—**Original**—

Usefulness of Self-Selected Scenarios for Simple Triage and Rapid Treatment Method Using Virtual Reality

Satoshi Harada[1,2], Ryotaro Suga[2,3], Kensuke Suzuki[1,2], Shinnosuke Kitano[4], Kenji Fujimoto[5], Kenji Narikawa[1,2], Mayumi Nakazawa[1,2] and Satoo Ogawa[1,2]

[1]Department of Emergency Medical Science, Faculty of Medical and Health Science, Nippon Sport Science University, Kanagawa, Japan
[2]Graduate School of Medical and Health Science, Nippon Sport Science University, Kanagawa, Japan
[3]Department of Emergency and Critical Care Medicine, Nippon Medical School, Tokyo, Japan
[4]Department of Emergency and Critical Care Medicine, Nippon Medical School Tama Nagayama Hospital, Tokyo, Japan
[5]Yokohama Fire Bureau, Kanagawa, Japan

Background: Repeated triage training is necessary to maintain and improve the accuracy of simple triage and rapid treatment (START), a popular triage method. Virtual reality (VR) may be more effective than conventional training methods. This study aimed to verify the educational usefulness of START using VR originally developed for students.
Methods: A VR was initially developed with a function that allowed students to select the triage procedure and its evaluation. Triage was performed using a simple modified START method, and eight scenarios were developed. The participants included 70 paramedic students classified into VR and live lecture groups. They took a 20-question written test that evaluated their academic ability before the course. After the course, a practical test and a 20-question written test were conducted. The total score of the practical test was 43 points. Triage procedure (1 point), observation and evaluation (1-5 points), and triage categories (1 point) were evaluated in this test.
Results: The VR and live lecture groups consisted of 33 and 29 participants, respectively. No significant differences were observed pre- and post-test. In the practical test, the median (interquartile range) score was 29 (26-32) and 25 (23-29) for the VR and live lecture groups, respectively, with the VR group scoring significantly higher (P=0.03).
Conclusion: Our results confirmed the educational usefulness of selective VR for active learning of START. Therefore, VR combined with live lectures and simulations would be an optimal educational technique. (J Nippon Med Sch 2024; 91: 99–107)

Key words: virtual reality, triage, mass casualty incidents, education, training

Introduction

Mass casualty incidents occur suddenly and without warning. Disaster types vary widely, and many casualties in a brief period can overwhelm the local healthcare system[1]. Emergency medical services personnel, who may be the first at the scene of a disaster, have the opportunity to triage the injured; therefore, triage education is necessary for emergency medical services personnel working during the acute phase at disaster sites. While various triage methods exist worldwide, the most used primary triage tool in the United States is Simple Triage and Rapid Treatment (START), developed in the 1980s by Hogue Hospital and the Newport Beach Fire Department in California[2,3].

Triage is intended to recognize and assist in dealing with several injured or sick people urgently and expeditiously[4]. Disasters involving multiple injured or sick people occur infrequently, and there is little opportunity to

Correspondence to Satoshi Harada, Department of Emergency Medical Science, Faculty of Medical and Health Science, Nippon Sport Science University, 1221–1 Kamoshida-cho, Aoba-ku, Yokohama, Kanagawa 227–0033, Japan
E-mail: satoshi.harada@nittai.ac.jp
https://doi.org/10.1272/jnms.JNMS.2024_91-111
Journal Website (https://www.nms.ac.jp/sh/jnms/)

Table 1 Scenario

Scenario	Triage color	Body position	Able to walk	Spontaneous respiration	Position airway	Respiratory rate	Palpable pulse	Mental status
1	Green	Sitting	○	○	-	10-29	○	○
2	Black	Supine	×	×	×	-	×	×
3	Red	Supine	×	×	○	<10	○	×
4	Red	Supine	×	○	-	<10	○	○
5	Red	Sitting	×	○	-	≥30	○	○
6	Red	Sitting	×	○	-	10-29	×	○
7	Red	Sitting	×	○	-	10-29	○	×
8	Yellow	Sitting	×	○	-	10-29	○	○

The following triage items were observed and evaluated: "whether the patient can walk," "whether the patient breathes spontaneously," "respiratory rate," "whether the radial artery is palpable (pulse reproduced audibly: 0, 50, 70 or 120 beats/min)," and "whether the patient responds to the follow-up."

gain experience in a disaster setting. However, repeated triage training is necessary to respond to sudden, large-scale disasters with skill and accuracy[5,6]. It must be performed with suitable equipment, instructors, and locations. Information and communication technology are also essential for providing training that can be performed at any time. Virtual reality (VR), which has recently become popular, has been used in various fields, including sports, tourism, military, education, and medicine, and has been reported to promote the motivation and involvement of students and academic staff, in addition to increasing the learning speed[7]. VR is an immersive and effective training tool according to emergency medicine studies[8,9]. Practical training using VR can be performed at any location provided that the equipment is available, allowing learning to be tailored to the needs of students[10].

Previously, a VR-based START training course reported improved triage accuracy, intervention, speed, and self-efficacy[11]. VR education for START can potentially become a method for training individuals in disaster preparedness[12]. To date, VR education has utilized content reproducing the scenario as a passive training course. Education that involves role-playing is effective in improving knowledge and skills[13]. We hypothesized that self-selective teaching materials, in which VR changes actively based on the results of one's observations, would be useful for triage training. Our project focused on comparing the educational usefulness of self-selective role-playing VR and conventional live lectures on the knowledge and skills taught during START education.

Materials and Methods

Study Design

This study was an analytical prospective randomized controlled trial.

Subjects

First-year students were enrolled in the 2022 simulation course at the Department of Emergency Medical Science, Faculty of Medical and Health Science, Nippon Sport Science University, Japan. At the time, they had not attended START lectures at the university.

Preparation of Teaching Materials

The triage was performed using a simple modified START method. The participants were fourth-year paramedics students. Eight scenarios representing the four triage categories were created: five red, one yellow, one green, and one black (**Table 1**). An Insta360 ONE X2 camera (Insta360, Shenzhen, China) was set at 50 cm above the ground, equivalent to the eye level of the triage operator, and fixed in place. The audio was recorded using Zoom H2n (Zoom Corporation, Tokyo, Japan), and the VR was edited using Adobe Premiere Pro (Adobe Inc., San Jose, CA, USA). The video was trimmed, the frontal position was adjusted, and unnecessary backgrounds were blurred. VR videos were uploaded to cloud (Jolly Good Inc., Tokyo, Japan). The following triage items were observed and evaluated: "whether the patient can walk," "whether the patient breathes spontaneously," "respiratory rate," "whether the radial artery is palpable (pulse reproduced audibly: 0, 50, 70, or 120 beats/min)," and "mental status." A role-playing system was created to determine the next steps from the participant's perspective. After the observations were completed, the viewpoint was placed on a button to select the triage category, and the text "Correct answer" was displayed on the screen if all observations, procedures, and categories were correct. From this viewpoint, the selection decision time was set at 3 s. The video was downloaded to a Pico G2 4K VR head-mounted display (Pico

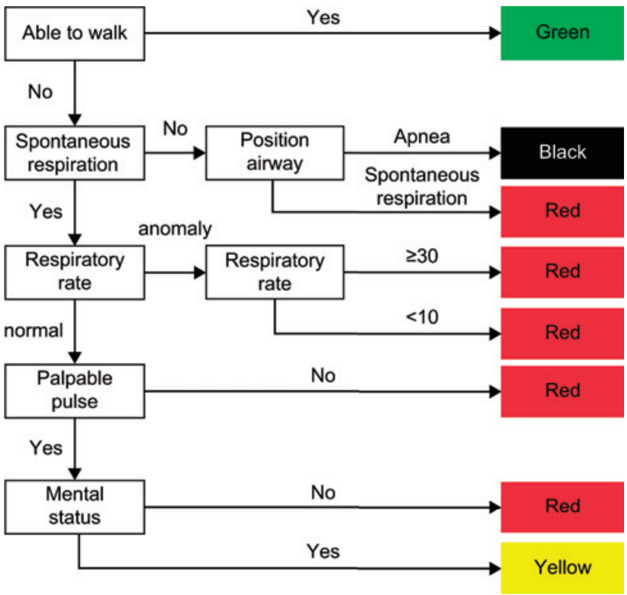

Fig. 1 Triage flow chart

Technology Co., Ltd. Beijing, Haidian Qu, China) and an iPad (Apple Inc., Cupertino, CA, USA).

Practical Training

The implementation date was January 16, 2023. Participants were not notified of the workshop theme. The eight groups assigned to daily practice were divided into two groups using random numbers: one to watch the VR (VR group) and the other to attend a conventional lecture (live lecture group). During pre-course guidance, the group was given a piece of paper with a flowchart of the START procedure and a 10-min online explanation (**Fig. 1**). A pre-test was administered to examine students' academic abilities before the course. A practical test was administered after the completion of the course. After the practical test, a post-test was conducted to examine the knowledge of the VR and live lecture groups.

Time to Prepare and Present Lectures

Live lecture preparation consumed 60 min for research, 60 min for slide preparation, 20 min for lecture preparation, and 20 min for giving the lecture, all of which adds up to a total of 140 min.

Written Test

Twenty questions on triage, equivalent to those on the national paramedic exam, were asked. They were validated by the department, and the VR material was selected from eight questions from the scenarios created. Each question was scored as one point. The same questions were used for the pre-test and post-test, but the order of the questions was changed using random numbers for each test. The answers were written on a marking sheet.

Selective VR Viewing

The participants were divided into four groups of eight to nine subjects, and all head-mounted displays were connected to one iPad per group. The order in which the VR was viewed was determined by each group using a random number. The following explanations were given to the subjects: the VR would select the triage procedure, observation and evaluation, and triage categories from their perspective; the selection could be made by gazing at the button at the top of the VR for 3 s; if the VR was not completed within 2 min after it started, it was terminated. The triage procedure, observation and evaluation, and triage categories were indicated as correct only if all related questions were answered correctly. Palpation of the radial artery was set according to the sound of a metronome. After the subject wore the head-mounted display, the video was started simultaneously in each group using an iPad. If sickness occurred while viewing the VR video or a fall due to physical movement occurred, the video was stopped.

Live Lectures

All participants gathered in one classroom at the university, and the lecture was given by a faculty member who was a qualified paramedic. The lecture content was prepared based on the 10th edition of the Paramedic Standard Textbook[14] and presented in PowerPoint. Faculty members were allowed to answer the students during the lecture verbally.

Practical Test

Partitions separated the venue so that the subjects could not see each other. The order of scenarios was determined using random numbers for each group. The eight original scenarios used in the VR materials were applied, and all subjects started simultaneously. Nine subjects from each group had one rest booth. A Resusci Anne simulator (Laerdal, Stavanger, Norway), which is designed for advanced cardiovascular life support training, was set to respond to each scenario with or without body position, respiration, respiratory rate, and palpable pulse at the radial artery. Subjects were told that the pulse could be palpated only with the left hand of the Resusci Anne simulator. For all simulators, the blood pressure was 120/80 mmHg, and the pulse rate was 80 beats/min, which is the average setting for the VR video. An evaluator verbally responded to call responses, obedience responses, and other content that could not be reproduced by Resusci Anne simulator. The subject performed eight scenarios, and the time limit for triage was 2 mins or less per scenario.

Table 2 Score sheet

Scenario	Triage procedure	Able to walk	Spontaneous respiration	Position airway	Respiratory rate	Palpable pulse	Mental status	Triage categories	Total points
1	1	1	-	-	-	-	-	1	3
2	1	1	1	1	-	-	-	1	5
3	1	1	1	1	-	-	-	1	5
4	1	1	1	-	1	-	-	1	5
5	1	1	1	-	1	-	-	1	5
6	1	1	1	-	1	1	-	1	6
7	1	1	1	-	1	1	1	1	7
8	1	1	1	-	1	1	1	1	7
Total points	8	8	7	2	5	3	2	8	43

In each scenario, the triage procedure was scored as 1 point, the observation and evaluation scenario were scored as 1-5 points, and the triage categories were scored as 1 point, with a maximum score of 3-7 points per scenario and a total score of 43 points for the eight scenarios.

The practical test was conducted by eight qualified paramedics affiliated with the university. In each scenario, the triage procedure was scored as 1 point, the observation and evaluation scenario were scored as 1-5 points, and the triage categories were scored as 1 point, with a maximum score of 3-7 points per scenario and a total score of 43 points for the eight scenarios (**Table 2**). There are four triage categories: I (red, urgent treatment group), II (yellow, non-urgent treatment group), III (green, no treatment or minor injury group), and zero (black, death or life-threatening injury group). Accuracy of triage procedures, i.e., over-triage (OT) and under-triage (UT), were examined. UT is the prioritization of patients with more severe injury or disease than the assumed color, and OT is the prioritization of patients with milder injury or disease than the assumed color. We examined the subject's decision-making process during the screening of injured and ill patients.

Statistical Processing

Statistical analyses were performed using IBM SPSS Statistics version 27 (IBM Corporation, Armonk, NY, USA). Each test was tested for normal distribution using the Shapiro-Wilk test. The pre-test and post-test scores were analyzed using the Mann-Whitney U test and Wilcoxon signed-rank sum test. The practical test results (total score and each scenario) were analyzed using the Mann-Whitney U test. The significance level was set at less than $P<0.05$. The triage procedure and categories for each scenario were analyzed using Fisher's exact tests and chi-square test, respectively. A P value of <0.05 was set as the significance level.

Ethical Considerations

Ethics review committee

This study was conducted after a review and approval by the Ethics Committee of Nippon Sport Science University (Approval No. 023-H008). It was performed according to the latest version of the Declaration of Helsinki.

Obtaining consent from subjects

An explanatory document was prepared to explain the research's purpose to the participants, and their consent was obtained. Participants were aware that participation in the study was voluntary, that they would not be subjected to any disadvantageous treatment if they did not agree to participate, that they could withdraw their written consent even after agreeing to participate, and that any withdrawn data would be discarded.

Voluntary nature of research participation

Regardless of their consent to participate in the study, the lecture was conducted with the same content for all students. This study excluded students who had not completed all programs.

Results

Selection of Research Subjects

Seventy students (53 men and 17 women) were included in this study. Thirty-six participants (27 males and 9 females) were in the VR group, and 34 (26 males and 8 females) were in the live lecture group. In the VR group, two absent students and one who did not take the initial written test were excluded, and 33 students were included in the study. The median age (range) was 19 (19-19) years, and the number of men was 24 (73%). In the live lecture group, three absent students and two who

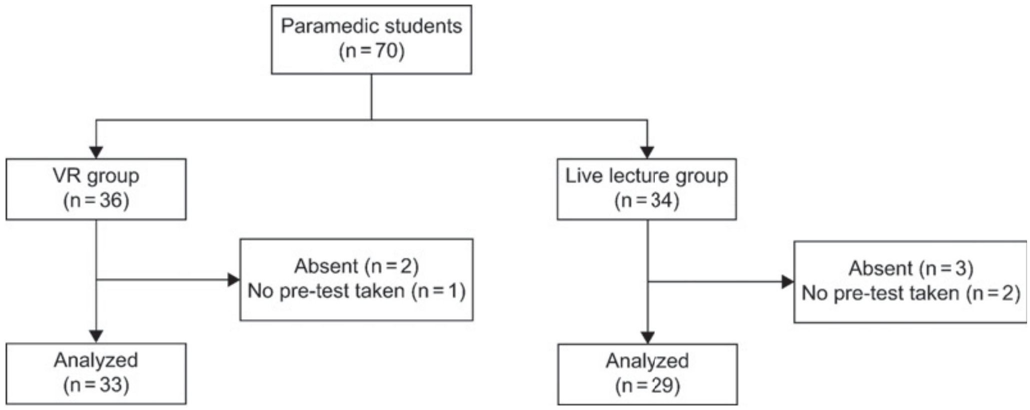

Fig. 2 Flow diagram depicting student assignment and grouping

Table 3 Written test

Category	VR group (n=33)	Live lecture group (n=29)	P value
Pre-test	14 (10-16)	13 (10-16)	0.92
Post-test	15 (13-16)	16 (13-17)	0.12

Pre-test and post-test are each worth 20 points. The data are presented as the median (interquartile range).

Table 4 Practical test

Scenario	VR group (n=33)	Live lecture group (n=29)	P value
1	3 (2-3)	2 (2-3)	0.37
2	3 (2-5)	3 (2-3)	0.02
3	3 (2-4)	2 (2-3)	0.44
4	3 (2-4)	3 (2-4)	0.82
5	3 (3-5)	3 (2-4)	0.15
6	4 (3-5)	4 (3-5)	0.71
7	5 (4-6)	3 (3-5)	0.01
8	5 (4-7)	5 (4-6)	0.81
Total points	29 (26-32)	25 (23-29)	0.03

Scenario one: three points, Scenario two: five points, Scenario three: five points, Scenario four: five points, Scenario five: five points, Scenario six: six points, Scenario seven: seven points, Scenario eight: seven points, Overall: 43 points. The data are presented as the median (interquartile range).

did not take the initial written test were excluded, and 29 students were included in the study. The median age was 19 (19-19) years, and the number of men was 23 (79%) (**Fig. 2**).

Written Tests (Pre-Test and Post-Test Scores)

Academic ability was confirmed at two different time points to examine the results of this study (**Table 3**). The VR and live lecture groups had a median pre-test score of 14 (10-16), and 13 (10-16), respectively, showing no significant difference (P=0.92) between the groups. The VR and live lecture groups had a median post-test score of 15 (13-16) and 16 (13-17), respectively, with no significant difference (P=0.12) between the groups. Post-test scores improved significantly from the pre-test scores within both groups (VR group: P<0.01, live lecture group: P<0.01).

Practical Test

The total score and scores for each scenario of the practical test were examined. Regarding total scores, the VR group had a median score of 29 (26-32), and the live lecture group had a median score of 25 (23-29), showing a significant difference between the groups (P=0.03). In scenario two, the VR and live lecture groups had a median score of 3 (2-5), and 3 (2-3), respectively (P=0.02), whereas in scenario seven, the VR and live lecture groups had a median score of 5 (4-6) and 3 (3-5), respectively (P=0.01). Thus, a significant difference in median scores was observed between both groups in scenarios two and seven each (**Table 4**).

In relation to triage procedure, the mean percentage of correct responses was 34% and 24% in the VR and live lecture groups, showing a significant difference in the total scores (P=0.02). The VR group had a higher percentage of correct responses in scenarios one to three, five, seven, and eight of the triage procedure. Both groups had the same percentage of correct responses in scenario four. The live lecture group had a higher percentage of correct responses in scenario six, whereas scenario two was significantly supported in the VR group (P=0.04) (**Table 5**).

In relation to the triage categories, the mean percentage of correct responses was 72% and 66% in the VR and live lecture groups, respectively; the VR group had a higher percentage (P=0.18). The VR group had a higher

Table 5 Practical test (triage procedure)

Scenario	VR group (n=33)	Live lecture group (n=29)	P value
1	19 (58)	14 (48)	0.61
2	11 (33)	3 (10)	0.04
3	5 (15)	1 (3)	0.20
4	7 (21)	6 (21)	1.00
5	9 (27)	5 (17)	0.38
6	7 (21)	7 (24)	1.00
7	14 (42)	7 (24)	0.18
8	18 (55)	13 (45)	0.61
Total points	90 (34)	56 (24)	0.02

The data are presented as the number of correct answers (%)

Table 6 Practical test (triage category)

Scenario	VR group (n=33)	Live lecture group (n=29)	P value
1	28 (85)	23 (79)	0.57
2	28 (85)	21 (72)	0.23
3	20 (61)	16 (55)	0.67
4	20 (61)	14 (48)	0.33
5	23 (70)	15 (52)	0.15
6	26 (79)	22 (76)	0.78
7	25 (76)	22 (76)	0.99
8	20 (61)	21 (72)	0.33
Total points	190 (72)	154 (66)	0.18

The data are presented as the number of correct answers (%)

percentage of correct responses in scenarios one to six of the triage categories. Both VR and live lecture groups had the same percentage of correct responses in scenario seven, and the live lecture group had a higher percentage in scenario eight. The two groups showed no significant difference in scores; the mean OT was higher in the VR group for scenarios six to eight. The mean OT was higher in the live lecture group for scenarios one, three, and four. No OT was observed for scenario five in both groups. The mean UT was higher in the VR group for scenarios three. The mean UT was higher in the live lecture group for scenarios two and four to eight. In both groups, no UT occurred in scenario one and no OT occurred in scenario two (**Table 6**).

Discussion

This study compared the results of written and practical tests of VR-based training and conventional live lectures. No significant differences were found in the written test scores. In the practical test, the VR group scored significantly higher on the total score and the scores for scenarios two and seven. The VR group had significantly higher total score and scenario two score for triage procedures. No significant differences were observed in terms of triage categories. A pre-test was administered to ascertain the student's academic performance before the study, and no difference in academic performance was found between the two groups, indicating that the academic achievement before the lecture was equivalent in the two groups. Behmadi et al.[15], found no statistically significant difference in mean test scores between the group that received traditional lectures on START triage at the beginning to mid-semester and the group that received virtual simulation training later in the semester. In contrast, Omori et al.[16] compared a 15-min lecture on infection control between a VR group and a conventional lecture group and found that the VR group scored significantly higher in the post-test. Additionally, Zhao et al.[17], observed that the passing rate of the examination was significantly higher in the VR group than in the traditional lecture group. In the post-test, no significant differences were found between the two groups. One disadvantage of using VR is that, although it enables participants to visualize the situation in the field, it does not allow them to record what they have learned in real-time. Questions or issues during VR viewing cannot be recorded; therefore, they may be hard to recall at the end of the session. In contrast, in the case of live lectures, the topic could be discussed directly with the instructor, and questions could be recorded. Since this was a single lecture, no significant differences might have been observed. Therefore, increasing the number of students examined and confirming their knowledge retention is necessary.

The VR used in this study was self-selecting, and the scenarios changed in a role-playing fashion. Heidarzadeh et al.[4] compared START triage instruction in a role-playing group and a traditional lecture group, and found that knowledge, attitude, and performance scores increased in both groups. Performance scores were higher in the role-playing group than in the lecture group. A typical VR provides a 360° view within the created video. However, since the story continues, the viewer may not be able to maintain concentration even while re-watching the video. The role-playing method and time limit for decision-making may enable the students to concentrate better. One possible explanation for the VR group's higher score in scenario two is that it was the only group that used the airway securement technique.

In the live lecture, students were taught the airway clearance procedure to be performed during triage; however, they were not allowed to practice it. This result was also evident from the number (%) of correct answers in the triage procedures. A possible explanation for the higher scores of the VR group in scenario seven is that more evaluation items had to be observed. The total score for the triage procedure was significantly higher in the VR group. The more the evaluation procedures, the greater the number of observations required, and it is possible that the VR group was able to confirm images that allowed them to envision the site in advance; thus, the evaluation procedure proceeded smoothly. Scenario eight also involved the same number of triage procedures; however, there was no significant difference in the results of the practical tests. Nevertheless, the number (%) of correct responses to the triage procedure was higher for scenarios seven and eight in the VR group. However, identifying the effective content of the video/lecture from this study's findings was not possible. When comparing first-person and third-person educational approaches, the first-person approach may be more effective[18,19]; however, it is necessary to compare and study the educational effects of various filming methods.

Triage categories were not significantly different between the two groups. Franc et al.[20] found that START triage was 73% accurate, which may not be accurate enough. OT may provide more services than necessary to patients, thus consuming personnel, time, and equipment, and UT may endanger human life. When comparing OT and UT in each group (except for scenario one: green with no UT and scenario two: black with no OT), the UT rate was higher in both groups for the six remaining scenarios, (i.e., two scenarios with OT and four scenarios with UT); this may be because good results were possibly prioritized in case of incorrect evaluation procedures. For example, a follow-up response to each scenario is assume as the evaluation proceeds, even when respiration is slow. Typically, slow respiration is considered red, but a mental status response makes the assessment yellow. Students may make errors in their judgment of triage categories if they make mistakes in the evaluation procedure because they have not yet acquired enough knowledge. Video games have been reported to improve the overall accuracy of in-game triage and decreased UT[21]. In the present study, the live lecture group showed more UT rates. The fact that the practical test involved mannequins in both groups may have decreased the tension of the students and increased the UT rate in the live lecture group because they did not see the injured person. Thus, VR, which can reproduce a scenario, may decrease UT rates. The percentage of correct answers was given in six scenarios by the VR group and one scenario by the live lecture group, suggesting that VR was more effective in teaching practical skills. Triage is not completed when performing START; it is repeated instead. Machine learning has the potential to improve prediction accuracy in the field of medicine[22]. There are also reports showing that machine learning models can outperform START in accuracy[23]. Therefore, machine learning can be used to improve triage accuracy.

The use of VR can reduce the burden on the faculty involved. Preparation for this live lecture took a total of 140 minutes: 60 for research, 60 for slide preparation, and 20 for class preparation on the day of the lecture. A VR video can be created once and used repeatedly. Effective use of VR is also expected to have secondary effects, such as reducing faculty lecture preparation and lecture time. By having students view the same VR video, differences in instructional content given by faculty can be reduced and standardized education can be provided. In addition, the same educational effect can be achieved in situations where lectures are restricted due to pandemic restrictions.

This study consisted of VR and live lectures, followed by a practical test. A faculty member conducted the live lecture, and the self-selective VR method was student-centered. Practicing lectures and role-playing improves knowledge and skills and is effective in triage education[4]. It has also been reported that combining VR with active learning has the potential to improve educational effectiveness[24,25]. Using VR in role-playing facilitates the visualization of scenarios and active learning. In this study, live simulation was only conducted for practical testing. Zhang et al.[26] reported that combining VR with skills training was more effective than traditional training. Moreover, students are better prepared when they experience live simulation after initial VR training[27]. Live simulations allow training using five human senses (sight, hearing, smell, touch, and taste). However, VR alone can only reproduce sight and hearing. In this study, touching an injured person during respiration, observing the radial artery, or airway securing procedures was impossible. In live simulations, the setting method makes it more feasible to reproduce the scenario. Thus, an effective combination of VR, live simulation, and live lectures will lead to the most significant educational effect.

There are several limitations to this study. First, questions were allowed during the live lecture but not during the VR video, which may have affected the results. Second, the VR group scored 67% and the live lecture group scored 58% in the practical test. The practical test scores of the VR and live lecture groups for the triage procedures were also 34% and 24%, respectively. As the subjects were first-year college students, they may have received a low grade because they had insufficient medical knowledge. In the future, it is necessary to examine the lecture method with different subjects.

In conclusion, this study compared the usefulness of VR and live lectures on the education of students and dispensation of knowledge and skills. VR is useful for teaching practical skills. No significant differences were observed in knowledge or education. Instead of using only one method for education, combining VR and live lectures, followed by live simulation, would be the optimal teaching method.

Acknowledgements: We would like to express our deep gratitude to Professor Hiroyuki Yokota of Nippon Sport Science University Graduate School for useful discussions and comments and advice on this paper.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest: None declared.

References

1. Ben-Ishay O, Mitaritonno M, Catena F, Sartelli M, Ansaloni L, Kluger Y. Mass casualty incidents - time to engage. World J Emerg Surg. 2016 Feb 3;11:8.
2. Bazyar J, Farrokhi M, Khankeh H. Triage systems in mass casualty incidents and disasters: a review study with a worldwide approach. Open Access Maced J Med Sci. 2019 Feb 12;7(3):482–94.
3. Nakao H, Ukai I, Kotani J. A review of the history of the origin of triage from a disaster medicine perspective. Acute Med Surg. 2017 Jul 14;4(4):379–84.
4. Heidarzadeh H, Heidarzadeh Z, Azadi A. Comparison of pre-hospital triage training by role playing and lecture on nursing students' knowledge, attitude, and performance. Nurs Open. 2020 Apr 21;7(4):935–42.
5. Dittmar MS, Wolf P, Bigalke M, Graf BM, Birkholz T. Primary mass casualty incident triage: evidence for the benefit of yearly brief re-training from a simulation study. Scand J Trauma Resusc Emerg Med. 2018 Apr 27;26(1):35.
6. Pouraghaei M, Sadegh Tabrizi J, Moharamzadeh P, Rajaei Ghafori R, Rahmani F, Najafi Mirfakhraei B. The effect of START triage education on knowledge and practice of emergency. J Caring Sci. 2017 Jun 1;6(2):119–25.
7. Rojas-Sanchez MA, Palos-Sanchez PR, Folgado-Fernandez JA. Systematic literature and bibliometric analysis on virtual reality and education. Educ Inf Technol (Dordr). 2023;28(1):155–92.
8. Semeraro F, Ristagno G, Giulini G, et al. Back to reality: a new blended pilot course of Basic Life Support with Virtual Reality. Resuscitation. 2019 May;138:18–9.
9. Semeraro F, Ristagno G, Giulini G, et al. Virtual reality cardiopulmonary resuscitation (CPR): comparison with a standard CPR training mannequin. Resuscitation. 2019 Feb;135:234–5.
10. Pottle J. Virtual reality and the transformation of medical education. Future Healthc J. 2019 Oct;6(3):181–5.
11. Vincent DS, Sherstyuk A, Burgess L, Connolly KK. Teaching mass casualty triage skills using immersive three-dimensional virtual reality. Acad Emerg Med. 2008 Nov;15(11):1160–5.
12. Lowe J, Peng C, Winstead-Derlega C, Curtis H. 360 virtual reality pediatric mass casualty incident: a cross-sectional observational study of triage and out-of-hospital intervention accuracy at a national conference. J Am Coll Emerg Physicians Open. 2020 Aug 17;1(5):974–80.
13. Delnavaz S, Hassankhani H, Roshangar F, et al. Comparison of scenario based triage education by lecture and role playing on knowledge and practice of nursing students. Nurse Educ Today. 2018 Nov;70:54–9.
14. [Paramedic Standard Text Editorial Committee]. [The 10th edition of the Paramedic Standard Textbook]. 10th rev. ed. Tokyo: Herusu Shuppan; 2022. p. 232–42. Japanese.
15. Behmadi S, Asadi F, Okhovati M, Ershad Sarabi R. Virtual reality-based medical education versus lecture-based method in teaching start triage lessons in emergency medical students: virtual reality in medical education. J Adv Med Educ Prof. 2022 Jan;10(1):48–53.
16. Omori K, Shigemoto N, Kitagawa H, et al. Virtual reality as a learning tool for improving infection control procedures. Am J Infect Control. 2023 Feb;51(2):129–34.
17. Zhao G, Fan M, Yuan Y, Zhao F, Huang H. The comparison of teaching efficiency between virtual reality and traditional education in medical education: a systematic review and meta-analysis. Ann Transl Med. 2021 Feb;9(3):252.
18. Gorisse G, Christmann O, Amato AE, Richir S. First- and third-person perspectives in immersive virtual environments: presence and performance analysis of embodied users. Front Robot AI. 2017 Jul;4(33):1–12.
19. Borrego A, Latorre J, Alcaniz M, Llorens R. Embodiment and presence in virtual reality after stroke. A comparative study with healthy subjects. Front Neurol. 2019 Oct 10;10:1061.
20. Franc JM, Kirkland SW, Wisnesky UD, Campbell S, Rowe BH. METASTART: a systematic review and meta-analysis of the diagnostic accuracy of the simple triage and rapid treatment (START) algorithm for disaster triage. Prehosp Disaster Med. 2022 Feb;37(1):106–16.
21. Cicero MX, Whitfill T, Walsh B, et al. 60 seconds to survival: a multisite study of a screen-based simulation to improve prehospital providers disaster triage skills. AEM Educ Train. 2018 Jan 31;2(2):100–6.
22. Otaguro T, Tanaka H, Igarashi Y, et al. Machine learning for prediction of successful extubation of mechanical ventilated patients in an intensive care unit: a retrospective observational study. J Nippon Med Sch. 2021 Nov 17;88(5):408–17.
23. Sigle M, Berliner L, Richter E, et al. Development of an anticipatory triage-ranking algorithm using dynamic simulation of the expected time course of patients with trauma: modeling and simulation study. J Med Internet

Res. 2023 Jun 15;25:e44042.
24. Fabris CP, Rathner J, Fong A, Sevigny CP. Virtual reality in higher education. Int J Innov Sci Math Educ. 2019 Oct; 27(8):69–80.
25. Philippe S, Souchet AD, Lameras P, et al. Multimodal teaching, learning, and training in virtual reality: a review and case study. Virtual Real Intell Hardw. 2020 Oct; 2(5):421–42.
26. Zhang D, Liao H, Jia Y, et al. Effect of virtual reality simulation training on the response capability of public health emergency reserve nurses in China: a quasi-experimental study. BMJ Open. 2021 Sep 22;11(9):e048611.
27. Mills B, Dykstra P, Hansen S, et al. Virtual reality triage training can provide comparable simulation efficacy for paramedicine students compared to live simulation-based scenarios. Prehosp Emerg Care. 2020 Jul-Aug;24(4):525–36.

(Received, August 24, 2023)
(Accepted, September 15, 2023)
(J-STAGE Advance Publication, December 8, 2023)