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A Pilot Non-Inferiority Study of Effectiveness of Face-to-Face Versus Virtual Reality on Undergraduate Physiotherapy Students' Confidence and Self-Efficacy With Tracheostomy Skills

TRACH-VR

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ABSTRACT

Introduction: The number of tracheostomies performed annually in resource-rich countries is estimated at 250 000. Without adequate training, staff caring for patients with tracheostomies can feel underprepared, lacking both competence and confidence. Training is essential to support both patients and health care staff but is often sporadic and nonstandardized and rarely includes those at preregistration level. The purpose of this study was to explore the potential for delivering a newly developed virtual reality (VR)-based tracheostomy education with traditional face-to-face teaching to undergraduate physiotherapy students.

Methods: A pilot non-inferiority study with randomization of interventions comparing traditional face-to-face teaching with a VR-based tracheostomy education program. The content of both training approaches was standardized and based on local existing education content. The primary outcome was changes in knowledge, confidence, and self-efficacy.

Results: Thirty-nine undergraduate physiotherapy students were recruited, with 18 (47.4%) receiving tracheostomy training via VR. All participants demonstrated significant improvements in knowledge, confidence, and self-efficacy when comparing pre- and posttraining. A greater change was observed in those receiving VR-based training although not statistically significant. Additional results showed a reduction in facilitator activity during the VR sessions but a requirement for technical support.

Conclusions: VR-based tracheostomy training is equivocal to face-to-face training for increasing undergraduate students' knowledge, self-efficacy, and confidence. There may be additional benefits of VR-based training including reduced facilitator training time, but these need to be further assessed considering the technical support required for immersive technology.

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INTRODUCTION

The number of tracheostomies performed annually in resource-rich countries is estimated at 250 000,[1] with approximately 15 000 completed annually within the United Kingdom.[2] There are a variety of reasons that people may need a tracheostomy including prolonged mechanical ventilation, airway obstruction, or in conjunction with head and neck surgery.[3] Following the insertion

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of the tracheostomy tube, people will be cared for in a variety of environments, which may include intensive care units, acute wards, rehabilitation environments, and in the community.[4]

Very conservative estimations suggest that at least 1 in 5 people with a tracheostomy will have an adverse event within their acute admission, with the severity of events ranging from a requirement for additional medical input to death.[1]

The delivery of standardized education regarding tracheostomy care and emergency care has been shown to decrease the number and severity of adverse events.[2,5,6] Furthermore, health care staff who have received tracheostomy training feel more confident and competent in caring for patients with tracheostomies.[1,2]

Traditionally, the mode of teaching delivery for tracheostomy training is multi-professional and delivered face-to-face. However, this frequently lacks standardization[5] and is reliant on the availability of faculty members to conduct the session alongside the ability to release clinical staff to attend. Exposure to tracheostomy training in undergraduate health care programs is very limited, with reliance on work-based learning while on clinical placement. For many undergraduate health care students, they may not encounter patients with tracheostomies until after qualification.

Virtual reality has already been shown to be an effective tool for the delivery of learning and education for patients and health care staff, across a wide range of clinical specialties.[7-10] The use of virtual reality (VR) enables better experimental, collaborative, and interprofessional learning.[11] This is particularly true for clinical situations which are high risk and where learner exposure is very limited. Furthermore, VR education has the potential benefits of allowing remote access to training, reduced requirements for access to training and simulation rooms, and increased learner flexibility to access training.[12] Similarly, this more flexible learning approach, allowing practice on demand, may reduce the burden of training during clinical shifts.[13] Within tracheostomy care, VR has previously been shown to have the potential to be equivocal to traditional face-to-face teaching within multi-professional cohorts of participants. Authors have reported that VR enhances trainees' self-efficacy and satisfaction,[14] with the additional benefits of being able to be delivered remotely, reduced faculty requirements, and increased flexibility for participants.[11]

However, these previous studies have been completed with participants working within the health service with some experience in caring for patients with tracheostomies. To date, no research has explored the potential for VR-based tracheostomy training in those receiving undergraduate training, with only limited clinical experience. Demonstrating the potential for VR to deliver education and simulation-based learning at an undergraduate level may help to overcome the challenges facing health care education providers, better preparing "tomorrows clinicians" for clinical practice.

Based on the above, the aim of this study is to determine whether VR tracheostomy training is at least equivocal to traditional face-to-face teaching for physiotherapy students within undergraduate training.

METHODS

Trial Design

A pilot non-inferiority study with randomization of interventions comparing traditional face-to-face teaching with a VR-based tracheostomy education program.

Study Setting

This study was conducted within a single higher education institute (HEI) in Wales providing a Bachelor of Science (BSc) Hons Physiotherapy Program. Tracheostomy training was provided by members of the research team who are primarily employed by the partnering National Health Service (NHS) University Health Board but hold honorary contracts with the HEI. All training was completed on-site on the HEI campus.

Participants

A convenience sampling strategy was used to recruit level 5 and 6 undergraduate physiotherapy students from within the host HEI, who were undertaking clinical placements within the partnering NHS organization. Within the HEI, students start clinical placements in level 5, and therefore, recruitment prior to this stage was deemed not appropriate. Participants were recruited via advertisement of the study on the virtual learning environment, announcement at the start of face-to-face teaching sessions and at the beginning of the clinical placement within the partnering NHS organization. Participants were recruited over a 9-month period, with all participants given a unique study ID so that responses were anonymized. Participants were deemed eligible for inclusion based on them being undergraduate BSc (Hons) physiotherapy students (level 5 and 6) and were able to provide informed consent.

Participants were excluded if they had any contraindications to the use of VR (eg, diagnosis of epilepsy; seizure disorder; other neurological diseases; self-reported migraine; flashing light or motion sensitivity; motion sickness; claustrophobia; severe hearing or visual impairment; vestibular system dysfunction; and injury to the eyes, face or neck), had previous experience of caring for patients with a tracheostomy in situ, or had received previous face-to-face or VR tracheostomy training (eg, tracheostomy training provided during previous clinical placements).

Interventions

Face-to-Face Training

Comprised 2-hours of tracheostomy training completed by a qualified physiotherapist specializing in

tracheostomy care (who was also a member of the research team). The ratio of faculty to participants was a maximum of 1:10. The training protocol was standardized based on the National Tracheostomy Safety Programme and captured the key aspects of tracheostomy care and emergency management usually delivered by the partnering NHS organization. Training for tracheostomy care elements lasted for 75 minutes. For the emergency management simulation element, 3 participants will be directly involved (1 acting as first responder and 2 as helpers), with all remaining participants observing. All participants received a pre-brief and de-brief session lasting approximately 15 minutes each, with 15 minutes allocated to completion of the emergency scenario itself. The purpose of the pre-brief was to prepare the participants for the scenario and to plan roles within the simulation. The debrief provided an opportunity to reflect on participants' experience of the simulation (not the teaching method, eg, VR or face-to-face) and to consolidate any learning.

Virtual Reality-Based Training

VR-based training was delivered utilizing the Rescape VR tracheostomy platform, which was previously developed via an innovation grant project and led by the chief investigator.[15,16] The training consisted of a 2-hour VR session in which participants observed a series of 180-degree videos based on the key elements of tracheostomy training (as per Figure 1). This process lasted 60 minutes with regular short breaks from using VR. Following this process, all participants had the opportunity to practice the emergency management process within the VR platform lasting 15 minutes. This included an introduction to using VR and a chance to practice any techniques prior to participating in any scenario-based training. Following which, participants completed a VR tracheostomy emergency management scenario (15 minutes). As per the face-to-face training, the facilitator-to-participant ratio was 1:10, and participants received a pre-brief and debrief session of 15 minutes each as per the face-to-face group. The facilitator also provided technical support as required. Participants were able to have regular breaks from wearing the VR headsets, with each "mini session" of VR lasting no more than 10 minutes.

FIGURE 1. Virtual Reality (VR)-Based Tracheostomy Education. (A) Participant using VR. (B) Video-based VR content for tracheostomy emergency. (C) Changing tracheostomy inner tube in VR. (D) Multi-person VR tracheostomy emergency scenario.

Outcome Measures

The primary outcome measure was participants' knowledge, confidence, and self-efficacy in the completion of tracheostomy skills and emergency management (according to the National Tracheostomy Safety Programme algorithm) using a pre-designed questionnaire completed pre- and posttraining (Supplemental Digital Content 1-3, available at: http://links.lww.com/JACPT/A27).

Secondary outcome measures included instructor time (including time spent in direct teaching), requirement for additional technical support (VR element only), and average duration of tracheostomy training sessions vs expected duration.

Sample Size Calculation

Given the pilot nature of the study, no formal sample size calculation was completed. Traditionally tracheostomy training is delivered to groups of between 5 and 10 participants, allowing the delivery of both lecture-style and simulation-based training. Therefore, the sample size of 40 (20 per group) was chosen to reflect clinical practice. Due to access to VR headsets and space requirements, sessions were limited to a maximum of 10 participants.

Randomization

For convenience, teaching sessions rather than participants were randomized to either a VR or face-to-face training. Four sessions were planned for completion. Using the process of sealed envelopes, each session was randomized to either VR or face-to-face on a 1:1 ratio. Participants attending that session were not informed of which method of training would be received prior to consenting. Each session was planned for 10 participants.

Blinding

Due to the nature of the intervention, it was not possible to blind the participants as to which group, they had been randomized. On the completion of data collection and prior to analysis, all participants were independently assigned a unique identifier, and the intervention was

coded by an independent member. Analysis was then completed by the chief investigator (who was part of the teaching team) blinded to the intervention groups. This was unblinded once the analysis was complete.

DATA ANALYSIS

All questionnaire data were collected electronically using Microsoft Forms. Median and quartile ranges were used to describe the data. To compare the quantitative variables between the 2 study groups, and for pre- and posttraining comparison, nonparametric testing was used. All data analysis was performed using SPSS v27 software. The significance level was defined as $P < .05$.

Ethical Considerations

Ethical approval for the study was provided by the Cardiff University School of Healthcare Sciences (HCARE) Research Ethics Committee (REC992). There was no requirement for NHS Research Permissions or review by an NHS Research Ethics Committee (REC). All participants provided written informed consent and were free to withdraw at any point until completion of the tracheostomy training (face-to-face or VR).

RESULTS

Demographics

A total of 38 participants were recruited, with 1 participant excluded prior to consenting as meeting one of the exclusion criteria. Of these 38, 24 (63.1%) were level 5 students, with the remaining at level 6. Of the 38, 20 received face-to-face training, with 18 undergoing tracheostomy training via VR. Further demographic details are shown in Table 1. Four sessions were completed over a 9-month period between April and December 2023 (Figure 2).

Knowledge, Confidence, and Self-Efficacy

Pre-training scores for knowledge were similar across both groups, with those in the VR group having lower confidence and self-efficacy scores, although no statistical significance was noted ($P = .095$ and $P = .504$, respectively).

All outcome scores increased following the course ($P < .01$ for all outcomes). The scores for pre- and post-training scores for both interventions are shown in Table 2. Those within the VR group demonstrated greater improvement across all measures, with differences in pre- and post-scores of +5.0 ($P < .01$), +30.0 ($P < .01$), and +11.0 ($P < .01$) for knowledge, confidence, and self-efficacy, respectively. There was no statistical difference between the improvements seen for any outcomes between the face-to-face and VR groups (knowledge, $P = .228$; confidence, $P = .447$; and self-efficacy, $P = .358$).

Secondary Outcomes

Both the face-to-face and VR sessions were planned to take 2-hours to complete. Over the 4 sessions, the average session length was 115.5 minutes. Sessions completed in VR took slightly longer to complete (VR = 119.5 vs F2F = 111.5).

The time in which the facilitator was active during the session was much higher within the face-to-face sessions, with active involvement throughout the face-to-face session, as opposed to being active for an average of 37 minutes during the VR sessions.

The facilitator activity during the VR sessions was to provide an initial overview and instructions for the use of the VR headsets, followed by technical support as required. Over the 2 VR-based sessions, there were 33 occasions where technical support was required, at an average of 1.83 per participant. The most common reason for requiring technical support was accidental loading of already completed content (n = 14), disconnection from Wi-Fi (n = 11), and content not loading as expected (n = 4).

No participants reported any adverse events from either the face-to-face or VR-based training. Due to self-report cognitive fatigue, one participant required slightly longer rest periods between the use of the VR but was able to complete all training modules within the time allocated and reported no ongoing issues on completion of the training.

TABLE 1. Demographics of Participants Including Prior Clinical Experience

	Face-to-Face (n = 20)	Virtual Reality (n = 18)
Level 5 student (n, %)	12 (60.0%)	12 (66.6%)
Level 6 student (n, %)	8 (40.0%)	6 (33.3%)
Female (n, %)	13 (65.0%)	11 (61.1%)
Clinical placements completed, median (range)	4 (2-6)	4 (3-7)

DISCUSSION

In this pilot study involving undergraduate level 5 and 6 BSc Physiotherapy students, tracheostomy training delivered via VR was non-inferior to traditional face-to-face training. Both forms of methods of training resulted in significant improvements in participants' knowledge, confidence, and self-efficacy. Tracheostomy training delivered via VR was associated with reduced facilitator time. We need to highlight the novelty of the study. This is the first known study to explore the development of undergraduate physiotherapy students' knowledge and skills in tracheostomy care using VR. This will pave the

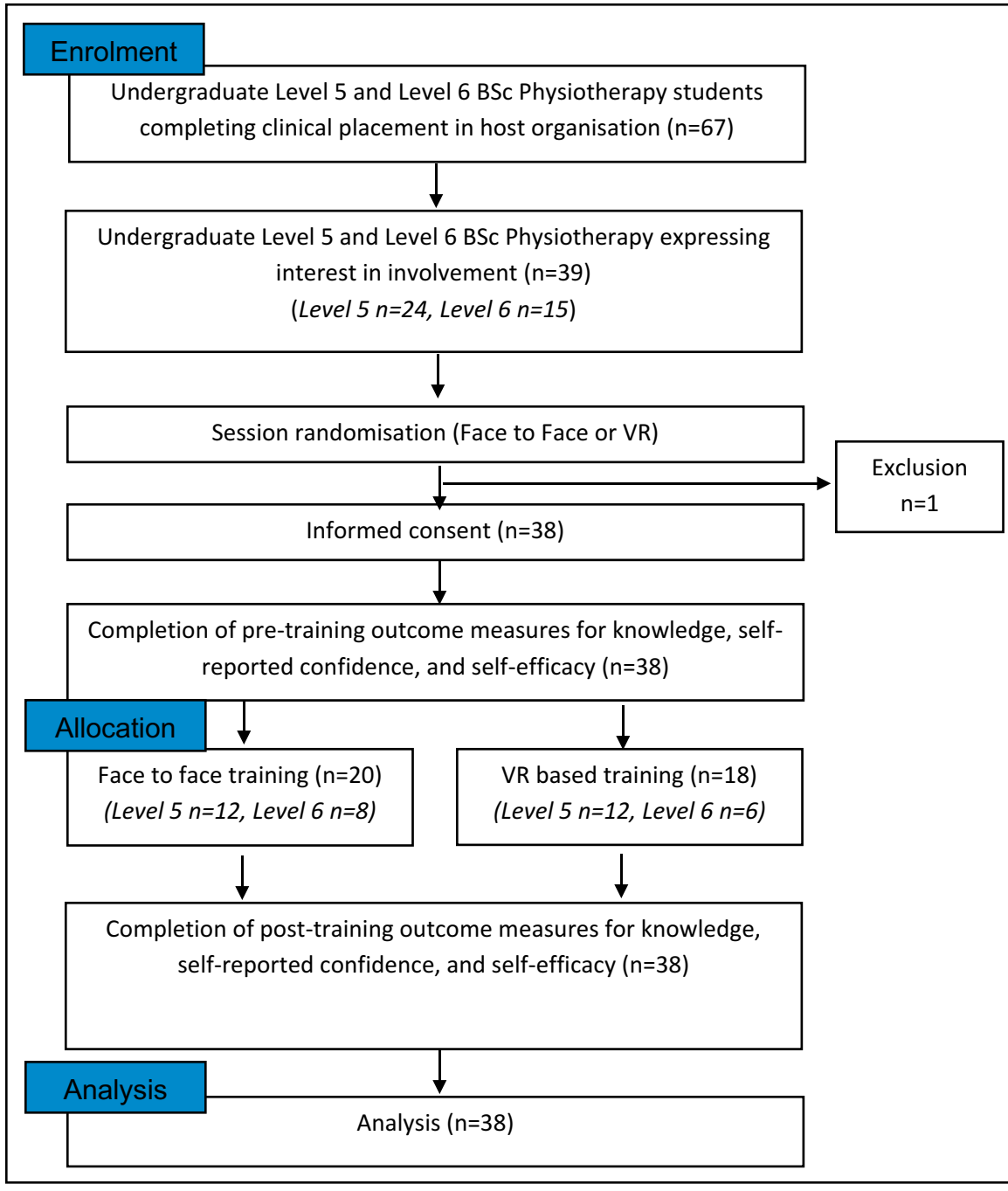

FIGURE 2. Consort Diagram for Participant Involvement and Randomization.

way for others who are considering using VR as a teaching/learning modality.

Our results align with those previously reported within the literature. Using the same Rescape VR-based system, VR has been shown to be equivocal to face-to-face teaching in registered health care professionals. Interestingly, as per our study, those receiving training via VR had lower baseline scores but showed greatest improvement over the duration of the training.[11] Similar findings have also been reported using alternative VR-based systems, with participants reporting higher levels of satisfaction and confidence compared to more traditional methods.[14]

Historically, a culture of learning and education for health care staff and those training to become health care professionals has been recognized with high

TABLE 2. Median Scores for Each Primary Outcome Measure for Face-to-face and Virtual Reality Groups

	Face-to-Face (n = 20			Virtual Reality (n = 18)		
Outcome	Pre	Post	Difference	Pre	Post	Difference
Knowledge	17.0 (16.0-19.75)	22.0 (21.0-23.0)	+4.0 (2.0-5.75)	17.0 (14.75-19.25)	22.5 (20.0-24.0)	+5.0 (3.0-7.25)
Confidence	36 (24.75-42.5)	62.5 (58.0-68.75)	+26.5 (20.0-36.0)	30.5 (21.75-36.75)	61.0 (59.0-66.25)	+30.0 (22.75-35.5)
Self-efficacy	15 (12.0-18.0)	24.0 (22.25-26.0)	+9.0 (7.0-11.75)	12 (10.0-14.25)	23.0 (22.0-24.25)	+11.0 (9.75-14.25)

importance.[17,18] However, the current challenges facing the NHS are impacting this, with the delivery of education often seen as burdensome both financially and for staff.[19]

Digital technology has the potential to overcome these educational challenges and support current and future health care professionals.[20] VR has immense potential, particularly in the delivery of education on low-frequency but high-consequence incidents, eg, an emergency scenario resulting from a blocked or displaced tracheostomy. Furthermore, VR education brings an experiential awareness of humanistic skills, such as effective interaction and communication between health and care staff to patients and service users. These contexts bridge the importance of human connectivity, a theme that cannot be underestimated when considering emerging technologies.[21]

However, we also recognize the potential barriers to using VR. In this pilot study, we reported 33 occasions in which technical support was required. Of these, many were accidental and avoidable, eg, participants incorrectly selecting content, but issues with Wi-Fi connectivity and failure to load content did occur. While this is manageable within a small group such as those in this study, attempting to use VR-based content with much larger participant groups would have increased challenge, increasing the numbers of facilitators required and placing additional demand on digital infrastructure. Additionally, the use of VR for simulation-based activity requires physical space. Participants need to be able to move to interact with the virtual world and therefore are at risk of harm if space is insufficient. These issues would be present in both HEIs and within clinical practice.

While the early signs for using VR are extremely positive, future research is clearly needed. A larger multicenter randomised controlled trial with other health care undergraduate students is recommended. Understanding the ideal ways to design, create, and deploy VR-based technologies will be key, especially how VR can be used in conjunction with other teaching methods. In our case, we focused on a low-frequency, high-risk scenario (a blocked tracheostomy tube). Future studies should also consider how VR can be used for higher frequency events with significant clinical impact, eg, falls prevention and pressure sore management, which would require "roll-out" across a potentially much larger workforce. Additionally, the value proposition of VR needs exploration. This should include the cost impacts to individuals, services, and environment in terms of time, carbon footprint, and long-lasting sustainability.

Limitations

We acknowledge that we did not meet our original recruitment target of 40 participants. This was due to unforeseen challenges in the ability to recruit undergraduate students while on clinical placements. Our provisional plan was for participants to undertake the training during available space within their academic program; however, this was deemed not possible. While we believe the impact of this change in recruitment approach was negligible as all were at similar levels of training and similar clinical experience, however, we recognize that this limited the population of undergraduate students with only 67 out of a possible cohort of 225 undergraduate students (all students at level 5 or level 6 within host HEI) given opportunity for inclusion. We also recognize that, in our recruitment process, we did not consider the specific learning requirements of the undergraduate students, those with additional learning needs, or those who may have difficulty with the duration of the training session. Further studies should take this into account and ensure parity between the groups prior to initiating training.

We chose to randomize by session rather than individuals. This was done for ease of recruitment timing and to ensure the availability of adequate participants for each session. To offset any bias caused, a session using VR and face-to-face was completed for both the level 5 and 6 undergraduate students.

In this study, VR has shown the potential to be noninferior to traditional face-to-face training and may indeed have some other additional benefits that were not measured. However, we also identified some challenges to the

delivery of VR-based education. Many of these are reflected in the secondary outcomes and include challenges with Wi-Fi and technology issues. We also note that the delivery of VR requires sufficient space to allow participants to move around, a degree of digital literacy, and the requirement for facilitation by an individual with appropriate technical and clinical knowledge and skills in the delivery of education via VR (eg, the ability to troubleshoot issues with the VR hardware, as well as provide required pre- and de-briefs within the scenario context). For the current study, we appreciate we had the benefit of facilitators that were expert practitioners in tracheostomy care and had significant knowledge of VR. We recognize that this may not be applicable with wider deployment or when providing training on multiple clinical scenarios via VR. This may then introduce a requirement for additional facilitator training or additional facilitator numbers per session to provide adequate support.

CONCLUSIONS

In a study of undergraduate physiotherapy students, VR-based tracheostomy training was as effective as traditional face-to-face teaching in terms of improvement in knowledge, self-reported confidence, and self-efficacy. VR-based training was also associated with reduced facilitator activity time; however, there is a requirement for support to overcome observed technical challenges including digital infrastructure. VR-based education clearly has the potential to increase access to learning opportunities within HEIs and across the health service, with the clear aim of improving the quality of care provided to those requiring healthcare service.

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