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ORIGINAL RESEARCH

Psychometric Validation of the Chinese Version of the Virtual Reality System Usability Questionnaire

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Objective: The usability questionnaire of the English version of the virtual reality system was localized to verify its reliability and validity in ICU patients, providing a scientific assessment tool for clinical practice.

Methods: The Brislin translation model was adopted to complete the cross-cultural adaptation of the scale. A total of 331 ICU patients from a tertiary hospital in Zhengzhou City were included through convenience sampling for item analysis, validity and reliability tests.

Results: The Chinese version of the scale consists of 3 dimensions and a total of 9 items. The Cronbach's α coefficient of the total scale was 0.821 and the split-half reliability was 0.782. The content validity index at the item level ranged from 0.833 to 1.000, and the average content validity index at the scale level was 0.978. Exploratory factor analysis extracted three common factors, with a cumulative variance contribution rate of 67.017%. The factor loadings of each item ranged from 0.609 to 0.876, and no items were deleted. Confirmatory factor analysis showed that the standardized path coefficients of all items were within the acceptable range. These results indicate that the adapted questionnaire is a psychometrically sound instrument.

Conclusion: The Chinese version of VRSUQ has good reliability, validity and cultural adaptability. It not only fills the gap of a VR system usability assessment tool that is both culturally and clinically applicable for ICU patients in China, but also overcomes the limitations of existing international tools. Proven tools can be directly applied to clinical practice to guide the optimization of VR intervention measures, thereby enhancing patient experience and intervention effectiveness. In the future, its universality needs to be verified through multi-center research.

Keywords: cultural adaptation, intensive care units, virtual reality, reliability, validity

Background

The application of virtual reality (VR) in intensive care units (icus) is gradually expanding. Its immersive and interactive features provide new approaches for alleviating patients' anxiety and depression and promoting early rehabilitation.[1] However, the realization of its clinical effectiveness largely depends on the availability of the VR system, that is, whether patients can effectively and smoothly use the system under their physiological and cognitive limitations.[2] In the high-risk environment of the ICU, precise assessment of system availability is a key link to ensure patient safety, improve intervention compliance and optimize intervention effects. Insufficient availability not only weakens the rehabilitation value of VR, increases the physical and psychological burden on patients, but may also directly lead to the failure of clinical application.[3]

Against this backdrop, evaluating patients' VR experiences is becoming increasingly important. However, the existing internationally common tools have obvious limitations when evaluating the VR experience of ICU patients in China. For instance, the system availability scale does not cover core VR dimensions such as immersion and motion sickness;[2] Kalawsky's VRUSE scale has too many items and imposes an excessive burden on critically ill patients;[4]

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However, the assessment framework proposed by Sutcliffe et al neglects the evaluation of adverse reactions and is difficult to comprehensively reflect the patient experience.[5] Furthermore, most of these tools are developed based on Western cultural and language backgrounds, and their expression methods and conceptual structures may not conform to the cognitive and expression habits of Chinese patients, thereby leading to measurement deviations.

In recent years, cross-cultural nursing and rehabilitation research has continuously emphasized that scales must undergo systematic cultural adaptation and psychometric verification when introduced to new populations. Guo et al[6] found in the validation of the Chinese version of the Postpartum Depression Literacy Scale that ignoring cultural adaptation would significantly affect the reliability and validity of the scale; Biniok et al[7] also pointed out that when adapting the virtual reality vertigo scale to culture, it was confirmed that the directly translated items, due to not conforming to the local symptom description habits, would underestimate the discomfort and satisfaction of users in the VR experience. These studies suggest that directly using unadapted non-localized tools may not accurately capture the usage experience of ICU patients in China and may even mislead clinical judgments.

The Virtual Reality System Availability Questionnaire (VRSUQ) developed by Kim et al[8] has to some extent made up for the deficiencies of previous tools. It covers three dimensions: "effectiveness, efficiency, and satisfaction", with a total of 9 items. It is both simple and VR-specific, and shows good reliability and validity in the general population. However, this tool has not yet been translated into Chinese across cultures and verified in the ICU population of China. Given that ICU patients in China generally have characteristics such as low educational level, heavy cognitive load, and significant differences in cultural expression methods,[9] it is urgently necessary to conduct systematic cultural adaptation and psychometric evaluation of VRSUQ to form a reliable tool suitable for the local clinical environment.

Therefore, this study aims to form a Chinese version of VRSUQ through cross-cultural adaptation and test its reliability and validity in Chinese ICU patients, providing a VR system assessment tool that is both culturally adaptable and psychometric robustness for clinical practice, thereby promoting the scientific and individualized application of VR in critical care in China.

Methods

Research Objectives

The aim of this study is to conduct cross-cultural debugging of the English version of VRSUQ and verify its reliability and validity in ICU patients, providing a scientific assessment tool for clinical practice. The research was reported in accordance with the COSMIN guidelines for the selection of consensus-based Health Measurement tools.[10,11]

Participants

By using convenience sampling, patients who met the inclusion criteria were selected for this study in the ICU of a tertiary grade A hospital in Zhengzhou City from May 2024 to April 2025. Convenience sampling was adopted for feasibility considerations, aiming to rapidly recruit a sufficient number of eligible ICU patients from a single center for validation of reliability and validity. All the research subjects gave informed consent and voluntarily participated in this study.

The determination of the sample size is based on the following considerations. Firstly, according to the participant-item ratio criterion commonly used in scale cross-cultural adaptation research (usually 5:1 to 10:1),[12] the 9-item scale of this study requires at least 45 to 90 participants; Secondly, confirmatory factor analysis, as a complex multivariate analysis technique, usually requires a sample size of no less than 200 cases.[13] In addition, we estimated that approximately 20% of the questionnaires would be invalid or dropped out. To meet all the above requirements and ensure the robustness of the analysis, we planned to recruit 350 participants. The 331 valid questionnaires collected in the end fully met the sample size requirements for factor analysis.

Introduction to the VRSUQ Scale

The VRSUQ scale was developed by Kim et al[8] in 2023 and is mainly used to assess the perception of virtual reality experiences. It consists of three dimensions and a total of nine items. Each item adopts the Likert 5-point scoring system,

ranging from "strongly opposed" to "strongly agreed", with scores of 1 to 5 respectively. The total score ranges from 0 to 100 points. The higher the total score, the better the experience and the stronger the usability of the VR system. The overall Cronbach's α value ranged from 0.752 to 0.773, indicating good validity.

The Localization of the VRSUQ Scale

After obtaining the formal authorization and permission of the original scale author, this study carried out the Chinese translation of the scale in accordance with the Brislin translation theory framework.[14] The process is as follows: (1) Forward translation: A nursing professor with study experience in the United States and a graduate student majoring in nursing independently translated the scale forward, forming the Chinese version of VRSUQ1 and the Chinese version of VRSUQ2. (2) The research team and the translator discussed together and integrated the two Chinese versions, forming A comprehensive Chinese draft A that is consistent with the original scale in terms of language and logic. (3) Reply: Two postgraduate students majoring in nursing who had passed the College English Test Band 6 and had not participated in the preparatory work were selected. Each of them independently carried out the backtranslation work and formed their own backtranslation versions (VRSUQ1 and VRSUQ2). The research team compared and analyzed these two backtranslation versions with the original scale and made multiple revisions and improvements to the comprehensive version A until its expression form is completely consistent with the original text, the official Chinese version of the comprehensive draft B is finally determined and published. (4) Expert panel review: Criteria for expert inclusion: ① Master's degree or above; ② Intermediate or above professional title; ③ Have more than 5 years of working experience in the ICU. Ultimately, 7 experts were included, all with master's degrees, including 2 associate professors of nursing, 2 associate chief nurses, 2 head nurses and 1 attending physician. Their ages ranged from 36 to 48 years (40.88±4.76) years, and their working years were 6 to 25 years (15.50±7.07) years. The expert authority index ranged from 0.80 to 0.95. Among them, two nursing professors have experience in guiding research in the intersection of nursing and computer science. Experts were invited to conduct two rounds of discussions and reviews on the language expression of the scale, the correlation between the items and the usability of the VR system, and whether it is suitable for ICU patients to fill in, and formed the Chinese version of the comprehensive draft C.(5)Pre-survey: By using convenience sampling, 20 patients who met the inclusion criteria were selected from the ICU of a tertiary grade A hospital in Zhengzhou City in May 2024. All the research subjects gave informed consent and voluntarily participated in this study. Inclusion criteria: ① Age ≥18 years old; ② The length of stay in the ICU is ≥48 hours; ③ Richmond Restlessness and Sedation score of −1 to +1 or Glasgow Coma Scale score of ≥12;[9] ④ Be capable of effective communication; ⑤ Voluntarily participate in this study and give informed consent. Exclusion criteria: ① Suffering from cognitive impairment or mental illness such as intellectual disability or dementia; ② Has severe visual or hearing impairment; ③ There are various contraindications for activities, such as severe cardiopulmonary insufficiency, recent major surgeries or traumas, intracranial lesions, uncontrolled endocrine or metabolic disorders, etc. For the questions encountered by the patients during the filling process, the research team provided on-site explanations to assist them in completing the questionnaire completely and ensure the completeness of the collected data. Based on the opinions of the subjects and experts in the field, the research team made meticulous modifications and improvements to the content of the scale by referring to the original English version of VRSUQ, and created a VRSUQ with Chinese characteristics.

Reliability and Validity Tests of the Scale

Survey Subjects

By using the convenience sampling method, ICU patients in a tertiary grade A hospital in Zhengzhou City, China were selected as the survey subjects from June 2024 to April 2025. The inclusion and exclusion criteria for patients were consistent with those of the pre-survey.

Investigation Tools

① Chinese version of VRSUQ: It consists of 9 items and is used to evaluate the usability of VR systems. ② General information Survey Form: It includes 9 items such as the patient's hospitalization number, bed number, name, gender, age, educational level, marital status, occupation, and disease name.

Data Collection and Quality Control methods

After obtaining the approval of the relevant departments and department heads of the hospital, this study selected eligible patients from the ICU as the research subjects. Two professionally trained researchers clearly expounded the research objectives and their significance to the patients and conducted the investigation after obtaining their consent. This study employed domestic virtual technology equipment, and patients participated in a total of three VR experiences. Project One: Scenic Video: Patients need to wear helmets to experience three VR videos: "Spring in the North", "Dreamy Beach", and "Underwater Exploration". Patients are in a 360° surround video scene, experiencing the spring after the revival of all things, the dreamy white sand and blue sea, and the mysterious underwater world. Project Two Venting Room: The patient wears a helmet and uses a controller to smash the bottles and jars in front of them in the game as if they were negative emotions. Each type of bottle and jar will make a different sound when broken. Project Three: Cognitive Mini-Game: The module recreates real-life scenarios and allows users to perform multiple tasks within it, such as marking calendars, finding animals, making bracelet gifts, and building blocks. Patients wear helmets and cooperate with controllers to complete these tasks.

All participants completed the three VR modules in a fixed order in sequence, with a total experience time of 20 to 25 minutes. The module sequence was not randomized, aiming to provide patients with a progressive experience process from passive acceptance to active participation. A total of 350 questionnaires were distributed in this study (excluding the 20 from the previous pre-survey), and 331 valid questionnaires were ultimately retrieved, with an effective recovery rate of 94.57%. The specific VR content and on-site photos of patients participating in the VR project are shown in Figures 1–3.

Figure 1 The VR content experienced by the patient.
Note: The first one on the left, "Spring in the North": Nature awakens after a long winter, plants start to blossom, and patients experience the beauty of spring in the blooming gardens and bustling cities. The second from the left is the dreamy beach: The patient looks into the distance on the beach with dreamy white sand and blue sea, feeling the interplay of the white sand and the green sea water. Right one: Underwater Exploration: Led by a turtle, embark on a wonderful and peaceful journey, slowly traversing the mysterious underwater world. Surrounded by colorful coral reefs and leisurely swimming schools of fish, each stroke brings new discoveries. Right second cognitive mini-game: The module recreates real-life scenarios and allows users to perform multiple tasks within it, such as marking calendars, finding animals, making bracelet gifts, and building blocks. Patients complete these tasks by wearing helmets and using controllers. The third venting room on the right: The patient wears a helmet and uses a controller to smash the bottles and cans in front of them in the game as if they were negative emotions. Each type of bottle and can makes a different sound when broken.

Figure 2 The patient experiencing an immersive landscape video.
Note: The four patients in the picture are experiencing the landscape video of Project One.

Methods for Testing the Reliability and Validity of the Scale

In the project analysis and reliability and validity test, this study did not include the general information of patients (including gender, age, marital status, educational level, and disease type) as covariates in the statistical model. Instead, by using the convenience sampling method, patients of various types were purposefully selected (see Table 1), aiming to make the sample represent the typical patient group in the ICU. The aim is to verify the psychometric characteristics of the Chinese version of VRSUQ as a universal tool, that is, to evaluate its reliability and validity in the overall population of mixed ICU patients, rather than to test its differences among different subgroups. This study hypothesizes that patients' perception of the availability of VR systems is a common experience that transcends their background information. Based on this, all valid samples are analyzed as a whole.

Normality Test

To ensure that the probability density distribution of the data is a normal distribution, normality tests need to be conducted on 331 sets of data, including skew and kurtosis tests. The main purpose is to determine whether the measured data have good symmetry and peaks. Kline indicates that when the skewness is within ±3 and the kurtosis is within ±10, it suggests that the questionnaire sample data basically follow a normal distribution.[15]

Project Analysis

The project analysis in this study was conducted through the decision value method and correlation coefficients. In the decision value method, 131 questionnaires were randomly selected and the samples were divided into high-score groups (27%) and low-score groups (27%) based on their total scores. Then, an independent sample *t*-test was used to evaluate the significant differences between the two groups. When the critical ratio (CR) was greater than 3.0 and the P-value was less than 0.05, this item had a good discriminatory power. It should be preserved.[16] This study also needs to calculate the Pearson correlation coefficient to reflect the degree of correlation between each item and the total score of the scale. If the

Figure 3 The patient participating in an interactive treatment scene.
Note: The four patients in the picture are experiencing the Catharsis room in Project Two and the cognitive mini-game in Project Three.

correlation coefficient (r) is less than 0.400, it indicates that its connection with the core concept is relatively weak and needs to be modified or deleted.[17] Meanwhile, the correlation coefficients among each item are all less than 0.7, indicating that there is good discrimination among the items.[18]

Table 1 Summary of Measurement Indicators of VRSUQ in Chinese Version

Inspection Category	Specific Indicators	Evaluation Criteria	The Method Adopted in This Study
Normality test	Skewness, kurtosis	The skewness is within ±3 and the kurtosis is within ±10	Method of moments
Project Analysis	Decision value	CR > 3.00, and $P < 0.05$	Independent sample *t*-test
	Item-total score correlation coefficient	r ≥ 0.40	Pearson correlation coefficient
	Correlation coefficient between items	r<0.70	Pearson correlation coefficient

(*Continued*)

Table 1 (Continued).

Inspection Category	Specific Indicators	Evaluation Criteria	The Method Adopted in This Study
Validity test	Content validity index	I-CVI > 0.78	Expert Review (Two Rounds of Inquiry)
	Content validity index at the scale level	S-CVI/Ave > 0.90	Expert Review (Two Rounds of Inquiry)
	Exploratory factor analysis	KMO > 0.80, Bartlett's test: $P < 0.05$; The cumulative variance contribution rate is greater than 50%. Factor loading is greater than 0.40	Principal component analysis, maximum variance rotation method
	Confirmatory factor analysis	$\chi^2/df < 3.00$, RMSEA < 0.08, CFI/IFI/TLI > 0.90	Maximum likelihood method
Reliability test	Internal consistency reliability	$\alpha > 0.70$	Cronbach's α coefficient
	Half-reliability	> 0.70	Spearman-brown formula

Validity Test

The validity of the scale was evaluated by content validity and structural validity. Seven experts with cross-cultural adaptation experience were selected for content validity. Two rounds of expert inquiries were used for analysis. The Likert 4-point scoring system (ranging from "completely irrelevant" to "highly relevant", with a score of 1 to 4) was used to represent the degree of correlation between each item and the usability of the VR system. The content validity index (I-CVI) and the overall average content validity index of the scale (S-CVI/Ave) were calculated by using formulas. When I-CVI>0.78 and S-CVI/Ave>0.90, it was considered that the scale had good content validity.[19] Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were used for evaluation in structural validity: (1) Exploratory factor analysis: First, the data fit is determined through the KMO statistic and Bartlett's sphericity test. If the KMO value is greater than 0.8 and the Bartlett's test reaches a significant level, it is considered that the data is suitable for exploratory factor analysis. Then, principal component analysis was utilized and the maximum variance orthogonal rotation method was adopted to extract the common factors. The eigenvalue greater than 1 was selected as the screening condition, and the factor loading greater than 0.40 was used as the criterion to retain the scale items. Finally, when the cumulative variance contribution rate reached more than 50%, it could be determined that the scale had good structural validity.[17] (2) Confirmatory factor analysis: The model is evaluated using the maximum likelihood method, and the following fitting indicators are used to determine whether the model meets the ideal standard: If the chi-square value/degree of freedom ($\chi 2/df$) is less than 3.000, the root mean square error approximation (RMSEA) is less than 0.08, and the comparative fitting index (CFI), incremental fitting index (IFI), and Tucker-Lewis index (TLI) are all greater than 0.90, the model is considered to fit well.[20]

Reliability Test

The reliability of the scale is expressed by internal consistency reliability and split-half reliability. If Cronbach'sα coefficient is greater than 0.70, it indicates good reliability.[21] The split-half reliability is expressed by the Spearman-Brown method. If the split-half reliability is greater than 0.70, it indicates that the split-half reliability of the scale is good.[22]

Summary of Measurement Indicators of the Scale

To systematically present the psychometric characteristic assessment process of the Chinese version of VRSUQ, this study summarizes the key indicators, evaluation methods and judgment criteria adopted in the reliability and validity tests, as detailed in Table 1.

Statistical Methods

The data were processed by two software, SPSS 25.0 and AMOS 26.0. The counting type variables were described by frequency and its proportion, while the continuous type variables were expressed by mean ± standard deviation. When screening projects, both the decision value method and the correlation coefficient method were used for testing. The testing of

validity included content validity and structural validity. The former was determined through expert review, while structural validity was mainly tested through exploratory factor analysis and confirmatory factor analysis. The reliability test adopts internal consistency reliability and split-half reliability. The statistical significance level was set at $P < 0.05$.

The "randomization" feature of this study is mainly reflected in the random division of the overall sample during the data analysis stage. After obtaining 331 valid questionnaires, with the help of the "Random Case Selection" function in SPSS 25.0 software and by using the method of generating random numbers, the overall sample was randomly divided into two sub-samples: Sub-sample 1 (n = 131), which was used to conduct project analysis, exploratory factor analysis and reliability test; Sub-sample 2 (n = 200) is specifically used for confirmatory factor analysis. This random division is designed to ensure that CFA is conducted on samples independent of exploratory factor analysis EFA, thereby effectively avoiding overfitting of the model and more rigorously testing the factor structure of the scale.

Ethics Approval

This research protocol was approved by the Biomedical Research Ethics Committee of Henan University (Approval Numbers: HUSOM2024-418, HUSOM2024-434). All participants were informed of the research details and signed the written informed consent form.

Results

Cultural Debugging and Pre-Survey Results

Based on the expert opinions and the problems encountered by ICU patients during the filling process, the research team held a discussion, modified the language expression of some items, and no items were deleted. Entry 5: Given that VR is primarily used to assist ICU patients in their early recovery, the concept of "learning" was deemphasized following expert discussion; as a result, the original sentence "I think this system is user-friendly, straightforward to learn, and designed in such a way that most people will find it easy to adapt to." was revised to "I think this system is very user-friendly and designed in a simple way that most people can adapt to easily."; Entry 8: The term "motion sickness" is unfamiliar to ICU patients. Therefore, an explanation for motion sickness in Entry 8 is provided, and the original sentence "I felt dizzy, motion sickness, or a headache while experiencing virtual reality." was replaced with "During virtual reality experiences, I feel symptoms of cybersickness such as nausea, sweating, vomiting, stomach discomfort, or headaches."; Entry 9: Some expressions do not conform to the cultural background of our country. The original sentence "While experiencing virtual reality, I felt mental burdens such as tension, frustration, and time pressure." has been replaced with "During virtual reality experiences, I feel a lot of mental stress, such as feeling anxious, frustrated, or like I don't have enough time.". The pre-survey shows that the number of items is appropriate, and the patients' filling time is about 8 to 15 minutes. The Chinese version of the VRSUQ is shown in Figure 4.

Characteristics of Participants

A total of 331 ICU patients were included in this study, and their basic characteristics are shown in Table 2. The sample was mainly male (59.21%), with a wide age distribution (18.73% were ≤30 years old, 41.39% were 30–60 years old, and 39.88% were ≥60 years old), and married people accounted for 74.62%. The educational attainment is mainly primary school and below (48.34%), followed by junior high school and senior high school (37.16%). The disease types cover common ICU diseases such as respiratory system, circulatory system and nervous system, and the samples have good representativeness.

Normality Test Results

After the normality test of 331 data in this study, the absolute values of the skeviness of the item scores ranged from 1.397 to 2.962, and the absolute values of the kurtosis ranged from 0.587 to 8.556. None of them exceeded the critical standards of skeviness ±3 and kurtosis ±10, indicating that the data distribution was basically symmetrical without significant deviation, and it could be considered to approximately follow a normal distribution. It meets the requirements of subsequent factor analysis and other parameter tests. The statistics table of normality test is shown in Table 3.

The Chinese version of the Virtual Reality System Usability Questionnaire (VRSUQ)

This questionnaire asks about your feelings after experiencing virtual reality. There are no right or wrong answers. Please answer each question as accurately as possible. For each question, please circle the number that best describes your feeling. If you strongly disagree, circle 1; disagree, circle 2; neutral, circle 3; agree, circle 4; strongly agree, circle 5. The higher the number, the more you agree with the statement. Please answer each question based on your true feelings.

1. The system responded well to my manipulations as expected with no delays.

   Strongly disagree 1 2 3 4 5 Strongly agree

2. I think the virtual reality system provides clear feedback on my manipulations.

   Strongly disagree 1 2 3 4 5 Strongly agree

3. I kept making errors/mistakes while using the virtual reality system.

   Strongly disagree 1 2 3 4 5 Strongly agree

4. I could clearly understand the information presented within the virtual environment.

   Strongly disagree 1 2 3 4 5 Strongly agree

5. I think this system is very user-friendly and designed in a simple way that most people can adapt to easily.

   Strongly disagree 1 2 3 4 5 Strongly agree

6. I think it is easy to correct errors made during virtual reality experiences.

   Strongly disagree 1 2 3 4 5 Strongly agree

7. I enjoyed the virtual reality experience.

   Strongly disagree 1 2 3 4 5 Strongly agree

8. During virtual reality experiences, I feel symptoms of cybersickness such as nausea, sweating, vomiting, stomach discomfort, or headaches.

   Strongly disagree 1 2 3 4 5 Strongly agree

9. During virtual reality experiences, I feel a lot of mental stress, such as feeling anxious, frustrated, or like I don't have enough time.

   Strongly disagree 1 2 3 4 5 Strongly agree

Figure 4 The Chinese version of the VRSUQ.
Notes: Reprinted from Applied Ergonomics, Volume 119, Kim YM, Rhiu I, Development of a virtual reality system usability questionnaire (VRSUQ), pages 104319, Copyright 2024, with permission from Elsevier.[8]

Table 2 General Information of the Survey Subjects (n=331)

Project	Classification	n (%)
Gender	Male	196 (59.21)
	Female	135 (40.79)
Age (years)	≤30	62 (18.73)
	30~60	137 (41.39)
	≥60	132 (39.88)
Marital status	Married	247 (74.62)
	Unmarried	56 (16.92)
	Divorced or widowed	28 (8.46)
Educational attainment	Primary school and below	160 (48.34)
	Junior high school and senior high school	123 (37.16)
	Bachelor's degree or above	48 (14.50)
Disease type	Respiratory system diseases	72 (21.75)
	Circulatory system diseases	69 (20.85)
	Neurological diseases	43 (12.99)
	Digestive system diseases	57 (17.22)
	Urinary system diseases	62 (18.73)
	Endocrine system diseases	28 (8.46)

Table 3 Statistical Table of Normality Test

					Skewness		Kurtosis	
Entry	Minimum Value	Maximum Value	Average Value	Standard Deviation	Statistics	Standard Error	Statistics	Standard Error
1	1	5	4.251	1.015	−1.637	0.134	2.209	0.267
2	1	5	4.272	0.965	−1.767	0.134	3.130	0.267
3	1	5	4.375	0.904	−1.629	0.134	2.363	0.267
4	1	5	4.517	0.788	−1.834	0.134	3.591	0.267
5	1	5	4.447	0.950	−1.896	0.134	3.015	0.267
6	1	5	4.202	1.255	−1.397	0.134	0.587	0.267
7	1	5	4.393	1.091	−1.842	0.134	2.322	0.267
8	1	5	4.462	0.928	−2.074	0.134	4.096	0.267
9	1	5	4.662	0.849	−2.962	0.134	8.556	0.267

Project Analysis Results

The results of the project analysis showed that the CR values of each item ranged from 5.230 to 10.697, all greater than 3.000. The differences in scores between the high-score group and the low-score group on all items were statistically significant (all $P < 0.001$), indicating that each item had good discriminatory ability. Furthermore, the correlation coefficients between the scores of each item and the total score of the scale ranged from 0.571 to 0.738 (all $P < 0.001$), all of which were higher than the recommended standard of 0.400. The correlation analysis coefficients among the items ranged from 0.114 to 0.635, indicating that each item was highly consistent with the overall measurement objective of the scale, and no items needed to be deleted. This stage of analysis confirmed the validity of all initial items, laying the foundation for subsequent validity and reliability analyses. The correlations among the items of the Chinese version of VRSUQ are shown in Table 4, and the correlation coefficients between the total table and each item, as well as the deleted α coefficients, are shown in Table 5.

Table 4 Correlation Between Each Item of the Chinese Version of VRSUQ and the Total Score of the Scale (n=331)

Entry	1	2	3	4	5	7	8	9
1	1	–	–	–	–	–	–	–
2	0.401[a]	1	–	–	–	–	–	–
3	0.465[a]	0.490[a]	1	–	–	–	–	–
4	0.158	0.346[a]	0.204[b]	1	–	–	–	–
5	0.300[a]	0.209[b]	0.114	0.401[a]	1	–	–	–
6	0.291[a]	0.337[a]	0.260[a]	0.464[a]	0.590[a]	–	–	–
7	0.323[a]	0.347[a]	0.335[a]	0.458[a]	0.268[a]	1	–	–
8	0.303[a]	0.226[a]	0.252[a]	0.316[a]	0.208[b]	0.432[a]	1	–
9	0.301[a]	0.241[a]	0.273[a]	0.386[a]	0.264[a]	0.625[a]	0.523[a]	1

Note: For a, the correlation is significant at the 0.01 level (two-tailed); for b, the correlation is significant at the 0.05 level (two-tailed).

Table 5 The Correlation Coefficients of the Chinese Version of the VRSUQ Total Table with Each Item and the Deleted α Coefficient of the Item

Entry	Correlation Coefficient between the Total Table and Each Item	The α Coefficient That Has Been Deleted
1	0.609	0.807
2	0.619	0.806
3	0.571	0.810
4	0.633	0.803
5	0.603	0.810
6	0.738	0.793
7	0.728	0.790
8	0.602	0.806
9	0.677	0.797

Validity Test Results

Content Validity

Through two rounds of expert inquiries, the I-CVI of the Chinese version of VRSUQ ranged from 0.833 to 1.000, all higher than the recommended standard of 0.78. The S-CVI/Ave was 0.978, which was higher than the critical value of 0.90. These results indicate that each item of the scale can effectively reflect the feelings and experiences of ICU patients when using VR devices, and it has excellent content representativeness.[20] Compared with the original VRSUQ which did not clearly report content validity indicators, the Chinese version, through systematic cross-cultural debugging and expert evaluation, has a more thorough quantitative assessment of content validity, ensuring the cultural relevance and semantic clarity of the items among the ICU patient population in China.

Structural Validity

Exploratory Factor Analysis

Exploratory factor analysis showed that the KMO value was 0.807 and the Bartlett's sphericity test χ^2 value was 363.917 ($P < 0.001$), indicating that the data were suitable for factor analysis. By using principal component analysis and combining with the maximum variance rotation method, three common factors with eigenvalues greater than 1 were extracted, and the cumulative variance contribution rate was 67.017%. This result confirmed the factor structure efficacy highly consistent with the cumulative variance contribution rate (70.88%) of the original VRSUQ. Both far exceeded the 50% psychometric standard and were at an excellent level. The loading of each item on its respective factor ranges from 0.609 to 0.876, with no cross-loading or loading lower than 0.40. The factor structure is consistent

Table 6 Factor Loading Matrix of the Chinese Version of VRSUQ (n=331)

Item	Satisfaction	Effectiveness	Efficiency
1. The system responded well to my manipulations as expected with no delays.	0.173	0.729	0.164
2. I think the virtual reality system provides clear feedback on my manipulations.	0.116	0.746	0.239
3. I kept making errors/mistakes while using the virtual reality system.	0.196	0.827	−0.006
4. I could clearly understand the information presented within the virtual environment.	0.409	0.101	0.609
5. I think this system is very user-friendly and designed in a simple way that most people can adapt to easily.	0.046	0.107	0.876
6. I think it is easy to correct errors made during virtual reality experiences.	0.263	0.215	0.778
7. I enjoyed the virtual reality experience.	0.743	0.257	0.245
8. During virtual reality experiences, I feel symptoms of cybersickness such as nausea, sweating, vomiting, stomach discomfort, or headaches.	0.755	0.154	0.119
9. During virtual reality experiences, I feel a lot of mental stress, such as feeling anxious, frustrated, or like I do not have enough time.	0.842	0.137	0.174

Notes: Reprinted from Applied Ergonomics, Volume 119, Kim YM, Rhiu I, Development of a virtual reality system usability questionnaire (VRSUQ), pages 104319, Copyright 2024, with permission from Elsevier.[8]

with the original scale and is respectively named "Effectiveness" (3 items), "Efficiency" (3 items), and "Satisfaction" (3 items). The details of the factor loading matrix of the Chinese version of VRSQ are shown in Table 6. The scree plot is shown in Figure 5.

Confirmatory Factor Analysis

Confirmatory factor analysis further supported the stability of the three-factor structure, and all model fitting indicators met the ideal standards: χ^2/df was 1.230 (< 3.0), RMSEA was 0.034 (< 0.08), IFI was 0.974, TLI was 0.958, and CFI was 0.972 (all > 0.90). It is comparable to the original VRSUQ (such as RMSEA=0.048, CFI=0.983), with a lower RMSEA value, indicating a better fit between the model and the data of ICU patients in China. These indicators collectively indicate that the three-factor structure of the scale has a good fit in the ICU patient sample in China, and the structural validity has been verified. The standardized structural model of the Chinese version of VRSUQ is shown in Figure 6.

Reliability Test Results

Reliability analysis showed that the Cronbach's α coefficient of the Chinese version of the VRSUQ total scale was 0.821, and the α coefficients of each dimension were respectively: effectiveness 0.709, efficiency 0.731, and satisfaction 0.765,

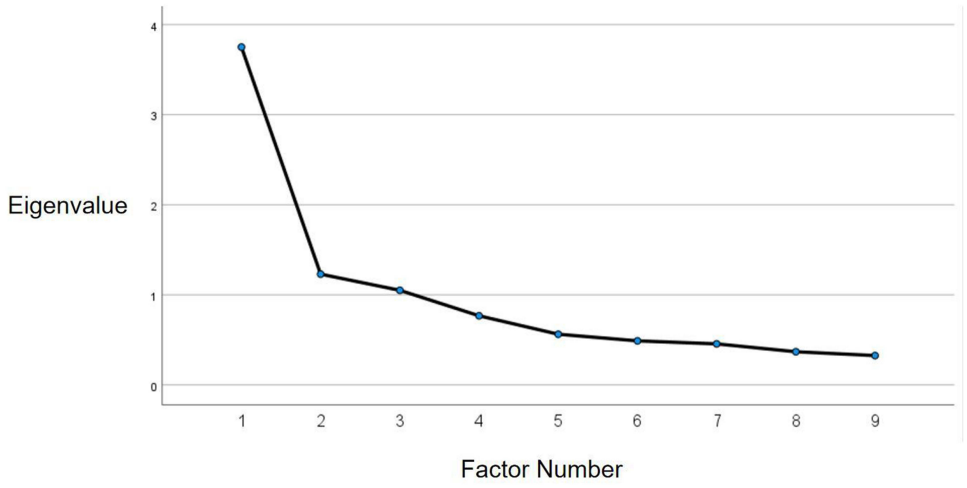

Figure 5 Scree plot for factor analysis of the VRSUQ.

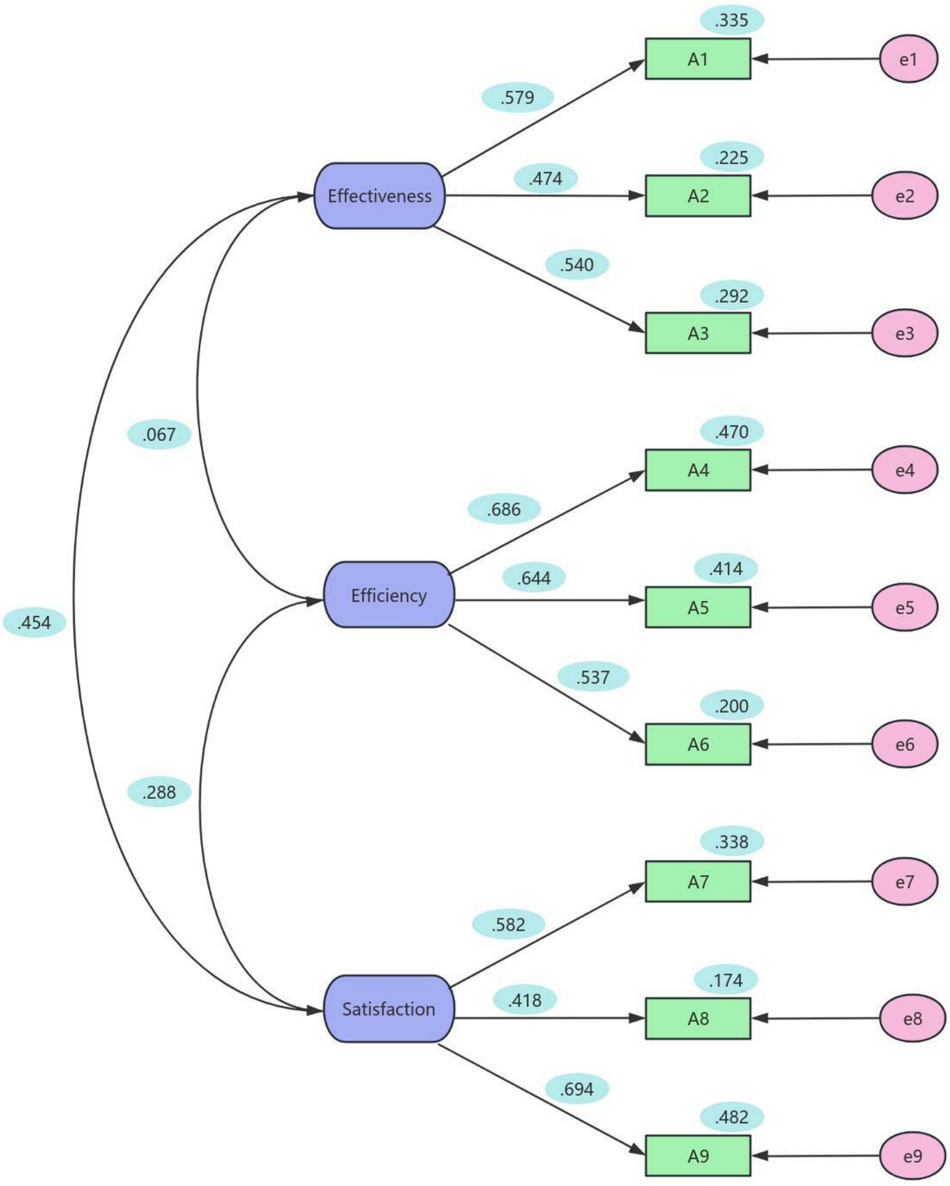

Figure 6 Standardized structural model of VRSUQ in Chinese version.
Note: A1 to A9 are items 1 to 9.

all of which were higher than the critical value of 0.70, indicating good internal consistency of the scale. Compared with the original VRSUQ (total scale α=0.836; effectiveness =0.773, efficiency =0.752, satisfaction =0.759), the α coefficients of the total scale and the "effectiveness" and "efficiency" dimensions in the Chinese version are slightly lower, while the reliability of the "satisfaction" dimension is comparable. This subtle difference may be related to the characteristics of the study population. The subjects of this study were ICU patients, whose physiological state, cognitive load and familiarity with VR technology were all different from those of healthy ordinary users in the original study, which might lead to slightly greater variability in their responses. Despite this, all reliability indicators of the Chinese version exceeded the widely accepted psychological measurement standard of 0.70, confirming that it remains a reliable measurement tool in the ICU patient population in China. In addition, the split-half reliability of the total scale was 0.782, and the split-half reliability of each dimension was 0.745, 0.795, and 0.828 respectively, which were also higher than the recommended value of 0.70. This further verified the robustness of the scale's reliability from different measurement methods.

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Discussion

Cultural Debugging and Clinical Applicability of the Chinese Version of VRSUQ

Against the backdrop of continuous innovation in critical care concepts and the rapid development of VR technology applications, system availability assessment has become an important link influencing whether VR technology can fully exert its rehabilitation potential in the ICU. Appropriate assessment tools can not only objectively reflect patients' real experiences during the use of VR, but also help medical staff promptly identify and optimize problems in the intervention, thereby enhancing patients' compliance and the effectiveness of the intervention. In recent years, a series of patient-centered care models have been proposed in the field of critical care, such as the "ABCDEF Bundle Strategy",[23] the "eCASH concept",[24] and the "ESCAPE Strategy",[25] emphasizing the importance of early activity, emotional management, and minimal sedation. However, these multi-dimensional intervention measures are often difficult to be fully implemented due to the limitations of human resources, time and resources.[26] With its advantages of immersion, interactivity and imagination, VR technology can integrate multiple rehabilitation elements into one, providing patients with a rehabilitation experience that is both interesting and functional. It has shown broad application prospects in icus.[27]

This study strictly followed the Brislin translation model and, through a systematic cross-cultural adaptation process, developed a Chinese version of VRSUQ suitable for ICU patients. In the process of translation and backtranslation, the research team not only pays attention to the equivalence of language, but also focuses on the cultural fit of concepts and the comprehension ability of patients. Make it more in line with the cognitive state and rehabilitation goals of ICU patients. The Chinese version of VRSUQ, while maintaining the three-dimensional structure of the original scale of "effectiveness, efficiency and satisfaction", has further strengthened its clinical applicability in the ICU patient population in China through cultural adjustment. This tool provides timely and quantified feedback for medical staff by obtaining patients' basic usage experiences of the VR system, helping to achieve individualized optimization of VR intervention.

Psychometric Comparison Between the Chinese Version of the VRSUQ and Domestic VR-Related Assessment Tools

The Chinese version of VRSUQ for cultural adaptation in this study is not the first assessment tool for VR experience in China, but it has a unique positioning in terms of scale structure, target population and assessment dimensions. Compared with the Chinese version of the Immersion Scale (IPQ) revised by Wang Xi et al,[28] both adopt a three-factor structure and have similar cumulative variance contribution rates (VRSUQ: 67.017%; IPQ: 49.84%), indicating that the Chinese VR scale has cross-tool consistency in structural stability. However, IPQ focuses on evaluating users' spatial presence, sense of participation and realism in the VR environment, and pays more attention to the immersive experience at the perception-cognitive level. VRSUQ, on the other hand, focuses on three operational dimensions of system availability: effectiveness, efficiency, and satisfaction, which are closer to the functional and comfort needs of ICU patients during actual use. In terms of reliability performance, the Cronbach's α coefficient (0.821) of the VRSUQ total scale is superior to that of the total scale reliability (0.757) of the Chinese version of IPQ, and the reliability of each dimension is also generally higher (VRSUQ: 0.709–0.765; IPQ: 0.608–0.679). This might be related to the fact that the VRSUQ items are designed more concisely and have clearer goals, making them particularly suitable for ICU patients with higher cognitive loads.

Compared with the Chinese version of the Simulated Scene Vertigo Questionnaire (SSQ) revised by Zhang Xiaoxiang et al,[29] VRSUQ complements the verification of sample features and the assessment of targets. SSQ focuses on assessing physiological discomfort symptoms during VR use (such as nausea, eye movement discomfort, and disorientation). Its target population mainly consists of healthy college students, with a cumulative variance contribution rate of 45.3% and a reliability coefficient ranging from 0.60 to 0.75. VRSUQ, on the other hand, is targeted at ICU patients and places greater emphasis on the overall usability and user experience of the system. Its psychometric indicators perform better among similar populations ($\alpha > 0.70$, cumulative variance contribution rate > 65%), demonstrating its applicability in specific clinical populations.

In conclusion, the Chinese version of VRSUQ has reached or surpassed the level of existing domestic VR assessment tools in terms of structural clarity, reliability and validity indicators, and clinical applicability. It fills the gap in the usability assessment of VR systems for critically ill patients and provides a localized tool with both theoretical structure and practical value for clinical use.

Psychometric Comparison Between the Chinese Version of the VRSUQ and International VR-Related Assessment Tools

The Chinese version of VRSUQ for cultural adaptation in this study, compared with the widely used VR assessment tools internationally, demonstrates unique advantages for clinical populations while ensuring the rigor of psychometrics. Compared with the System Availability Scale (SUS) developed by Brooke,[2] both are general-purpose tools that pursue simplicity and efficiency. As the industry's gold standard, SUS has relatively good reliability. However, its 10 items are derived from traditional software interface evaluations and do not cover core VR dimensions such as immersion and motion sickness. The structural validity is not targeted enough for VR experiences. Although the Chinese version of VRSUQ is also a short scale with 9 items, its reliability and validity are outstanding. Through strict cross-cultural debugging and clinical verification, the Chinese version of VRSUQ ensures that its items can accurately reflect the core experience of critically ill patients when using the VR system.

Compared with Kalawsky's VRUSE scale,[4] both are dedicated to comprehensively evaluating VR systems. VRUSE covers 100 items across 10 dimensions, with broad content validity. However, its large volume of questions imposes an excessive burden on ICU patients, has low feasibility, and has not reported clear reliability and validity indicators in patient groups. In contrast, the Chinese version of VRSUQ not only has a significant advantage in the number of items, but also has an I-CVI ranging from 0.833 to 1.000 and an S-CVI/Ave ratio as high as 0.978. Each item of the scale can effectively reflect the feelings and experiences of ICU patients when using VR devices. It indicates that while maintaining the depth of assessment, it is more suitable for clinical populations with limited cognitive states.

Compared with the Virtual Reality Motion Sickness Questionnaire (VRSQ) developed by Kim et al,[30] the two complement each other in terms of validity construction. VRSQ focuses on the two dimensions of eye movement and disorientation in motion sickness. Its reliability (α=0.847 for the eye movement dimension and α=0.886 for the disorientation dimension) is superior to that of this study. However, the goal of VRSQ is to assess physical discomfort symptoms, while the Chinese version of VRSUQ focuses on the overall usability of the system and user satisfaction, providing a more comprehensive "system performance - user experience" joint evaluation solution for clinical practice.

In conclusion, compared with representative VR assessment tools in the international community, the Chinese version of VRSUQ has achieved a better balance among structural fineness, robustness of reliability and validity, and clinical feasibility. It not only makes up for the limitations of international common tools in terms of culture, cognition and clinical scenarios when directly applied to ICU patients in China, but also its psychometric characteristics have reached an excellent level among similar international tools.

Clinical Application Prospects and Cross-Scenario Universality

The significance of the Chinese version of VRSUQ lies not only in providing an immediately available assessment tool for the ICU environment, but also in its wide potential applications and cross-population applicability. In clinical practice, this scale can serve as an indicator for evaluating patient outcomes, directly and quantitatively capturing patients' acceptance of VR intervention and the quality of their experience. Based on the assessment results, medical staff can identify in real time the problems encountered by patients during the use of VR, and then dynamically adjust the intervention plan to achieve individualized rehabilitation. For instance, for patients with low scores in the "satisfaction" dimension, it is possible to explore the replacement of VR content. For those with low scores in the "efficiency" dimension, the operation guidelines or equipment adaptation can be optimized. From a management perspective, this tool provides a unified comparison benchmark for different VR systems or intervention programs, which helps hospitals conduct evidence-based procurement and cost-benefit assessment, ensuring that the most effective and patient-experience technologies are introduced into clinical practice.

Beyond the specific environment of ICU, the Chinese version of VRSUQ also has high potential for universal application. Its concise 9-item structure and robust psychometric characteristics make it very easy to implement in other clinical departments. For instance, in the field of rehabilitation medicine, it can be used to assess the availability of VR for motor function training in patients with stroke or spinal cord injury. In the department of psychiatry and psychology, the acceptance of VR exposure therapy or relaxation scenarios by patients with anxiety and depression can be measured. In the geriatrics department, the interaction experience between elderly patients with cognitive impairment and VR cognitive training games can be tested. These applications can further verify and expand their validity as medical VR assessment tools.

Therefore, in the future, the Chinese version of VRSUQ can be cross-validated in different disease populations and medical scenarios, accumulate clinical data, and explore its correlation with outcome indicators such as functional recovery speed, pain score, and length of hospital stay, thereby promoting the scientific and humanized application of VR technology.

Limitations of the Research

Although this study strictly adhered to the scale development norms, there were still limitations. Firstly, there are inherent challenges in conducting usability evaluations in the ICU. The subjects of this study were ICU patients, whose physiological states (such as sedation levels, fatigue levels, and pain levels) and cognitive states (such as the risk of delirium and inattention levels) may fluctuate over time. The uncertainty of this state may affect the stability and consistency of its evaluation of VR experience. Although this study set strict inclusion criteria, a single, immediate assessment may not be able to fully capture the dynamic experiences of patients under different physiological states. Future research can introduce repeated measurements to explore the relationship between patient state stability and VRSUQ scores.

Secondly, the demographic characteristics and cultural background of the sample also have potential influences on the filling out of the scale. The samples of this study mainly came from a single medical center and were mainly composed of those with junior high school education or below (85.5%). Although this sample structure reflects the population characteristics of some icus in China, it also limits the universality of the research results. Educational level may influence patients' understanding of the Likert scale grade concept and the way they interpret abstract dimensions such as "effectiveness" and "satisfaction". For instance, patients with a low level of education may tend to choose extreme answers or avoid negative evaluations. Furthermore, deep-seated cultural factors, such as the possible courtesy bias or authoritative compliance tendency of Chinese patients when facing medical staff, may lead them to be more inclined to give positive and friendly feedback in their evaluations, thereby overestimating the scores on the scale. Although we have localized and optimized the expression in the pre-survey, this potential social approval is difficult to completely eliminate.

These limitations do not diminish the value of this study; rather, they reveal its clear scope of application and development path. They indicate that the Chinese version of VRSUQ is most suitable for the population with similar characteristics to the samples of this study in China in its current form. Future research needs to adopt multi-center collaboration to include patients with a broader range of educational backgrounds, geographical origins, and socio-economic statuses, in order to test the measurement equivalence of the scale in different subgroups and further analyze the impact of cultural factors on the evaluation of VR experiences.

Conclusion

This study cross-cultural adapted the Chinese version of VRSUQ, filling the gap of domestic VR system availability assessment tools for ICU patients. It has been verified that this scale has good reliability, validity and cultural adaptability, and is a robust assessment tool with psychometric characteristics. This tool can objectively obtain patients' feelings and experiences towards VR technology, providing immediate and quantified feedback for clinical medical staff, helping to identify and optimize problems in VR intervention, thereby promoting the transformation of VR technology from technology-oriented to patient-centered clinical practice. Future research should verify its universality in a broader

patient population through multi-center collaboration and explore its association with key clinical outcomes to further expand its application depth in critical care and other rehabilitation fields.

Abbreviations

ICU, Intensive Care Unit; VR, Virtual Reality; VRSUQ, Virtual Reality System Usability Questionnaire; S-CVI/Ave, scale's average content validity index; I-CVI, content validity index; EFA, exploratory factor analysis; CFA, confirmatory factor analysis; KMO, Kaiser–Meyer–Olkin; TLI, Tucker-Lewis index; IFI, incremental fit index; CFI, comparative fit index; RMSEA, root mean square error of approximation; χ^2/df, chi-square to degrees of freedom ratio.

Data Sharing Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki (as was revised in 2013). This study was approved by the Biomedical Research Ethics Committee of Henan University (HUSOM2024-418, HUSOM2024-434), and all participants provided informed consent and voluntarily participated in the study.

Consent for Publication

Written informed consent for publication of the patients' clinical details and clinical images was obtained from each participant. All participants were shown the final manuscript and gave explicit permission for its publication in print and online formats, including any accompanying images, videos, or audio recordings.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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