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Virtual reality simulation increases Chinese physicians' and lab technicians' familiarity and confidence regarding proper clinical wastes segregation/disposal: a 2-year pilot study

Szu-Hsien Wu,[1,2] Ying-Ying Yang [iD],[2,3] Chia-Chang Huang,[2,3] Chih-Wei Liu,[1,2] Ling-Yu Yang,[2,3] Chen-Huan Chen,[2,3] Shou-Yen Kao,[1] Fa-Yauh Lee[1]

ABSTRACT

Although they receive regular training, the survey we administered to our junior physicians and lab technicians revealed that they lack *familiarity* and *confidence* regarding the proper segregation/disposal of clinical wastes. In this pilot prospective study, carried out between September 2017 and September 2019, we developed a virtual reality (VR) simulation and integrated it into the steps of Gangen's training flow. Next, we analysed objective performance, recorded by the App in the VR system as well as the subjective self-assessments of 96 junior physicians and lab technicians after two practices of VR games. Before receiving training, lab technicians' self-assessed *familiarity* and *confidence* regarding proper clinical wastes segregation/disposal were higher than among physicians. Compared with the first VR game, we noted greater improvement in accuracy as well as a higher percentage of shortened time to complete 10 actions of segregation/disposal of VR clinical wastes, among junior physicians/male trainees, that of junior lab technicians/female trainees in the second VR game. Most of the trainees (81%–88%) reported that they found the VR game-based training to be *useful,* in contrast to poster-mass media-based training. Our initial positive results indicated the possibility of applying this VR game-based simulation system to regular institution-wide staff education in future.

INTRODUCTION

Improper clinical wastes management (CWM) carries a substantial risk to the hospital staff, patients, the community and public health as well as the risk of transmission of healthcare-associated infections. A meta-analysis showed that lack of awareness and motivation among healthcare staff is the main reason for the high proportion of improper CWM-related occupational hazards.[1 2] Failure to dispose of contaminated needles and syringes in the correct way causes serious threats through dangerous repackaging and recycling.[3] Hence, it is important for well-trained staffs to separate them at the location of they are used.

However, a systemic review revealed that healthcare professionals' *familiarity* and *confidence* regarding proper clinical wastes segregation/disposal are not enough.[4–6] Previous trainings for clinical wastes segregation/disposal are based on poster, power point presentation lecture and discussion.[7 8] The use of game design in non-game contexts has gained popularity by incorporating external rewards to encourage learning.[9] Through ongoing evaluation and recording, games make learning outcomes testable and accessible.[10] Virtual reality (VR) simulation and games make learning easy and fun by providing real-time human-system interaction. To boost the effectiveness of training and evaluation, we developed new VR simulation system by integration of elements of games (supervise and uncertainty) and VR (immersion and a sense of control).[11 12]

Objectives

We judged the effectiveness of this new simulation model through both objective and subjective evaluations of the performance of junior trainees' (physicians and lab technicians) in the VR system.

METHODS
Settings

We conducted this prospective and pretest/post-test study in a 2800-bed 6000-staff medical centre and teaching hospital in Taipei, Taiwan from September 2017 to September 2019.

Background for implementing the new simulation model

Usually, the *familiarity* and *confidence* for proper clinical waste segregation/disposal among junior physicians is introduced through printed hand-outs, PowerPoint presentation, posters or videos. In 2017, a regular survey randomly selected 45 post-trained junior physicians (n=26) and lab technicians (n=19); it demonstrated that they still lack *familiarity* (40% of very familiar, 18/45) ((1=not very familiar, 2=average, 3=very familiar) with the meanings of the colour coded bins used to collect clinical wastes as well as categories of clinical wastes) and *confidence* (49%, 22/45) (have *confidence* (yes/no) for proper clinical wastes segregation/disposal). Thus, through the *define*, *design* and *development* phases, the education commentate spent 2 years developing the VR game-based simulation system and Gagne's flow (online supplementary figure 1, figure 1A,B and online supplementary
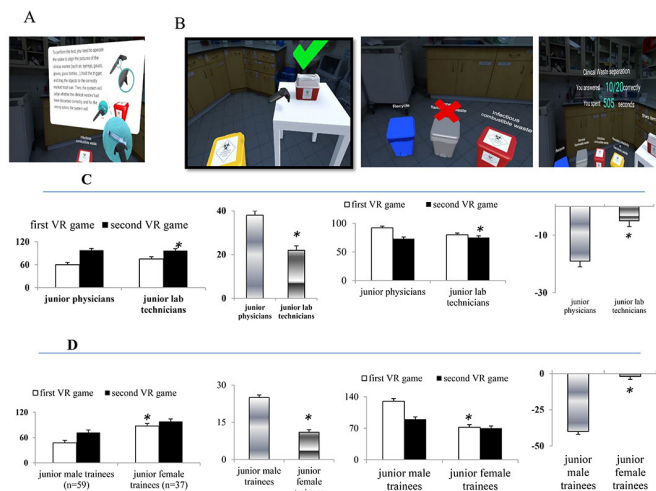
Figure 1 (A) Initial login page of the VR simulation system; (B) trainee picks up randomly appearing clinical wastes into proper bins and system response to each action. Accuracy (%) of VR games of clinical wastes segregation/disposal. Δ% of accuracy between first VR game and second VR game, relative time to complete the VR game (/mean spent time of naive trainee in first VR game). Δ% of relative time to complete 10 actions from first VR game to second VR game (C) between junior physician and lab technicians and (D) between junior male and junior female trainees. *P<0.05 versus junior physician group or versus junior female trainees; #p<0.05 versus first VR game score. VR, virtual reality.

table 1). The *define* phase consisted of forming a participatory team and performing a feasibility study to establish the appropriateness of employing VR technology. In *design* phase, we selected, sequenced and organised the presentation of the learning contents. In the *development* phase, we established the *e* platform for smart login, developed various components of the VR simulation and incorporated App for an objective evaluation and immediate feedback as well as assessing the effectiveness of one-to-one learning and small group specialists.

Participants

In addition to physicians, lab technicians often work with sharp objects and infectious specimens while collecting, preparing and analysing samples of blood, tissue and body fluids in hospital. So, 53 voluntary junior physicians and 43 junior lab technicians were consecutively enrolled.

VR game-based simulation system

In a VR simulated environment, the trainee recognises 10 randomly appearing pictures of clinical wastes (either infectious, contaminated or hazardous (like discarded sharps, non-sharp, blood, body fluids, toxic chemicals, pharmaceuticals, medical devices, radioactive substances) wastes), picks it up with control and puts it into the right bin in both first and second game (figure 1B). We incorporated the App system into the VR system to subjectively record the accuracy rate and time for complete 10 actions of clinical wastes segregation/disposal in the first and second VR games (figure 1B and online supplementary table 1) as well as to provide feedback to each trainee.

Statistical methods

Series of 2-samples student's *t* tests was used to compare various parameters between groups.

RESULTS

Table 1 suggests that the proportion of the range of ages does not differ between junior physician and lab technicians. We observed a lower share of female trainees among lab technicians. More lab technicians had previously received poster/mass media-based training for clinical wastes segregation/disposal. Before receiving training, lab technicians had greater *familiarity* and *confidence* regrading proper clinical waste segregation/disposal in contrast to physicians. Notably, the postpractice *familiarity* and *confidence* were similar between the groups. The percentage (*familiarity*: 425% versus 157%; *confidence*: 709% versus 276%) of improvement was higher among physicians than lab technicians. In both groups, a high proportion (81%–88%) of trainees reported that they found the VR game-based simulation training *useful* in comparison to poster/mass media-based training,

Junior physicians gained more benefits from the training than junior lab technicians

Figure 1C shows that accuracy rate in the first VR game among lab technicians was higher than that of physicians. The relative time to finish 10 actions of VR game (speed) is shorter (faster) among physicians than that of lab technicians (figure 1C). The accuracy rate and speed were similar between both groups in the second VR game. In comparison to the first VR game, in the second VR game simulation, we witnessed more improvement in accuracy and more shortened times to complete 10 actions among junior physicians than among junior lab technicians (figure 1C).

Table 1 Comparison between groups				
	Physicians		**Laboratory technicians**	
% of distribution of range of age (<20/20–30/30–40 years)	5/37/11 (10/70/20%)		8/31/4 (18/72/10%)	
Gender (F/M)	28/25 (53/47%)		9/34 (21/79%)*	
% of previously receiving training	6 (11%)		13 (30%)*	
% of *very familiar* with the meaning of colour coding of *bins* and category of clinical wastes	Pre-VR	Post-VR	Pre-VR	Post-VR
	8 (16%)	45 (84%)#	12 (28%)*	31 (72%)#
		↑425% from pre-VR data		↑157% from pre-VR data
Having confidence (% of yes) on proper clinical wastes segregation/ disposal and educate others	Pre- VR	Post-VR	Pre-VR	Post-VR
	6 (11%)	47 (89%)†	9 (21%)	34 (79%)†
		↑709% from pre-VR data		↑276% from pre-VR data
VR-based training is *useful* (% of yes) than poster/mass media-based training	Post-VR: 43 (81%)		Post-VR: 38 (88%)	

*P<0.05 versus physicians.
†P<0.05 versus pre-VR data; *familiarity* (1=not very familiar, 2=average, 3=very familiar).
VR, virtual reality.

The junior female trainees performed better than the male trainees

Notably, the accuracy in first VR game among female trainees is higher than that of male trainees (figure 1D). Further, the relative time to complete 10 actions of VR game (speed) is shorter (faster) among female trainees than that of male trainees (figure 1D). In comparison with first game, greater improvement in accuracy (male trainees: 25%; female trainees: 11%) and greater percentage of shorten of time to complete 10 actions (speed, male trainees: 40%; female trainees: 2%) are noted among male trainees than that among female trainees in the second VR game simulation (figure 1D). So, the final accuracy and speed are similar between female and male groups.

DISCUSSION

The general and hazardous waste types should be properly segregated at their source of generation.[11] However, in this systematic review, studies mentioned the absence of proper waste segregation practices that result in high proportion of hazardous clinical wastes than the hazardous waste threshold predicted by the WHO.[6 12 13] In one study, even the amount of hazardous waste was higher than the general waste.[14] This could be because that during the segregation process, even if a very small amount of hazardous waste is added to the general waste category, then the entire mass of the general waste can be unnecessarily polluted by the hazardous waste. For example, a syringe and needle after injection to an infectious patient should be disposed in the infectious waste bin, but instead it will be put in general waste bin and it will make infectious the whole non-infectious waste. Then, we developed VR game-based simulation training to solve this critical condition and found that VR game approach makes learning interesting and engaging.

In our study, the baseline performances of our female trainees are better than males. This might be because females usually play major roles in managing household waste in family that make them more sophisticated with clinical waste segregation/disposal.

In our study, laboratory technicians are more knowledgeable than the physicians in proper clinical waste segregation/disposal because laboratory technicians are more involved in taking blood samples, handling the blood and body fluid or discarding syringes. In our study, the self-reported questionnaires for *familiarity*, *confidence* and *usefulness* are completed immediately before and after training and that can be avoided for the recall bias.[15] In addition to the objective self-assessment, the performances of trainees are subjectively assessed by App in the VR system.

CONCLUSION

This pilot study suggested that our self-developed VR system training system and flow have the potential to widely apply among institution-wide multidisciplinary staffs for proper clinical wastes segregation/disposal.

ORCID iD
Ying-Ying Yang http://orcid.org/0000-0002-7719-0397

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