Effectiveness of VR and Traditional Training in Medical Education for Mass Casualty Management: An OSCE Evaluation

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Abstract

Background: Effective training in mass casualty incidents (MCIs) is crucial for medical students, particularly in scenarios such as road traffic accidents. Traditional lecture-based training is common, while VR offers immersive and potentially superior learning. This study evaluates VR-based training against traditional methods to determine which approach better enhances both theoretical knowledge and practical skills in MCI management.

Objective: This study aimed to evaluate the effectiveness of VR-based training compared to traditional lecture-based training for medical students in managing MCIs, specifically focusing on road traffic accidents. The primary assessment was performed using an Objective Structured Clinical Examination (OSCE) and a theoretical knowledge test

Methods: A randomized controlled trial was conducted with 46 medical students receiving emergency medicine training. Participants were randomly assigned to either a VR group or a traditional lecture group, with each group receiving a 2-hour training session on mass casualty management. The training effectiveness was evaluated through pre- and post-training knowledge tests, OSCE performance, and post-training feedback questionnaires. Statistical analyses were performed to compare the two groups

Results: Baseline characteristics were well-matched between groups. The VR group demonstrated significantly higher post-test scores (83.96 ± 13.11) compared to the traditional group (72.17 ± 20.89, $p = 0.03$). The learning gain was also significantly greater in the VR group (40.26 ± 15.61) compared to the traditional group (28.26 ± 17.04, $p = 0.02$). OSCE results showed the VR group consistently outperformed the traditional group across all stations, with significant improvements in triage, injury assessment, and overall scene management. Additionally, feedback from the post-training questionnaire revealed that the VR group reported greater confidence in performing critical tasks

Conclusions: VR-based training offers a more effective and engaging approach for teaching mass casualty management compared to traditional methods. It enhances both theoretical knowledge and practical skills, helping to better prepare students for high-pressure scenarios such as MCIs. As VR technology continues to evolve, its integration into medical education holds strong potential for improving preparedness and clinical performance in emergency settings

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Keywords: Virtual reality；Mass casualty management；Road Traffic accidents；Medical education; OSCE Station

1 Introduction

Mass casualty incidents (MCIs) are complex emergencies in which numerous injured individuals need simultaneous medical care under resource constraints [1],[2]. Among these, road traffic accidents are one of the most frequent causes[3], contributing significantly to global injury-related mortality and morbidity. Traffic collisions involving numerous casualties generate substantial challenges for healthcare systems, particularly at the initial triage and management stages, where accurate decisions and effective resource allocation are critical for improving outcomes[4]. Preparing healthcare professionals to respond effectively to such situations requires not only theoretical knowledge but also the ability to make rapid decisions and deliver care under pressure[5].

Traditional medical education methods for teaching mass casualty management have typically relied on didactic lectures and simulated case discussions. While these approaches provide foundational knowledge, they often lack the immersive and realistic environments that help students develop the essential skills needed for real-life MCI scenarios, such as rapid triage decision-making and situation assessment[6]. These limitations have prompted a growing interest in using virtual reality (VR) as an educational tool. By immersing learners in customized, highly interactive environments, VR has the potential to simulate complex emergency situations in a safe and controlled setting[7]. Importantly, VR enables students to experience a fully interactive scene, such as a simulated road traffic accident with multiple casualties, allowing them to practice triage, patient assessment, and resource management as if they were in a real-life emergency scenario[8].

In recent years, VR-based simulations have been increasingly adopted in medical education for fields including trauma care and surgical training[9]. Research[10] has highlighted VR's capacity to improve clinical skills acquisition, procedural accuracy, and even decision-making speed in high-pressure environments. However, evidence on the effectiveness of VR in comparison to traditional instructional methods[11], particularly within the context of mass casualty management, remains underexplored. Few studies have rigorously evaluated VR-based training for large-scale accident management, specifically focusing on road traffic injuries where the decision-making process can be complex and challenging[12].

To adequately assess the practical application of VR in such scenarios, the Objective Structured Clinical Examination (OSCE) serves as an optimal evaluation tool. OSCE provides a structured and objective assessment of clinical decision-making, procedural skills, and critical thinking in a variety of medical contexts[13]. By developing OSCE stations that reflect key components of mass casualty management, such as triage, initial stabilization, and injury assessment, we can effectively evaluate the knowledge and skills gained through VR-based learning relative to traditional approaches. Previous studies support the use of OSCE in assessing skills beyond theoretical knowledge, as it provides performance-based data that is crucial in evaluating readiness for real-world practice[14].

This study aims to compare the effectiveness of VR-based training against traditional lecture-based instruction in teaching mass casualty management, with a focus on road traffic accident scenarios. Using OSCE as the primary assessment method, we evaluate medical students' performance in critical tasks such as scene assessment, triage decision-making, and injury evaluation. We hypothesize that students exposed to fully immersive VR simulation will outperform their peers who underwent conventional training in terms of clinical performance and decision-making abilities in a simulated mass casualty setting.

2 Methods

2.1 Study Design and Setting

This study is a randomized controlled trial (RCT) designed to compare the effectiveness of virtual reality (VR)-based training versus traditional lecture-based training for teaching medical students mass casualty management in the context of road traffic accidents. The primary endpoint involves assessing students' performance in simulated mass casualty scenarios using an Objective Structured Clinical Examination (OSCE) and a written examination to evaluate theoretical knowledge. Additionally, self-reported satisfaction and learning experiences will be collected through post-training questionnaires.

The study will be conducted at Guangxi Zhuang Autonomous Region People's Hospital, located in Nanning, China, between January 2024 and October 2024. The participants are medical students who are receiving emergency medicine training during their hospital-based studies. Each educational session—whether VR-based or lecture-based—lasts for two hours, and all participants will be given the same amount of class time.

Participants are randomly assigned to either the VR group or the Traditional Lecture group, with the allocation ratio being 1:1. Both groups are exposed to the same curriculum content focused on managing mass casualty incidents resulting from road traffic accidents. The key differences lie in the teaching methods: the VR group engages with an immersive, dynamic simulation of a mass casualty scenario, while the Lecture group receives conventional didactic instruction on the same topic.

2.2 Participants

A total of 46 participants were enrolled in the study. These participants were medical students or medical doctors who were undergoing emergency medicine training at emergency department. Inclusion criteria required students/doctors to be actively participating in emergency medicine and mass casualty training as part of their ongoing professional development. Participants were excluded if they had previous formal training or significant prior experience in mass casualty management or if they reported conditions (such as severe motion sickness) that could affect their ability to utilize virtual reality equipment.

All eligible participants were randomly assigned to either the VR group or the Traditional Lecture group in an equal 1:1 ratio, with 23 participants in each group. Prior to participation, each individual provided written informed consent after receiving an explanation of the study's objectives, procedures, risks, and benefits. Participation was voluntary, and participants were free to withdraw at any time without penalty. Care was taken to ensure that the demographic characteristics were balanced between the two groups to reduce potential confounding variables. The participants' confidentiality and data privacy were maintained in accordance with hospital policies and research ethics guidelines.

2.3 Training intervention

Participants in both the VR and Traditional Lecture groups received the same core curriculum content focusing on mass casualty management due to road traffic injuries. Each training session lasted 2 hours. The key distinction between the two groups was the method of content delivery.

VR Group

Students in the VR group were trained using a fully immersive HTC VIVE virtual reality system, which allowed for interactive 360-degree engagement with a simulated mass casualty scenario. The utilized software, Road Traffic Injury VR Software 1.0, was specifically developed by the Emergency Department of Guangxi Zhuang Autonomous Region People's Hospital and was designed to simulate realistic road traffic accident scenarios. This virtual environment presented participants with multiple casualty situations featuring various types of injuries, such as traumatic brain injuries, severe hemorrhaging, fractures, and respiratory complications.

During the simulation, students utilized the HTC VIVE motion controllers to conduct patient assessments and perform emergency procedures, such as airway management and bleeding control. They were additionally tasked with making critical resource allocation decisions under time pressure and in the presence of environmental distractions, such as loud noises and visual obstructions, to simulate the chaos of real-world road traffic accidents. The immersive VR experience allowed participants to practice triage, injury evaluation, and decision-making in a highly controlled yet highly interactive environment. The total training time for the VR group was 2 hours, after which the students completed the post-test assessments.

Traditional Lecture Group

The Traditional Lecture group received instruction through standard classroom-based, didactic lectures, which covered the same learning objectives as the VR group, namely, triage, injury evaluation, and mass casualty management principles applied to road traffic incidents. The 2-hour session involved PowerPoint presentations, instructor-led discussions, and case studies. However, no immersive or interactive elements were available to the participants in this group, and their engagement with the content was largely passive, relying on the conceptual understanding provided through the instructor.

Both groups received equal time for exposure to the curriculum direction and were evaluated through the same methods of assessment post-training.

2.4 Evaluation Methods

To assess the effectiveness of both training methods, students' knowledge and skills were evaluated using three assessment tools: a written knowledge test, an Objective Structured Clinical Examination (OSCE), and a post-training feedback questionnaire.

Written Knowledge Test

Students in both groups were administered a written multiple-choice exam both before and after the training as a measure of their theoretical knowledge of mass casualty management. The test consisted of 20 questions designed to assess competency in areas such as triage protocols, injury identification, and emergency management according to standardized mass casualty guidelines. The time allocated for completing each test was 30 minutes. The maximum possible score was 100 points.

OSCE Stations

A structured clinical skills examination (OSCE) was conducted after the training to evaluate students' practical abilities in managing mass casualty scenarios. The OSCE comprised three stations, each simulating a different key component of mass casualty management based on the road traffic accident scenario and focusing on different clinical tasks. Each OSCE station was scored out of 30 points, with a total possible score of 90 points across all three stations.

Station 1: Scene Evaluation and Initial Management

Students were introduced to a simulated mass casualty event with multiple victims. They were expected to conduct an initial scene evaluation, identifying the most critically injured patients and deciding on immediate life-saving measures such as airway management, hemorrhage control, or vascular access. Emphasis was placed on their ability to correctly assess the situation and prioritize treatments within the context of limited resources.

Station 2: Triage

This station focused entirely on triage, where students had to classify simulated victims using a standardized system (such as START triage) based on their severity of injury. Students were required to justify their categorizations (e.g., red—immediate, yellow—delayed, green—ambulatory, black—deceased) within a time-limited scenario. Resource allocation and victim prioritization were components of the assessment.

Station 3: Detailed Injury Evaluation

In this station, students had to carry out a thorough assessment of an individual simulated patient with severe injuries (e.g., traumatic brain injury, chest trauma), determine a diagnosis, and outline the advanced management steps necessary to stabilize the patient. Specific aspects such as monitoring vital signs, intravenous access, and creating a treatment plan were evaluated.

Post-Training Feedback Questionnaire

Following the completion of both the lecture-based and VR-based training, students were asked to complete a Likert-scale questionnaire evaluating their experience. Questions assessed their satisfaction with the teaching method, their perceived competence in managing mass casualty scenarios, and their preferences for future training. The questionnaire consisted of five scaled questions, with scores ranging from 1 (strongly disagree) to 5 (strongly agree), and one open-ended question allowing for qualitative feedback.

2.5 Statistical Analysis

All data from the tests and assessments were collected and anonymized for analysis. Descriptive statistics were used to summarize baseline characteristics and test scores. For continuous variables such as OSCE results and written exam scores, paired t-tests or Mann-Whitney U tests were performed to assess within-group and between-group differences in pre- and post-test scores. Changes in performance across the three OSCE stations were also analyzed using repeated-measures ANOVA to detect variations in skill improvement across different practical tasks. Chi-square tests or Fisher's exact tests were used to compare categorical responses from post-training questionnaires, such as preferences for future training methods. Statistical significance was set at $P < 0.05$. All analyses were conducted using SPSS Version 25.0 and R Version 4.3.1.

3 Result

3.1 Baseline Characteristics

The baseline characteristics of the participants in both groups were comparable (Table 1). The proportion of male participants was similar between the VR group (52.17%) and the traditional group (56.52%). The mean age of participants in the VR group was 26.30 ± 1.73 years, while in the traditional group it was 26.26 ± 2.01 years, with no significant difference (p = 0.94). Additionally, the average work experience was 2.82 ± 1.05 years in the VR group and 2.87 ± 1.19 years in the traditional group, with no statistically significant difference observed (p = 0.89). These results indicate that the two groups were well-matched in terms of gender, age, and work experience prior to the intervention.

Table 1. Baseline Characteristics of Participants

Characteristics	VR Group (n = 23)	Traditional Group (n = 23)	*P*-value
Gender, male (%)	12(52.17%)	13(56.52%)	
Age (years, mean ± SD)	26.30±1.73	26.26±2.01	0.94
Work Experience (years)	2.82±1.05	2.87±1.19	0.89

Fig 1. Detailed views of VR training and OSCE assessments.(A) Simulation process within the VR training module.(B) User interaction and operation screen during VR exercises.(C) Desktop simulation for triage categorization.(D) Examination setup for injury assessment evaluation.

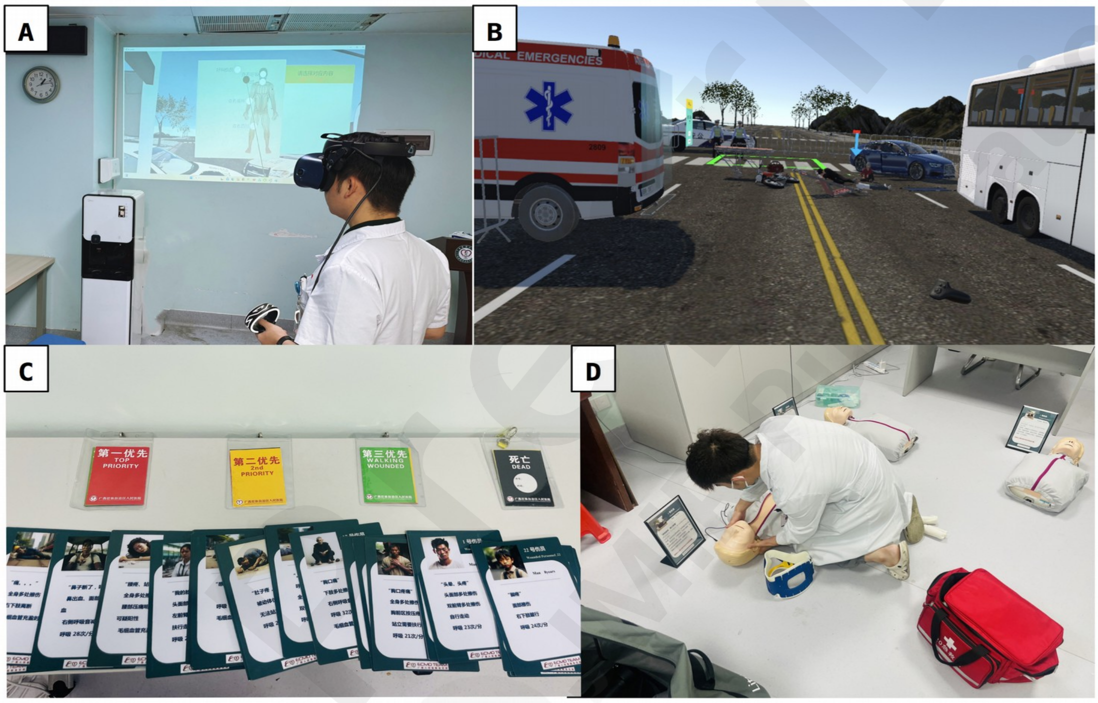


Table 2. Results from the pre- and post-training knowledge tests

Metric	VR Group (Mean ± SD)	Traditional Group (Mean ± SD)	*P*-value
Pre-Test Score	43.66±10.24	43.91±9.99	0.94
Post-Test Score	83.96±13.11	72.17±20.89	0.03
Learning Gain	40.26±15.61	28.26±17.04	0.02

3.2 Theoretical Knowledge Test Results

The pre-training knowledge test scores were comparable between the VR group (43.66 ± 10.24) and the traditional group (43.91 ± 9.99), with no significant difference observed (p = 0.94). However, after the training, the VR group demonstrated significantly higher post-test scores (83.96 ± 13.11) compared to the traditional group (72.17 ± 20.89), with a p-value of 0.03. Additionally, the learning gain, calculated as the difference between pre- and post-test scores, was significantly greater in the VR group (40.26 ± 15.61) than in the traditional group (28.26 ± 17.04), with p = 0.02. These findings suggest that the VR-based training resulted in superior knowledge acquisition compared to traditional lecture-based training (Table 2).

3.3 OSCE Performance Results

Table 3 presents the components and scoring breakdown for each of the three OSCE stations, each of which has a maximum score of 30 points. The focus of each station is essential for evaluating students' hands-on skills and decision-making abilities while managing a mass casualty incident. The OSCE performance was measured before and after training for both the VR group and the Traditional group. Each group was assessed on their ability to manage key aspects of mass casualty triage and basic initial treatment procedures. Table 4 summarizes the pre- and post-training results for both groups across all three OSCE stations, where a maximum cumulative score across the three stations is 90 points.

The results of the OSCE assessments showed significant improvements in both the VR and Traditional groups after the training. While there were no significant differences between the two groups during the pre-test for each station, the VR group consistently outperformed the Traditional group in post-test scores across all three stations: scene evaluation, triage, and injury assessment. The VR group demonstrated significantly higher post-training scores overall, indicating that VR-based training more effectively enhanced students' practical skills in managing mass casualty scenarios compared to traditional lecture-based methods (P < 0.01 for all post-test comparisons) .

3.4 Post-training Feedback Questionnaire Results

The questionnaire results (Table 5) indicated that the VR group showed significantly greater improvements compared to the traditional group in several key areas. For example, 95.65% of participants in the VR group reported enhanced ability to perform injury assessments during mass casualty incidents, compared to 82.61% in the traditional group (P < 0.05). Understanding of triage principles was also higher in the VR group (86.96% vs. 47.83%, *P* < 0.01). Additionally, more participants in the VR group felt confident in performing scene evaluations (78.26% vs. 39.13%, *P* <0.01) and managing specific traumatic conditions (78.26% vs. 52.18%, *P* < 0.05). The VR group exhibited greater improvement in decision-making under resource constraints (65.21% vs. 34.79%, *P* < 0.01). While no significant difference was found regarding the structure and timing of the training sessions (*P* = 0.59), confidence in applying gained knowledge in real-world scenarios approached statistical significance in the VR group (100% vs. 86.96%, *P* < 0.05).

Fig 2. OSCE station scores before and after training for VR and Traditional groups, highlighting significant improvements post-training (A) Scores for each OSCE station—scene evaluation, triage, and injury assessment—before and after training in the VR and Traditional groups. The full score for each station is 30 points. (B) Cumulative OSCE scores before and after the training for both groups, with a maximum total of 90 points. **P < 0.01 indicates significant differences between post-training scores of the VR and Traditional groups.

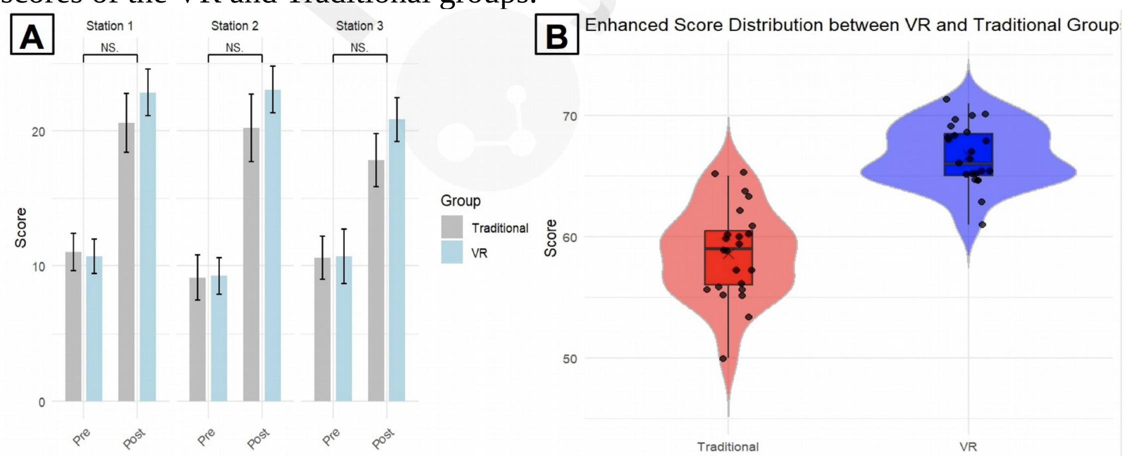


Table 3. OSCE Station Content and Scoring details

OSCE Station	Scoring Criteria (6 points each)	Maximum Points

Station 1: Scene Evaluation	Personal Protective Equipment (PPE)	6
	Assessment of Scene Safety	6
	Communication with Traffic and Fire Departments	6
	Information Gathering and Reporting	6
	Mechanism of Injury Analysis	6
Station 2: Triage	Triage Process Order	6
	START Method Selection	6
	Time	6
	Accuracy	6
	Decisiveness	6
Station 3: Initial Injury Assessment	Airway	6
	Breathing	6
	Circulation	6
	Nervous system	6
	Environment and exposure	6
Total score		90

Table 4. OSCE Scores Pre- and Post-Training for two Groups

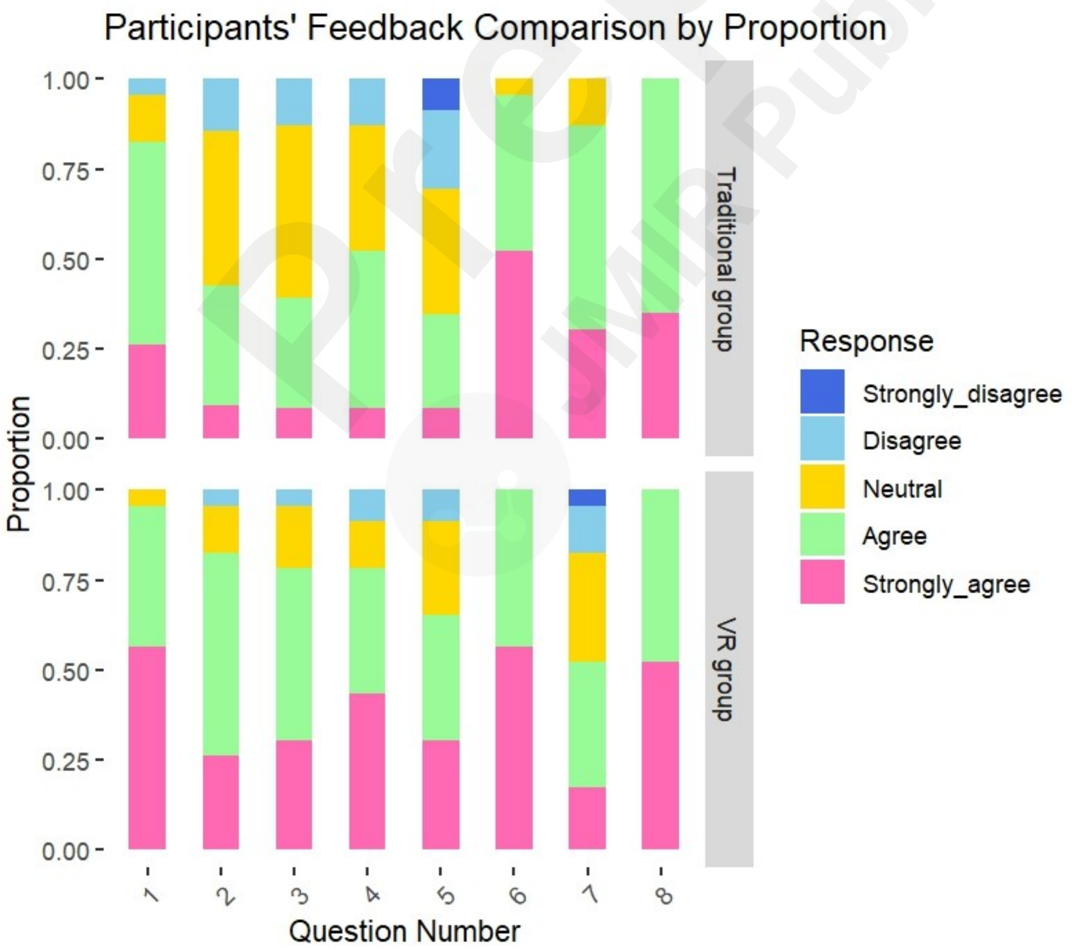
Category	VR Group (n=23)	Traditional Group (n=23)	*P*-value
Station 1			
Pre-Test Score (Mean ± SD)	10.70±1.26	11.04±1.39	0.39
Post-Test Score (Mean ± SD)	22.83±1.74	20.57±2.18	<0.01
Station 2			
Pre-Test Score (Mean ± SD)	9.26±1.36	9.13±1.68	0.78
Post-Test Score (Mean ± SD)	23.04±1.71	20.22±2.50	<0.01
Station 3			
Pre-Test Score (Mean ± SD)	10.70±2.01	10.61±1.58	0.87
Post-Test Score (Mean ± SD)	20.83±1.63	17.83±1.95	<0.01
Total			
Pre-Test Score (Mean ± SD)	30.65±2.69	30.78±3.29	0.89
Post-Test Score (Mean ± SD)	66.70±2.45	58.61±3.73	<0.01

Table 5. Post-Training Questionnaire Results: VR vs. Traditional Training

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	*P*-value
he training effectively improved my ability to perform injury assessments during mass casualty incidents.						
group	0(0.00%)	0(0.00%)	1(4.35%)	9(39.13%)	13(56.52%)	<0.05
itional group	0(0.00%)	1(4.35%)	3(13.04%)	13(56.52%)	6(26.09%)	
gained a thorough understanding of the principles and application of triage in mass casualty events as a t of the training.						
group	0(0.00%)	1(4.35%)	2(8.70%)	10(43.48%)	10(43.48%)	<0.01
itional group	0(0.00%)	3(13.04%)	9(39.13%)	9(39.13%)	2(8.70%)	
ollowing the training program, I feel confident in performing an initial scene evaluation of mass casualty ents.						
group	0(0.00%)	1(4.35%)	4(17.39%)	11(47.83%)	7(30.43%)	<0.01
itional group	0(0.00%)	3(13.04%)	11(47.83%)	7(30.43%)	2(8.70%)	
he training enhanced my ability to manage specific traumatic conditions, such as traumatic brain injuries,						

orrhages, and fractures, in a mass casualty setting.						
group	0(0.00%)	2(8.70%)	3(13.04%)	8(34.78%)	10(43.48%)	<0.05
itional group	0(0.00%)	3(13.04%)	8(34.78%)	10(43.48%)	2(8.70%)	
feel the training improved my decision-making abilities regarding resource allocation and prioritization in a trained mass casualty scenario.						
group	0(0.00%)	2(8.70%)	6(26.09%)	8(34.78%)	7(30.43%)	<0.01
itional group	2(8.70%)	5(21.74%)	8(34.78%)	6(26.09%)	2(8.70%)	
he structure and timing of the training sessions were appropriate for covering the essential principles of casualty management.						
group	0(0.00%)	0(0.00%)	0(0.00%)	10(43.48%)	13(56.52%)	0.59
itional group	0(0.00%)	0(0.00%)	1(4.35%)	10(43.48%)	12(52.17%)	
he training content provided me with a deeper understanding of the overall management strategies required ass casualty incidents.						
group	1(4.35%)	3(13.04%)	7(30.43%)	8(34.78%)	4(17.39%)	0.26
itional group	1(4.35%)	4(17.39%)	11(47.83%)	5(21.74%)	2(8.70%)	
feel confident in applying the knowledge and skills acquired from this training to real-world mass casualty arios.						
group	0(0.00%)	0(0.00%)	0(0.00%)	11(47.83%)	12(52.17%)	<0.05
itional group	0(0.00%)	0(0.00%)	3(13.04%)	13(56.52%)	7(30.43%)	

Fig 3. Answers to questions 1-8 (Q1-Q8) as a stacked bar chart, displayed for two groups separately.



4 Discussion

This study demonstrated that VR-based training is more effective than traditional lecture-based methods in preparing medical students for managing mass casualty incidents, particularly in the context of road traffic accidents. The VR group's superior performance was observed not only in written knowledge tests but also in practical skills assessments evaluated through an Objective Structured Clinical Examination (OSCE). The OSCE specifically highlighted the VR group's enhanced capabilities in critical real-world tasks, such as scene management, triage decision-making, and injury assessment under stress. By offering structured, objective stations designed to simulate mass casualty scenarios, the OSCE was able to capture the nuanced improvements in clinical judgment and decision-making enabled by the immersive VR training. Additionally, participants in the VR group reported greater confidence in their ability to handle mass casualty scenarios, further confirming the effectiveness of VR in a highly interactive and realistic environment. These findings support our hypothesis that integrating VR simulations with OSCE-based evaluations provides a robust platform for assessing both the acquisition of theoretical knowledge and the development of practical, hands-on skills essential in emergency settings.

The findings of this study align with existing research on the benefits of VR in medical education, particularly in fields such as trauma care and CPR training, where VR has been shown to enhance procedural accuracy and decision-making under pressure[15], [16]. However, a key distinction of this study is the integration of OSCE station to evaluate practical skills in mass casualty management—an area that has received limited attention in VR-based training research. Unlike written examinations, which primarily assess theoretical knowledge, the OSCE provides a structured and standardized framework for evaluating hands-on skills and real-time decision-making in simulated emergency scenarios. Previous studies[17], have highlighted the utility of OSCEs in emergency medicine, but most relied on static, mannequin-based simulations. In contrast, our incorporation of a fully immersive VR platform adds a dynamic layer of interactivity that closely replicates real-world mass casualty events, such as multi-victim road traffic accidents. This combination of VR training with OSCE-based assessment offers a more comprehensive evaluation by not only capturing improvements in theoretical knowledge but also demonstrating superior clinical performance in high-pressure, resource-limited environments. These findings suggest that VR, when paired with OSCE, provides an optimal framework for assessing both cognitive and psychomotor skills in medical professionals.

The enhanced performance of the VR group in this study can be attributed to several key factors inherent to the immersive nature of VR simulations. Unlike traditional lecture-based instruction, VR provides an interactive environment that closely mimics real-world scenarios, enabling learners to engage in critical decision-making while being exposed to realistic stressors, such as time pressure and chaotic environments[18]. This type of experiential learning fosters not only knowledge acquisition but also the development of situational awareness and practical problem-solving skills, which are crucial in mass casualty management. The immersive VR platform used in this study allowed participants to practice complex tasks—such as rapid triage and resource allocation—in a controlled yet highly dynamic setting. This interactive engagement promotes active learning, leading to better retention of information and faster reflexes when faced with decision-making in emergency contexts. Importantly, VR also offers the advantage of repeated practice without the risks associated with live patients, thus allowing students to hone their skills in a safe yet challenging environment[19]. These factors, combined with the objective assessment capabilities of the OSCE, explain the superior clinical outcomes observed in the VR group, highlighting the potential of VR as a highly effective tool for bridging the gap between theoretical knowledge and real-world clinical application.

One of the major strengths of this study is its randomized controlled trial (RCT) design, which minimizes potential biases and ensures a balanced comparison between the VR and traditional training groups. The random allocation of participants and the 1:1 ratio between the groups helped maintain homogeneity in baseline characteristics, such as age, gender, and work experience, thereby reducing confounding variables. Another key strength is the integration of Objective Structured Clinical Examination (OSCE) as the primary method of practical skill evaluation. The use of OSCE is widely accepted as a gold standard for objective assessment of clinical competence, and its inclusion ensures that the skills being measured—particularly in areas such as triage, scene management, and injury evaluation—accurately reflect real-world clinical demands in mass casualty settings[20]. Additionally, combining OSCE with VR for skill assessment offers a unique advantage, as it allowed participants to engage in repetitive, immersive practice while being objectively evaluated in real-time. This dual approach strengthens the validity of the study's findings by providing both subjective self-assessment feedback and quantifiable performance metrics[21]. Finally, the focus on mass casualty management, a critical yet underexplored area in medical education, enhances the study's relevance, as healthcare systems around the world increasingly face the challenges of emergency response in complex, multi-victim scenarios.

Despite its strengths, this study has several limitations that should be acknowledged. First, the relatively small sample size (n = 46) may limit the generalizability of the findings to broader populations of medical students or healthcare professionals. While the results are encouraging, larger-scale studies are needed to confirm these findings and explore whether they are consistent across different training environments and demographic groups. Second, while VR offers a highly immersive experience, it cannot fully replicate all the complexities and stressors of real-world mass casualty events[22]. Factors such as emotional stress, unpredictable resource availability, and the physical demands of working in chaotic environments are not entirely captured in the virtual simulations, which may affect how students apply these skills in actual emergency situations[23]. Furthermore, the training duration was limited to two hours, which may not have been sufficient to allow for full skill mastery or long-term retention. Future research should consider extending the exposure to VR training and conducting follow-up assessments to evaluate skill retention over time. Lastly, the cost and accessibility of advanced VR equipment may pose a challenge for widespread adoption, particularly in resource-limited settings. Although VR technology is becoming more affordable, its integration into medical education curricula on a larger scale still requires careful consideration of cost-effectiveness[24].

The findings of this study emphasize the potential of VR-based training in enhancing medical education focused on emergency medicine and disaster response, particularly in the context of road traffic injuries and mass casualty incidents. Future research should explore the long-term retention of skills acquired through VR training in these high-pressure scenarios, as well as the transferability of these skills to real-world emergency settings. Longitudinal studies following graduates into clinical practice could help determine how well VR-trained students perform under actual mass casualty conditions, where factors such as emotional stress, resource scarcity, and unexpected environmental variables come into play.Moreover, expanding VR-based simulations to cover a broader variety of disaster scenarios, such as natural disasters and large-scale public emergencies, could further strengthen the preparedness of healthcare professionals in managing diverse mass casualty incidents. These simulations could incorporate more complex triage algorithms, refined injury assessment techniques, and advanced decision-making under critical resource constraints, providing trainees with comprehensive exposure to different emergency contexts[25].

For practical implementation, the combination of VR with structured evaluation methods like the OSCE offers a powerful tool for assessing both cognitive knowledge and clinical performance in disaster scenarios. Training programs in emergency medicine should consider integrating VR simulations into their core curricula, particularly for students and professionals preparing to face the growing demands of disaster response and mass casualty management. Ultimately, incorporating VR in the educational pipeline for emergency and disaster medicine could significantly improve clinical competency and decision-making capabilities, enhancing the overall responsiveness and effectiveness of healthcare systems in crisis situations.

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5 Conclusion

This study demonstrates that combining VR-based training with the OSCE framework offers a powerful and effective approach to teaching mass casualty management, particularly in critical areas such as triage, injury evaluation, and decision-making. The immersive nature of VR enhances practical skill acquisition, while OSCE provides a structured and objective means to evaluate both theoretical knowledge and clinical performance. Together, these tools represent a promising advance in emergency and disaster management training, offering a more realistic and comprehensive learning experience compared to traditional methods.

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Supplementary Files