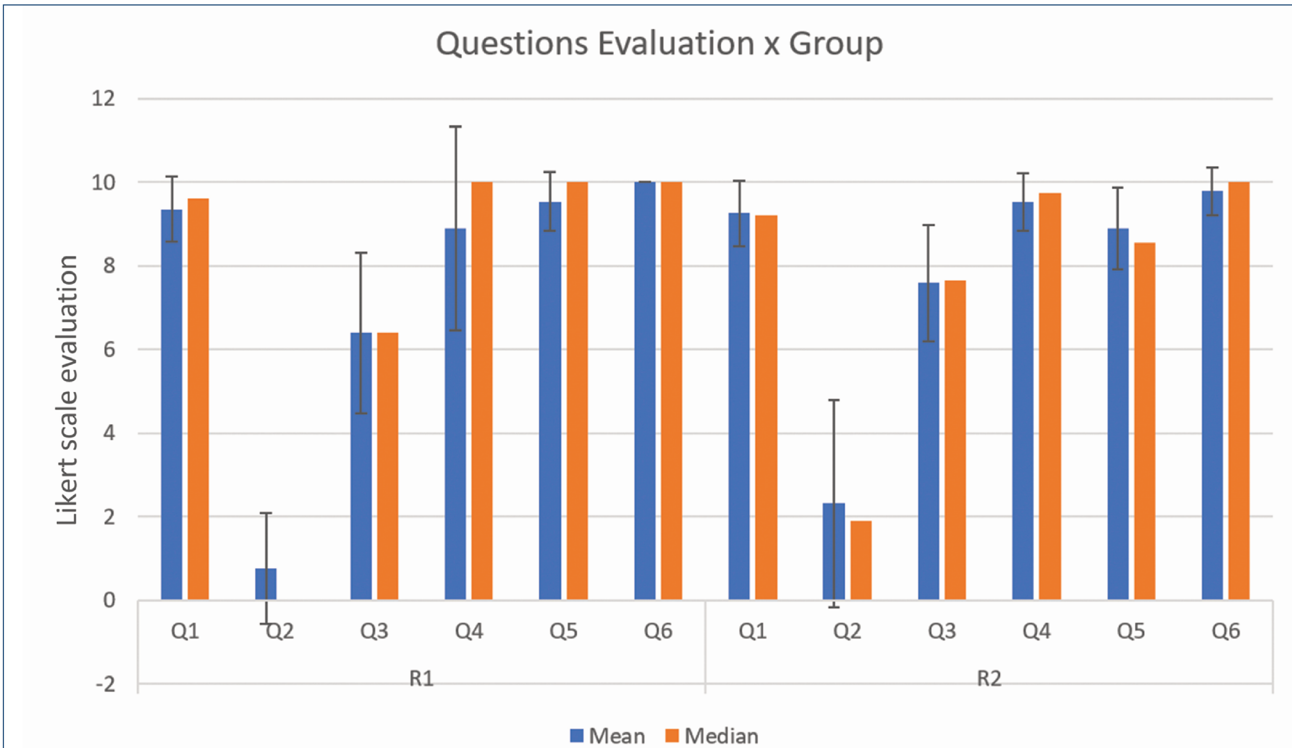
The total time required to perform the procedure after the course was significantly shorter than before the course, regardless of the group of residents (p<0.0001). Before the course, R1 had a mean of 173.7 s±91.28 s and R2 had a mean of 112.8 s±17.66 s; after the course, they had a mean of 19.2 s±112.8 s and 14.3 s±9.36 s, respectively. There was no difference between the two groups of residents (R1 vs R2) in the time required to perform the procedure before (p=0.1617) or after (p=0.3133) the course. There was also no interaction between time and groups (p=0.2974), indicating that the training was equally effective in both groups.

Number of punctures on the matrix surface

The number of punctures done after the course was significantly lower than before the course, regardless of the group of residents (R1 vs. R2) (p<0.0001). Before the course, R1 had a mean of 2.2 punctures±0.92 and R2 had a mean of 1.5 punctures±0.32; after the course, they had a mean of 1.1 punctures±0.71 and 1.0 puncture±0.0, respectively. There was no difference in the number of punctures done by the two groups of residents (R1 vs R2) before (p=0.0747) or after (p=0.0527) the course. There was also no interaction between time and groups (p=0.1368), indicating that the training was equally effective in both groups.

Questionnaire

Overall, the resident physicians' evaluation of the course was positive. This evaluation included their understanding of the basic, introductory nature of the course, the course workload and methods of assessment, and a subjective analysis of their confidence and improvement in performing the procedures. The model was seen as a useful tool for teaching the basic steps of FNAB and for improving their technique in executing the procedure. There was no significant difference between the two groups of residents in their answers to the questionnaire (Figure 3).



Q: question; R1: first-year residents; R2: second-year residents.

Figure 3. Statistical analysis of residents' responses to each of the questions (Q) based on the Liekert 10-point psychometric scale. Overall, there was a positive response to the course in matters of basic understandings, nature of the course, workload, and methods, with an increase in their confidence. No significant difference was observed between the two groups.

DISCUSSION

There is increasing emphasis on the use of simulation for training of ultrasound-guided procedures in medical education across multiple specialties[8-10], and the use of models is a promising method for improving teaching in interventional radiology as it allows for training before initiating the procedure on patients[1,4,5]. The traditional training for interventional procedures in radiology, in which the trainee performs the procedure first on a live patient, can lead to adverse outcomes and patient dissatisfaction[11].

Homemade and inexpensive models can improve ultrasound-guided procedural skills[11,12]. Studies that developed models focused on training ultrasound-guided procedures for medical residents identified improvement in ultrasound-guided procedural skills[1,11,13] and reported increased comfort and confidence in performing these procedures after training[11,13].

In this study, we used a gelatin-based model that is easy to reproduce, inexpensive, versatile, and capable of simulating the echotexture of thyroid tissue. Our results indicate that even with a short training period, the model significantly reduced the number of punctures done and the total time required to perform the procedure. In addition, there was a subjective improvement in performance and confidence in executing the procedures.

Limitations

Although there was a significant reduction in the number of punctures and the total time required to perform the procedure, these improvements will not necessarily be reproduced in clinical practice. The number of punctures was studied to simulate the number of punctures on the patient's skin, as an indicator of the degree of procedure complexity. However, there is no evidence in the literature that a greater number of punctures leads to or is indicative of worse clinical outcomes.

Another limitation of the study was that completion of the procedure was based on ultrasound identification of the needle within the target (a measure adopted to enhance the lifetime of the model). However, this approach did not include essential FNAB steps that are necessary to acquire an adequate sample and the correct preparation of the blade.

The small sample size of only 20 resident physicians, the fact that the study was done in a single academic center, and the decision not to use the puncture guide during training are other potential limitations of this study.

Future prospects

Our findings, together with the promising results of other investigations in the simulated training of resident physicians in ultrasound-guided procedures[1,2,9,11], as well as the proven benefits in clinical practice of using models for training, such as training in laparoscopic surgery simulators demonstrating improvements in the performance of resident physicians in the operating room procedure[14] and the use of simulation devices for instructing surgical residents and fellows in basic endovascular techniques improving resident performance in a catheter-based intervention[15], indicate that future studies should assess whether training with models directly correlates with better clinical results in interventional radiology.

CONCLUSION

An inexpensive and feasible model enabled the adequate training of resident physicians to perform the punctures, with an improvement in the level of subjective confidence and in objective measures. Future research should assess how these improvements relate to overall competency and safety in the performance of ultrasound-guided FNAB.

AUTHORS' CONTRIBUTIONS

FML: Conceptualization, Data curation, Formal Analysis. **VRDY:** Conceptualization. **KAAS:** Conceptualization, Writing – original draft. **FR:** Writing – review & editing. **SSJD:** Writing – review & editing.

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APPENDIX

QUESTIONNAIRE

1. How effective was the course for your learning?

0 ---10

2. How safe did you feel in performing the procedures before the course?

0 ---10

3. How safe do you feel now in performing the procedures after the course?

0 ---10

4. For a basic introductory course, what did you think of the course load?

0 ---10

5. Were the methods of evaluation adequate?

0 ---10

6. How necessary is it for the Department to have a model for biopsy training?

0 ---10

Note.

Q1: How effective was the course for your learning?
Q2: How safe did you feel in performing the procedures before the course?
Q3: How safe do you feel now in performing the procedures after the course?
Q4: For a basic introductory course, what did you think of the course load?
Q5: Were the methods of evaluation adequate?
Q6: How necessary is it for the Department to have a model for biopsy training?