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Society for Simulation in Healthcare
STORM

Simulation Technology & Operations Resource Magazine (STORM)

STORM highlights exemplar work contributing to the advancement of healthcare simulation operations. All submissions are peer reviewed before publication in the STORM special edition of the SSH Simulation Spotlight. With articles covering training, policy & procedure, emerging technologies, and professional development, STORM has everything needed to stay current and well-rounded in the pursuit of simulation operations excellence.

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Letter from the STORM Editorial Board

Dear Simulation Operations Professionals,

I am writing to share my insights and experiences regarding career development for Simulation Operations Specialists (SOS), which I believe would be beneficial to the readers of STORM Magazine. As an Associate Professor of Pediatrics, Cardiology and Biomedical Sciences, and Medical Director of Simulation at Cedars Sinai Medical Center, I have witnessed the transformative power of simulation operations in healthcare education and its potential for career advancement.

Career Advancement for Simulation Operations Specialists

Simulation Operations Specialists play a critical role in the successful implementation and management of simulation-based education. Their expertise in technology, logistics, and educational methodologies is essential for the smooth functioning of simulation programs. Here are some pathways for career development for SOS professionals:

1. Technical Skill Enhancement: Continuously updating technical skills is paramount. SOS professionals should seek training in the latest simulation technologies, software, and equipment. Mastery of these tools not only ensures efficient operation but also positions the SOS as an indispensable resource within their institution.
2. Educational Contributions: Involvement in the educational aspect of simulation, such as scenario development and facilitation, can significantly enhance an SOS's career. Participating in or leading workshops and training sessions for healthcare staff and students allows SOS professionals to demonstrate their expertise and commitment to education.
3. Certification and Advanced Credentials: Pursuing certifications like Certified Healthcare Simulation Operations Specialist (CHSOS) and CHSOS-Advanced (CHSOS-A) is crucial. These certifications validate the specialist's skills and knowledge, making them more competitive for advanced roles and leadership positions. As a part of the CHSE-A subcommittee, I helped launch the CHSOS-A working group that eventually developed into a committee after the CHSOS-A was launched.
4. Leadership Opportunities: Taking on leadership roles within simulation centers or committees can further career development. As an SOS gains experience, they can aspire to positions such as Simulation Center Manager or Director of Simulation Operations. Leadership roles provide opportunities to influence the direction of simulation programs and contribute to strategic planning and decision-making.
5. Research and Innovation: Engaging in research related to simulation operations can lead to publications and presentations at conferences. This scholarly activity not only contributes to the field but also establishes the SOS as a thought leader, opening doors to further career opportunities and collaborations.
6. Networking and Mentorship: Building a strong professional network through associations like the Society for Simulation in Healthcare (SSH) is invaluable. Networking provides access to job opportunities, collaborative projects, and mentorship. Additionally, serving as a mentor to new SOS professionals can enhance leadership skills and professional standing.

Mentorship and Professional Development

Mentorship plays a critical role in career development. I have had the privilege of mentoring numerous SOS professionals, helping them navigate the complexities of the simulation field and achieve their career goals. Establishing a strong network through professional associations provides valuable opportunities for collaboration, knowledge exchange, and career advancement.

Conclusion

In conclusion, the role of Simulation Operations Specialists is integral to the success of simulation-based education. By continuously enhancing technical skills, pursuing advanced certifications, engaging in research, and taking on leadership roles, SOS professionals can achieve significant career growth and contribute meaningfully to the advancement of healthcare simulation.

I hope these insights encourage and inspire readers to explore the potential of simulation operations in their career journeys, bringing their expertise to the STORM magazine to share their work in the different categories of publication i.e. Emerging Technologies, Policy & Procedure, Career and Training. Thank you for considering my perspectives for publication in STORM Magazine.

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The Impact of Virtual Reality Headset Selection on Cybersickness Severity

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Conflict of Interest Statement
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Abstract

Background: Although a wide range of factors have been implicated in the development of cybersickness, the target headset selection has also been identified as a significant contributing factor. This study compares measures of cybersickness between the Meta Quest 2 and Meta Quest Pro headsets.

Methods: Thirty-four subjects between the ages of 19 and 30 participated in a three-minute-long simulated roller-coaster ride. Differences in Simulation Sickness Questionnaire (SSQ) scores and measurements taken from a hand-held dial that allowed for the moment-to-moment recording of discomfort levels were recorded.

Results: Significant findings include decreased SSQ scores for participants using the Meta Quest Pro headset and increases in the oculomotor and disorientation components of the SSQ score related to interpupillary distance (IPD) mismatch.

Conclusion: As researchers consider the implementation of VR headsets for a particular application, it would be prudent to evaluate the IPD adjustability of the headset in question. By comparing it to the typical IPD range of the population where it will be deployed, it may be possible to reduce the contribution of IPD mismatch on the severity and incidence of cybersickness.

Introduction

Virtual Reality (VR) training offers an opportunity to increase engagement in students by encouraging active participation through physical interaction with objects in the virtual environment (Fabris, et al., 2019) and allowing for a greater understanding of concepts through self-directed inquiry and exploration (Maresky et al., 2019). However, cybersickness, a form of motion sickness experienced within Head-Mounted Device (HMD) virtual reality devices, poses a threat to the quality of the VR educational experience. Occurring in as many as 40% of participants (Moro et al., 2017), cybersickness impedes the deployment of VR within institutional settings.

The technical capabilities of HMDs differ substantially, and these differences have been shown to be contributing factors in the development of cybersickness (Caserman et al., 2021). As universities contemplate investments in VR, price is a significant consideration. For example, the Meta Quest 2 was priced at $399 on release compared to $1499 for the Meta Quest Pro (*Meta Quest Pro Vs Meta Quest 3 (Comparison) - VRcompare*, 2023). However, if the technological advancements in newer, more expensive headsets contribute to a significant decrease in cybersickness symptoms, the additional investment may increase the effectiveness of VR learning experiences. Currently, there are no published studies evaluating these two headsets for any differences in their associated incidence and severity of cybersickness. For this reason, understanding the degree to which more advanced HMDs may mitigate cybersickness is crucial in maximizing the effectiveness of VR and promoting its adoption as an experiential medium.

Motion Sickness Nomenclature

The term ‘cybersickness’ was first coined by McCauley and Sharkey (1992) to refer to motion sickness symptoms that specifically occur in HMD virtual reality. While the terms ‘cybersickness’ and ‘VR sickness’ are synonyms describing identical symptomatology (Chang et al., 2020; Gallagher & Ferre, 2018; Saredakis et al., 2020), they are distinct from other terms seen in the literature such as motion sickness, simulation sickness, and visually induced motion sickness. Motion sickness encompasses all symptoms that result from motion, whether it is real or simulated. Simulation sickness refers to motion sickness symptoms that occur during a simulated experience whether it be virtual reality, fixed-base aircraft simulators, or driving simulators (Kennedy et al., 1993). Visually induced motion sickness is a subset of simulator sickness resulting from the use of visual display devices to simulate an experience. This includes VR, immersive rooms, cinemas, and video game systems (Keshavarz et al., 2019).

HMD Selection and Cybersickness

Gender (Stanney et al., 2020), age (Arns & Cerney, 2005), anxiety level (Paillard et al., 2013), manner of locomotion (Kim & Rhiu, 2021; Lin et al., 2022; Mayor et al., 2021) , and manner of presentation of visual information (Budhiraja et al., 2017; Liu & Chen, 2022; Won & Kim, 2022) have all been identified as factors in the development of cybersickness. Additionally, the target headset selection has been identified as a significant contributing factor (Caserman et al., 2021).

VR headsets vary significantly in their technical specifications (Table 1). For example, when comparing the Meta Quest 2 and the Meta Quest Pro, the Meta Quest Pro headset contains a faster processor and a faster default refresh rate of 120 Hz compared to 90 Hz in the Meta Quest 2, which could result in less latency (Heaney et al., 2023). Increased latency can result in display lag, a situation where the movements of the user’s view in the virtual world are delayed significantly enough from the real-world movement of their head to produce cybersickness (Kim, Luu, & Palmisano, 2022).

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Table 1

Technical Specifications of Past and Current Commercially Available HMDs

Headset	Release Date	Display Type	Resolution (per eye)	IPD Adjustment (mm)	Refresh Rate (Hz)	Horizontal FOV (deg)	Vertical FOV (deg)	Price at Release (USD)
Oculus Rift DK1	Mar 2013	OLED	1280x800	Fixed 63.5	60	90	90	$300
Oculus Rift DK2	Jul 2014	OLED	1920x1080	Fixed 63.5	75	93	99	$350
Oculus Rift	Mar 2016	AMOLED	1080x1200	58-72	90	87	88	$599
HTC Vive	Apr 2016	OLED	1080x1200	61-72	90	108	97	$799
Sony Playstation VR	Oct 2016	OLED	960x1080	58-70	120	96	111	$299
HTC Vive Pro	Apr 2018	AMOLED	1440x1600	61-72	90	98	98	$799
Oculus Rift S	May 2019	LCD	1280x1440	58-72	80	88	88	$399
Oculus Quest	Nov 2019	OLED	1440x1600	58-72	72	93	93	$399
Meta Quest 2	Oct 2020	LCD	1832x1920	58,63,68	72	97	93	$399
Meta Quest Pro	Oct 2022	LCD	1800x1920	55-75	90	106	95	$1,499

Note. This table compares technical specifications of different HMDs (*Meta Quest Pro Vs Meta Quest 3 (Comparison) - VRcompare*, 2023). *OLED: organic light-emitting diode; AMOLED: active matrix organic light-emitting diode; LCD: liquid crystal display; IPD: interpupillary distance; FOV: field of view.*

Headsets also differ in their ability to adjust the interpupillary distance (IPD), which has been shown to be the primary driver of gender-based differences in motion sickness (Stanney et al., 2020). The Meta Quest 2 has only three possible IPD settings: 58, 63, and 68 mm. In contrast, the Meta Quest Pro is continuously adjustable between 55 and 75 mm.

Measuring Cybersickness and Predisposition to Cybersickness

For the purposes of this research, the Simulator Sickness Questionnaire (SSQ) (Kennedy, 1993) was used to assess perceived simulation symptoms before and after the intervention. The Motion Sickness Susceptibility Questionnaire (MSSQ) short form (Golding, 1998) and the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ) short form, also developed by Golding (2021), were used to assess predisposition to motion sickness symptoms.

The SSQ elicits responses for 16 different symptoms categorized as components of nausea, oculomotor symptoms, or disorientation (Kennedy, 1993). Total SSQ scores range from 0 to 235 (Walter et al, 2019). Based on data obtained from studies on military pilots, SSQ scores are categorized as follows: less than 5 is negligible, 5-10 is minimal, 11-15 is significant, and 16-20 is concerning (Bimberg, 2020).

The MSSQ evaluates the childhood and adult history of motion sickness on various modes of transportation. The raw MSSQ scores range from 0, indicating never experiencing any of the modes, to 54, indicating frequently feeling sick on all modes. The scoring for each mode is as follows: 0 is never felt sick, 1 is rarely felt sick, 2 is sometimes felt sick, and 3 is frequently felt sick.

The VIMSSQ assesses susceptibility to five different symptoms: headache, fatigue, dizziness, nausea, and eyestrain. These symptoms can occur when using visual display devices such as smartphones, tablets, video games, and virtual reality glasses. The score ranges from 0, which indicates no symptoms, to a maximum of 18. Higher scores indicate greater susceptibility to visually induced motion sickness symptoms

Eliciting Cybersickness

Because of the significant disparity in virtual versus real-world motion, the standard experience for eliciting cybersickness in virtual reality is a simulated roller coaster ride (Eftekharifar et al., 2021; Gavgani et al., 2017; Grassini et al., 2021; Nesbitt et al., 2017; Stanney et al., 2020). For this study, we used the commercially available Epic Roller Coaster software by B4T Games (Balneário Camboriú, Brazil). The roller-coaster simulation consisted of a three-minute first-person view in the seated position.

Methods

Participants

After receiving IRB approval, thirty-four subjects, 15 males and 19 females, were recruited from a university nursing program to participate in the study. Participants were between the ages of 20 and 34. Inclusion criteria include the following: willingness to participate, binocular vision with or without corrective lenses, and no restriction that would prevent the donning of a virtual reality headset. Exclusion criteria include the following: known history of significant motion sickness, known history of motion sickness lasting longer than 15 minutes produced by virtual reality use, known severe history of balance disorder or dizziness, known history of seizure disorder, known cardiac condition, known migraine disorder, current cold or flu symptoms, alcohol use within the past 12 hours, pregnancy at the time of data collection, known history of severe hearing deficit, and age less than 18 years. An explanation of the testing procedure was provided before obtaining signed consent to participate.

Study Procedure

Prior to beginning the roller-coaster simulation, participants completed the Motion Sickness Susceptibility Questionnaire (MSSQ), the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ) short form, and a baseline Simulator Sickness Questionnaire (SSQ) questionnaire. In addition, a brief demographic questionnaire was obtained.

During the roller-coaster simulation, subjects used a handheld device, called the discomfort dial, with a roller wheel to indicate their current level of motion sickness severity. The discomfort levels ranged from 0 to 10. Subjects were informed that discomfort levels were categorized as follows: level 1 is no discomfort, levels 2-4 are mild discomfort, levels 4-7 are moderate discomfort, and levels 8-10 are severe discomfort. The device provided audio feedback indicating the numeric level of severity to a wireless speaker mounted near the subject.

Participants were then randomly assigned to either the Meta Quest 2 or Meta Quest Pro group. Participant demographics are presented in Table 2. The Meta Quest 2 group consisted of 9 males and 8 females with an average age of 24.2 ± 3.7 years. The Meta Quest Pro group consisted of 6 males and 11 females with an average age of 24.8 ± 3.9 years.

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Table 2

Demographic Data and IPD Measurements

Demographics	Meta Quest 2	Meta Quest Pro
# of Subjects	17 (8 female)	17 (11 female)
Age (years)	24.2 ± 3.7	24.8 ± 3.9
IPD (mm)	62.8 ± 2.9	61.9 ± 2.9

Note. Data in this table are presented as the mean ± standard deviation for each group, except for number of subjects. *IPD: Interpupillary Distance; mm: millimeter.*

The participants' interpupillary distances were measured and averaged for each group (Table 2). The Meta Quest 2 group exhibited an average IPD of 62.8 ± 2.9 millimeters. The Meta Quest Pro group exhibited an average IPD of 61.9 ± 2.9 millimeters. The IPD setting of the device was adjusted to match the participant. If a participant did not match one of the three IPD settings on the Meta Quest 2 headset, then the nearest IPD was used. If the participant's IPD was exactly in between two of the three available Meta Quest 2 IPD settings, then the higher IPD setting was used. No individuals exhibited an IPD measurement outside of the minimum and maximum IPD range of either device. Immediately following the roller-coaster simulation, each participant completed the SSQ again.

Data Analysis

Data from the VIMSSQ, MSSQ, and discomfort dial were collated and de-identified. Statistical analysis was performed in RStudio (R Core Team, 2023). The net SSQ total was calculated by subtracting the pre-intervention SSQ scores from the post-intervention SSQ scores. The same process was repeated for the nausea, oculomotor, and disorientation components of the SSQ.

Ordinary least squares regression analysis was performed comparing VIMSSQ score, MSSQ score, gender, headset condition, and IPD mismatch in millimeters with the net SSQ total, the nausea component of the SSQ score, the oculomotor component of the SSQ score, the disorientation component of the SSQ score, the onset of discomfort, the average discomfort level, and the average peak discomfort level. All regressions were evaluated using robust standard error type HC1 and evaluated against diagnostic tests of assumption. Two observations were identified during analysis as significant outliers and removed from the dataset. This resulted in 32 total observations, with 16 from the Meta Quest 2 group and 16 from the Meta Quest Pro group.

Results

For each group, the average of the VIMSSQ, MSSQ, IPD mismatch, net SSQ Total, and SSQ components is presented in Table 3. Additionally, Table 3 includes data collected from the discomfort dial, such as the onset of discomfort, average discomfort level, and average peak discomfort levels for each group.

Table 3

VIMSSQ, MSSQ, SSQ and Discomfort Dial Data

Measurement	Meta Quest 2	Meta Quest Pro
VIMSSQ	2.6 ± 3.1	3.1 ± 3.3
MSSQ	4.7 ± 6.7	8.0 ± 11.2
IPD mistmatch (mm)	1.24	0
SSQ Total	20.4 ± 22.3	23.5 ± 24.1
SSQ Nausea	20.8 ± 22.1	21.8 ± 30.9
SSQ Oculomotor	9.8 ± 14.9	14.7 ± 14.8
SSQ Disorientation	27.8 ± 29.5	28.7 ± 32.0
Onset of discomfort (secs)	46.9 ± 37.5	65.0 ± 74.7
Avg discomfort level	2.7 ± 1.3	2.5 ± 1.6
Avg peak discomfort level	6.2 ± 2.7	4.9 ± 2.9

Note. Data in this table are presented as the mean ± standard deviation for each group. *VIMSSQ: Visually Induced Motion Sickness Susceptibility Questionnaire; MSSQ: Motion Sickness Susceptibility Questionnaire; IPD: interpupillary distance; SSQ: Simulation Sickness Questionnaire; secs: seconds; Avg: average.*

VIMSSQ

VIMSSQ scores demonstrated no significant relationship to the net SSQ total, SSQ component scores, discomfort onset time, or average discomfort level. For every one-unit in VIMSSQ score, the average peak discomfort level is predicted to increase by 0.28 units (95% CI: 0.002-0.558, $p = 0.044$, $R^2 = 0.25$), controlling for age, gender, headset type, and IPD mismatch.

MSSQ

The MSSQ score demonstrated no significant relationship to the net SSQ total, SSQ component scores, onset of discomfort, average discomfort level, or average peak discomfort level.

Gender

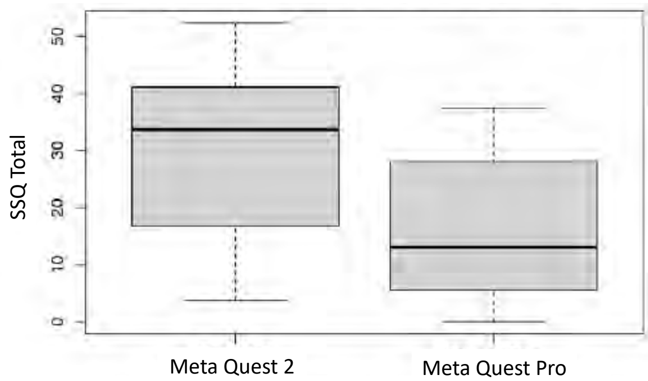
Gender demonstrated no significant relationship to the net SSQ total, SSQ component scores, onset of discomfort, average discomfort level, or average peak discomfort level.

Headset Condition

The headset condition, either Meta Quest 2 or Meta Quest Pro, demonstrated no significant relationship to SSQ component scores, onset of discomfort, average discomfort level, or average peak discomfort level. However, it did exhibit a significant effect on the net SSQ total. The use of the Meta Quest Pro headset is predicted to decrease the net SSQ total by 11.24 points (95% CI: 1.27-21.2, $p = 0.03$, R^2=0.15) when ignoring all other independent variables (Figure 1). No significant interactions were noted with gender.

Figure 1

Comparing Net SSQ Total between Headset Condition



Note. The net SSQ total was calculated by subtracting the pre-intervention SSQ scores from the post-intervention SSQ scores. *SSQ: Simulation Sickness Questionnaire.*

IPD Mismatch

The average IPD mismatch for the Meta Quest 2 group was 1.24 millimeters with a range of -2 to +2 millimeters. Because the Meta Quest Pro allows for continuous IPD adjustment within the range of 55-75 millimeters, no participants in the Meta Quest Pro group had a mismatch between their IPD measurement and the IPD setting of the device.

The IPD mismatch in millimeters demonstrated no significant relationship to the net SSQ total, nausea component of the SSQ score, onset of discomfort, average discomfort level, or average peak discomfort level. However, there was a significant relationship between IPD mismatch in millimeters and both the oculomotor and disorientation components of the SSQ score. For every 1-millimeter increase in the absolute mismatch between the participant's IPD and the IPD setting of the headset, the difference between the pre-intervention and post-intervention oculomotor component of the SSQ score was predicted to increase by 14.63 points (95% CI: 4.3-25.0, p=0.01, R^2 =0.35), controlling for age, gender, and headset model (Figure 2A). Similarly, for every 1-millimeter increase in the absolute mismatch between the participant's IPD and the IPD setting of the headset, the difference between the pre-intervention and post-intervention disorientation component of the SSQ score was predicted to increase by 24.86 points (95% CI: 11.5-38.2, p<0.001, R^2=0.44), controlling for age, gender, and headset model (Figure 2B). The correlation between the headset condition and IPD mismatch variables was observed to be 0.76. Removing the headset condition as an independent variable predicted a 12.04-point increase (95% CI: 5.42-18.65, p<0.001, R^2=0.34) in the oculomotor component of the SSQ score and a 17.32-point increase (95% CI: 8.50-26.13, p<0.001, R^2=0.39) in the disorientation component for every one-unit increase in IPD mismatch, controlling for gender and age.

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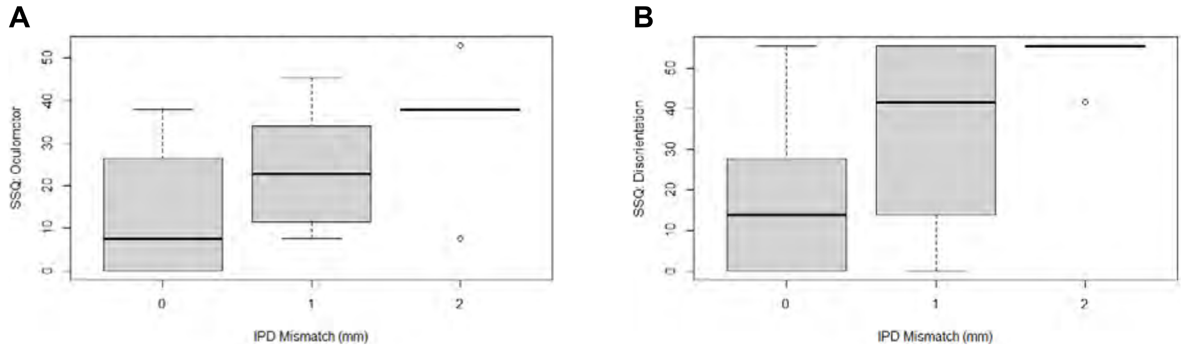
Figure 2

Relationship between IPD Mismatch and SSQ Component Scores



Note. Panel A: Relationship between IPD mismatch and the difference in the pre-intervention and post-intervention oculomotor component of the SSQ score. Panel B: Relationship between IPD mismatch and the difference in the pre-intervention and post-intervention disorientation component of the SSQ score. *SSQ: Simulation Sickness Questionnaire; IPD: interpupillary distance; mm: millimeters.*

Discussion

In this study, we evaluated the relationships between VIMSSQ score, MSSQ score, gender, headset condition, and IPD mismatch on the SSQ total score, SSQ component scores, onset of discomfort, average discomfort level, or average peak discomfort level. While MSSQ score and gender exhibited no significant effect, a relationship was noted between the VIMSSQ score and the average peak discomfort level. An increase of one unit in the VIMSSQ score is predicted to result in a 0.28-point rise in the peak discomfort level. For instance, a participant with a VIMSSQ score of 8 would be expected to have a peak discomfort level that is 1.4 points, or 14%, higher than that of a participant with a VIMSSQ score of 3. The short amount of time required to complete the VIMSSQ and relevance to predicting peak discomfort may provide some utility in identifying participants at risk for increased cybersickness symptoms before they engage in a VR simulation.

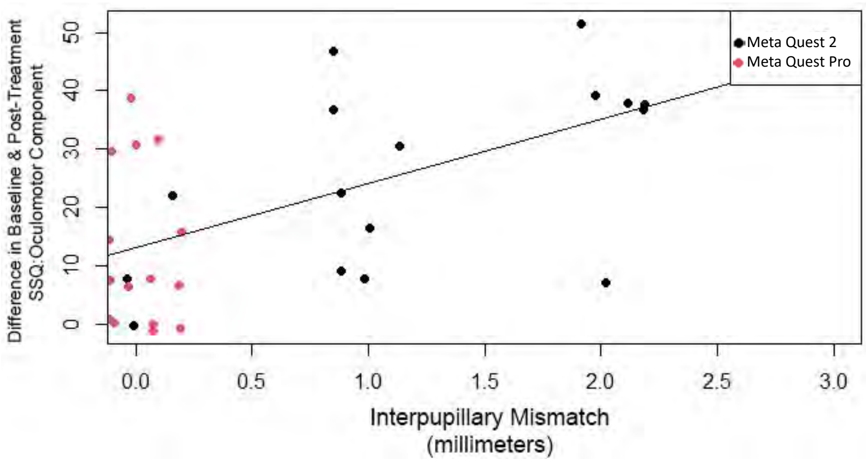
Additionally, the headset condition and IPD mismatch exhibited significant effects. Prior studies have identified female gender as contributing to the incidence of cybersickness (Biocca, 1992; Clemes & Haworth, 2005). More recent studies found gender to not be influential on cybersickness (Davis, Nesbitt, & Nalivaiko, 2014; Melo, Vasconcelos-Raposo, & Bessa, 2018). Stanney et al. (2020) discovered that while gender had a significant main effect on the development of cybersickness in a high-intensity roller-coaster simulation, the primary factor driving increased cybersickness in females was IPD mismatch. This study noted the HTC Vive headset used had an IPD range of 60.5 - 74.4 mm. This range would not fit approximately 35% of Asian, Caucasian, and African American females. The results of our study seem consistent with findings demonstrating no main effect of gender, but a significant contribution of IPD mismatch to the oculomotor and disorientation components of the SSQ score (Figure 2).

Because the Meta Quest 2 has only three IPD settings, only three of the sixteen participants included in the analysis for the Meta Quest 2 had a perfect IPD fit (Figure 3). Seven participants exhibited an IPD mismatch of 1 mm and six exhibited an IPD mismatch of 2 mm. In contrast, the Meta Quest Pro has an IPD range of 55-75 mm. Because of the larger range and capability of continuous adjustment, all participants using the Meta Quest Pro had a headset IPD setting that exactly matched their measured IPD. It must be considered that the accuracy of

IPD adjustment could be a significant contributing factor in the lower SSQ scores associated with the Meta Quest Pro headset in at least some persons. Knowing one's own IPD and ensuring that the headset is set appropriately could result in decreased symptoms.

Figure 3

Relationship between IPD Mismatch and SSQ Oculomotor Component Scores



Note. An increasing trend in the SSQ oculomotor component scores is noted as the IPD mismatch increases. All Meta Quest Pro scores and three Meta Quest 2 subjects exhibited an IPD mismatch of zero. *SSQ: Simulation Sickness Questionnaire.*

At the time of this writing, Meta has discontinued the Meta Quest Pro in favor of the less expensive Meta Quest 3, priced at $499. The Meta Quest 3 retains the occlusive goggle design of the Meta Quest 2 but offers several improvements over the Meta Quest Pro. It has a higher resolution of 2064 x 2208 compared to 1800 x 1920, a faster refresh rate of 120 Hz vs 90 Hz, and a wider horizontal field of view of 110 degrees vs 106 degrees. Additionally, it is 28% lighter (*Meta Quest Pro Vs Meta Quest 3 (Comparison) - VRcompare*, 2023). Although the Meta Quest 3 retains the continuous IPD adjustment, it decreases the IPD range from 55-75 millimeters down to 58-71 millimeters. In this study, subjects using the Meta Quest Pro experienced an IPD mismatch of zero. However, if the Meta Quest 3 had been used, three subjects (18.8%) would have experienced an IPD mismatch of 1 mm.

Limitations

The small sample size used in this research presents a limitation to the interpretation of findings. Similarly, the use of a convenience sample of nursing students at a single university in the southeast United States could limit the generalizability of the results to other populations. Finally, other characteristics of the Meta Quest Pro not evaluated in this study which could influence the SSQ score include the following: higher frame rate, lower latency, comfort-related design features such as balanced front-to-back weight distribution and open goggle design.

Conclusion

In this study, VIMSSQ scores proved of use in predicting the peak symptoms experienced in a roller-coaster simulation. The Meta Quest Pro headset demonstrated a notable reduction in cybersickness as measured by the total SSQ score. More significantly, it appears that the wide range and accuracy of the IPD adjustment of the Meta Quest Pro headset contributed to significant decreases in the oculomotor and disorientation components of the SSQ score. As researchers consider implementing VR headsets, it would be prudent to evaluate the IPD adjustability of the headset. Comparing this with the average IPD range of the population may help to reduce the contribution of IPD mismatch on the severity and incidence of cybersickness.

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Assessing the Efficacy of a New Radiology Simulation Laboratory in Medical Education

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Brief Description

Diagnostic radiology is a diverse medical specialty essential to effective and efficient diagnosis and treatment. To promote interest and awareness in this specialty, medical students should have the opportunity to explore an engaging radiology curriculum and gain fundamental skills. Historically, radiology education in the undergraduate medical setting has been limited due to challenges in providing hands-on learning and stimulating critical thinking (O'Connor et al., 2016). To address these obstacles, we designed a new radiology simulation lab as part of the radiology elective curriculum for medical students. One year after the lab's implementation, medical students who participated were surveyed regarding the lab. Overall, medical students positively ranked the lab's structure, education, timeline, and enjoyment. These results highlight the value of an interactive radiology curriculum in undergraduate medical education.

Introduction

Diagnostic radiology is a diverse medical specialty essential to effective and efficient diagnosis and treatment. A successful radiologist must have attention to detail, the ability to work in fast-paced and stressful situations, and strong critical thinking skills (Collins et al., 2002). Medical students and radiologists from across the United States argue that radiology needs to have a greater role in medical education for all medical students, regardless of career ambitions (Dmytriw et al., 2015; Gunderman et al., 2003; Zwaan et al., 2017).

Given these calls to action and the unique skillset of radiologists, medical students should have the opportunity to explore an engaging radiology curriculum and gain fundamental skills. One challenge with radiology education is providing hands-on learning and stimulating critical thinking (O'Connor et al., 2016). Radiologists typically work alone, and the traditional observational model may not be ideal for students and faculty. A shadowing student may lose focus after watching the radiologist interpret many images, while a radiologist may not have adequate time to review images with the student during a busy day (Redmond et al., 2020). In this model, students may not be exposed to classic radiology cases and are not actively engaged in reading images. This may lead to decreased interest in the field and greater uncertainty in interpreting radiological images (Redmond et al., 2020).

To address these challenges, institutions across the country have implemented flipped classroom and simulation-based programs that have successfully enhanced learner knowledge, engagement, and interest in radiology (Belfi et al., 2015). At Creighton University School of Medicine, a new radiology simulation lab has been added to the radiology elective for medical students. The radiology simulation lab is an automated course featuring introductory and instructional videos, hands-on case viewing, and post-educational radiology read-out sessions for ten radiology subspecialties. The course is divided into the following subspecialties: chest, advanced cardiothoracic, gastrointestinal, genitourinary, neurosciences/neuroradiology, orthopedic/musculoskeletal, women's, interventional radiology, nuclear medicine/oncology, and pediatric imaging.

The simulation course is divided into subspecialties to teach level-appropriate radiology topics for optimizing patient care and understanding at three educational levels: medical students, mid-level providers (such as physician assistants and advanced practice nurses), and non-radiology residents. This radiology simulation course offers radiology content specific to various specialties and accessible to learners at different educational levels. Each subspecialty is expected to take approximately two to three hours to complete. The ten subspecialties contain two to six different radiology educational teaching topics, each consisting of an instructional video, radiology case viewing, and post radiology read-out session.

The instructional videos cover fundamental radiology topics and the interpretation of various diagnoses or differential diagnoses within the subspecialty. The educational topics are based on the Association of University Radiologists Alliance of Medical Student Educators in Radiology Curriculum, Competencies and Learning Objectives for Medical Students (*AMSER Curriculum, Competencies, and Learning Objectives*, 2023). These radiology topics parallel Radiology Aquifer Cases and can function as stand-alone or supplementary teaching tools to Radiology Aquifer Case Modules (*Aquifer Radiology*, 2024).

At our institution, the simulation lab is conducted as an in-person learning activity with small groups of three to four students. The course is a ten-day elective, with one day dedicated to each radiology subspecialty. Each day, the students begin one of the modules with a 10-minute teaching video before working as a group to view and diagnose the accompanying radiology cases. For example, on the neuroradiology day, there are five different education topics/modules: Approach to Head Trauma, Early Signs of an Acute Stroke, Cervical Spine Fractures, Epidural Hematoma, and Subdural Hematoma. Within these five educational topics, there are multiple case examples and a single post read-out session. The read-out video features a radiologist interpreting the case, highlighting the approach to reading the radiology exam, and identifying key radiologic findings. This allows students to verify their findings and interpretation of the images.

Approximately 50-60 educational topics and 400 student-level radiology cases (including radiographs, ultrasound, CT, MRI, PET imaging, mammography, and interventional procedures) have been chosen for medical students, allied health students, and non-radiology residents. These topics are organized in the ten subspecialities mentioned previously.

The cases are on a Picture Archiving and Communication System (PACS) driven workstation to simulate the work of a healthcare professional viewing the case. Horos PACS system is a free, open-source medical image viewer based on OsirX (Pixmeo SARL, Geneva, Switzerland), designed specifically for storing and viewing for medical imaging. Horos PACS allows students to launch, view, and manipulate images as a radiologist would when interpreting radiology exams. Since Horos is a free software program and the main operational component for running a radiology simulation lab, other institutions can easily develop and maintain similar labs. After downloading Horos, faculty can select appropriate images, deidentify them to remove patient information, and upload them to Horos PACS for viewing.

The students complete one of the ten radiology subspecialties sections each day of their elective. They are introduced to radiographs, computer tomography, MRI, PET imaging, nuclear medicine, and mammography. All images were selected from patients at our institution and chosen by a subspecialized attending radiologist to best exemplify their teaching topics. All images were de-identified and given unique a unique four-digit radiology simulation lab case number. Case numbers were assigned and grouped by radiology subspecialty. For multiple images of the same patient, the case numbers share the same first three digits, while the last digit is unique to each image.

The radiology simulation lab was originally developed to be an in-person learning activity. However, given the popularity of the educational material, a portion of this curriculum has moved to a YouTube channel named RadiologyEspresso for remote viewing (www.youtube.com/@radiologyespresso101). This YouTube channel allows not only our Allied Health Programs students but also other students globally to view teaching videos, example cases, and post read-out session videos. The RadiologyEspresso YouTube channel lacks the ability to view the numerous case examples on the PACS driven workstation.

The radiology simulation lab was recently implemented into the radiology elective curriculum, so we aimed to evaluate student perspectives of the lab. In this study, we surveyed fourth-year medical students who completed the lab during their radiology elective. We aimed to better understand where the new curriculum is successful and where it could be improved, especially regarding the structure, education, and time spent for the simulation lab.

Methods

Fourth-year medical students at Creighton University School of Medicine who participated in the radiology simulation lab from June 2022 to March 2023 were invited via email to complete the survey. The survey consisted of several Likert-scale multiple-choice questions. For each question, participants ranked their degree of agreement with a statement as follows: 1 = Strongly disagree, 2 = Somewhat disagree, 3 = Neutral, 4 = Somewhat agree, and 5 = Strongly agree. The survey was voluntary and anonymous to encourage honest and constructive feedback. To analyze the data, 1-sample *t*-tests were used to compare the sample average against a population value of 3, which is equivalent to neutral. A p-value less than 0.05 was considered statistically significant. The 95% confidence intervals (CI) were drawn from bootstrapping with 1000 samples.

Results

Thirty-nine students participated in the new simulation lab and were invited to complete the survey. Of those, 25 medical students responded, resulting in a 64% response rate. The survey questions, average response, 95% CI, and p-value are described in more detail in Table 1. All items evaluating simulation lab structure, education, timeline, and enjoyment received ratings higher than neutral (3), and these differences were statistically significant. Students agreed they learned more about subspecialties as evidenced by question 1. They also became more confident in their ability to interpret images (questions 2-5) and practice their clinical decision-making skills independently (question 4).

(Continued on next page)

Table 1

Radiology Simulation Lab Survey Results

Question no.	Survey question	Mean (95% CI)	P-value
1	I found the radiology simulation lab to be well organized by radiology subspecialities	4.40 (4.12, 4.64)	<.001
2	I found the radiology simulation lab format (watching recorded mini video lectures followed by case viewing and read out sessions) to be a well-structured educational format.	4.56 (4.36, 4.76)	<.001
3	Watching the recorded mini video lectures was more educational than my time spent learning radiology at the PACS workstation with the resident/attending.	4.00 (3.68, 4.32)	<.001
4	Viewing and interpreting the radiology cases in a small group was more educational than my time spent learning radiology at the PACS workstation with the resident/attending.	3.76 (3.44, 4.04)	<.001
5	Receiving immediate feedback by viewing Dr. Schubert's recorded read-out sessions and her interpretations of the cases was more educational than my time spent learning radiology at the PACS workstation with the resident/attending.	4.16 (3.88, 4.44)	<.001
6	The educational content provided in the radiology simulation lab was more appropriate for my level of medical training than the educational content provided at PACs	4.16 (3.88, 4.40)	<.001
7	Overall, my time in the radiology simulation lab was more educational compared to my time spent viewing radiology cases at the PACS workstation with the resident/attending.	4.00 (3.72, 4.28)	<.001
8	My time in the radiology simulation lab was more enjoyable compared to my time spent viewing radiology cases at the PACS workstation.	3.64 (3.24, 4.04)	.005
9	I found the radiology simulation lab to be an excellent complimentary hands-on experience in addition to the education provided in the aquifer case-based modules.	4.80 (4.64, 4.96)	<.001

Note. Mean responses to Likert-scale questions in the simulation lab survey. Statistical analysis was performed using 1-sample t-test, compared against the population average of 3 (neutral). P-values less than 0.05 were considered significant.

Discussion

The radiology clerkship aims to give medical students insight into how radiologists work and fundamental image interpretation skills. In the traditional model of radiology education, this proves challenging as students are only given passive learning opportunities, such as shadowing or listening to didactic lectures. With the rise of electronic learning in radiology, we now have the capability for students to immerse themselves in radiology through simulation (Zafar et al., 2014).

Overall, the students at our institution had a positive experience learning in the simulation lab as they combined traditional classroom learning with an interactive simulation lab. This is consistent with prior work demonstrating medical students preferred an active learning environment as opposed to a passive one in radiology education (Zou et al., 2011). Moreover, students perceived they were able to learn better in the simulation lab. Other institutions that implemented similar flipped classrooms found that students who participated performed better on competency exams compared to those learning through a traditional classroom (Friedman et al., 2017). Students also enjoyed learning in the radiology simulation lab more than shadowing. An educational model where students enjoy the learning experience and are engaged may help better solidify concepts and provide valuable exposure to radiology. Other researchers in the field have recently encouraged the use of similar case-based models for third- and fourth-year medical students in their radiology elective (Farmakis et al., 2023).

This initial research project aimed to gather insight and early feedback from the students on their perception of the radiology simulation lab as a novel educational tool. We focused on the students' enjoyment of the elective and their subjective education benefit. Future research should objectively assess the educational impact. For instance, a pretest of students' interpretation of images could be compared to a posttest evaluation at the end of the two-week elective.

Conclusion

Our results indicate medical students had a positive learning experience in the new radiology simulation lab at our institution. They positively ranked the design, content, scheduling, and satisfaction of the lab. This study highlights the feasibility of a simulation-based radiology curriculum, and we call for a more interactive and engaging radiology education model.

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A Case Study in the Creation of Free Digital Avatars as an Embedded Participant Substitute in Simulation Based Medical Education

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Brief Description

Simulation-based medical education (SBME) has been shown to be a valuable adjunct to traditional didactic instruction and clinical exposure, affording trainees the opportunity to engage in medical decision-making and error analysis without endangering live patients. SBME facilitates the acquisition of procedural competencies, team coordination, effective communication, and comprehension of medical protocols within a controlled and psychologically safe setting. Nevertheless, the implementation of SBME with appropriate fidelity to meet a session's objectives is constrained by the demand for multiple embedded participants (EP) to ensure optimal simulation outcomes. The aim of this manuscript is to present a case study in the creation of free digital avatars for use in scenario-based, multi-modal simulation activities. Use of digital avatars can reduce the need for human EPs, while maintaining the psychological and conceptual fidelity of the scenario.

Introduction

Simulation-based medical education (SBME) has witnessed a notable surge in prominence over the last two decades, becoming an indispensable component of medical education curricula across various training levels (McGaghie et al., 2016). Prospective trainees increasingly prioritize programs which integrate robust simulation curricula alongside traditional didactic instruction (Everson et al., 2020). SBME offers educators the opportunity to replicate complex clinical scenarios within a controlled environment (Frey-Vogel et al., 2022), serving as a viable substitute for direct patient encounters (Cheng et al., 2014). Extensive empirical evidence underscores SBME's efficacy as an instructional modality (Frey-Vogel et al., 2022). When implemented adeptly, SBME has demonstrated a capacity to attenuate medical errors and enhance patient safety (Lamé & Dixon-Woods, 2020). Moreover, SBME furnishes a secure platform for trainees to scrutinize genuine errors and refine procedural and communication protocols (Kava et al., 2017). The Accreditation Council for Graduate Medical Education has advocated vigorously for the integration of SBME into residency programs, endorsing a broad conception of SBME that encompasses diverse modalities such as standardized patients, objective structured clinical examinations, and task trainers, among others (Goolsarran et al., 2018).

SBME offers a plethora of significant advantages, yet its effective implementation necessitates considerable investments in terms of time, resources, and manpower (Acton et al., 2015; Ker et al., 2021; Zendejas et al., 2013). The number of embedded participants (EP) needed for simulation scenarios fluctuates depending on multiple factors such as the simulationist's preferences and the need for inclusion to meet the defined learning objectives. An EP is an individual who is trained to play a role in a simulation encounter to help guide the scenario. The EP serves as an important resource for SBME, interacting with the learners and increasing engagement (Koca et al., 2023). The EP is often called upon to provide key information during the simulation activity. If the learner is going astray, the EP can help redirect the participant through the delivery of cues (Watts et al., 2021). Embedded participants increase the realism of the simulation activity. Portraying the role of another health care provider or family member adds to the environmental and psychological fidelity (Watts et al., 2021).

The EP is meant to be an adjunct and should not unduly exert influence on the learner's behavior. However, EP performances can vary greatly if not properly trained, negatively impacting the learner experience (Watts et al., 2021). Hiring, training, and directing human role players as embedded participants requires resources of time and money (Koca et al., 2023). The creation and use of digital avatars can be more cost effective, while also alleviating the variability of performance among human EPs.

To address these challenges, we created and deployed simple, free custom digital avatars to reduce the demand for human volunteers as an EP. The aim of this manuscript is to show the step-by-step process of creating free digital avatars for use as EPs in scenario-based, multi-modal simulation activities. We hypothesized that digital avatars could reduce the need for additional volunteers to act as EPs while maintaining situational realism and psychological safety. This would most benefit novice simulationists and curriculum development specialists, as well as those conducting simulations with limited financial or human resources.

Use of Avatars in SBME

An effective simulation scenario often necessitates the engagement of multiple human participants beyond the simulationist. The multi-discipline nature of patient management parallels the complexity inherent in simulation aimed at replicating real-life situations (Frey-Vogel et al., 2022). However, achieving such fidelity is challenged by constraints such as limited faculty availability, scheduling intricacies, and familiarity with simulation instruction. The creation of digital avatars emerges as a pragmatic solution (Hatton, 2023).

Digital avatars can assume diverse roles essential to the realistic enactment of a scenario. Avatars can play the part of the parent, bedside nurse, other healthcare provider, social worker, chaplain, or other role necessary for a realistic scenario. Moreover, these avatars can be programmed to deliver both scenario-specific dialogues and general statements, thereby facilitating their utilization in subsequent simulations. Standardized digital avatars can be systematically amassed into a repository for integration into future simulation scenarios.

Avatars can be customized to embody varying genders, ages, ethnicities, and demographic profiles, incorporating accents or linguistic diversity to mirror the patient population or healthcare workforce of specific regions. Presenting diverse voices through simulations while encouraging self-reflection, are essential for reducing biases and microaggressions (Picketts et al., 2021). Avatars can be intentionally created to promote diversity and counter targeted recruitment of human role players (Picketts et al., 2021). These avatars can be placed in various environments, such as hospital wards, homes, or public places like concerts, making them useful and scalable for different types of simulations. They prove instrumental in navigating challenging patient interactions as well as assuming roles of actors in critical medical resuscitation scenarios.

A well-structured setup allows for versatile access to these avatars during scenario facilitation. They can be linked to QR codes for convenient retrieval via individual smart devices. Moreover, they are adaptable to be viewed remotely via various display mediums, including television screens, computers, or touchscreen tablets. Digital avatars are not limited to high fidelity scenarios. They can enhance tabletop scenarios, low-fidelity manikins, and simple standardized patient encounters by acting as patients and providing predetermined responses, thus improving the realism of the simulation (Howard, 2018).

Avatar development and facilitation

Our simple process allows for immediate creation and integration without requiring additional funding or stakeholder support. It is a good introduction for the technologically naïve to integrate new skills into their live-action simulation events.

Creation of free digital avatars

Creation of an avatar clip takes approximately twenty-minutes and requires a computer with internet capabilities and appropriate storage. An account must be created on each website listed below; however, all websites offer a free trial period. A sample of a completed digital avatar video with standardized prompt using the steps described below can be found at https://shorturl.at/OkmOx. There are three parts to creating a digital avatar:

- Part 1: Create the digital avatar image using PlaygroundAI (https://playgroundai.com)
- Part 2: Create the audio using ElevenLabs (https://elevenlabs.io/)
- Part 3: Combine the image and audio using D-ID (https://d-id.com/)

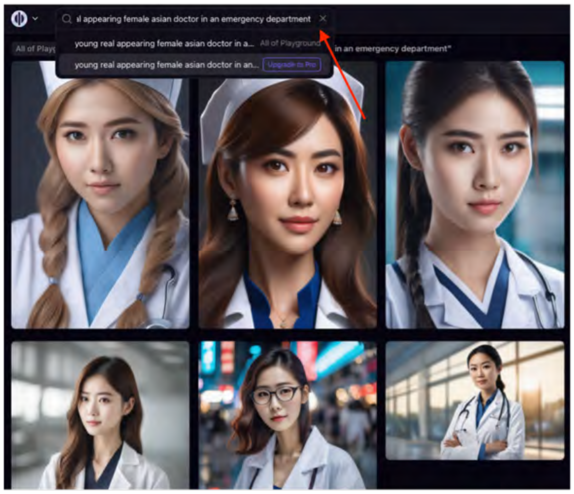
Part 1: Create the digital avatar image

1. Access https://playgroundai.com
2. Create an account.
3. In the top toolbar, enter a description of your desired image with as much specificity as possible. Consider the avatar's age, race, image realism, dress, background environment, and other details such as props or identifying markers (e.g., stethoscope, tattoos, piercings, and profile vs. full body image) (Figure 1).
4. Download and save the digital avatar.

(Continued on next page)

Figure 1

Playground AI Website Layout with Search Toolbar



Note. Sample view of Playground AI screen when developing a basic avatar image.

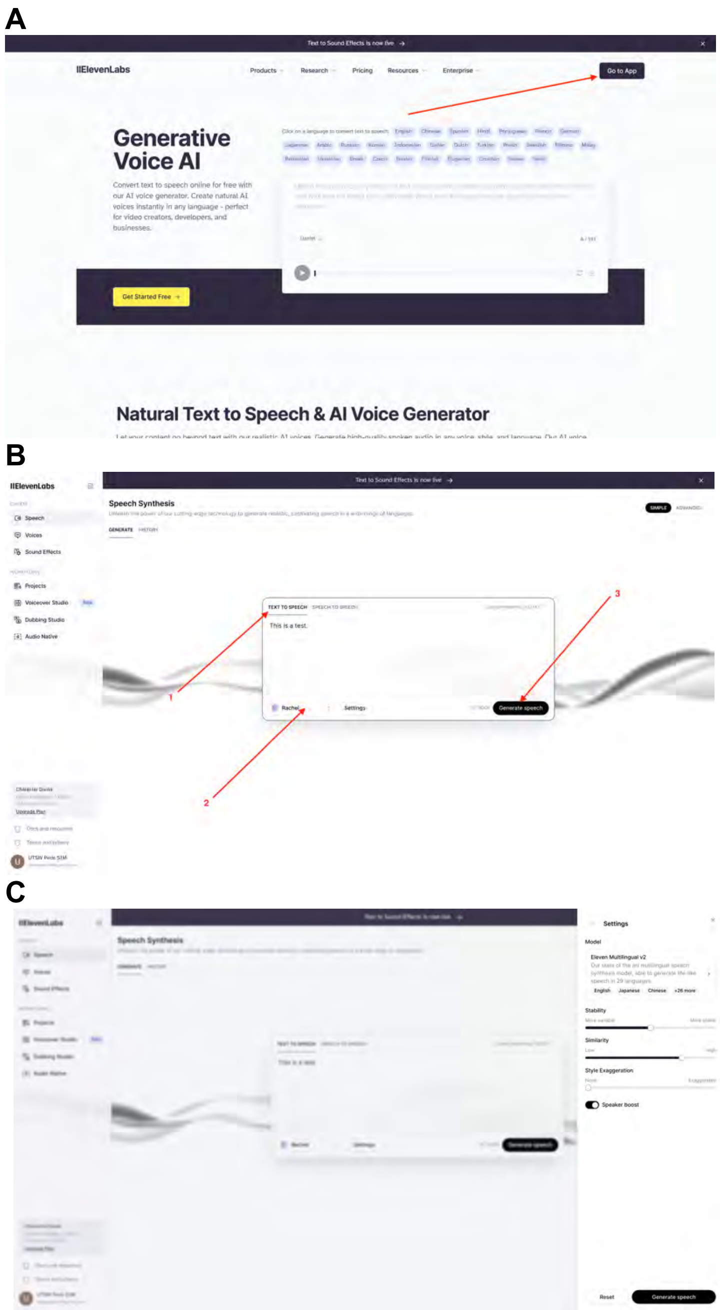
Part 2: Create the audio

1. Access https://elevenlabs.io
2. Create an account.
3. Click “Go to App” in the upper right-hand corner (Figure 2A).
4. In the “Speech Synthesis” page, ensure “Text to Speech” is selected (Figure 2B, arrow 1). Type out your audio message.
5. Beneath the text box, click the “Rachel” drop down box to hear a sample of different voices. Choose your desired avatar voice from the list (Figure 2B, arrow 2).
6. To the right of the “Rachel” drop down box, click “Settings”. A right-hand box will appear to select the spoken language of the avatar (Figure 2C).
7. Once you have typed your audio message and adjusted the settings, select “Generate” to create the audio file (Figure 2B, arrow 3).
8. Download and save the audio file.

(Continued on next page)

Figure 2

Steps to Create Audio using Eleven Labs



Note. Steps to create audio using ElevenLabs. Panel A: ElevenLabs home page. Panel B: Text to Speech page. Panel C: Avatar voice settings.

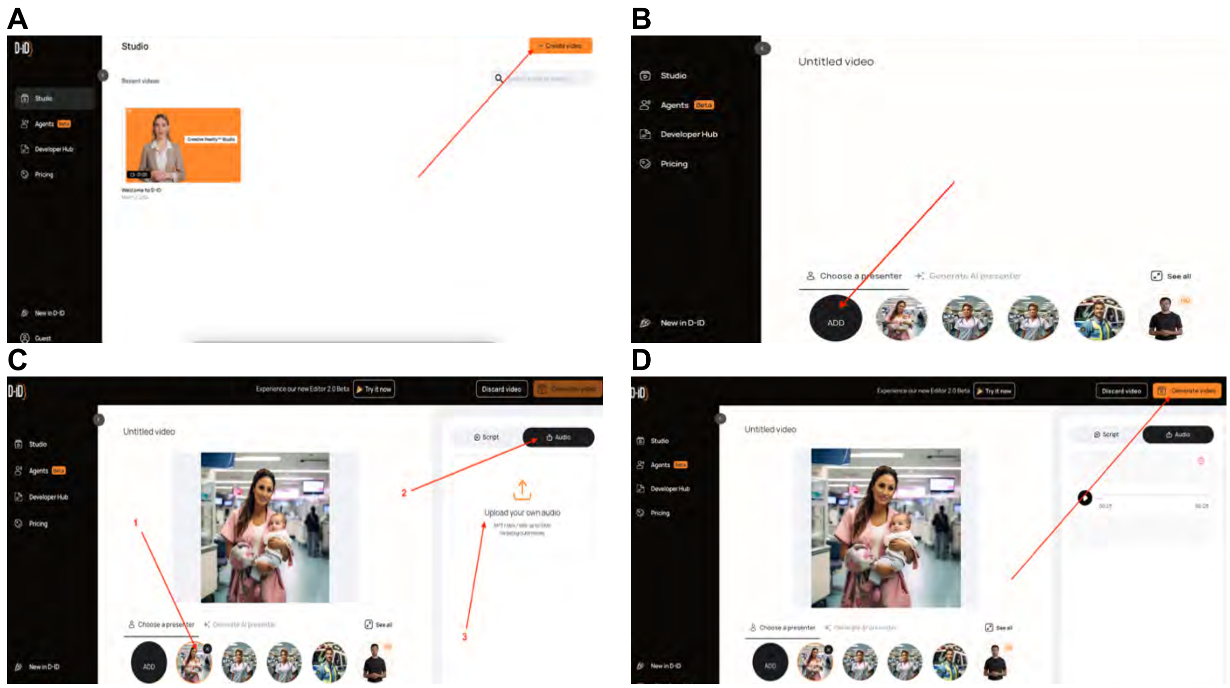
Part 3: Combine image and audio

1. Access https://d-id.com/
2. Establish an account associated with a free trial period.
3. Click “Create Video” (Figure 3A).
4. Click “Add” to upload the avatar created from Playground AI (Figure 3B).

5. Ensure your created image is selected. Click “Audio” to upload the voice clip created from Eleven Labs (Figure 3C).
6. Click “Generate Video” and download the finalized avatar (Figure 3D).

Figure 3

Steps to Combine Image and Audio using D-ID



Note. Panel A: Initial screens in the D-ID website. Panel B: Uploading the avatar image saved from Playground AI into D-ID website. Panel C: Uploading the audio generated using Eleven Labs. Panel D: Click “Generate Video” and download the finalized avatar.

If the dialogue or image needs to be edited, an entirely new avatar image will need to be created. The generated images can be reused with different dialogue to maintain continuity throughout a scenario.

Discussion

We have implemented these custom digital avatars in our live-action simulations with pediatric residents, pediatric pharmacy residents, and pediatric emergency medicine fellows with improving execution. They have been used in scenarios such as multi-injury trauma, beta-blocker ingestion, cardiac arrest, and multi-system inflammatory syndrome in children. Most of our avatars play the EP role of the caregiver or other healthcare provider (i.e., bedside nurse or paramedic). In these roles, the avatars provide the scenario prompt, the patient’s history of present illness, or ‘lifesaving’ interventions when the scenario goes awry. The avatars are displayed to the entire team via a television screen or to individual participants through a QR code accessed on smart devices.

We have received verbal feedback that participants enjoy procuring information from “people” they do not know. Participants also reported that it mimics real-life history taking and data gathering. Using avatars also standardizes the experience across learner groups, ensuring all trainees receive a similar learning experience.

In the future, we hope to have multiple displays to represent an individual avatar. This will more accurately simulate a hospital environment by incorporating multiple embedded participants simultaneously. This would enhance the simulation by replicating various environmental noises.

Conclusion

The creation of digital avatars is a promising technology accessible to simulationists. This technology has the potential to address barriers to SBME execution highlighted in the literature. This includes lessening the burden to secure adequate human volunteers to ensure psychological and conceptual fidelity. Digital avatars also serve to expand representation and diversity of embedded participants. Avatars offer an innovative solution for both experienced and novice simulationists to uphold fidelity and psychological safety. Here, we offer a simple and free method to create digital avatars that can reflect diverse patient populations or healthcare workforces. This process enables simulationists to seamlessly integrate digital avatars into scenario-based, multi-modal simulation activities without requiring additional technological, financial, or human resources.

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Precision in Practice: Mastering Family Nurse Practitioner Primary Care Skills with Simulation

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Brief Description

Primary care providers must master a diverse skill set to properly care for their patients in the primary care setting. As nurse practitioner (NP) education evolves, national standards set by the American Association of Colleges of Nursing (AACN) and National Organization of Nurse Practitioner Faculties (NONPF) prompt skill competency through quality NP education. Primary care skills are an essential component of NP education; however, many challenges are associated with successfully teaching and learning these skills. In this article, cost-effective simulation examples are described for five common primary care skills.

Background

NP education is evolving towards competency-based education that is demonstrable, observable, and measurable. Consequently, students learn to cohesively apply disciplinary knowledge of content through psychomotor and cognitive domains to adeptly care for individuals. The National Task Force for Quality NP Education (NTF), supported by AACN's *The Essentials: Core Competencies for Professional Nursing Education* and NONPF's *NP Role Core Competencies,* requires NP programs to prepare students for nationally recognized patient care competencies, including direct patient-care skills (NTF, 2022; AACN, 2021; NONPF, 2022). However, family nurse practitioner (FNP) students face several potential limitations to learning and mastering these skills: limited accessibility and the unpredictable nature of patient encounters, lack of structured environment for deliberate practice, and time constraints in busy clinical settings. All these factors restrict the availability, extent, and quality of deliberate practice and potential learning scenarios. Ethical considerations related to performing a procedure on a patient for the first time further impact the breadth and depth of skill acquisition. These challenges highlight the importance of using simulation to overcome the limitations traditional clinical learning environments, while ensuring students accountability using a standardized competency checklist (Appendix A).

Simulation offers a safe, structured environment that mimics real-world scenarios without exposing patients to potential risks (Alinier & Oriot, 2022). In the simulated setting, FNP students can refine primary care skills without the pressures of live clinical encounters. This environment encourages a trial-and-error approach, fostering a culture of experimentation and continuous improvement. The controlled environment also facilitates deliberate practice, enabling students to reinforce essential skills to achieve mastery. Moreover, simulation scenarios can target areas where students may lack exposure in clinical settings (Chernikova et al., 2020), such as primary care procedural skills. Overall, the safety afforded by simulation empowers NP students to build confidence and competence, preparing them to be practice-ready in the complexities of healthcare settings (Bailey & Emory, 2022; Zulkosky et al., 2021).

The purpose of this article is to present cost-effective simulations for five procedural skills commonly performed by FNPs in primary care settings. It also illustrates how FNP students, novice practicing NPs, nursing faculty, or preceptors can adapt these simulations to cultivate Collectively, the authors of this manuscript have more than 60 years' experience as advance practice providers and more than 45 years in simulation, holding various best-practice simulation certificates. Collaboratively, they served as subject matter experts to develop authentic representation of common skills in primary care.

Methods

Preclinical FNP students (n=123) participated in the skills simulation. Students completed five simulations as follows: suturing, incision and drainage, shave biopsy, paronychia drainage, and subungual hematoma trephination. Students were given a survey before and after the simulation to rate their confidence level for an individual skill. The rating scale ranged from 0, indicating no confidence in skill readiness, to 10, indicating feeling completely prepared to conduct these skills in the clinical setting (Appendix B). Qualitative feedback on the delivery of skills training and students' concerns were also collected. Pre-and post-simulation survey results were averaged and analyzed using paired t tests.

Suturing

Suturing is a common skill that involves using stitches to approximate and secure wound edges, facilitating the natural healing process. This skill is performed by healthcare providers to close lacerations, incisions, or other wound types to promote healing, minimize scarring, and reduce the risk of infection.

Procedure Indications. Indications for suturing include a wound or laceration that will not heal easily without assisted closure. Examples include wounds in high-use areas like the hand; those where minimal scarring is important like the face; those requiring closure to aid in hemostasis; and those that are large enough that natural closure would be prohibitive.

Example Simulated Case Presentation for Suturing. A patient presents to clinic with a laceration to their left thumb. The patient was cutting vegetables when the knife slipped and cut the flexor side of the thumb measuring 2 cm in length. Bleeding is controlled at present.

Procedure Supplies. The estimated cost per student is $48.34. The supplies used include the following:

- Premade suture pads
- Suture training kit:
    - 3-0 curved cutting needle suture
    - Needle holder
    - Hemostat
    - Scissor
    - Pick-up with teeth
    - Scalpel

- Simulated Lidocaine (labeled NOT FOR HUMAN USE. EDUCATION ONLY.)
- Alcohol pads
- 4x4 gauze
- 3 cc syringe
- 18-, 22-, or 25-gauge needles

Step-by-step Simulation Description. Simulated skin tissue with premade suture pads is used for students to practice suturing skills. The compiled 'suture training kit' described above is rolled into a blue surgical towel and provided to students with the premade suture pad (Figure 1).

Figure 1

Supplies for Simulated Procedures

Note. This figure shows the general set up for the simulated skills learning activity.

Suturing Procedure Process. Students receive a brief introduction in preparation for the experience. Students are educated on how to choose an appropriate suture type and technique based on the wound type. The students are provided an opportunity to familiarize themselves with equipment such as the laceration tray supplies, the packaged sutures, and the simulated sterile environment. For the simulated thumb laceration, the students are provided with simulated lidocaine and instructed on administration of local anesthesia to the wound. The students are provided detailed instructions on how to perform the various suture techniques including: simple interrupted, continuous (locking and non-locking), subcuticular, and mattress stitch. Faculty and staff are available to assist and answer questions while students practice on the simulated skin.

Incision and Drainage

Incision and drainage (I&D) is widely used for the management of skin and soft-tissue abscesses, particularly in emergency departments and outpatient settings. Most abscesses are caused by *Staphylococcus aureus,* and I&D is recommended unless the abscess is small and draining spontaneously (Becker, 2023).

Example Simulated Case Presentation for Incision and Drainage. A patient presents with a two-day history of a swollen, tender, erythematous lesion located on the upper thigh. Upon inspection, the nurse practitioner notes the lesion is fluctuant and recommends I&D.

Procedure Indications. In most cases, patients with an abscess will require I&D. A trial of antibiotics with manual expression of pus can be considered in cases of small fluid collections. However, antibiotics are generally inadequate once a collection of pus has formed (Derksen, 2020; Pastorino & Tavarez, 2023). Possible contraindications include abscesses that are large and deep, or near vascular and/or nervous structures. Abscesses in certain locations, such as perirectal or periareolar, should be referred for surgical management due to high risk for potential complications (Pastorino & Tavarez, 2023).

Procedure Supplies. The estimated cost per student is $25.84. The supplies used include the following:

- "Pus Pocket" Ingredient List
    - 1 cup of quick oats
    - 2 cups of warm water
    - 2 drops of yellow food coloring
    - Latex gloves (cut off glove fingers at the palm) or finger cots
- Procedure Supplies
    - #11 scalpel
    - Iodoform packing strips
    - Q-tips
    - 4x4 gauze
    - Antiseptic solution
    - Simulated Lidocaine (labeled NOT FOR HUMAN USE - EDUCATION ONLY)
    - 3 cc syringe
    - 18-, 22-, or 25-gauge needles

Step-by-step Simulation Description. The process for making the simulated pus pockets using the above ingredients is quite simple. Mix oatmeal and water; you may need more water to create a soupy texture. Microwave the mixture for 1 minute. Allow to cool for 2 minutes. Add food coloring for desired color. Insert 3-5ccs of oatmeal mixture into finger cot and tie off tightly. Finger cots may be frozen for storage. When ready to use, room temperature oatmeal "pus pockets" are placed under premade suture skin to simulate an abscess. A small square can be cut from the back of the pad for better fit of the oatmeal pocket (Figure 2).

Figure 2

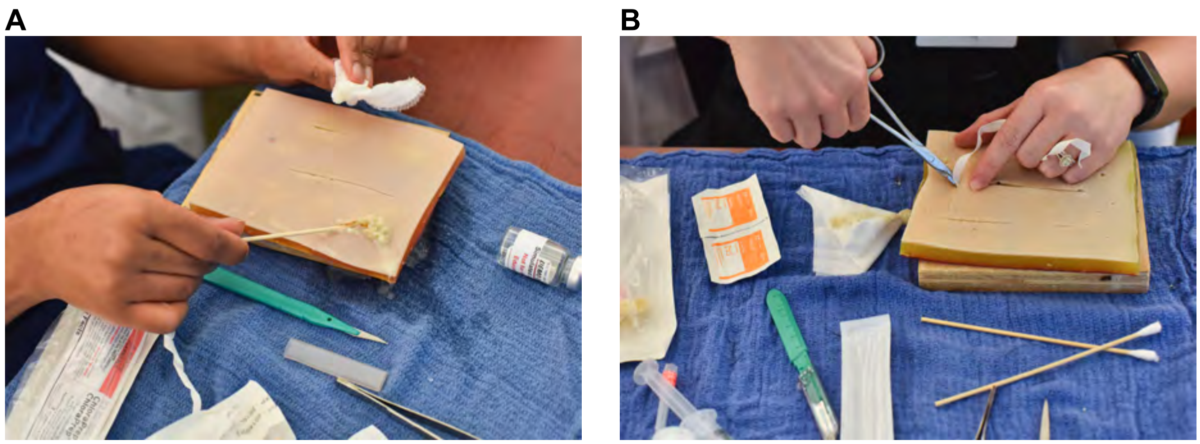
Oatmeal "Pus Pockets" for Incision & Drainage Simulation

Note. This figure shows the final product of the 'pus pockets' that are placed under the simulated skin for incision and drainage.

Incision and Drainage Procedure Process. Using the oatmeal “pus pocket” and premade suture skin as described above, students are instructed to begin by preparing the area with antiseptic solution and drawing up simulated lidocaine. Faculty guide students through the process of anesthetizing the area, focusing on tissue around the base of the simulated abscess. Using a #11 scalpel, students are instructed to make a simple linear incision directly over the center of the simulated abscess and manually express drainage from the oatmeal “pus pocket.” Students are taught to use hemostats to break up loculations and collect a sample for culture and sensitivity using a Q-tip. Then, faculty demonstrate how to irrigate the simulated abscess cavity using isotonic saline solution. Finally, students practice packing the wound using iodoform packing strips (Figure 3).

Figure 3

Incision & Drainage Simulation



Note. These figures show the process of the incision and drainage simulation. Panel A: This figure shows the contents of the “pus pocket” once the incision is made and the wound begins to drain. Panel B: This figure shows the wound being packed with iodoform packing strips.

Shave Biopsy

A shave biopsy is a medical procedure in which a thin, superficial layer of tissue is removed from the skin using a scalpel or similar instrument. This type of biopsy is commonly performed to diagnose or investigate skin conditions, such as suspicious moles or skin lesions.

Example Simulated Case Presentation for Shave Biopsy. A patient presents with a single, brown scaly skin lesion on their back that has recently increased in size. Borders are well demarcated. Given the recent increase in growth, there is some concern for malignancy. Because the lesion appears confined to the epidermis, a shave biopsy is recommended to obtain a sample for pathological examination.

Procedure Indications. Shave biopsy can be a quick and effective means of removing external lesions of the epidermis in primary care (Alguire & Mathes, 1998). Shave biopsy can be used for two purposes: to remove cosmetic or uncomfortable lesions or to assist in accurately diagnosing a potentially cancerous lesion. For instance, this is particularly useful when the differential includes actinic keratosis and squamous cell carcinoma. Lesions that can be safely removed by shave biopsy include actinic keratoses, seborrheic keratoses, warts, skin tags, and superficial basal cell or squamous cell carcinomas. Lesions connected to pigmented epidermis should not be removed by shave biopsy, as doing so may artificially decrease the estimated thickness of a melanoma lesion. This could lead to inaccurate staging and prognosis.

Procedure Supplies. The estimated cost per student is $2.38. The supplies used include the following:

- Clementine orange
- Permanent marker
- #15 Derma Blade/razor blade

Step-by-step Simulation Description. Place an ink dot with a permanent marker on the orange to simulate the abnormal skin lesion. More than one lesion (ink dot) can be applied to the orange. Shave biopsy may be completed with a #15 Derma Blade, or a razor blade held between the provider's thumb and middle finger (Alguire & Mathes, 1998). For the purposes of this simulation, a #15 Derma Blade is used (Figure 4).

Figure 4

Simulated Shave Biopsy

Note. This figure shows the shave biopsy simulation on an orange.

Shave Biopsy Procedure Process. Shave biopsies are clean procedures; sterile gloves are not required (Alguire & Mathes, 1998). Students prepare for biopsy by injecting anesthetic directly below the lesion marked on the orange, allowing the lesion to be easily differentiated from the epidermis. The students are instructed to hold the #15 Derma Blade parallel to the orange, simulating the patient’s skin. The lesion is swiftly removed in a single motion. During this, students practice stabilizing the lesion with the index finger of the opposite hand to prevent tearing or excessive bleeding with lesion excision. Students are then instructed to hold firm pressure at the site to reduce the risk of bleeding. Suturing is not needed with this type of biopsy. The site is then covered in a thin application of antibacterial ointment or petrolatum, to prevent becoming overly dry. This is followed by a non-adherent dressing and a gauze dressing with tape. Finally, faculty discuss the process of sending the lesion for biopsy.

Paronychia Drainage

Paronychia is an infection of the tissue surrounding fingernails or toenails. It can be chronic, usually due to a fungal infection lasting longer than six weeks, or acute, typically staphylococcal or mixed pathogens (Dulski & Edwards, 2023). Acute paronychia is common and may account for more than one-third of nail/finger infections (Billingsley & Vidimos, 2022).

Example Simulated Case Presentation for Paronychia. A patient presents to the clinic with pain, redness, and swelling around the nail of the right index finger. The patient mentions they frequently perform tasks involving moisture, such as dishwashing, and recalls a minor injury to the nail fold. On examination, there is noticeable tenderness, erythema, and swelling around the proximal and lateral nail folds of the right index finger. Based on the clinical presentation, a diagnosis of acute paronychia is suspected.

Procedure Indications. An abscess under the nail or skinfold is an indication for incision and drainage to prevent further tissue involvement. Because this is often done in primary or urgent care, FNP students are introduced to the procedure with a simulated abscess on a finger model. It is worth noting that many cases of paronychia in a toenail, such as an ingrown toenail, are treated with an avulsion procedure to remove the toenail and are not included in this content (Macneal & Milroy, 2023).

Procedure Supplies. The estimated cost per student is $12.79. The supplies used include the following:

- Supplies to create a sterile field:
    - Sterile gloves
    - Drape
    - Other PPE (as needed)
- Antiseptic solution
- Simulated lidocaine (labeled NOT FOR HUMAN USE - EDUCATION ONLY)
- 25- to 27-gauge needle for anesthetic block
- # 11 scalpel blade or 18- to 23-gauge needle
- Irrigation solution
- Dressing material
- For the simulated model finger
    - Plastic finger molds
    - Unflavored gelatin packet and water
    - Glycerin
    - Lotion
    - Liquid foundation makeup
    - Bubble wrap

Step-by-step Simulation Description. Step 1: Pour one package unflavored gelatin into mixing cup. Add three teaspoons of water and mix gently by swirling the cup. Allow to sit until dissolved for about two minutes without stirring. Add three teaspoons glycerin and stir until reaching the consistency of apple sauce. Microwave for eight seconds. Liquid should be smooth and without lumps. Add a few drops of lotion for fragrance. Add liquid makeup to create desired simulated skin color and mix well. Step 2: Cut bubble wrap into individual bubbles and trim well, while maintaining the seal of the bubble. Mix lotion with yellow and/or green food color to desired shade of simulated pus. Draw tinted lotion into a syringe and inject a small amount into the flat side of each bubble. Step 3: Pour a thin layer of the gelatin mixture into finger mold and allow to sit until firm – about 10 minutes. Place the lotion-filled bubble into the nail area of the finger mold, then fill completely with gelatin mixture. Allow to sit until firm and not sticky. Carefully remove simulated paronychia finger from mold. The simulated finger mimics a pus-filled lesion as may be found in an anatomical digit affected by paronychia. (Figure 5). The authors have included a detailed description of the simulation process at this link: https://mediaspace.uab.edu/media/Paronychia+Finger/1_utk3dhdr.

Figure 5

Paronychia Simulated Finger

A B C

Note. These figures shows the process of preparing the paronychia simulation. Panel A: This figure shows the final product of the simulated pus for the paronychia. Panel B: This figure shows the process of creating the gelatin finger models. Panel C: This figure shows the simulated paronychia drainage.

Paronychia Drainage Procedure Process. After anesthetizing the area, students are instructed to use an instrument such as a scalpel or hypodermic needle to lift and open the affected skinfold. Any pus may be expressed from the abscess through manual decompression. The affected area is then irrigated with normal saline and covered with a bandage. Faculty discuss that a culture may be needed for more severe or persistent cases, and antibiotics may be considered for patients deemed at higher risk for complications.

Subungual Hematoma Trephination

Subungual hematoma trephination is a commonly performed procedure in the primary care setting involving the drainage or removal of blood accumulated beneath the nail surface (Beach, 2020). This often occurs due to trauma or injury to the fingertip, causing bleeding and subsequent pooling of blood under the nail.

Example Simulated Case Presentation for Trephination of a Subungual Hematoma. A patient presents to the clinic after accidentally slamming their finger in a door. The fingertip is swollen, and the nail appears dark reddish purple. The patient reports throbbing pain, and the pressure under the nail is causing significant discomfort. Given the clinical signs and symptoms, the FNP may recommend a trephination to alleviate pain and prevent potential complications.

Procedure Indications. Indications for trephination may include the following: severe pain due to the pressure caused by the accumulated blood under the nail; a large or expanding subungual hematoma which may lead to more pressure and pain; signs of compromised circulation to the affected finger, such as persistent numbness or color changes; cosmetic concerns; and a risk of permanent damage to the nail or surrounding tissues.

Procedure Supplies. The estimated cost per student is $0.98 plus $13.00 for an optional Cautery pen. The supplies used include the following:

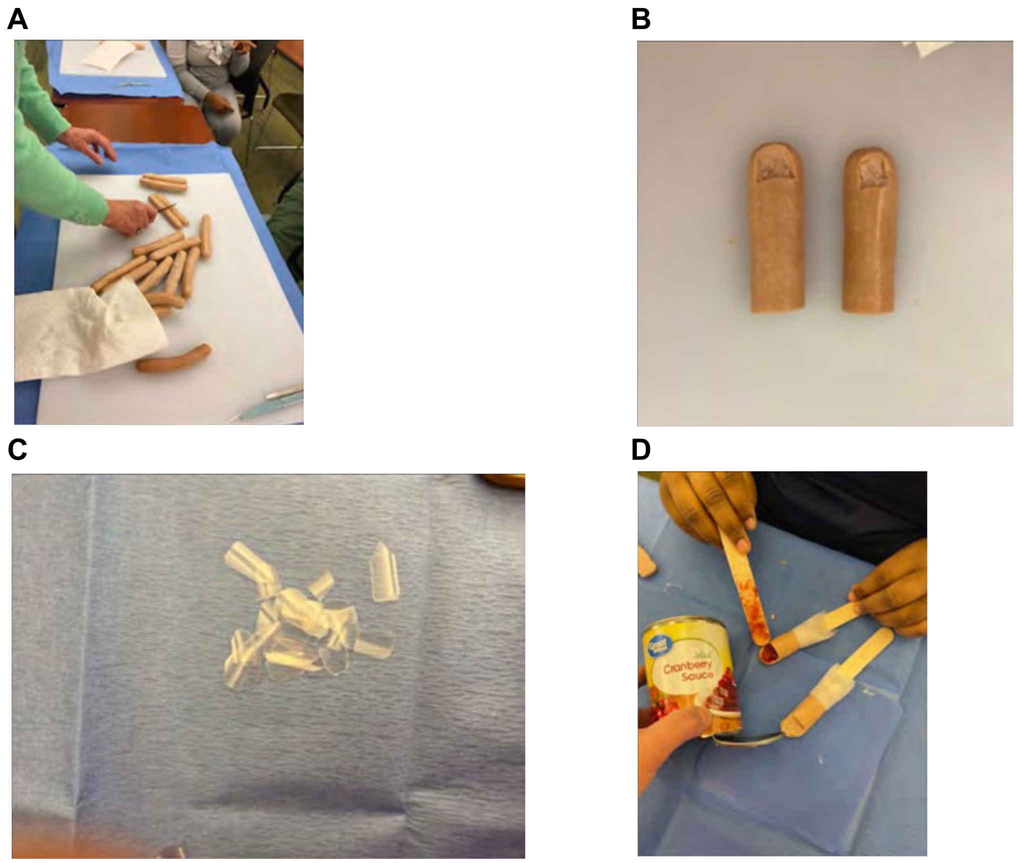
- Subungual Hematoma Finger Supplies
    - Hot dogs
    - Cranberry sauce without berries
    - Tape
    - Tongue blades
    - Medicine cups (or similar firm clear plastic) cut into the shape of fingernails
- Procedure Supplies
    - 18-gauge needle
    - Cautery pen (optional)
    - Non-sterile 2x2 gauze sponges
    - Disposable absorbent incontinent pad

Step-by-step Simulation Description. Using a hot dog to simulate a fingertip, cut the hot dog in half. Then, cut each half lengthwise to create four “fingertips.” Hollow out the rounded end of each “fingertip.” Then, tape the base to a tongue blade, aligning the rounded ends. Place a small amount of cranberry sauce to the hollowed-out area and secure the plastic “fingernail” to the hot dog over this area (Figure 6). The authors have included a detailed description of the simulation process at this link: https://mediaspace.uab.edu/media/Subungual+Hematoma/1_jmehx1rg.

(Continued on next page)

Figure 6

Subungual Hematoma Simulated Finger



Note. These figures shows the process of the subungual hematoma simulation. Panel A: This figure shows the preparation of the hot dogs to become “fingers.” Panel B: This figure shows the approximate size of the nail bed cut into the hot dogs. Panel C: This figure shows the medicine cup pieces cut into “fingernails.” Panel D: This figure shows the application of the “hematoma” (cranberry sauce) prior to covering it with the nail (cut medicine cup).

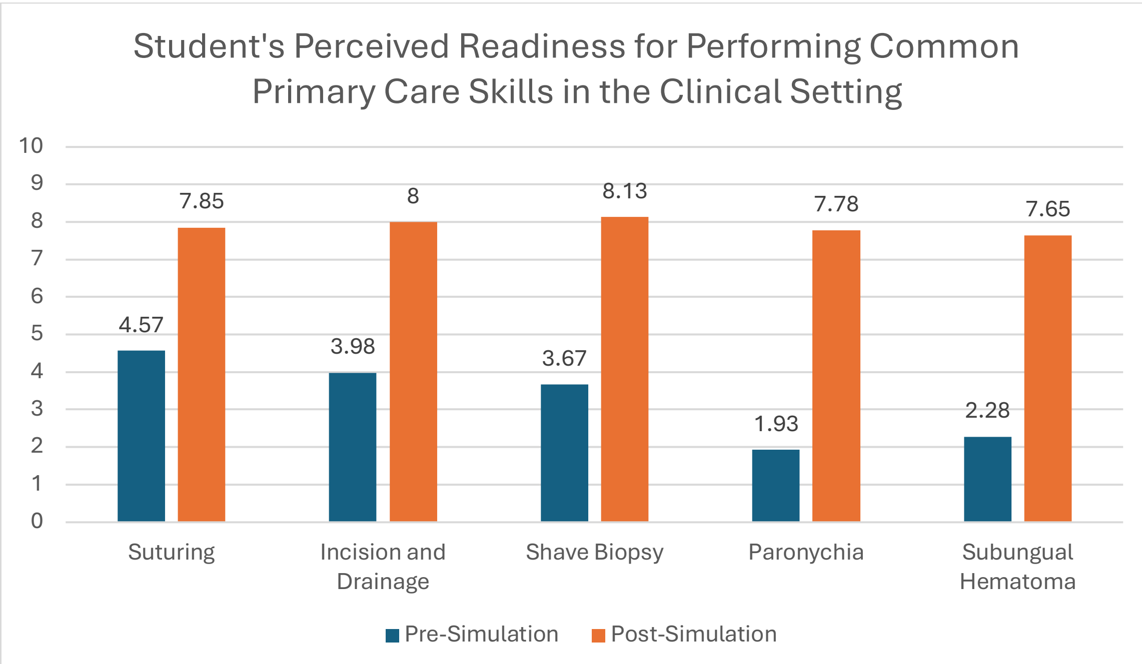
Subungual Hematoma Evacuation Procedure Process. Students practice evacuating the simulated subungual hematoma by first cleaning the site with an appropriate antiseptic. There is no need to anesthetize the digit (Pingel & McDowell). Using a cautery pen, they will then cauterize the nail, stopping when the blood is released. Alternative to cautery, they can create a bore hole with an 18-gauge needle. Caution should be taken to ensure the cautery does not start a fire. Once the hole is made in the nail bed, students express the simulated blood with gentle pressure. They are instructed to clean the site with mild soap and water and apply antibiotic ointment and bandage. Students are told that cautery is contraindicated with acrylic nails. Also, if a patient presents with a nail that is not intact, trephination should not be attempted, and a referral is needed.

Results

Analysis of student’s perceived clinical skill readiness revealed an average pre-simulation score of 3.286 and post-simulation score of 7.882 (Figure 7). Comparing pre- and post-simulation perceived readiness, every session yielded a significant improvement ($p<0.001$).

Figure 7

Pre- and Post-Simulation Survey Results



Note. This figure displays the student's perceived readiness for performing common primary care skills in the clinical setting with the blue bar representing the pre-simulation results and the orange bar representing the post-simulation results.

Discussion

FNP students' confidence in overall perception of readiness to begin clinicals showed significant improvement for each skill taught. Analysis revealed paronychia management (+5.85) and subungual hematoma (+5.37) sessions had the greatest difference in readiness means, yet every session yielded a significant improvement in students' perceived readiness for clinicals ($p<0.001$). Qualitative feedback from the simulation included themes of optimized educational engagement, enhanced confidence, and reduced fear of performing these skills in the clinical setting. Development and implementation of simulation-based education for primary care FNP students provides a safe and effective environment for learning and demonstrating skills commonly done in the outpatient setting. Although the costs of simulation can be burdensome to NP programs, the simulations presented here cost less than $100. Innovative use of common items can be an inexpensive solution that still achieves high-impact results. We learned that as much as our students value live models, they also found the simple, low-fidelity methods extremely effective.

Conclusion

Integration of simulation in NP education is a transformative approach to support competency-based education and the mastery of primary care procedural skills for FNP students. Simulation offers FNP students a safe and affordable space for deliberate practice, helping them develop the confidence, competence, and versatility essential for navigating the complexities of primary care practice in accordance with AACN and NONPF competencies. As the healthcare landscape continues to evolve, the value of simulated scenarios in mastering essential skills cannot be overstated. Simulation enhances the educational experience for FNP students and contributes to the delivery of high-quality, person-centered care and competent, practice-ready NPs.

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Appendix A

Skill Competency Checklist Example

BASIC SUTURING	SATISFACTORY / UNSATISFACTORY	COMMENTS	PLAN FOR IMPROVEMENT
Student must perform correctly*:			
Washes hands and dons gloves			
Selects correct instruments/sutures			
Correct placement of needle in needle driver			
Inserts needs perpendicular to skin			
Exits smoothly			
Bite no closer than 0.5 cm			
Equal bites on either side of wound			
Curvature of needle followed			
Smooth passage of needle, no hesitancy			
Instrument tie technique			
Initial double wrap throw			
Square knot			
Ties at least three knots			
Leaves 0.5 cm after cutting suture			
Adequate eversion of wound edge			

Appendix B

Student Pre- and Post-Survey Example

1. This is an anonymous survey intended to assess student's level of knowledge and confidence in activities completed today. Aggregate results from this survey will be used to help faculty improve course content and delivery. By clicking 'Agree' below, you agree to allow faculty to use your data for quality improvement purposes.

- ◯ Agree
- ◯ Disagree

2. Please respond with your level of agreement with the following statements, considering BEFORE(Pre)/AFTER(Post) you attended this Intensive. I AM CONFIDENT I CAN EFECTIVELY COMPLETE THE FOLLOWING SKILLS:

	Strongly Disagree Strongly Agree 0 1 2 3 4 5 6 7 8 9 10
Suture	
Skin biopsy	
Paronychia	
Subungual hematoma	
Irrigation and Debridement	

3. Please respond to the following statements, considering BEFORE(Pre)/AFTER (Post) you attended this Intensive. I AM VERY KNOWLEDGEABLE ABOUT THE FOLLOWING TOPICS:

	Strongly Disagree Strongly Agree 0 1 2 3 4 5 6 7 8 9 10
Minor In-Office Procedures	

4. Please provide your comments, positive or negative, related to this learning experience.

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

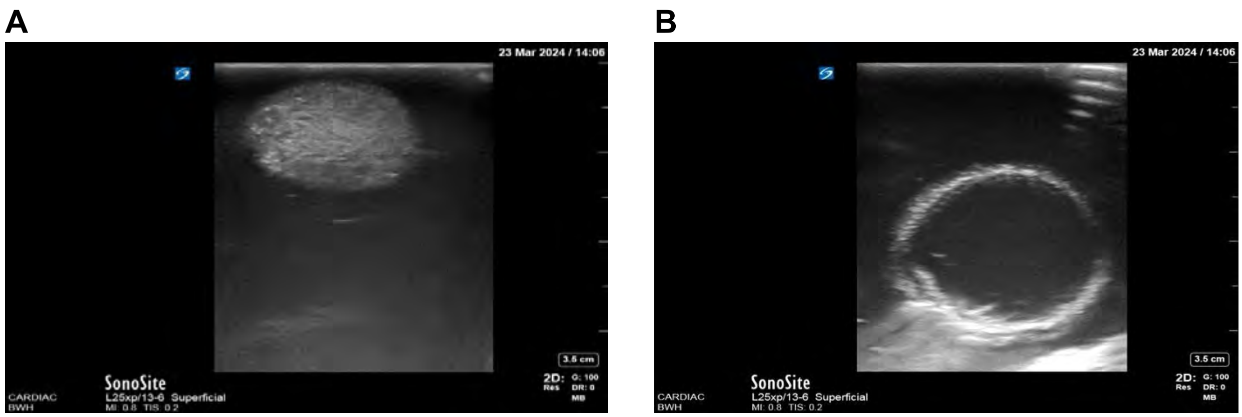
Model Design

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).

(Continued on next page)

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.

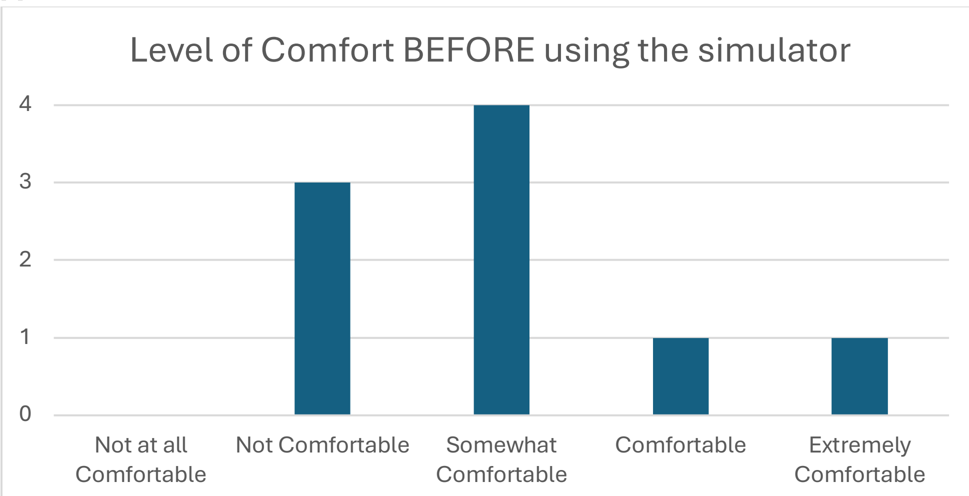
Results

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).

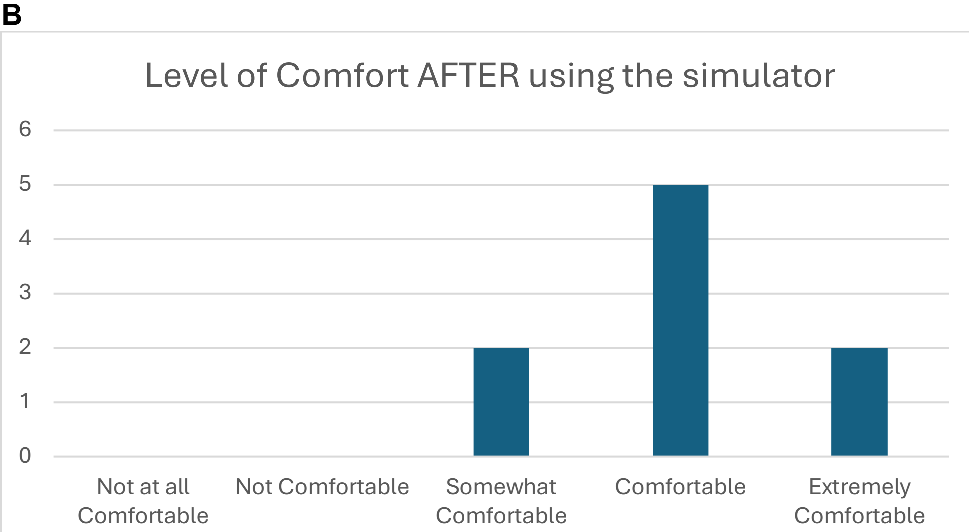
Figure 3

Level of Comfort with Ultrasound-Guided Neck Biopsy

A



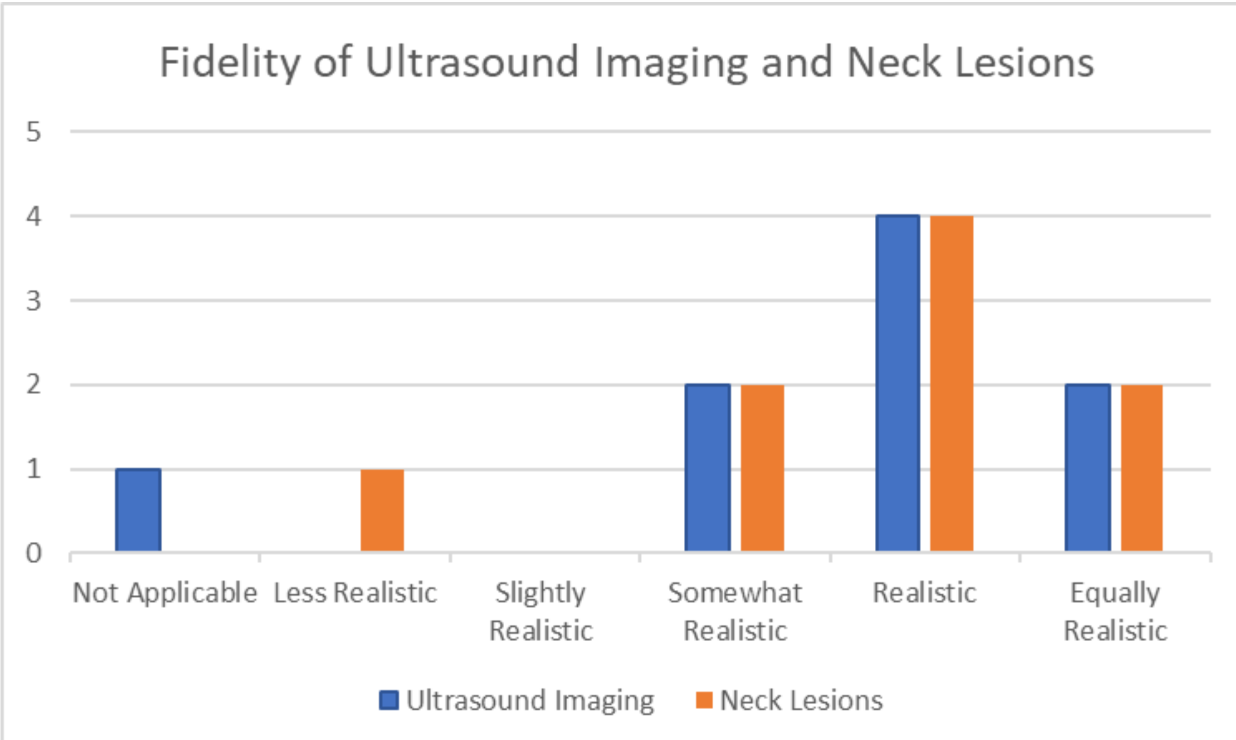
B



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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