Validation of the Intu-VR-Vention Program for Enhancing Medical Training Through Virtual Reality (VR) Storyboard Integration for Intubation

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VALIDATION OF THE INTU-VR-VENTION PROGRAM FOR ENHANCING MEDICAL TRAINING THROUGH VIRTUAL REALITY (VR) STORYBOARD INTEGRATION FOR INTUBATION

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ABSTRACT

This study introduces a new approach to enhance intubation medical training by developing an immersive Virtual Reality (VR) storyboard. Focused on practicality, our research aims to enhance medical education by leveraging the impact of VR technology. The hypothesized benefits include heightened trainee engagement, improved procedural knowledge retention, and enhanced critical decision-making skills. The VR storyboard comprises ten scenes, each representing a key step in the intubation procedure, aligning with recent developments and incorporating real-life complexities.

Developed collaboratively with board-certified physicians, medical students, and software programmers, our methodology integrates practice-based guidelines and fosters interdisciplinary collaboration. The scenes, spanning from patient interaction to handover to the surgical team, create an authentic yet simulated learning environment. Preliminary results from comprehensive focus group assessments, combining quantitative metrics and qualitative insights, demonstrate positive impacts on trainee engagement, procedural knowledge retention, and critical decision-making skills.

In summary, this systematic and transformative approach to intubation training offers a tailored learning experience. The VR storyboard method holds promise for reshaping medical training beyond intubation education, marking a significant advancement in immersive educational technology.

Keywords: Virtual Reality, Intubation Training, Medical Education, Immersive Learning, Storyboard Integration, Interdisciplinary Collaboration, Educational Technology, Focus Group Assessment, Medical Simulation, Procedural Knowledge, Critical Decision-Making, Healthcare Training

1. INTRODUCTION

Proper management of the airway is a fundamental skill crucial for both hospital personnel and rescue services, as emphasized in literature [1]. It stands as a primary consideration in the care of critically ill patients [2]. The umbrella of airway management encompasses a defined set of guidelines and clinical procedures aimed at preserving or reinstating the uninterrupted flow of air to and from the lungs [2]. Among these techniques, endotracheal intubation holds prominence as a widely employed method. This procedure involves the use of a laryngoscope to visualize the patient's vocal cords, allowing the insertion of an endotracheal tube into the trachea and facilitating optimal lung ventilation [2].

Conventional medical education adopts a didactic approach, often posing challenges in the acquisition of procedural skills, particularly for adult learners in medicine, as evidenced by existing literature [3]. Recognizing this limitation, a 2002 working group comprising experts concluded that simulation-based education stands out as an optimal modality for effective learning [3]. Nevertheless, traditional manikin-based simulations exhibit drawbacks, such as a lack of realism, demanding extensive setup, the need for dedicated staff, and limitations on the number of learners accessing the simulation center simultaneously [4]. To address these limitations, computer-based technologies have rapidly evolved, with virtual reality (VR) emerging as a transformative tool in various domains of medical education, encompassing surgical training, trauma decision-making skills, and cardiopulmonary resuscitation training [5]. VR, offering a realistic, immersive, and on-demand experience, has become a pivotal component in modern medical education methodologies [5].

This study aims to revolutionize intubation medical training by introducing an innovative approach centered around the development of an immersive VR storyboard. Emphasizing practicality, our research underscores the transformative potential of this storyboard-based method in the realm of medical education. We hypothesize that the implementation of this storyboard approach will not only reshape the landscape of intubation training but will also guide the creation of a VR platform that significantly enhances key facets of medical learning. These facets include heightened trainee engagement,

improved procedural knowledge retention, and augmented critical decision-making skills. The overarching goal is to transcend traditional teaching methods and provide a comprehensive and effective learning experience.

Our storyboard-based methodology is meticulously designed to transform the intubation procedure into a dynamic and narrative-driven VR experience, aligning closely with clinical practice guidelines. Drawing from authoritative bodies such as the American Society of Anesthesiologists (ASA), American Association for Respiratory Care (AARC), and medical education literature, our methodology ensures not only procedural accuracy but also educational efficacy. The collaborative synergy within our team, comprised of board-certified physicians, medical students, VR developers, and research scientists, ensures a systematic approach that integrates medical expertise, educational insights, and technological proficiency.

The storyboard consists of 10 scenes, spanning from initial patient interaction to handover to the surgical team, which collectively contribute to the creation of an authentic yet simulated learning environment. By strategically designing 10 scenes, each meticulously representing a key step in the intubation procedure, we seek to bridge the gap between theoretical knowledge and practical application. Developed in accordance with practice guidelines and reflective of real-life complexities, these scenes mark milestones in our iterative development process. These scenes, far from being mere simulations, align with recent developments and present a diverse array of scenarios reflective of real-life complexities.

To comprehensively assess the efficacy of our development and training method, we conduct focus group assessments. These assessments cover a spectrum of quantitative metrics, including trainee performance metrics, engagement levels, and knowledge retention rates, along with qualitative insights gathered through structured interviews. This dual-pronged approach enables a thorough exploration of perceptions, preferences, and potential areas for improvement. The results emanating from our preliminary assessments offer a glimpse into the positive impact on trainee engagement, procedural knowledge retention, and critical decision-making skills. The integration of VR elevates scene realism and fosters a dynamic and interactive learning environment.

2. MATERIALS AND METHODS

This section outlines the materials, procedures, and methodologies employed in the development and evaluation of the VR storyboard for intubation training.

2.1 Development of the VR Storyboard

The collaborative development involved a multidisciplinary team, including board-certified physicians, medical students, and software programmers. The process focused on creating a comprehensive and effective learning tool for intubation training. The ten scenes depicting key steps in the intubation procedure (see Figure 1 for examples) were designed in

alignment with recent developments and real-life complexities. Practice-based guidelines from reputable medical organizations, such as the ASA and the AARC, served as the foundation for accurate scene representation. The development process followed an iterative approach, incorporating feedback from the collaborative team to continuously refine each scene.

2.2 Focus Group Assessments

To evaluate the effectiveness of the VR storyboard, comprehensive focus group assessments were conducted, encompassing both quantitative metrics and qualitative insights. Ten medical students currently enrolled at the University of Nebraska Medical Center College of Medicine participated in comprehensive focus group assessments. The participants provided informed consent before engaging in the assessments. They offered quantitative ratings on aspects like realism, engagement, and information retention on a scale from 1 to 5. Structured surveys gathered qualitative feedback, encouraging participants to provide detailed insights, make suggestions for improvement, and highlight positive aspects.

2.3 Data Analysis

Quantitative data from the ten medical students were analyzed using standard descriptive statistical methods to derive average ratings and identify trends. Qualitative feedback from each participant was systematically categorized to extract common themes and unique insights. The synthesis of both quantitative and qualitative data, specifically from the study participants, forms the basis for drawing conclusions on the impact and effectiveness of the VR storyboard in intubation training.

3. RESULTS AND DISCUSSION

3.1 Results

The focus group evaluations yielded comprehensive insights into the VR storyboard's effectiveness for intubation training, offering a nuanced understanding of participant perceptions across various simulation scenes.

Scene-Specific Evaluations:

1. **Nurse's Role:** Participants lauded the nurse's "seamless introduction," emphasizing its "clear and informative" nature, contributing significantly to the "realistic atmosphere" of the simulation. On a scale from 1 to 5, where 1 is 'not at all' and 5 is 'to a very high extent,' the interaction with the nurse received an average rating of 4.8, showcasing its integral role in creating a realistic and immersive experience.
2. **Crash Cart Inventory:** Participants expressed confidence in the virtual environment's portrayal of checking the crash cart, citing the effectiveness of the "checklist" and "early hands-on practice" with items. The average rating for the effectiveness of the scene in

conveying information about checking for the necessary tools was 4.4, with suggestions for improvement, including a "brief tutorial on tool functionality" and "clearer tool labels."

3. **Patient Condition Assessment:** The scene received an average rating of 4.4 for providing an appropriate amount of information for checking the patient's condition. Positive feedback highlighted the "appropriate amount of information," "clear vitals," and engaging presentation. Suggestions for improvement included providing more context on abnormalities, incorporating multiple-choice questions, and adding a problem list.

4. **Oxygenation Scene:** Participants rated the scene 4.4 for effectively conveying the importance and techniques of optimizing oxygen saturation. Positive feedback highlighted that the information was "informative," "clear," and "engaging" with interactive elements. However, one participant suggested that the scene lacked depth in explaining the importance of optimizing oxygen saturation, citing a need for a sense of urgency.

5. **Clearing of Oral Cavity:** The scene received an average rating of 4.6 for the level of detail and accuracy in the steps involved in clearing the patient's mouth. Positive feedback emphasized the accuracy of details, realistic tools, and a well-organized sequence of actions. Some participants suggested improvements, such as providing more details on the types of obstructions.

6. **Endotracheal Tube Preparation:** Participants gave an average rating of 4.6 for the clarity of instructions and actions required to prepare the tube. Positive feedback highlighted that the instructions were "clear" and "well-explained," guiding them effectively through the process. Some suggested improvements, particularly during tube sizing, were to enhance overall clarity and provide additional feedback.

7. **Laryngoscope Insertion:** The portrayal of inserting the laryngoscope received a perfect average rating of 5, with participants overwhelmingly praising the realism and effectiveness of the scene. Positive feedback included comments on the "realistic" movement of the head and neck, spot-on visuals, and authentic reactions of the body.

8. **Addressing Airway Obstructions:** Participants rated the virtual environment's performance in highlighting a need to address airway obstructions at 4.8. Some suggested improvements in accuracy, especially in detecting subtle obstructions, to make the simulation more effective.

9. **Initial Intubation Guidance:** Participants provided an average rating of 4.8 for the guidance during the initial intubation, generally acknowledging the effectiveness of the simulation in guiding them through the process. Some suggested that a bit more detailed feedback, especially in confirming proper placement, could enhance the overall experience.

10. **Decision-Making Scenario:** The decision-making scenario received an average rating of 4, with participants appreciating the introduction of critical decision points.

Some suggested that there is room for improvement in complexity to truly mimic the complexities encountered in real scenarios.

11. **Overall Informativeness:** Participants gave an average rating of 5 for the overall informativeness of the VR storyboard for intubation. The general sentiment was overwhelmingly positive, with participants describing the simulation as engaging, clear, and providing valuable educational content.
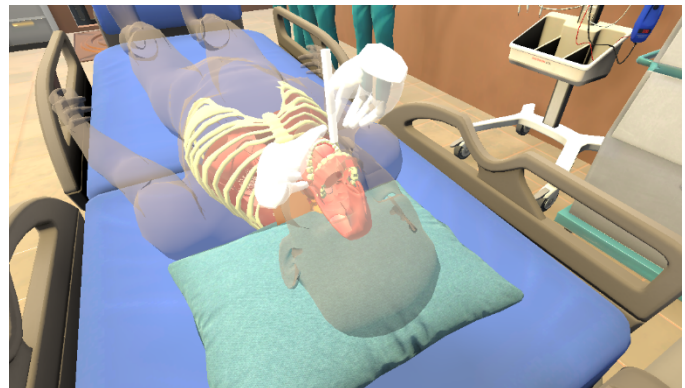

FIGURE 1: EXAMPLES OF VR SCENES. SCENE 2: CHECKING TOOLS. THE STUDENT REFERENCES A CHECKLIST TO SELECT APPROPRIATE TOOLS FROM THE CRASH CART. SCENE 3: CHECKING PATIENT. ONE COMPONENT OF CHECKING THE PATIENT IS TO SIZE THE ENDOTRACHEAL TUBE AND LARYNGOSCOPE APPROPRIATELY.

3.2 Discussion

This study demonstrates a transformative approach to improve intubation medical training by employing an immersive VR storyboard. Our focus on practicality underscores the transformative impact of VR technology on medical education. The hypothesized benefits, including heightened trainee engagement, improved procedural knowledge retention, and enhanced critical decision-making skills, are substantiated through comprehensive evaluations. The collaborative development process, involving board-certified physicians, medical students, and software programmers, integrates practice-based guidelines and fosters interdisciplinary collaboration. The 10 scenes, representing key steps in the intubation procedure, align with recent developments and exhibit

real-life complexities, validating the efficacy of our systematic approach.

Our storyboard-based methodology, shaped by insights from authoritative sources such as the ASA and the AARC, successfully transforms the intubation procedure into a narrative-driven VR experience aligned with clinical practice guidelines. This approach ensures procedural accuracy and educational efficacy, addressing our primary objectives.

Preliminary results validate the transformative potential of the VR storyboard, showcasing a positive impact on trainee engagement, procedural knowledge retention, and critical decision-making skills. Scene-specific evaluations provide nuanced insights into the effectiveness of the storyboard. The positive reception of the nurse's role, crash cart inventory, patient condition assessment, oxygenation scene, clearing of the oral cavity, endotracheal tube preparation, laryngoscope insertion, addressing airway obstructions, initial intubation guidance, and decision-making scenario collectively reinforces the achievement of our goals. Acknowledging the realism and effectiveness of the laryngoscope insertion scene, participant feedback aligns with our objectives of enhancing critical decision-making skills. Evaluations of instructions for preparing the endotracheal tube affirm the clarity and effectiveness goals.

The collaborative development of the VR storyboard substantiates our hypothesis, confirming its positive impact on trainee engagement, procedural knowledge retention, and critical decision-making skills. The iterative process, guided by objectives, yields a dynamic and interactive learning environment. Future enhancements, informed by participant feedback, will further solidify the transformative potential of the VR storyboard, positioning it as a cornerstone in reshaping the landscape of medical training beyond intubation education.

4. CONCLUSION

In this paper, we have outlined a VR storyboard approach to intubation training and validated the developed simulation with a user study. The study's systematic approach, guided by qualitative insights and quantitative metrics, underscores the positive impact on trainee engagement, procedural knowledge retention, and critical decision-making skills. The VR storyboard emerges as an innovative and transformative platform, marking a significant milestone in reshaping the landscape of medical training beyond the scope of intubation education.

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APPENDIX: FOCUS GROUP QUESTIONS

1. General: To what extent did the interaction with the nurse contribute to creating a realistic and immersive experience?
2. General: On a scale from 1 to 5, where 1 is 'not at all' and 5 is 'to a very high extent,' how much did the interaction with the nurse contribute to creating a realistic and immersive experience?
3. Crash Cart: How confident do you feel in the virtual environment's portrayal of the process of checking for necessary tools on the crash cart, with 1 being not confident at all and 5 being highly confident?
4. Crash Cart: Provide qualitative feedback on the effectiveness of the scene in conveying information about checking for the necessary tools.
5. Patient Assessment: On a scale from 1-5, to what extent does the scene provide an appropriate amount of information for checking the patient's condition? (Consider factors such as clarity, comprehensiveness, and relevance in your rating.)
6. Patient Assessment: Provide qualitative feedback on the effectiveness of the scene in conveying information about checking the patient's condition.
7. Oxygenate Scene: To what extent did the virtual simulation effectively convey the importance and techniques of optimizing oxygen saturation, with 1 being ineffective and 5 being very effective?
8. Oxygenate Scene: Share qualitative feedback on the clarity and impact of the information provided during the oxygenation scene.
9. Clear Oral Cavity: Rate the level of detail and accuracy in the steps involved in cleaning the patient's mouth of secretions or foreign bodies, with 1 being not detailed and accurate and 5 being highly detailed and accurate.
10. Clear Oral Cavity: Offer qualitative feedback on the realism and effectiveness of the steps in cleaning the patient's mouth.
11. Prepare ET Tube: Were the instructions and actions required to prepare the tube clearly communicated, with 1 being unclear and 5 being very clear?

12. Prepare ET Tube: Provide qualitative feedback on the overall clarity and effectiveness of the instructions for preparing the endotracheal tube.

13. Place Laryngoscope Scene: How realistic was the portrayal of inserting the laryngoscope into the patient's mouth for visualization, with 1 being not realistic and 5 being very realistic.

14. Place Laryngoscope Scene: Share qualitative feedback on the realism and effectiveness of the laryngoscope insertion scene.

15. Check for Airway Obstruction: On a scale from 1 to 5, rate the virtual environment's performance in highlighting a need to address airway obstructions, with 1 being not effective and 5 being highly effective.

16. Check for Airway Obstruction: Provide qualitative feedback on the virtual environment's performance in addressing and airway obstructions.

17. Initial Intubation: How well did the virtual simulation guide you through the process of introducing the endotracheal tube into the airway and confirming its proper placement, with 1 being not effective and 5 being highly effective.

18. Initial Intubation: Offer qualitative feedback on the guidance provided during the initial intubation, including any feedback received.

19. Decision-making scenario: On a scale from 1-5, how well did the virtual simulation incorporate a realistic decision-making scenario based on the success or failure of the initial intubation attempt?

20. Overall: Share qualitative feedback on the effectiveness of the decision-making scenario and its impact on the overall experience.

21. Overall: On a scale from 1-5 with 1 being not effective and 5 being most effective, how informative was the VR simulation for intubation?

22. Overall: Offer qualitative feedback on the overall informativeness of the VR simulation, considering factors such as engagement, clarity, and educational value.