Design and Implementation of a Low-Cost Neck Biopsy Simulator in Medical Simulation

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Conflict of Interest Statement

The authors of this manuscript declare no conflicts of interest.

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Brief Description

As there is an ever-growing weight placed on maintaining patient safety and attaining expertise in ultrasound guided procedures for medical trainees, advancements in medical simulation have provided avenues for clinical skills development and education for essential services like radiology (Echenique & Wempe, 2019; Parsee & Ahmed, 2023). We designed and built an innovative neck biopsy simulator using inexpensive and repurposed materials for an educational session in our simulation center. Post-session surveys obtained feedback from neuroradiology fellows on the model's efficiency and realism. Survey findings revealed participants gained procedural confidence after using the simulator. Survey results also demonstrated the ultrasound imaging of the simulator was realistic.

Introduction

A neck biopsy is a relatively safe procedure commonly performed by radiologists for patients with enlarged or suspicious neck lymph nodes. However, the neck soft tissues include many high-risk structures in a small space like the carotid artery, internal jugular vein, trachea, and important nerves like the vagus and phrenic nerves. Biopsy-related injury to these structures can cause serious harm. As ultrasound guided procedures become more common, providers must be knowledgeable in identifying abnormal findings under ultrasound. As Learned et al. (2016) states, "Effective US-guided biopsy requires technical experience, strong clinical acumen, and skillful biopsy technique." Past studies found core needle biopsies to reliably detect malignancy in neck lesions with an accuracy rate of 96%. Additionally, there are few complications associated with the procedure, making it a popular treatment choice (Adeel et al., 2021; Novoa et al., 2011). In addition to core biopsy, ultrasound guided fine needle aspiration (FNA) is an important skill for sampling salivary lesions, small lymph nodes, lymph nodes in locations too risky for core biopsy, and to aspirate cysts. In a retrospective study conducted in Leeds teaching hospitals, samples obtained through FNAs reliably detect malignancy in salivary glands and lymph nodes (Carr et al., 2010). Medical simulation offers an excellent educational modality to learn and practice interventions like biopsies and aspirations in a safe and controlled environment (Giannotti et al., 2022).

Neck biopsy simulators are expensive and difficult to find in the simulation market. For these reasons, we designed an inexpensive neck biopsy simulator using gelatin, Manzanilla olives, and latex glove water balloons for radiology trainees to use. This was included as part of a simulation skills course hosted at a medical simulation center affiliated with a tertiary health care center. The course curriculum consisted of a one-hour session using the neck biopsy simulator. For this session, the learning objective was to increase learner comfort with needle utilization for neck lesion aspirations and biopsies. Following the course, post-session surveys were distributed to obtain a subjective measure of the simulator's effectiveness and user comfort. We hypothesize that our novel simulator will provide a reproducible, realistic, and quality educational experience for our participants.

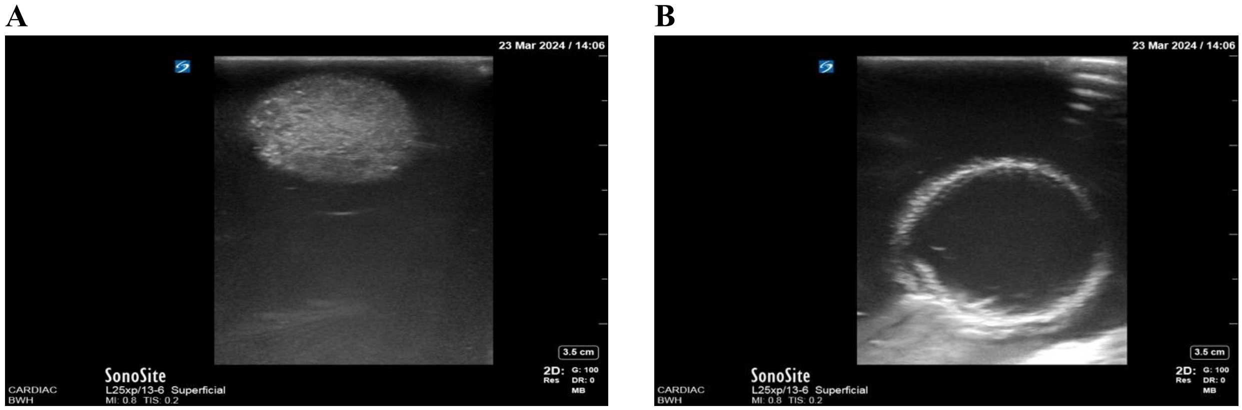
Methods

Model Design

The model was designed using inspiration from a breast model pioneered by the STRATUS Center for Medical Simulation which was implemented and studied for biopsy training in Rwanda (Hey et al., 2023). Using a glass jar, unflavored gelatin, hot water, manzanilla olives, latex gloves and food coloring, we engineered a simulated neck model compatible with sonography. The gelatin was whisked evenly with boiling water and food coloring to create the solution for the base for the simulator. The addition of food coloring allows for opacity and replication of skin tone. The solution was then poured into glass jars in four layers, refrigerating between layers for solidification. Water balloons and olives were introduced in the second and third layers to simulate solid and cystic lesions, respectively, for aspiration and biopsy. The water balloons were made from cutting off the fingers of sterile latex gloves. The fingers were filled halfway with water and tied off at the top. Between layers, air bubbles were removed from the solution, as this can diminish the ultrasound image quality. Before the next layer was poured, the solution was confirmed to be tacky from refrigeration and not purely fluid. This allowed for ideal nodule placement between layers. The simulated nodules varied in echogenicity: the water balloons appeared anechoic, and the olives appeared hyperechoic, relative to the gel (Figure 1). This allowed for differentiation between the two types of masses. After pouring the last layer, it is important to ensure the gelatin model has completely solidified to avoid the model breaking during the simulation. The final cost to create ten neck simulators was $52.28, which is $5.23 per model (Table 1).

Figure 1

Echogenicity Under Ultrasound in Model



Note. Images were captured using a SonoSite X-Porte Ultrasound device (*Sonosite X-Porte | FUJIFILM Sonosite*, 2019). Panel A: Image of the manzanilla olive under ultrasound Panel B: Image of the water balloon under ultrasound.

Table 1

Cost of Materials for Simulator and Total Cost

Model Component	Cost of Component	Vendor
Knox Unflavored Gelatin (1 lb.)	$20.31	Amazon
Chefmaster Liqua-Gel Food Color	$14.99	Amazon
Manzanilla Olives (with pits)	$6.99	Wal-Mart
Latex Gloves (Any)	$9.99	Amazon
Total Cost	$52.28	
Estimated Total Cost Per Model	$5.23	

Note. Items are typically bought in bulk and individual units are used to create the model. Due to inflation the costs of components are subject to change in value. Prices are reflective of USD in February of 2024.

Model Implementation for Participants

The simulator was available for use in a simulation skills course. In addition to the simulator, the set up included an 18-gauge 10-centimeter biopsy device with a 17-gauge 7-centimeter introducer needle, a 5-milliliter syringe with a 25-gauge 1.5-centimeter needle attached for aspiration, and an ultrasound machine for imaging (Figure 2). A towel was provided to mount the simulator, allowing participants to practice needle insertion from different angles. For each participant, we created one neck model with an even mix of three solid nodules and three cysts for an hour-long procedural practice.

Figure 2

Neck Simulator with Standard Setup

Note. Participants were given one hour to practice biopsies and FNAs using the equipment above with guidance from senior faculty. For the simulation sessions, ultrasound machines made by different manufacturers were given to participants which are not included in the image above.

Data Collection

The institutional review board at our institution determined this study to be exempt. Nine participants, 8 neuroradiology fellows (PGY6) and 1 interventional radiology resident (PGY5), participated in the study. Participants who have used the model or attended the session before were excluded from completing the survey again. After using the simulator, participants completed an anonymous post-simulation survey consisting of nine questions and space for additional comments (Appendix A). This survey gathered data regarding the simulator's functionality, user's level of experience, and user's comfort with performing neck biopsies. This survey was developed by the authors to address the research questions of this study. Questions were delivered using a 5-point Likert scale.

Statistical Methods

Pre- and post-simulation procedure comfort scores were compared using a Wilcoxon rank sum test. P-values less than 0.05 were considered significant. Statistical analyses were performed in R version 4.4.0.

Results

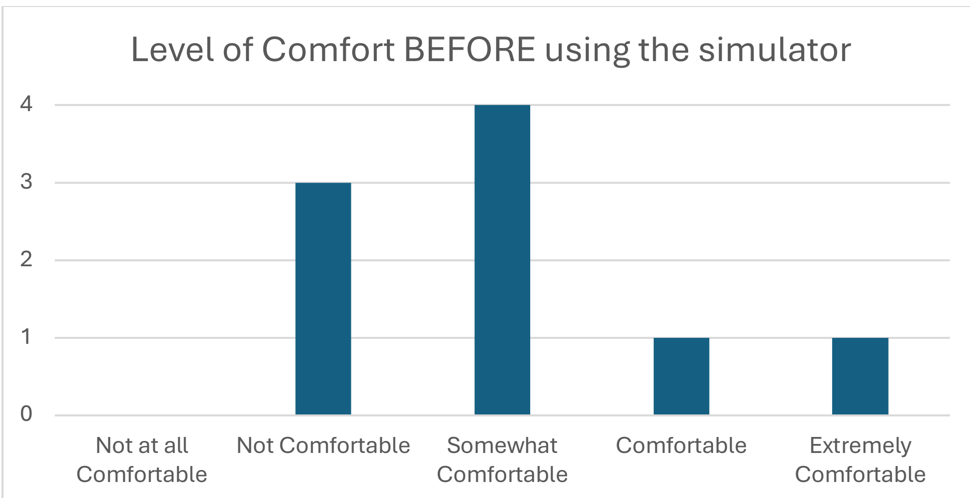
Of the nine participants, two had never performed a neck biopsy prior to these sessions. User procedure comfort was rated on a Likert Scale from 1 (Not Comfortable) to 5 (Extremely Comfortable). The median score for user procedure comfort rose significantly from 3 before the session (interquartile range: 2-3) to 4 (interquartile range: 4-4) after the session ($p = 0.03$). Of the nine participants, 8 (89%) reported an increase in procedural comfort, while one reported no change in comfort level (Figure 3). Participants rated how realistic our simulator was compared to other simulators and compared to live patients, on a scale of 1 (Less Realistic) to 5 (More Realistic). The average score for the realism of our simulator compared to other simulators was

3.6, and the average score compared to live patients was 3.3. Participants also rated how realistic the ultrasound imaging and neck lesions were on a scale of 1 (Less Realistic) to 5 (Equally Realistic). The average score of the ultrasound imaging and nodule fidelity were 4.0 and 3.6, respectively (Figure 4).

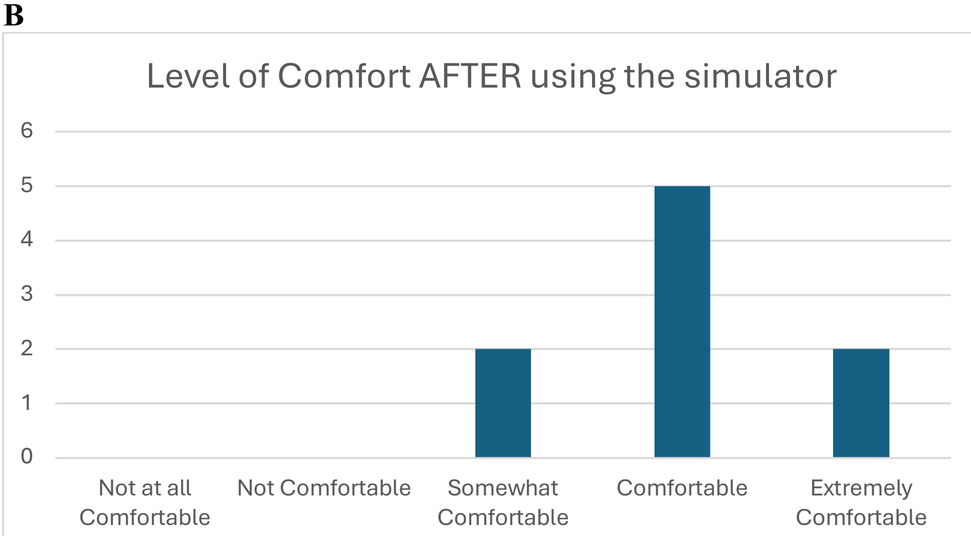
Figure 3

Level of Comfort with Ultrasound-Guided Neck Biopsy

A



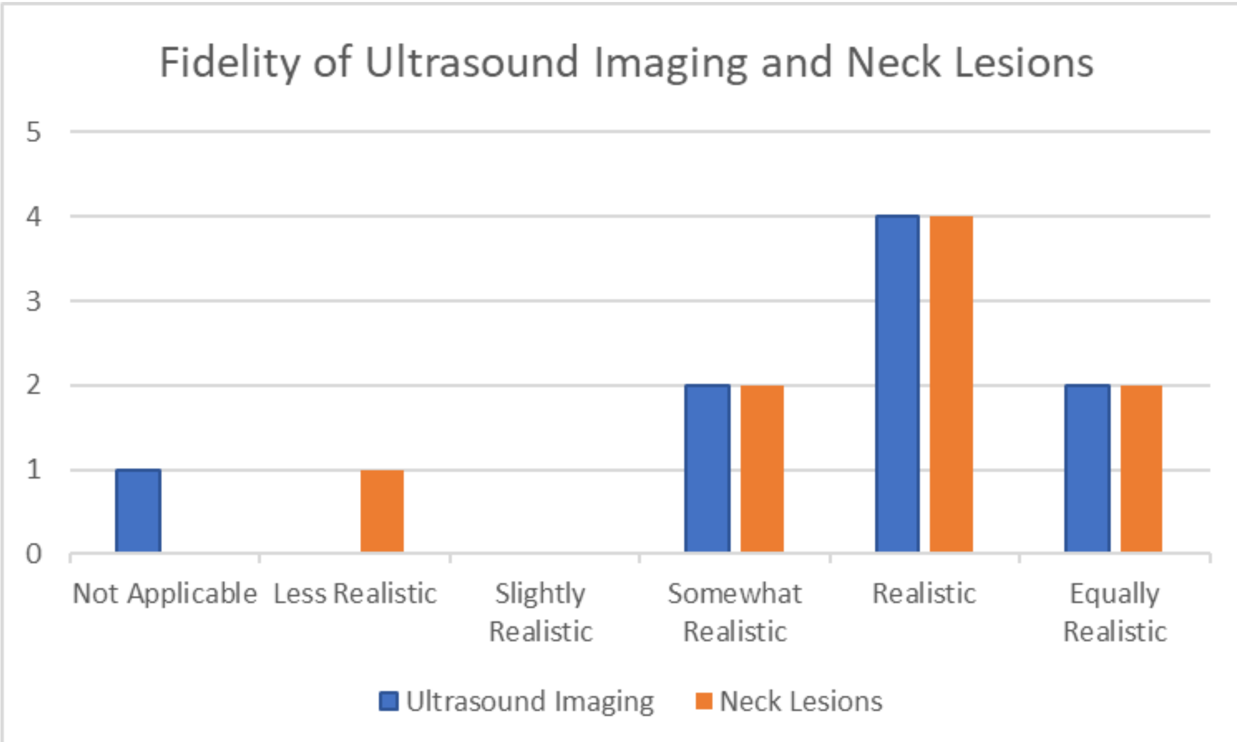
B



Note. The changes in user comfortability pre- and post- session as reported in participant surveys. Panel A: Reported levels of comfort from the nine participants BEFORE using the simulator. Panel B: Reported levels of comfort from the nine participants AFTER using the simulator.

Figure 4

Realism of the Ultrasound Imaging and Neck Lesions



Note. Feedback regarding the fidelity of ultrasound imaging and neck lesions (olives and water balloons) of the simulator, based on participant survey data.

Discussion

Our simulator has many strengths as demonstrated by the survey results. Overall, trainees found the neck biopsy simulator helpful in improving their procedural comfort. The simulator was also perceived positively amongst the cohort of participants with many giving the model a high-fidelity rating. In medical simulation, maximizing fidelity is critical as it helps participants suspend disbelief and make the most of educational experiences with simulators and manikins. With this in mind, we chose gelatin as the main component of our model due to its ability to produce an ultrasound image that somewhat replicates the echogenicity of human tissue. Gelatin offers several other advantages in simulation. It closely mimics the texture of human skin when palpating, is easily accessible, reproducible, and has been widely used in various innovative radiology simulators (Nhan et al., 2021). Previous studies (Giannotti et al., 2022; Hey et al., 2023) demonstrated the use of inexpensive gelatin phantoms like breast and neck models have the potential to improve the quality of patient care and procedural competencies in settings of all resource levels. In low-resourced settings, the utilization of low-priced and reproducible gelatin phantoms can minimize costs without sacrificing quality or learner satisfaction with the product.

Limitations of Simulator

Limitations of this simulator include the echogenicity of the simulated nodules, particularly with the olives. Solid nodules in humans can vary in echogenicity and can indicate malignancy risk in certain locations (Lee et al., 2022). Radiologists may have more experience with visualizing and performing biopsies on lesions with a broader range of echogenicity than what is provided in our simulator, potentially leading to disbelief. One participant commented that the olives were much harder to penetrate in comparison to real nodules, though the teaching faculty did not fully agree. To increase fidelity and suspension of disbelief, using diverse materials like grapes and blueberries could offer a wider range of echogenicity, size, and penetration characteristics for solid nodules. However, this would increase the cost of the model in comparison to using olives alone.

Limitations of Data

A limitation of the current study is the method of survey distribution. Because we administered the survey which consisted of pre- and post-simulation questions after the session, the learners may have experienced post-simulation sensitization. This could potentially bias the results. For future studies, employing separate pre- and post-simulation surveys would be more reliable to prevent sensitization. Another limitation is the low sample size, potentially impacting the validity of the results. The simulation sessions were run once to twice per month for five months with a single class of neuroradiology fellows. This made it difficult to get new participants, limiting our sample size. Future studies may benefit from a larger sample size. Another weakness includes the lack of variety in learner experiences as all the participants were imaging specialists. At our institution, neuroradiologists are the physicians performing these procedures on patients. However, we know this may not be applicable to other settings. Therefore, in future studies, obtaining feedback from other specialists like otolaryngologists and rural surgeons may improve the reliability of our trainer in different settings.

Conclusion

In this project, we designed a neck biopsy simulator for procedural training. Feedback from our participants demonstrated we were able to create an innovative simulator for procedural practice and education. We found that the radiology fellows reported feeling more comfort in procedure performance after practicing neck biopsies and aspirations on our trainer. Additional studies with a larger sample size may be required to further explore the applicability of this simulator among different environments and trainees with diverse medical experiences.

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Appendix A

Low-Cost Neck Model Survey

Low-Cost Neck Model Survey

1) What is your level of training? (Circle one)

PGY1 PGY2 PGY3 PGY4 PGY 5 PGY6

2) Prior to this session, have you ever performed a neck biopsy or aspiration? (Circle one)

Yes No Unsure

3) Prior to this session, have you ever observed a neck biopsy or aspiration? (Circle one)

Yes No Unsure

4) Using the scale below, please rate your comfort performing a neck biopsy or aspiration **PRIOR TO THIS SESSION** (Circle one)

1	2	3	4	5
Not at all comfortable		Somewhat comfortable		Extremely comfortable

5) Using the scale below, please rate your comfort in performing a neck biopsy or aspiration **AFTER THIS SESSION** (Circle one)

1	2	3	4	5
Not at all comfortable		Somewhat comfortable		Extremely comfortable

6) Compared with other simulators you have used, please comment on how realistic this model was to work with? (Circle one or select NA if not applicable)

1	2	3	4	5	N/A
Much less realistic				Much more realistic	

7) Compared with other cadavers or live patients, please comment on how realistic this model was to work with? (Circle one or select NA if not applicable)

1	2	3	4	5	N/A
Much less realistic				Equally as realistic	

8) Compared with cadavers or live patients, how realistic is the model under ultrasound imaging?

1	2	3	4	5	N/A

Less realistic Equally realistic

9) Compared to real nodules in patients, how do the olives and water balloons compare on the model?

1	2	3	4	5	N/A
Less realistic				Equally realistic	

Comments:____

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