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CONTENTS

Evaluating Initial Validity of a New Augmented Reality Simulator for Pediatric Laparoscopic Training

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Abstract

Introduction: Pediatric laparoscopic surgery (PLS) is an important procedure; however, complications can reach up to 28%. Despite this, pediatric simulation-based training (SBT) has received little scientific attention. To advance pediatric SBT, we aimed to evaluate initial face, content, and construct validity of a new Augmented Reality (AR) simulator for PLS since it has been shown to reduce medical errors.

Methods: Four experts and eleven novice residents from Hershey Medical Center were assigned to one of four conditions and performed a peg transfer on: (a) box trainer (BT) with no feedback (NF), then pediatric trainer (PT) with NF, (b) BT with NF, then PT with feedback (F), (c) BT with F, then PT with NF, (d) BT with F, then PT with F. Face/content validity was assessed using a 5-point Likert scale (1 = not realistic/useful, 5 = very realistic/useful). Construct validity was measured using time and errors (pegs dropped).

Results: Face validity illustrated that the AR simulator was perceived realistic on all statements (3.6 ± 0.9), including realism in training basic pediatric skills like depth perception (4.0 ± 0.8). Content validity illustrated the simulator's usefulness on all statements (3.9 ± 0.8), including as a training/testing tool (4.1 ± 0.7). Construct validity illustrated statistically significant differences in expertise for time ($p = 0.002$) and number of errors ($p = 0.012$).

Conclusions: The AR simulator demonstrated initial face, content, and construct validity for the peg transfer task. As such, it may be used to improve training in PLS with further development and validation across other laparoscopic tasks.

Introduction

Minimally invasive surgery (MIS) is a medical procedure that is performed over 10 million times annually in the United States to perform abdominal surgeries (Mattingly et al., 2022), resulting in less post-operative pain and complications (Sood et al., 2017). Over the past 20 years, there has been a significant rise in the use of MIS on children (Uecker et al., 2020). One MIS procedure where training can be improved is laparoscopic surgery (*Minimally Invasive Surgery*, n.d.), which is performed over 15 million times annually (*Laparoscopy*, n.d.) with a complication rate in pediatric laparoscopy up to 28% (Schukfeh et al., 2022). Research has shown that most serious complications during pediatric MIS are related to procedural methods and include hemorrhage, visceral or vascular injury, and gut diathermy injury (Sa et al., 2016). To train for laparoscopic surgery, one important set of technical skills required is the Fundamental of Laparoscopic Surgery (FLS) skills which include tasks such as peg transfer, knot-tying and suturing (SAGES FLS committee, 2019). FLS was developed to assess the core knowledge and skills needed by surgeons to conduct basic laparoscopic surgery procedures (Zheng et al., 2009). As a result, research has shown that being proficient in FLS skills improves performance in the operating room (Sroka et al., 2009). One example is the peg transfer task, which develops depth perception (Kolozsvari et al., 2011) and can negatively impact laparoscopic performance if not mastered (Suleman et al., 2010).

Simulation-based training (SBT) has proven to be effective in transferring skills to surgical settings (Dawe et al., 2013), enhancing patient safety in laparoscopic surgery (Gause et al., 2016; Vanderbilt et al., 2014), and is an effective teaching method in pediatric surgical education (Lopreiato & Sawyer, 2015). However, for simulators to be successfully integrated into training programs, they must first be validated to ensure they are effectively teaching and training the required skills. Specifically, simulators need to demonstrate three types of validation: face, content and construct validity (Leijte et al., 2019). Face validity pertains to how realistic the simulator is and whether it depicts what it is intended to depict (McDougall, 2007). Content validity involves assessing the suitability and usefulness of the simulator as a teaching method (Hung et al., 2011; McDougall, 2007). Finally, construct validity is the ability of a simulator to differentiate between experts and novice surgeons (McDougall, 2007). This helps ensure the realism and usefulness of simulators to be illustrative of skills required in a real-life surgical setting (Alsalamah et al., 2017) and its use as an evaluation tool (Gallagher et al., 2003). Specifically, validated laparoscopic simulators have been shown to have potential as effective and prominent training tools (Mori et al., 2022; Toale et al., 2022). However, simulators in pediatric surgery have received relatively few papers and scientific attention, which shows further research is needed in this field (Azzie at al., 2011; Najmaldin, 2007). Specifically, advanced skills needed for pediatric surgery cannot be taught using regular surgery simulation training (Georgeson & Owings, 2000). This highlights a need to design simulators to teach and overcome the difficulties associated with pediatric laparoscopic skills (Hamilton et al., 2011). One form of SBT used in laparoscopic simulation training is augmented reality (AR) simulators (Botden & Jakimowicz, 2008). AR simulators can provide haptic feedback (Botden & Jakimowicz, 2008) and enhance trainee's skills transfer to the clinical environment (Aggarwal et al., 2004; Van Sickle et al., 2005). A literature review conducted by Zhu et al. (2014) found that 96% of the papers reviewed illustrated that AR results in less training required, lower failure rates, improved performance, and a shorter learning curve.

To improve current training in pediatric laparoscopic surgery and capitalize on the effectiveness of AR simulators, a new augmented reality (AR) simulator was developed that integrates real-time feedback. However, the validity of this AR simulator has yet to be explored. Therefore, the goal of this study was to determine initial face, content, and construct validity of a new AR simulator for the FLS peg transfer task in pediatric and regular laparoscopic training.

Methods

Participants

Four experts and eleven novice medical residents from Hershey Medical Center were recruited. Residents were novices with no experience in laparoscopic or with less than 50 laparoscopic surgeries performed, and experts had performed more than 50 laparoscopic surgeries (Buzink et al., 2009). The demographics of the participants are shown in Table 1.

Table 1

Demographics of Participants

	Experts (n = 4)	Residents (n = 11)
Gender		
Male	3	9
Female	1	2
Ethnicity		
White	1	4
Asian	2	4
Hispanic/Latino	0	1
Black/African	0	1
American Indian/Alaska Native	1	0
More than one race	0	1
Specialty		
General Surgery	4	2
Internal Medicine	0	4
Anesthesia	0	4
Neurology	0	1
Years of experience in specialty		
0 years	0	6
1-3 years	0	5
5 years	2	2
>13 years	2	2
Number of laparoscopic surgeries performed		
0	0	9
1	0	2
>50	2	0
>2000	2	0
Previous laparoscopic training		
None	0	11
FLS	1	0
Fellowship	2	0

Note. FLS: Fundamentals of laparoscopic surgery.

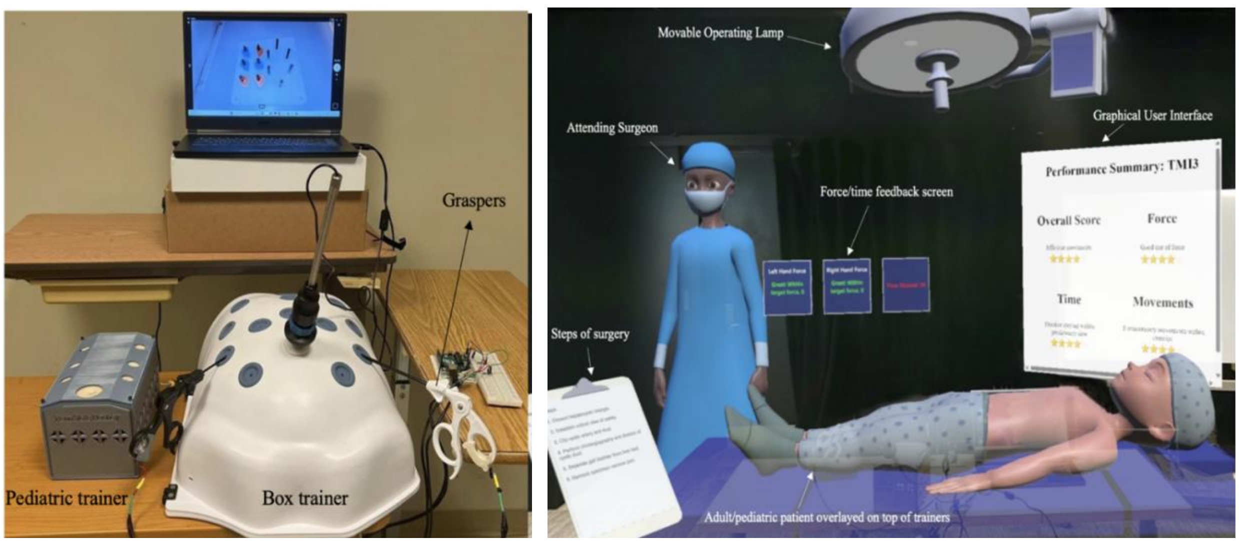
Equipment

A 3-D printed pediatric FSL laparoscopic trainer was developed with dimensions 230 mm x 140 mm x 126 mm. A commercially available Medicinology & Co standard box trainer with dimensions 455 mm x 395 mm x 220 mm was used for regular laparoscopic training. To provide real-time force and time feedback, an AR simulator using Microsoft HoloLens was developed. The AR simulator included a virtual patient, surgeon, clipboards with training instructions, operating lamp, heart rate monitor, and simulated post-training feedback. Figure 1 shows a visual representation of the equipment. The Tobii Pro 3 eye trackers were also used to track participants eye gaze data during the task.

Figure 1

Equipment set up

A Pediatric and box trainer **B** Virtual components in the AR simulator



Task and Study Conditions

In this study, participants had to complete the peg transfer task which involves 6 rubber pegs and a peg board. Participants were required to use laparoscopic graspers to grab each peg with their non-dominant hand, transfer it mid-air to their dominant hand, and then place it on the opposite side of the pegboard.

The peg transfer task was performed under one of four training conditions: (1) Regular Trainer$_{\text{no feedback}}$ then on Pediatric Trainer$_{\text{no feedback}}$, (2) Regular Trainer$_{\text{no feedback}}$ then on Pediatric Trainer$_{\text{feedback}}$, (3) Regular Trainer$_{\text{feedback}}$ then Pediatric Trainer$_{\text{no feedback}}$, or (4) Regular Trainer$_{\text{feedback}}$, then Pediatric Trainer$_{\text{feedback}}$. The AR simulator was used to provide feedback.

Procedure

First, procedures were explained and informed consent was obtained. Participants then received $15 compensation. Participants completed surveys on prior FLS experience, pre-self-efficacy, NASA Task Load Index (TLX) and mental workload. Next, experts were assigned to one of the four conditions, and residents were systematically distributed between conditions. In all conditions, participants used eye trackers. For the conditions with feedback, participants used the HoloLens on top of the eye trackers and watched a 32-second instructional video about the AR simulator. The eye trackers and HoloLens were calibrated for each participant.

Then, the peg transfer task was explained, and participants began performing the task. After completing the peg transfer task on each trainer, all participants completed a post self-efficacy, NASA TLX, workload and face and content validity questionnaires.

Outcome Measures

The main outcomes studied were face, content, and construct validity. Face validity was assessed using a 11-item questionnaire on a 5-point Likert scale, ranging from 1 (not at all realistic) to 5 (extremely realistic). Content validity was determined using an 8-item questionnaire on a 5-point Likert scale questionnaire, ranging from 1 (not at all useful) to 5 (extremely useful). Both the face validity (Arikatla et al., 2012; Sankaranarayanan et al., 2010) and content validity (Escamirosa et al., 2014; Schreuder et al., 2009) questionnaires were adapted from previous studies. Only survey responses from participants who received feedback on the AR pediatric trainer were used for this analysis, resulting in 3 experts and 8 residents.

Construct validity was assessed by measuring the time and number of errors during the peg transfer task. For each trainer, time to complete the peg transfer was recorded in seconds from the picking up the first peg to transferring the last peg (SAGES FLS committee, 2019). Errors were also quantified as the number of times pegs were dropped during the task (Rhee et al., 2014).

Results

Face Validity

The Mann Whitney results showed no statistically significant difference in the response scores between experts and novices ($p > 0.05$) for each question, see Table 2. Data is reported as mean ± standard deviation (SD). Results also showed that all 11 questions were rated above the median (3.0). The highest rated statements were related to realism to train basic laparoscopic skills like hand-eye coordination and depth perception (4.2 ± 0.6), instrument handling (4.2 ± 0.4) and realism to train basic pediatric laparoscopic skills (4.0 ±0.8). The lowest rated statements were related to realism of the surgical environment (3.0 ± 1.1) and overall realism of visualizations (3.3 ± 1).

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Table 2

Face Validity Results

	Experts (n = 3)		Residents (n = 8)		Overall		
Face Validity Questions	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value**
Realism of pediatric trainer	3.3	2.1	3.3	0.7	3.3	1.1	0.630
Realism of surgical environment (visual)	3.0	1.7	3.0	0.9	3.0	1.1	0.921
Overall realism of visualizations	4.0	1.0	3.0	0.9	3.3	1.0	0.194
Overall realism of manipulation (haptics)	4.0	1.0	3.1	0.8	3.4	0.9	0.279
Realism of the overall simulation	4.0	1.0	3.1	0.8	3.4	0.9	0.279
Realism of force feedback	4.3	0.6	3.3	0.7	3.5	0.8	0.085
Realism of time feedback	4.3	0.6	3.5	0.5	3.7	0.6	0.133
Realism of peg transfer	4.7	0.6	3.3	1.2	3.6	1.2	0.194
Realism of instrument handling	4.3	0.6	4.1	0.4	4.2	0.4	0.630
Realism to train basic laparoscopic skills (hand-eye coordination, depth perception)	4.7	0.6	4.0	0.5	4.2	0.6	0.194
Realism to train basic pediatric laparoscopic skills (hand-eye coordination, depth perception)	4.7	0.6	3.8	0.7	4.0	0.8	0.133

Note. SD: Standard deviation.

Content Validity

The Mann Whitney results showed no statistically significant difference in response scores between experts and novices ($p > 0.05$) for each question, see Table 3. Results also showed that all 8 questions were rated above the median (3.0). The highest rated statements were related to the usefulness of simulator in learning hand-eye coordination (4.3 ± 0.5), in learning ambidexterity skills (4.2 ± 0.6) and as a training tool and testing tool (4.1 ± 0.7). The lowest rated statements were related to the usefulness of simulator in learning depth-perception (3.3 ± 1.4) and time feedback (3.7 ± 0.9). All survey responses in the first three conditions who utilized the AR simulator were used.

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Table 3

Content Validity Results

	Experts (n = 3)		Residents (n = 11)		Overall		
Content Validity Questions	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-value**
Degree of usefulness of force feedback	3.7	1.5	3.9	0.8	3.8	1.0	1
Degree of usefulness of time feedback	3.7	1.5	3.8	0.7	3.7	0.9	0.921
Usefulness of simulator in learning ambidexterity skills	4.0	1.0	4.3	0.5	4.2	0.6	0.776
Usefulness of simulator in learning hand-eye coordination	4.3	0.6	4.3	0.5	4.3	0.5	0.921
Usefulness of simulator in learning depth-perception	2.3	1.5	3.6	1.3	3.3	1.4	0.279
Usefulness of simulator to train basic pediatric laparoscopic skills	3.7	0.6	3.8	0.7	3.7	0.6	1
Overall usefulness of simulator as a training tool	4.3	0.6	4.0	0.8	4.1	0.7	0.63
Overall usefulness of simulator as a testing tool	4.0	1.0	4.1	0.6	4.1	0.7	1

Note. SD: Standard deviation.

Construct Validity

A three-way mixed ANOVA was performed to evaluate the effects of expertise, condition, and trainer type on task completion time. The means and standard deviations for completion time are presented in table 4 below. The results indicated no statistically significant three-way interaction between condition, expertise and type of trainer, $F(3,7) = 0.185$, $p = .903$, $\eta^2 = 0.073$. The results also indicated no statistically significant two-way interaction between trainer type and conditions, $F(3, 7) = 0.409$, $p = 0.752$, $\eta^2 = 0.149$. All other two-way interactions were not statistically significant ($p > 0.05$). Simple main effect tests indicated that completion times were significantly lower for experts than for novices on the box trainer, $F(1, 13) = 16.529$, $p = 0.001$ and were significantly lower for experts than for novices on the pediatric trainer, $F(1, 13) = 7.942$, $p = 0.015$.

Table 4

Descriptive Statistics for Completion Time

Expertise	Trainer Type	Mean (seconds)	Standard deviation
Experts	Box trainer	82.7	7.18
	Pediatric trainer	55.25	14.52
Novices	Box trainer	248.3	79.45
	Pediatric trainer	150	65.17

Another three-way mixed ANOVA was performed to evaluate the effects of expertise, condition, and trainer type on number of errors. The means and standard deviations for completion time are presented in table 5 below. The results indicated no statistically significant three-way interaction between condition, expertise and type of trainer, $F(3,7) = 0.167$, $p = 0.916$, partial $\eta^2 = 0.067$. The results also indicated no statistically significant two-way interaction between trainer type and conditions, $F(3, 7) = 0.133$, $p = 0.937$, $\eta^2 = 0.054$. All other two-way interactions were not statistically significant ($p > 0.05$). Simple main effect tests indicated that number of errors were statistically significant lower for experts than for novices on the box trainer, $F(1, 13) = 16.529$, $p = 0.016$, and were significantly lower for experts than novices on the pediatric trainer, $F(1, 13) = 5.788$, $p = 0.032$.

Table 5

Descriptive Statistics for Number of Errors

Expertise	Trainer Type	Mean (seconds)	Standard deviation
Experts	Box trainer	0.5	1
	Pediatric trainer	0	0
Novices	Box trainer	7.09	4.64
	Pediatric trainer	3.4	2.73

Discussion

SBT can significantly enhance patient safety in laparoscopic surgery (Gause et al., 2016; Vanderbilt et al., 2014). To improve training in pediatric MIS, a new AR simulator was developed. This study aimed to determine initial face, content, and construct validity of the AR simulator. Results indicated no significant difference between experts' and novices' opinions on the face and content validity questionnaire, suggesting both groups found the AR simulator as realistic and useful. This consensus is important because experts and residents have different perceptions regarding their learning needs, so resident's perceptions should also be included when identifying needs in their training (Pugh et al., 2007).

All 11 statements on the face validity questionnaire were rated above the median (3.0), including the realism of the pediatric trainer and AR visualizations, which signifies the achievement of successful face validation for surgical simulators (Aritkatla et al., 2012; Dorozhkin et al., 2016). These results can indicate that the AR simulator achieved successful initial face validation and was perceived a realistic training tool in its initial stages. This is important because face validation ensures the simulator's potential utility and successful integration (Raje at al., 2016; Wentink, 2001). Similarly, all eight statements on the content validity questionnaire were rated above the median which can also be considered successful content validation (Dorozhkin et al., 2016). Both groups found the simulator useful for training hand-eye coordination, depth perception, force and time feedback, ambidexterity skills, and as a training and testing tool. Effective hand-eye coordination and depth perception are critical for laparoscopic surgery to avoid performance errors and ensure patient safety (Raje at al., 2016; Wentink, 2001). These results suggest the simulator's potential as a useful training tool since content validity can be illustrative of skills required in a real-life surgical setting (Alsalamah et al., 2017).

Results also showed that there were significant differences in time and errors between experts and novices on the pediatric and box trainers with and without the AR simulator, which demonstrates initial construct validity of the simulators. This ability to distinguish skill levels is essential for integrating simulators into medical education (McDougall, 2007). Such simulators can be used to evaluate and credential surgeons objectively (Duffy et al., 2004; Schout et al., 2009). Using objective approaches to assess surgical trainees has been more in demand to enhance and increase the effectiveness of skill transfer (Ahmed et al., 2013) and is crucial in ensuring patient safety in the operating room (Shaharan & Neary, 2014).

Overall, the AR simulator shows promise as a valuable training tool that could improve pediatric MIS training and potentially reduce operating room errors with further development and validation (Arikatla et al., 2012). However, a limitation of this study is its small sample size. Additionally, participants completed only half the peg transfer task on each trainer due to time constraints. Future work can recruit a larger population of participants that perform the complete peg transfer task to further validate the simulator and ensure validity.

Conclusion

The goal of this study was to determine initial face, content, and construct validity of a new AR simulator to contribute to the field of pediatric SBT. Surgical simulators must be validated before integrating them into medical programs. The results of our study showed that the AR simulator with the pediatric trainer was perceived to be a realistic and a useful training tool for learning skills such as hand-eye coordination and learning ambidexterity skills. In addition, it was able to differentiate between experts and novices on the peg transfer task. As such, the AR simulator may potentially work towards enhancing training in pediatric laparoscopic surgery. Future work will involve improving the current simulator and validating it across other laparoscopic training tasks.

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Enhancing Critical Care Outcomes Through TeleCritical Care Simulation Training

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Introduction

The Veterans Affairs (VA) National TeleCritical Care (NTCC) Program is the world's largest single TeleCritical Care service. It is designed to provide critical care expertise around the clock to over 70,000 Veterans annually. Leveraging advanced telehealth technologies and computer-enhanced algorithms, NTCC aims to enhance patient care outcomes through continuous support and collaboration with bedside clinical teams across 84 facilities and more than 1,200 Intensive Care Unit (ICU) beds. A vital component of this program is the integration of TeleCritical Care simulation training, which is a pioneering initiative that employs high-fidelity simulation to promote a culture of safety and continuous improvement aligned with High-Reliability Organization (HRO) principles.

Objectives

1. Describe the NTCC Program and its integration of TeleCritical Care simulation training.
2. Illustrate how NTCC enhances patient care outcomes through interprofessional simulation training.
3. Examine how NTCC Interprofessional Education (IPE) promotes a culture of safety and continuous improvement aligned with HRO principles.

About the VA National TeleCritical Care (NTCC) Program

Overview

The NTCC Program provides 24/7/365 critical care expertise to VA facilities, ensuring continuous patient monitoring and intervention. Currently, it covers 84 facilities with over 1,200 ICU beds, and an additional 14 facilities with 400 ICU beds are projected for future inclusion. The program supports the care of 70,000+ Veterans annually, with a daily average of 600-700 patients. This extensive network ensures that Veterans receive timely and high-quality critical care across the VA enterprise.

Technological Integration

NTCC employs advanced technologies, including real-time data access from electronic health records, imaging systems, waveforms, and clinical information systems, integrated through an enterprise telehealth software program. This setup allows continuous transmission and analysis of patient data using sophisticated algorithms, enabling the identification of at-risk patients and timely resource allocation for optimal care. The seamless integration of these technologies ensures that critical care teams have the most accurate and up-to-date information, facilitating better clinical decisions and outcomes.

Workforce

The NTCC team comprises board-certified critical care providers from various specialties and critical care nurses with diverse backgrounds such as trauma, cardiology, neurology, and military. The average critical care experience is 17 years for physicians and 13 years for nurses. This team of critical care experts brings a wealth of knowledge and experiences, ensuring high standards of care and fostering a collaborative environment that benefits both patients and staff.

NTCC Operational Divisions

The East and West divisions' expansive network allows NTCC to provide extensive support and coverage ensuring that critical care resources are always available to 84 geographically dispersed VA facilities. This ensures consistent, timely access to state-of-the-art intensive care for all acutely ill Veterans whenever critical care services are required. The West Division is headquartered in Minneapolis, MN and oversees 42 VA facilities. This includes six NTCC hubs in Chicago, Iowa City, Garland, Las Vegas, Los Angeles, and Minneapolis. The East Division is headquartered in Cincinnati, OH and oversees 42 VA sites. This includes five NTCC hubs located in Ann Arbor, Atlanta, Baltimore, Cincinnati, and Orlando.

NTCC Roles and Interventions

The NTCC program delineates specific roles for its providers and nurses, ensuring a clear and efficient workflow that enhances patient outcomes. These roles are critical in ensuring that the NTCC program can effectively support bedside teams, offering expertise and guidance that can make a significant difference in patient outcomes.

NTCC Provider Role

1. Writing orders
2. Guidance during emergencies
3. Critical care consultation
4. Ventilator and sedation management
5. ICU admission staffing during off-tour hours

NTCC Nurse Role

1. Proactive alerts to hospital staff based on patient changes
2. Safety risk and injury mitigation
3. Peer-coaching
4. Assistance during emergencies
5. Routine rounding

TeleCritical Care Simulation Training

TeleCritical Care simulation was pioneered at the VA Greater Los Angeles Healthcare System, an academic-affiliated facility that provides simulation training for new cohorts starting their ICU rotation. These simulations utilize bi-directional telecommunication to conduct high-fidelity simulation scenarios focused on critical care and emergency response that are aligned with the standards of the Society for Simulation in Healthcare and the International Nursing Association of Clinical Simulation (Figure 1). The pioneering efforts at this facility have set a benchmark for other VA facilities, demonstrating the effectiveness of TeleCritical Care simulation in improving healthcare practices.

Figure 1

TeleCritical Care Simulation

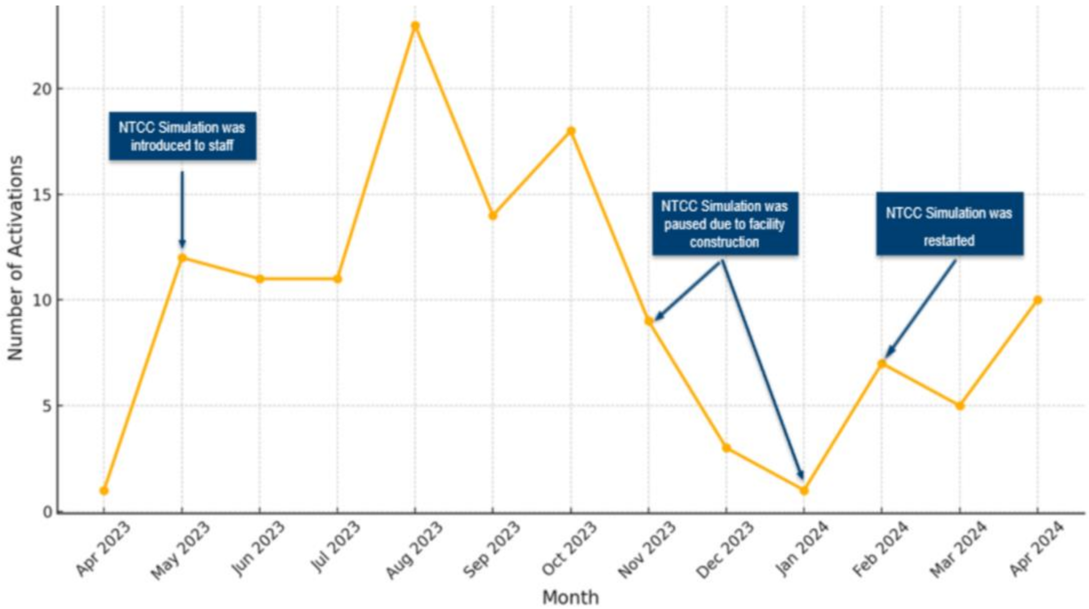
Outcomes of TeleCritical Care Simulation

Increased Utilization

The following table illustrates the number of NTCC emergency activations since the commencement of simulation training in April 2023, see Figure 2. The number of activations increased during months simulation training occurred and decreased when simulation training was paused due to construction (November to February). The data reflects growing utilization and effectiveness of NTCC services, demonstrating the program's impact on enhancing emergency response and patient care in the ICU.

Figure 2

NTCC Activations Over Time (April 2023 – April 2024)



Emergency Response Times and Interprofessional Collaboration

Utilization of NTCC service could potentially save up to 2.7 minutes per emergency response. The integration of simulation training has significantly increased the utilization of NTCC services, resulting in improved interprofessional collaboration, and enhanced speed and delivery of critical care interventions, ultimately leading to better patient outcomes:

- The average time for hospital providers to respond after emergency activation in the ICU nationally is 3.05 minutes (Arıkan et al., 2024; Morris et al., 2023; Patil et al., 2019; Weile et al., 2021; Winters et al., 2013).
- The average time for NTCC providers to respond after emergency activation in the ICU at NTCC affiliated facilities is 0.35 minutes (*VA Telehealth*, n.d.).
- The average time that could be saved using NTCC service per emergency response is 2.7 minutes.

Practice Barriers in Simulation

Excessive Autonomy

Excessive autonomy occurs when individual preferences lead to variability and complacency in practice standards (Veazie et al., 2019). This barrier can hinder the standardization and effectiveness of healthcare practices. To counteract excessive autonomy, the NTCC simulation incorporates several measures:

- Checklists: Standardized checklists ensure that all necessary steps are followed during critical care interventions, reducing variability, and enhancing consistency.
- Standardized emergency training: Regular training sessions provide opportunities for staff to practice and refine their skills in a controlled environment, reinforcing standardization and preparedness.

- Situation, Background, Assessment, Recommendation (SBAR): This standardized handoff tool ensures clear and concise communication between team members, reducing the risk of miscommunication and errors.
- Crew resource management models: These models promote team cohesion and effective collaboration, ensuring that all team members work together efficiently and effectively.

Craftsman Attitude

A craftsman attitude relies on specific individuals to carry out tasks, which can lead to dependency and variability in practice (Veazie et al., 2019). The NTCC simulation addresses this barrier by providing equivalent craftsmen resources and supporting shared mental models during crises. Key measures include:

- Rapid NTCC response: The NTCC team can respond to emergencies in 0.35 minutes on average, compared to the onsite emergency response team's 3.05 minutes average response time (Veazie et al., 2019). This quick response ensures that critical care interventions are initiated promptly.
- Early cardiovascular resuscitation and role clarification: NTCC's involvement ensures that resuscitation protocols are initiated early and that roles are clearly defined, enhancing the efficiency and effectiveness of the resuscitation efforts.
- Transition of emergency response team lead: The transition between NTCC and bedside teams is managed through quick debriefs, ensuring seamless coordination and continuity of care.
- Crowd control and triage assistance: NTCC team assists with crowd control and initial triage, ensuring that the resuscitation efforts are organized and efficient.
- Interprofessional collaboration: By bringing together experts from various specialties and disciplines, NTCC simulation ensures that all aspects of patient care are addressed comprehensively. This collaboration enhances the quality of care ensuring all team members contribute their unique perspectives and expertise.

Embracing HRO Principles

Deference to Practice

Deference to practice involves making decisions based on expertise rather than hierarchy (Veazie et al., 2019). Simulation training promotes this through:

- Assertive and respectful communication: The learners practice enhancing patient safety advocacy through clear and respectful communication, promoting team cohesion and inclusiveness.
- Safe psychological environments: NTCC simulation creates safe environments for teams to practice and develop their skills, encouraging open communication and continuous improvement (Figure 3).
- Team lead training: Simulation provides education for novice team leaders, ensuring they are prepared to utilize all available resources effectively.
- Inclusive language: The use of inclusive language, such as "we," "us," and "let's," promotes a sense of teamwork and collaboration, reinforcing the idea that everyone is working together towards a common goal.
- Specific and direct communication: During simulations, communication is focused on being specific and direct, avoiding ambiguity and ensuring that instructions and feedback are clear and actionable.

Figure 3

NTCC Simulation Environment

Sensitivity to Operations

Sensitivity to operations emphasizes awareness of team dynamics and expertise (Veazie et al., 2019). During simulations, NTCC:

- Assists with crowd control and role confirmation: NTCC staff help confirm the roles and expectations of the emergency response team, ensuring that everyone knows their responsibilities and that the resuscitation efforts are coordinated and efficient.
- Promotes mutual expectations and shared mental models: By clarifying roles and expectations, NTCC ensures all team members are on the same page and can work together effectively.
- Encourages open dialogue and non-punitive communication: Creating an environment where team members feel comfortable speaking up and sharing their observations and suggestions are crucial for continuous improvement and patient safety.
- Increase situational awareness: By minimizing interruptions and distractions during emergencies, NTCC simulation enhances situational awareness to prevent and mitigate errors. This ensures that all team members are fully engaged and able to respond effectively in critical situations.

Conclusion

The NTCC Program, through its integration of advanced telehealth technologies and simulation training, exemplifies an innovative healthcare practice that enhances patient care outcomes and promotes a culture of safety. By aligning with HRO principles and leveraging interprofessional education through NTCC simulation, the speed and delivery of critical care interventions for Veterans improves. As the program continues to expand, its impact on Veteran care and healthcare simulation training will undoubtedly set new standards in critical care delivery.

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Challenges and Lessons Learned from Implementing VR Into the Nursing Curriculum

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Introduction

The Ohio State University College of Nursing (OSUCON) has embarked on a transformative journey to revolutionize nursing education through the innovative application of extended reality (XR). Funded by the American Nurses Foundation Reimagining Nursing Grant, the initiative aims to disrupt the traditional methods of preparing pre-licensure nursing students, ensuring they are practice-ready in an increasingly complex healthcare environment. Nursing education has traditionally relied on classroom instruction, hands-on skills training, and high-fidelity simulations. While these methods have proven effective, they have limitations in terms of scalability, accessibility, and the ability to replicate complex, real-world scenarios. With the advent of XR, there is an opportunity to create a more immersive and flexible learning environment that can better prepare students for the demands of modern healthcare.

Traditional high-fidelity simulations, though valuable, are resource-intensive and often limited in availability. This is particularly challenging as scenarios with multiple patients increases the need for more faculty, staff, and physical space. These simulations are often completed in groups of 3 to 4 students, limiting the opportunity for nursing students to exercise individual clinical judgement. Often, the weaker student relies heavily on the strongest student in the group. VR can provide consistent, repeatable experiences to many students, making learning more engaging and realistic. Immersive technologies can enhance student engagement and realism. The ability to offer immediate feedback helps students learn from their mistakes and improve their skills. Students can repeat simulations in the headset without a significant increase in staffing or space needs. VR allows for a more personalized learning experience, optimizing each student's educational journey.

Project

The project includes a variety of clinical scenarios, covering clinical decision-making, pharmacological principles, and skills-based interventions. Scenarios also incorporate essential skills such as therapeutic communication, patient history-taking, and addressing social determinants of health. Students are screened for potential cybersickness to ensure they can participate comfortably in VR experiences. Feedback on patient care simulations is provided to each student at the end of the simulation, along with rationale and links to patient care guidelines. Students can repeat the simulation as many times as they want because they can access the program on a computer or headset and can log in from anywhere.

Community health students experienced homelessness in a VR headset by entering the tent of a homeless woman and viewing her lived experiences. They interacted with the few keepsakes she still possessed and were present in her current living situation, gaining insights into the social determinants of health. This application is free from Meta without a screen-based alternative. It was noted many students would opt out of the headset-based activity until an alternative screen-based scenario was created. Following the creation of the alternative experience, the number of students choosing to opt out of the headset decreased significantly. In the medical-surgical courses, students engaged in patient care simulations both in VR and on screen. Sophomore students participated in cardiac and respiratory assessment tutorials. Junior students cared for a young child or a pregnant woman experiencing complications. Graduate entry students performed a cardiac arrest scenario. These scenarios ranged from cardiac and respiratory assessments to managing complications in pregnant women and pediatric patients. In addition to individual simulations, the project also explored the potential of XR for group learning. In a junior medical-surgical course, a student in a VR headset projected the simulation onto a screen, allowing classmates to guide decision-making and procedures. This approach fostered collaboration and collective problem-solving, turning the experience into a group activity. The simulation was completed a second time to improve the group's performance.

Discussion

The success of the initial phase of the pilot has paved the way for expanded use of XR in nursing education. Looking to the future, we are planning to develop additional scenarios, including advanced clinical situations and communication skills for students to learn job interview techniques and how to navigate difficult conversations. Longitudinal studies will be conducted to evaluate the impact of VR on student outcomes and career readiness.

Lessons learned from the pilot include the need for a robust and standardized orientation to not only the software, but to the headset. Students struggled to use the headsets and controllers without formalized training. Screening for cybersickness was altered as the original version led to an exceptionally high number of students self-reporting cybersickness. Challenges include gaining faculty support, integrating the experience into the curriculum, and scheduling large numbers of students for VR experiences.

Conclusion

This innovative pilot project demonstrates the transformative potential of VR in nursing education. By providing immersive, scalable, and adaptable learning experiences, VR can significantly enhance the preparedness of nursing students for the complexities of modern healthcare. The initial outcomes are promising, lessons learned will assist other programs looking to implement VR successfully. This project lays a strong foundation for continued innovation and improvement in nursing education.

The Impact of Augmented Reality and Simulation-Based Training in Pediatric Laparoscopic Surgery Training

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Abstract

Introduction: In recent years, pediatric minimally invasive surgery (MIS) has grown, which is more complex than adult MIS. Serious complications can occur, but raining can decrease these risks. While medical simulation-based training (SBT) is effective, pediatric SBT is still in its infancy. Pediatric laparoscopic surgery (PLS) is one form of MIS that requires effective training. Thus, the goal of our study was to design an Augmented Reality (AR) and a pediatric simulator, then assess the impact of SBT with and without AR on PLS self-efficacy and performance.

Methods: Twelve novice residents and fourteen medical students from Hershey Medical Center were assigned to one training condition and completed a peg transfer task, with or without AR feedback, and starting with a regular box trainer (BT) (easier) first, then on the pediatric trainer (PT) (harder), or vice versa. Self-efficacy in laparoscopic surgery and practices was assessed using an 18-item questionnaire on a 5-point Likert scale. Time and number of pegs dropped were measured during the task.

Results: Wilcoxon signed rank tests revealed that self-efficacy improved pre- to post-training on the 18 self-efficacy statements ($p < 0.05$). Two-way ANOVA showed that starting with the easier BT first then on the PT improved time performance in the PT ($p = 0.003$). Hoteling's T2 revealed no significant difference in performance with AR feedback ($p > 0.05$).

Conclusions: SBT with and without AR can improve self-efficacy in PLS and starting with either task may improve performance in more complex tasks. Future work will develop and evaluate the effectiveness of AR feedback.

Introduction

Minimally Invasive Surgery (MIS) is performed by surgeons to operate on patients using small incisions, to minimize damage to the patient's body compared to open surgery (Anand et al., 2022) and to allow a quicker recovery, reduced pain, and shorter hospitalization duration (Dagorno et al., 2021). Specifically, pediatric MIS on children has increased rapidly over the last decade. However, there are technical challenges due to the diverse sizes and physiological differences within the pediatric population (Pogorelić, 2022). Due to the greater technical complexity of pediatric surgery compared to general surgery, caution and safety are essential during the procedure (Yokoyama et al., 2019). Additionally, pediatric MIS necessitates more psychomotor effort and skill from surgeons to account for smaller instruments and motion scaling compared to regular laparoscopic surgery (Hamilton et al., 2011).

Patient outcomes can also be impacted due to the learning curve associated with pediatric MIS (Uecker et al., 2020). Research has also shown that complication rates in pediatric MIS can reach up to 17% which includes bowel obstruction, bile leakage and infections (Uecker at al., 2020). The risks of these complications can decrease with experience and learning skills (Sa et al., 2016), and training and education (Esposito et al., 2019). However, pediatric simulation-based training (SBT) is still in its 'infancy' (Skertich et al., 2020). As such, more research in pediatric SBT is required. In addition, laparoscopic surgery is one form of MIS that requires more effective teaching strategies (Gallagher et al., 2003).

SBT has been shown to be effective in improving performance and reducing complications in medical training (Aydin et al., 2021). Specifically, self-efficacy, which is a measure of a trainee's confidence in carrying out a procedure or in providing patient care based on their own self-evaluation, is an important construct in SBT (Themason & Rosen, 2014). It has been linked to enhanced performance (Themason & Rosen, 2014) and is a critical component of safe surgical techniques and understanding of one's own capabilities (Anderson et al., 2020). However, approximately 92.3% of residents express shortcomings in their ability to perform medical procedures independently (Anderson et al., 2020). As such, Augmented Reality (AR) simulators are one form of SBT that can improve patient safety (Barsom et al., 2016), performance in surgeries (Williams et al., 2020) and confidence (Chiang et al., 2021). In addition, research indicates that simulation order with regards to starting with easier simulation training before advancing to more complex simulations, enhances performance during SBT (Brydges et al., 2010). Therefore, the goal of this study was to develop a new AR and pediatric simulator for laparoscopic training and understand the impact of SBT with and without AR on self-efficacy and performance in pediatric laparoscopic surgery (PLS).

Methods

This study aims to answer the following research questions (RQ).

RQ1: Do novices improve their pediatric laparoscopic self-efficacy over the course of simulation training?

The goal of this RQ was to understand whether novice's self-efficacy in PLS improves from pre- to post-simulation training. We hypothesize that laparoscopic self-efficacy will improve after training because prior work has shown that SBT can improve confidence in laparoscopic surgery (Barnes et al., 2015).

RQ2: Does simulation task order impact pediatric laparoscopic performance?

The goal of this RQ was to understand whether simulation order, starting with an easier task (regular box trainer) and then finishing with a harder task (pediatric trainer) or vice versa, would affect trainees' performance. It was hypothesized that performance in the harder task (pediatric) would improve when performed first on the easier task (regular) since research has shown that increasing the level of difficulty during simulation training improves performance (Brydges et al., 2010).

RQ3: Does providing AR feedback during simulation training improve performance?

The goal of this RQ was to understand whether providing visual AR feedback improves performance during laparoscopic training. It was hypothesized that individuals who received visual feedback during the task will perform better because prior work has shown that visual feedback during laparoscopic training can improve performance (Horeman et al., 2014).

Participants

A total of 26 participants were recruited over two sessions from Hershey Medical Center. The first session included 11 medical residents. While the second session included 14 medical students and 1 resident. All participants were novices since they either performed less than 50 laparoscopic procedures or had no prior experience with the procedure (Buznik et al., 2008). Demographics of the participants are reported in Table 1.

Table 1

Demographics of Participants

	Residents (n = 12)	**Students (n =14)**
Gender		
Male	9	2
Female	3	12
Ethnicity		
White	4	10
Asian	5	4
Hispanic/Latino	1	0
Black/African	1	0
American Indian/Alaska Native	0	0
More than one race	1	0
Specialty		
General Surgery	2	0
Internal Medicine	5	0
Anesthesia	4	0
Neurology	1	0
Years of experience in specialty		
0 years	7	0
1-3 years	5	13
4 years	0	1
Number of laparoscopic surgeries performed		
0	10	0
1	2	0
Previous laparoscopic training		
None	12	14

Study Equipment

An AR simulator was created using the Microsoft HoloLens 2, Unity software (version 2021.3.6), and the Mixed Reality Toolkit (version 1.2209.0). Specifically, this simulator was developed to provide more realistic training conditions and visualizations, haptic feedback and real-time feedback on force and time, see Figure 1. Feedback included digits turning red when the proficiency time exceeded the 48-seconds FLS standard (SAGES FLS committee, 2019) or force exceeded 0.4N (based on sensitivity of sensors). The AR simulator also includes a virtual patient, surgeon, and clipboard with training instructions.

Figure 1

Virtual component of AR simulator

Notes. Virtual components of AR simulator including virtual patient and surgeon, clipboards, heart rate monitor, operating lamp, feedback screens, and graphical user interface (GUI).

A 3D-printed pediatric trainer was developed which allows training of fundamental laparoscopic surgery (FLS) skills (SAGES FLS committee, 2019), see in Figure 2. We used the baseball diamond principle (Ismail & Mishra, 2014) to triangulate the instruments, resulting in the first port insertion for the laparoscopic camera, and the other two ports for the laparoscopic graspers, see Figure 2. This principle was also used to determine the dimensions of the pediatric trainer, resulting in measurements of 140 mm x 230 mm x 126 mm (Ismail & Mishra, 2014). The trainer also included a suture pad which is used as the abdominal ports for instrument insertion. A commercially available standard 'box trainer' for laparoscopic training was also used in this study with dimensions 455 mm x 395 mm x 220 mm. The Tobii Pro 3 eye trackers were also utilized to track eye gaze data.

Figure 2

Pediatric trainer

Notes. The 3D printed pediatric trainer was developed to train pediatric laparoscopic skills.

Procedure

First, procedures were explained and informed consent was obtained. Participants were compensated with $15 and completed four surveys: prior FLS experience, pre-self-efficacy, NASA Task Load Index (NASA-TLX) and mental workload. Next, Next, they were assigned to their condition. Participants in the first session were assigned to start with the Box Trainer (BT – easier) first: (1) Box Trainer$_{\text{no feedback}}$ then on Pediatric trainer$_{\text{no feedback}}$, (2) Box trainer$_{\text{no feedback}}$ then on Pediatric Trainer$_{\text{feedback}}$, (3) Box trainer$_{\text{feedback}}$ then Pediatric trainer$_{\text{nofeedback}}$, or (4) Box Trainer$_{\text{feedback}}$ then Pediatric Trainer$_{\text{feedback}}$. Participants in the second session were assigned to the same conditions but starting with the Pediatric Trainer (PT – harder) first: (1) Pediatric Trainer$_{\text{no feedback}}$ then on Box Trainer$_{\text{no feedback}}$, (2) Pediatric Trainer$_{\text{no feedback}}$ then on Box Trainer$_{\text{feedback}}$, (3) Pediatric Trainer$_{\text{feedback}}$ then Box Trainer$_{\text{nofeedback}}$, or (4) Pediatric Trainer$_{\text{feedback}}$ then Box Trainer$_{\text{feedback}}$. In the feedback conditions, participants used the HoloLens over eye trackers and watched a 32-instructional video about the AR simulator. This fundamental skill required residents to use the laparoscopic graspers to grab each of the 6 colored pegs from the pegboard with their non-dominant hand, transfer it mid-air to their dominant hand, and place it on the opposite side of the pegboard. After each task in each condition, participants completed 4 surveys: post-self-efficacy, NASA-TLX, workload and validation questionnaires.

Outcome Measures

The main outcomes were self-efficacy, simulation order, time, and number of errors. Self-efficacy was assessed with 18-item Likert Scale from “Not at all confident” (1) to “Extremely confident” (5), see Table 2. Simulation order was based on whether participants started with the BT or PT first. Time was recorded from picking up the first peg to releasing the sixth (SAGES FLS Committee, 2019). Number of errors was quantified by the number of dropped pegs (Rhee et al., 2014).

Statistical Analysis

All statistics were analyzed with SPSS (version 29.0) with a significance level 0.05. A Wilcoxon Signed-Rank Test determined statistical significance between the pre- and post-surveys (independent variables) on each of the 18 self-efficacy statement scores (dependent variable). The difference scores were approximately symmetrically distributed, as assessed by a histogram with superimposed normal curve. Data are expressed as median values.

Two Two-Way Mixed ANOVAs were conducted to examine the effects of simulation order (between-subjects factor) and type of trainer (box trainer vs pediatric trainer, within-subjects factor) on two dependent variables: time and number of errors. Assumption checks indicated that the data met the requirements for ANOVA. The dependent variables were normally distributed, as assessed by Shaprio-Wilk's test ($p > 0.05$), and there was homogeneity of variances (Levene's test, $p > 0.05$) and homogeneity of covariances (Box's M test, $p = 0.113$). However, Mauchly's test indicated a violation of sphericity for the two-way interaction ($p < 0.05$).

Lastly, a Hoteling's T^2 examined whether providing feedback through AR (independent variable) impacts time and number of errors (dependent variables). For both trainer types, the data were normally distributed (Shapiro-Wilk test, $p > 0.05$), and no univariate or multivariate outliers were identified based on boxplots and Mahalanobis distance ($p > 0.001$), respectively. Relationships between variables were linear as assessed by scatterplots, and no multicollinearity was detected ($|r| < 0.9$). Homogeneity of variance-covariance matrices was confirmed (Box's M test, $p = 0.205$). Data are expressed as mean ± standard deviation.

Results

RQ1: Do novices improve their pediatric laparoscopic self-efficacy over the course of simulation training?

A Wilcoxon-signed rank test showed a statistically significant median increase in pediatric laparoscopic post-self-efficacy compared to the pre-self-efficacy for all 18 statements ($p < 0.05$), with strong effect sizes of greater than 0.70, see Table 2.

(continued on next page)

Table 2

Self-Efficacy Results

Self-Efficacy Statements	Median Pre	Median Post	Z-Value	p-value	Effect size
Correctly and safely handle laparoscopic equipment	1.5	3	3.793	<0.001	0.74
Grasp the pegs with the laparoscopic instrument	2	3	4.070	<0.001	0.80
Maneuver the pegs through the designated path	1	3	4.184	<0.001	0.82
Apply the correct amount of force while performing the task	1	3	4.328	<0.001	0.85
Perform the task with precision and accuracy	1	3	4.082	<0.001	0.80
Adapt laparoscopic skills to different surgical scenarios	1	2	3.881	<0.001	0.76
Perform basic laparoscopic maneuvers in a pediatric case	1	3	3.575	<0.001	0.70
Complete peg transfer task within specified limit	1	3	4.033	<0.001	0.79
Perform laparoscopy based on different patient anatomy	1	2	3.460	<0.001	0.68
Use tactile feedback to adequately navigate through organs	1	3	3.697	<0.001	0.73
Perform the task in a pediatric case with precision and accuracy	1	2	3.731	<0.001	0.73
Maintain steady control of the laparoscopic equipment while performing task	1	3	4.010	<0.001	0.79
Conducting the entire task/procedure without any mistakes	1	2	3.337	<0.001	0.65
Conducting the entire task/procedure on a laparoscopic simulator	1	3	4.193	<0.001	0.82
Release pegs in the target area	1	3	3.909	<0.001	0.77
Preparing and identifying proper equipment	1	3	3.451	<0.001	0.68
Maintaining correct technique through the entire procedure	1	2	3.828	<0.001	0.75
Using the proper equipment in the proper order	1	3	3.901	<0.001	0.77

RQ2: Does simulation task order impact pediatric laparoscopic performance?

A two-way Mixed ANOVA was performed to evaluate the effects of simulation order and type of trainer on task completion time. The means and standard deviations for completion time are presented in table 3 below. Data are reported as mean ± standard deviation (SD). The results indicated a significant interaction effect between simulation order and type of trainer on time, $F(1,23) = 5.278$, $p = 0.025$, partial $\eta^2 = 0.199$. Simple main effects indicated that time was not statistically significant different between starting with easier box first than starting with pediatric first on the box trainer ($p = 0.220$). Simple main effects indicated that time was significantly lower when starting with easier box trainer first than starting with pediatric trainer first on the pediatric trainer ($p=0.003$).

Table 3

Descriptive Statistics for Time

Trainer type	Simulation Order	Mean (seconds)	Standard deviation
Box trainer	Box Trainer First	263.58	92.44
	Pediatric Trainer First	310.77	94.59
Pediatric Trainer	Box Trainer First	148	62.52
	Pediatric Trainer First	287.15	134.48

Another two-way mixed ANOVA indicated a significant interaction effect between simulation order and type of trainer on number of errors, $F(1,23) = 5.120$, $p = 0.033$, partial $\eta^2 = 0.182$. The means and standard deviations for number of errors are presented in table 4 below. Simple main effects indicated that number of errors was not statistically significant different between starting with easier box first than starting with pediatric first on the box trainer ($p = 0.288$). Simple main effects showed that number of errors was significant lower on pediatric trainer than box trainer in easier box trainer first, $F(1,11) = 7.040$, $p = 0.022$, partial $\eta^2 = 0.390$. Simple main effects showed that number of errors was not significant on any type of trainer in pediatric trainer first $F(1,12) = 0.02$, $p = 0.890$, partial $\eta^2 = 0.002$.

Table 4

Descriptive Statistics for Errors

Trainer type	Simulation Order	Mean (seconds)	Standard deviation
Box trainer	Box Trainer First	7.083	4.42
	Pediatric Trainer First	5.08	4.76
Pediatric Trainer	Box Trainer First	3.08	2.77
	Pediatric Trainer First	5.23	4.08

RQ3: Does providing AR feedback during simulation training improve performance?

In the BT simulation task, participants without AR feedback demonstrated shorter task times (281.4 ± 100) and fewer errors (5 ± 4.4) compared to the task times (295.4 ± 92.4) and errors (7.2 ± 4.7) in the AR feedback. However, these differences were not statistically significant, $F(2,22) = 0.667$, $p = 0.523$, Wilks' $\Lambda = 0.943$, partial $\eta^2 = 0.057$. Similarly, on the PT, participants without AR feedback showed shorter task times (211.8 ± 83.67) and fewer errors (3.6 ± 2.7) compared to the task times (233.3 ± 164.6) and errors (5.2 ± 4.2) in the AR feedback. Moreover, these differences were not statistically significant, $F(2,21) = 0.679$, $p = 0.518$, Wilks' $\Lambda = 0.939$, partial $\eta^2 = 0.061$.

Discussion

The goal of this study was to understand the impact of SBT with and without AR on PLS performance. For the first RQ, we found that novices self-efficacy improved from pre to post training in PLS, supporting our hypothesis that simulation-based training improves self-efficacy. Specifically, pediatric SBT with and without AR improved novices' self-efficacy. High self-efficacy is scientifically associated with effective application of acquired skills (Smith et al., 1995), and sufficient confidence is necessary for safe clinical practice (Gottlieb et al., 2021).

For the second RQ, we found that starting with an easier simulation task (BT) then progressing to a more complex task (PT), improved time performance in the PT task, but not for number of errors, partially supporting our hypothesis. This holds importance in medical simulation training because starting from easier to more difficult tasks during simulation training improves performance in the operating room (Grover et al., 2017). For our third RQ, we found that providing AR visual feedback during simulation training did not improve performance, refuting our hypothesis. This aligns with prior research showing no differences in performance with AR feedback, and participants also took longer to complete the task with feedback (Zahiri et al., 2017). Attentional selectivity, the ability to focus on task-relevant stimuli and ignore distractions can be a sign of expertise (Stefanidis et al., 2007). In addition, skilled surgeons can maintain selective intention and block out distractions (Anton et al., 2018), a quality our novice participants may have lacked, which could have affected their utilization of the AR feedback during the tasks.

Limitations in this study include a small sample size and variability of participants. In addition, due to time constraints of medical residents and students, they were only asked to complete half of the peg transfer task. Future work will analyze eye gaze data of novices and compare it with experts, to further understand the effectiveness of AR feedback during simulation-training. This could potentially help us identify strategies to train and increase novices' attentiveness to task relevant stimuli during their training to improve their performance. Future work will improve the fidelity of the AR simulator and ensure participants complete the full task.

Conclusion

To improve PLS training, an AR simulator with a pediatric laparoscopic trainer was developed, and the study aimed to determine the impact of SBT with and without AR in this field. The results of our study showed that pediatric laparoscopic self-efficacy of novices improved with and without AR training, simulation task order improved time performance in the harder pediatric task and providing AR visual feedback did not impact performance. This highlights the potential benefits of simulation training in improving self-efficacy and performance in PLS; however, more work is required to determine the full effectiveness of AR during training. As such, SBT with and without AR may work towards improving skill acquisition in PLS.

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The Use of Virtual Reality in Teaching Diagnostic Reasoning to Advance Practice Registered Nurse Students

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Conflict of Interest Statement

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Introduction

Advance practice registered nurse (APRN) students have many challenges to navigate in their role transition. One critical difference between a registered nurse (RN) and APRN education is the National Organization of Nurse Practitioner Faculties' (NONPF's) core competency of diagnostic reasoning (Smith et al., 2022). Clinical reasoning uses knowledge and experience to think critically through a clinical situation. In comparison, diagnostic reasoning requires developing a leading hypothesis, formulating a list of differential diagnoses, then implementing a plan of care (*Nurse Practitioner Role Competences (2022),* 2022; Smith et al., 2022).

Virtual reality (VR) software has been incorporated to develop clinical reasoning skills in undergraduate and postgraduate nursing students. VR has shown to enhance knowledge application and clinical performance with a significant improvement in the development of clinical reasoning skills, especially since the COVID-19 pandemic. However, there is little information in the literature about the use of VR in the transition between using clinical reasoning as an RN and using diagnostic reasoning as an APRN, leading to the exploration of using VR in an Adult-Gerontology Acute Care Nurse Practitioner (AGACNP) program.

Incorporating various teaching strategies provides options for APRN students to focus on what enhances their learning while allowing educators to maximize the students' potential to meet competencies. The visual, auditory, reading/writing, and kinesthetic (VARK) learning style approach engages multiple senses, creating a diverse learning style and experience (Prithishkumar & Michael, 2014). A blended learning format was created using the VARK learning style by adding VR to the existing didactic and hands-on procedural skills.

Methods

The incorporation of the VR software into the graduate nursing program was piloted within the AGACNP curriculum. Twelve students could simultaneously complete their individual VR patient case scenarios in the same room. The students act as the primary provider who can converse with and evaluate the patient, interpret clinical findings including laboratory and diagnostic results, and interact with a nurse. The software does not identify abnormal findings such as infiltrates on a chest radiograph. This gives the student an opportunity to practice identifying abnormal findings and using diagnostic reasoning to care for each patient. The VR patient case scenario is timed to last a maximum of 15 minutes. If students do not delegate tasks to the nurse, they run out of time, thus learning the importance of task delegation and time management in an emergent situation as a provider. The students were able to repeat the case until they achieved satisfactory results.

Following the completion of the scenario, there was an opportunity for self-debriefing by providing the student guided debriefing questions and individual performance data. The diagnosis, case summary, clinical findings, and expected learner actions are displayed, followed by critical aspects of care that went well and areas for improvement. Each action is time-stamped and contains a rationale, allowing the student to review and reflect on their performance before repeating the scenario. The software allows the faculty to review data and track improvement over time for an individual student or the entire class. Multiple VR acute care provider scenarios can be selected by the faculty that are preloaded for the students to participate. The students are provided a link and can sign up when convenient for them to be on campus to complete their VR experience in the VR lab. An unexpected benefit is the time and resource allocation because faculty do not need to be present to facilitate these sessions.

The curriculum was developed to prepare learners to demonstrate the advanced decision-making needed in acute clinical situations while providing diverse skills acquisition with the VARK learning-style approach (Prithishkumar & Michael, 2014). Using this design, the AGACNP student can practice diagnostic reasoning to formulate actual and differential diagnoses while making independent treatment decisions. The student can delegate tasks to bedside nurses. Visual and auditory learning was stimulated by including a didactic and hands-on procedure practice, whereas kinesthetic learning was encouraged by participating in the chosen VR patient case scenario.

The topic of spontaneous pneumothorax was chosen, and the didactic portion was delivered with an in-person lecture covering the acute management of pulmonary conditions. In preparation for the hands-on skills practice of chest thoracostomy, students were given access to procedural videos. Procedure indications and step-by-step techniques were covered during the pre-briefing session. Students were paired in groups of 2 or 3 to perform the thoracostomy procedure independently. Procedural technique, potential complications, and appropriate aftercare management were discussed during a post-debrief session.

The VR scenario followed promoting kinesthetic learning through movement and direct application of their acquired skills. The students were unaware of the scenario before the exercise to simulate a real-life clinical situation. In this scenario, a 77-year-old male patient who presented with the chief complaint of shortness of breath. The students could practice prompt recognition and proper intervention of a pneumothorax to prevent clinical deterioration. To meet the NONPF core competency of diagnostic reasoning, the student must draw upon previous knowledge, including history taking and physical assessment, to conclude the actual diagnosis of a pneumothorax while investigating and ruling out other differential diagnoses (*Nurse Practitioner Role Competences (2022)*, 2022). In addition, students had to formulate a plan of care, prioritize, and delegate tasks to perform tube thoracostomy promptly.

Results

After piloting the VR software, faculty created a Likert scale survey of 6 questions to understand what students thought about the VR scenario and whether it enhanced their understanding of the acute management of the primary diagnosis. Nearly all responses were overwhelmingly positive, with most students responding in the "strongly agree" category when asked whether the VR scenario solidified their knowledge of how to manage a spontaneous pneumothorax and increased enthusiasm in participating in future VR patient case scenarios. The students were asked about any physical side effects of symptoms such as headaches, dizziness, nausea, or vomiting. Primarily, mild headaches were reported, followed closely by dizziness (Oh & Son, 2022). None of the learners commented on these symptoms in the open-ended responses, although a student verbally shared that she was prone to motion sickness but experienced no symptoms. In conversation in the VR lab, one student expressed that he only had clear vision in one eye, had difficulty with video games, and was hesitant, yet was amazed that he could witness the full scope of the VR scenario. Of the 26 students, only one noted a negative response, mainly centered around the learner's inability to become familiar with the VR system in the allotted time. The plan to mitigate this is to provide a video tutorial covering the function of the VR system prior to the student's participation.

Discussion

One of the challenges in transitioning from an RN to an APRN is the ability to interpret diagnostic data, develop a hypothesis, and formulate a list of differential diagnoses (Smith et al., 2022). VR may help cultivate diagnostic reasoning in APRN education, providing scenarios for students to act as the provider and delegate tasks. The faculty concluded that the positives of VR were the ability of the students to self-schedule, limited faculty facilitation during scenario performance, and an additional tool to evaluate independent clinical performance. The students' enthusiasm for other opportunities to participate in VR enhanced our goal to incorporate VR throughout our AGACNP program.

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Elevating Healthcare Education Through Strategic Simulation Management

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Brief Description

Simulation isn't just a teaching tool; it's a catalyst for revolutionizing healthcare education. Achieving lasting impact requires more than great technology or clever scenarios. Strategic simulation management ties everything together: from curricular design to faculty development, to creating transformative learning experiences that prepare students for real-world challenges.

Building on the Best: Practice Standards as a Foundation

True excellence in simulation stems from five best practice pillars:

- Simulation Design: Clear, targeted learning outcomes that mirror clinical demands.
- Facilitation: Skilled guidance that turns participation into reflection into growth.
- Debriefing: Safe spaces for learners to unpack decisions and deepen understanding.
- Evaluation: Meaningful feedback loops that drive program improvement.
- Professional Integrity: Upholding ethics, learner safety, and inclusivity at every turn.

These elements, informed by organizations like INACSL and the NLN, serve as the anchor points for all simulation initiatives. Strategic simulation management is essential for advancing healthcare education. It entails designing, implementing, and evaluating simulation-based learning experiences. Key steps include establishing policies aligned with best practices, providing regular faculty training, and ensuring sufficient financial, technological, and human resources. Continuous improvement through evaluation and feedback, along with collaboration across institutions to share innovations, enhances simulation quality and outcomes. Adhering to these standards, healthcare professionals are more effective and ensure consistent, high-quality education.

Smarter Curriculum Integration

Despite the benefits, there are common challenges to integrating simulation into the curriculum. Resistance to change from faculty and students, as well as limited resources and funding, are typical obstacles. To overcome these challenges, it is important to provide evidence-based benefits of simulation to stakeholders, demonstrating its positive impact on learning outcomes. Strategic curriculum mapping ensures simulation isn't an add on; it becomes a core learning method. Integrating simulation effectively into curricula starts with asking the right questions:

- Where are the gaps? Conduct needs assessments to find missing links in clinical readiness.
- How do we align? Map simulations directly to course objectives, competencies, and accreditation needs.
- How do we minimize redundancy? Layer simulation experiences thoughtfully across programs for maximum impact.

Implementation: Strategy in Action

Effective simulation integration doesn't happen by chance. Key steps include:

- Early Engagement: Bring simulation planning into curriculum discussions from the start.
- Faculty Development: Invest in training to boost confidence and creativity in facilitation and debriefing.
- Technology Planning: Match tools to educational goals. Don't let the "shiny object" syndrome dictate your choices.
- Active Participation: Ensuring that learners are active participants in the simulation experience rather than passive recipients involves several techniques aimed at fostering engagement and maximizing learning outcomes.

Feedback Drives Growth

Transparency builds trust, drives improvement, and strengthens your case for ongoing support. Simulation programs thrive on transparent, ongoing evaluation:

- Learner Feedback: Use evaluations, self-reflections, and debrief notes to track engagement and growth.
- Program Reviews: Regularly assess your simulation program against goals and adjust based on what's working and what isn't.

Challenges and Smart Solutions

No simulation program is immune to roadblocks. Strategic simulation management means thinking proactively about obstacles and planning for success (Table 1).

Table 1

Challenges and Smart Strategies

Challenge	Smart Strategy
Faculty resistance	Showcase evidence-based outcomes and offer peer mentorship.
Resource constraints	Pursue grants, partnerships, and cross-disciplinary sharing.
Curriculum overload	Prioritize essential simulations linked to competencies.

Meeting Stakeholder Needs

Strategic simulation management addresses the diverse needs of key stakeholders in healthcare education and meets the evolving demands of healthcare education and practice:

- Learners: Ensure realistic, challenging scenarios aligned with learning objectives, providing hands-on practice and timely, constructive feedback to enhance engagement, satisfaction and outcomes.

- Faculty: Offers structured environments, training, resources, and collaborative opportunities to improve teaching effectiveness and share best practices.
- Clinical Partners: Aligns simulation training with real-world standards, preparing graduates for industry demands while fostering joint research and development opportunities.
- Administrators and Policymakers: Demonstrates improved outcomes and clinical readiness to secure support and funding for continuous innovation and improvement.
- Patients and Community: Produces competent professionals who deliver high-quality care, benefiting patient outcomes and community well-being.

Final Thoughts

Strategic simulation management elevates healthcare education beyond checklists and scenarios. It's about intentionally weaving simulation into the fabric of learning, ensuring the students graduate with the competence, confidence, and collaborative skills they need to thrive in healthcare's complex world. Simulation isn't just part of education's future. It is the future.

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