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Application of ultrasound simulation training in intensive care nursing teaching

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Abstract

Introduction The accuracy of ultrasound diagnosis of nurses in intensive care unit is helpful to improve the quality of nursing care. The traditional ultrasound teaching model has been unable to meet the needs of intensive care. Ultrasound simulation training as a new teaching model can improve the quality and efficiency of teaching. Therefore, the application of ultrasonic simulation training in intensive care ultrasound teaching hopes to improve the technical expertise, proficiency and accuracy of ultrasound use in intensive care nurses.

Methods A total of 40 nurses were divided equally into two groups. Twenty nurses in the control group were taught with the classic teaching method, and 20 nurses in the experimental group were taught with the ultrasound simulation training method. Each nurse practiced for about 15 min each time, three times a week, for a total of 30 days. After training, the theoretical and practical scores of the two groups were compared.

Result The experimental group were significantly higher than those of the control group, and the difference was statistically significant ($p < 0.05$) including the aspect of the theoretical scores ($p < 0.001$), practical scores ($p < 0.001$), and nursing satisfaction rates ($p < 0.05$).

Conclusions Compared with traditional teaching mode, ultrasonic simulation training is helpful to improve the teaching quality of intensive care nursing, and it can be tried to be applied to ultrasonic training in the future.

Keywords Ultrasound, Simulation teaching method, Classical teaching method, Intensive care, Nursing

Introduction

Recent years have witnessed a surge of progress in modern medical technology and specialty nursing. Ultrasound technology is being used increasingly in the field of intensive care nursing, covering vascular puncture auxiliary techniques, jejunal nutrition tube placement, pressure injury assessment, gastric residual volume, bladder urine residue, and assessment of deep venous thrombosis of the lower limbs [1]. The intensive care unit (ICU), a system of organized medical treatment and nursing care for critically ill patients, is designed to provide intensive and specialized medical treatment and nursing care during life-threatening organ system deficiencies, enhance monitoring capabilities, and offer various physiological organ support to maintain life [2–3]. Given the particularity and complexity of the ICU environment and patients' conditions, nursing staff are required to have solid and comprehensive professional knowledge, be equipped with expert monitoring and advanced skills, and possess high psychological qualities [4].

Ultrasound training in China is not part of the reference framework for the initial training of the nursing profession, and nurses of the nursing profession are required

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to continuously standardize the operation through additional training after entering the ICU ward. ICU nurses are required to have at least 3 years of experience and the title of nurse or above to reach the professional level of ultrasound use, and can participate in ultrasound training if they meet this requirement. Operating nurses receive their certificates one to two years after their ultrasound training. The basic courses of their training include all clinical and basic medical courses, including anatomy and physiology.

At present, critical care nursing staff still have inaccurate ultrasound nursing operation, unskilled technology and other problems, which urgently need to be solved. It is also mentioned in the Nursing Specifications for Clinical Operation Techniques of Severe Ultrasound that it hopes to improve the severe ultrasound technology of clinical nursing staff, solve nursing problems, and make the ultrasound technology of clinical nursing more scientific, standardized and homogeneous [5]. Therefore, training nurses in ultrasound procedures is important and helps to improve technical expertise and proficiency. However, the traditional nursing teaching model is no longer suitable for intensive care teaching courses and new efficient and high-quality teaching models need to be actively explored [6]. On the one hand, an efficient and high-quality teaching mode enables refresher nurses to master the basics of intensive care nursing, while, on the other hand, it improves the clinical nursing operative ability of refresher nurses and lays a solid foundation for future clinical nursing work [7]. Improving the professional ability of nurses can improve the quality of care, ensure the safety of patients, improve the quality of life and survival time of patients, and help reduce the mortality and disability rate of patients [7].

Traditional ultrasound teaching is mostly delivered through the use of real cases, although this can be easily affected by individual patient factors, the technical proficiency of the operator, ethical factors, etc., and it may be restricted by other factors that interrupt the procedure. In contrast, ultrasound simulation training is a learner-centered learning approach that provides standard and objective cases and standardized human body simulations for operator training. It is free from time and ethical constraints and can be repeated for intensive care training [8, 9]. Simulator based medical education (SBME) is becoming a popular method for improving the knowledge and performance of healthcare workers in various environments [10]. The ultrasound simulation system has emerged as a teaching mode in recent years and has been initially applied in a few medical disciplines. Simulation based training has been proven to reduce medical errors and provide a platform to enhance learners' knowledge, clinical skills, and performance in controlled environments, thereby improving patient care [11]. SBME is a learner centered approach that improves clinical technical skills through repeated practice and reflection before implementing these techniques on patients [12]. Ultrasound simulation training is an emerging teaching model in intensive care nursing education. Although the traditional method of real cases dominates, simulation training has attracted attention because of its advantages. For example, simulation training is a kind of standardized learning, which is different from variable real-life cases. It provides a consistent and objective learning experience compared to case studies; ultrasound simulation training allows for unlimited contact, and it allows for repeated practice without the constraints of real patients or ethical considerations [13]. In view of the lack of reports on ultrasound teaching, it has gradually become a focus of attention in ultrasound medicine education [14, 15]. Overall, the application of ultrasound simulation training in intensive care nursing appears to be in its early stages but holds promise for improving the efficiency and quality of nursing education [16]. For trainee nurses admitted to the ICU, scientific, reasonable, and standardized nursing teaching is required to fully improve their theoretical and technical levels, enabling them to better adapt to ICU clinical work quickly. Therefore, a key concern of nursing teaching staff is to provide high-quality training by applying ultrasound simulation technology to ICU nursing to enable trainee nurses to achieve the expected results.

The aim of this study was to compare the learning effects of traditional ultrasound training and simulated ultrasound training in order to explore an effective and high-quality nursing teaching model-intensive care ultrasound training, and to apply it to clinical practice.

Participants and methods

Participants

Forty nurses who received advanced training in the Department of Surgical Intensive Care Medicine of the China–Japan Friendship Hospital from January to December 2021 were selected as subjects using the convenience sampling method. Inclusion criteria: Clinical ICU nurses, and working years ≥ 3 years; Have a certain knowledge of nursing ultrasound; ③Nurses and above professional titles; 4. Informed consent, voluntary participation in this study. Exclusion criteria: ①Patients who are not on duty due to sick leave, maternity leave, etc.; ②Nurses' incomplete information, "incomplete information" refers to missing data in the subject 's records, which prevents us from accurately grouping or analyzing in the study. This study was a randomized controlled study. The methodology of this study follows the CONSORT. Using the random number table method, each nurse who received advanced training was assigned a digital label corresponding to a number between 1 and

40. Nurses were enrolled in the experimental group ($n = 20$) and the control group ($n = 20$) according to the random number table. The experimental group was given ultrasound simulation training. And the control group was implemented traditional ultrasound teaching. All the nurses involved in this study gave informed consent and volunteered to participate, and all the patients involved gave informed consent and obtained approval from the ethics approval board of this hospital.

The sample size was selected as convenience sampling method and all nurses who participated in the training were included because only 40 nurses met the inclusion and exclusion criteria in this training.

There are 20 nurses in the experimental group who have received advanced training, including 5 males, accounting for 25%, and 15 females, accounting for 75%; the average age of the experimental group among the research subjects is 23.45 ± 3.46 years old; the average working years of the experimental group is 3.657 (years); experimental group Group education level Associate/Bachelor/Master/Ph.D. = 18:2:0:0. There were 20 nurses in the control group who had received advanced training, including 8 males, accounting for 40%, and 12 females, accounting for 60%; the average age of the study subjects in the control group was 22.45 ± 3.73 years old; the average working years of the experimental group was 2.766 (years); The educational level of the experimental group was Associate/Bachelor/Master/Ph.D. = 19:1:0:0 (see Table 2).

Methods

The nursing instructors in both groups were essentially the same in terms of working years, professional titles, age, gender, etc., and the subjects in both groups were trained in theoretical knowledge and practical operation. According to the research, a working group was established, consisting of one head nurse, two senior teachers who have specialized in training ICU ultrasound knowledge and serve as national ultrasound trainers, and two intensive care physicians. The head nurse was responsible for selecting nurses and implementing training assessments, designing satisfaction questionnaires (Supplementary material 1); Senior teachers are responsible for providing strict training on ultrasound theory knowledge to nursing staff; The attending physician for intensive care is responsible for practical operation training.

Theoretical knowledge training

The same theoretical knowledge was taught in both groups and was delivered in the form of powerpoint(PPT) presentations. In addition, the instructors and the teaching content were the same in both groups. One session per week, each of 60 min duration of theoretical teaching, for four sessions. The content included ultrasound foundation, lung ultrasound foundation, ultrasound-guided arteriovenous puncture, ultrasound-guided peripherally inserted central catheter (PICC) puncture, ultrasound assessment of gastrointestinal motility, ultrasound-guided nasojejunal feeding tube placement, ultrasound determination of gastric residual volume and bladder urine residue, ultrasound screening of thrombus, bedside lung ultrasound examination (BLUE) process, and the application of ultrasound in skin pressure injury assessment.

Practical operation training

Practical operation content in the experimental group The subjects in the experimental group used an ultrasound simulator to participated in ultrasound simulation training practice after learning the relevant theory (Practice content is consistent with theoretical knowledge) (see Table 1). The ultrasound simulator uses real-time dynamic imaging and custom designed human models to perform chest, abdominal, and pelvic scans from basic cases to complex cases. Nurses can perform real ultrasound examination evaluations of the heart, abdomen, and pelvic structures, practice hand eye coordination and probe operation, and improve pathology and case recognition abilities.

The nurses were instructed by the teacher to operate in groups for 45 min, with five people in each group. Using a Vimedix Integrated Ultrasound Virtual Training System (USA) as a platform, the nurses who received advanced training learned to operate it on the basis of simulated cases while reviewing and consolidating their

Table 1 Ultrasound practice content of ICU nurses

	Specific contents
Ultrasound practice content	Ultrasound-guided arteriovenous puncture
	Ultrasound-guided peripherally inserted central catheter (PICC) puncture
	Ultrasound assessment of gastrointestinal motility
	Ultrasound-guided nasojejunal feeding tube placement
	Ultrasound determination of gastric residual volume and bladder urine residue
	Ultrasound screening of thrombus
	Bedside lung ultrasound examination (BLUE) process
	The application of ultrasound in skin pressure injury assessment

theoretical knowledge. The practical operational training was first explained and demonstrated by the training teacher, followed by selecting typical cases, assigning tasks, and allowing the group to freely discuss and practice. After completion, the learning results were reported one by one, with other members listening to the report, and the training teacher providing guidance. Finally, the group members refer to the results of others to improve their answers. Each nurse practiced for about 15 min each time, three times a week, for a total of 30 days. Each theoretical part is assessed by scoring after learning and practice.

Practical operation content in the control group The subjects in the control group participated in traditional teaching after learning the relevant theory and were instructed by the instructor to operate in groups for 45 min, with five people in each group. Patients were prepared in advance by the instructor according to the teaching content (Patient condition similar to simulated case in system); they were informed of the procedure, which commenced after permission was given. First, the instructor gave a practical demonstration, and the nurses who received advanced training practiced the technique. Then, the instructor gives the nurses a mark according to the teaching content. The nurses were promptly corrected and reviewed their performance to consolidate their theoretical knowledge. 1Each nurse practiced for about 15 min each time, three times a week, for a total of 30 days.

Assessment indicators

(1) After the two groups of training, theoretical test and operation test were performed on the lecture content, accounting for 50 points each. The theoretical knowledge test was a closed-book test which contains 25 objective questions and 5 subjective questions. And the subjective and objective questions each account for 25 points. The content included ultrasound foundation, lung ultrasound foundation, ultrasound-guided arteriovenous puncture, ultrasound-guided PICC puncture, ultrasonic evaluation of gastrointestinal motility, ultrasound-guided nasojejunal feeding tube placement, ultrasonic determination of gastric residual volume and bladder urine residue, ultrasound screening of thrombus, lung ultrasound basis, the BLUE process, and the application of ultrasound in skin pressure injury assessment. The practical test was standardized with reference to the standards set by the Chinese Critical Ultrasound Study Group (CCUSG) [17]. The questions were on a time-limited online survey. The examiners were all CCUSG-accredited lecturers who selected the same patient for pulmonary, abdominal, and thrombotic screening and skin pressure injury assessment. The refresher nurses each selected a patient for arteriovenous puncture assessment. Each practical test included 5 scoring items, including material preparation, operation image, operation time, instrument disinfection, and image interpretation. The examiners scored each nurse's performance in the assessment and recorded the results.

Through the pretest, the Cronbach α coefficient, retest reliability and content validity of the theoretical test are 0.804, 0.851 and 0.782, respectively. Cronbach α coefficient, retest reliability and content validity of the operation test were 0.791, 0.831 and 0.802, respectively.

(2) A self-made questionnaire was used to investigate the satisfaction of the two groups of refresher nurses with the teaching methods used (see Supplementary Material 1). Questions concerning satisfaction in the questionnaire were: Are you satisfied with the teaching method of ultrasound teaching theory: ① very satisfied, ② satisfied, and ③ dissatisfied.

All assessments were on paper as sent to nurse on site.

Statistical processing

The data was entered and confirmed by two researchers. All data in this study were statistically analyzed using SPSS 26.0 software. Measurement data were expressed as mean ± standard deviation (Mean ± *SD*), and two-tailed independent samples t-test was used to compare the two groups (data conformed to normality and homogeneity of variance). Enumeration data were presented as frequencies and percentages, and comparisons between two groups were performed using the χ^2 test. $p < 0.05$ indicated a statistically significant difference. Because multiple *t*-tests (Age, Working years)were involved, the scores of the two groups before and after intervention were compared using Bonferroni correction(Gender, Education). Test level $\alpha = 0.05/2 = 0.025$. Through Gpower software, in the case of existing sample size and corrected test level, the statistical power of *t* test and chi-square test were between 0.72 and 0.77.

Results

General information about the two groups

There was no significant difference in gender (1:3 vs. 2:3, $\chi^2 = 3.417$, $p = 0.988$) and age (23.45 ± 3.46y vs. 22.45 ± 3.73y, $t = 0.988$, $p = 0.375$) of the experimental group compared with the control group. The experimental group's working experience (3.657y vs. 2.766y, $t = 0.875$, $p = 0.385$), education level (18:2:0:0 vs. 19:1:0:0, $\chi^2 = 1.890$, $p = 0.340$) and other general There was no significant difference between the data and the control group. The experimental and control groups were comparable at baseline. See Table 2.

Comparison of the theoretical scores of the two groups

The mean of the theoretical score after of the experimental group ($M = 42.25$; $SD = 2.49$) is significant compared to

Table 2 General information about the two groups

Item	Experimental group ($n=20$)	Control group ($n=20$)	t/χ^2	*p*
Age(y)	23.45 ± 3.46	22.45 ± 3.73	0.988[a]	0.375
Working years(y)	3.657 ± 1.817	2.766 ± 1.571	0.875[a]	0.385
Gender(m/f)	5/15	8/12	3.417[b]	0.988
Education	18:2:0:0	19:1:0:0	-[c]	-
Associate	18	19		
Bachelor	2	1		
Master	0	0		
Ph.D.	0	0		

Note a: two-sample independent t test; b: chi-square test of four tables; c: Does not meet the conditions of the chi-square test

Table 3 Comparison of the theoretical scores between the two groups

Item	Experimental group ($n=20$)	Control group ($n=20$)	t	*p*
	M (SD)			
Test scores before training	35.45 ± 3.46	36.45 ± 3.73	0.879	0.385
Test scores after training	42.25 ± 2.49	37.80 ± 4.53	-3.853	***
t	-7.140	-1.029		
p	***	0.310		

Note t-tests were used to analyze the differences between two groups

Tableau 1 * < 0,05 ** < 0,01, *** < 0,001

Table 4 Comparison of the practical scores between the two groups

Item	Experimental group ($n=20$)	Control group ($n=20$)	t	*p*
Test scores before training	17.20 ± 1.74	17.35 ± 1.87	0.263	0.794
Test scores after training	38.80 ± 1.64	32.40 ± 1.35	-13.453	***
t	-40.442	-29.142		
p	***	***		

Note t-tests were used to analyze the differences between two groups

Tableau 1 * < 0,05 ** < 0,01, *** < 0,001

that of the score before the test, ($M=35.45$; $SD=3.46$), t (1,19) = -7.140; $p<0$, 0001. and the difference was statistically significant ($p<0.05$). The mean of the theoretical score after the experimental group ($M=42.2$; $SD=2.49$) is significant compared to that of the control group ($M=37.8$; $SD=4.53$), t (1,39) = -3.85; $p<0.001$. and the difference was statistically significant ($p<0.05$), as shown in Table 3.

Comparison of the practical scores of the two groups

The mean of the theoretical score after of the experimental group ($M=38.80$; $SD=1.64$) is significant compared to that of the score before ($M=17.20$; $SD=1.74$), and the difference was statistically significant ($p<0.05$). The mean of the theoretical score after the experimental group ($M=38.80$; $SD=1.64$) is significant compared to that of the control group ($M=32.40$; $SD=1.35$), $p<0.05$. and the difference was statistically significant ($p<0.05$), as shown in Table 4.

Comparison of satisfaction between the two groups

The results show that The experimental group had a significantly higher satisfaction rate at 60% ($n=12$) compared with the control group (50%, $n=10$), $\chi^2=18$, $p<0.001$. After the test, the teaching satisfaction of the experimental group was higher than that of the control group (90% ($n=18$) vs. 80% ($n=16$), $\chi^2=6$, $p<0.014$), and the difference was statistically significant ($p<0.05$), as shown in Table 5.

Discussion

The ultrasound simulation system is a promising simulation tool that can replicate complex interactions and environments that are not possible with traditional simulators [18]. Other studies have shown the effectiveness of using ultrasound simulation systems for training. Suarez Weiss et al. designed a two-week ultrasound simulation training for first-year radiology resident physicians, and the physicians stated that ultrasound simulation training can help improve knowledge perception and mastery [19]. Stergaard et al. found through a multicenter randomized controlled trial that training based on ultrasound simulators improved the performance of physicians in performing diagnostic ultrasound scans

Table 5 Comparison of nursing satisfaction between the two groups

Item	Experimental group ($n=20$)		Control group ($n=20$)		χ^2	*p*
	Satisfied	Dissatisfied	Satisfied	Dissatisfied		
Satisfaction before training	12	8	10	10	18	***
Satisfaction after training	18	2	16	4	6	*
χ^2	10		14			
p	**		***			

Note χ2 test was used to analyze the difference between the two groups

Tableau 1 * < 0,05 ** < 0,01, *** < 0,001

on patients [20]. Woodhead et al. explored the impact of simulation on gynecological ultrasound training and found that using simulation practices in gynecological ultrasound can help improve the abilities, skills, and confidence of trainees, as well as reduce patient discomfort [21]. According to the findings of this study, ultrasound simulation training has achieved remarkable results compared with traditional teaching. For one thing, ultrasound simulation training can standardize the technical skills of trainees. It provides standardized operating standards for many trainees via a professional simulation case basis, which is not open to influence by patients during real procedures and can be practiced repeatedly without causing discomfort or injury to patients. For another, the ultrasound simulation training system has a variety of training courses for different majors, the instructor can give professional guidance to trainees, enhance the trainees' ability to identify ultrasound image problems, and quickly improve the clinical operation level and theoretical knowledge of inexperienced operators [22]. This is consistent with the findings of a study on the ultrasound rotation of virtual multi-department nursing points for medical students. Ultrasound mini-teaching techniques improve trainees' ultrasound knowledge and image interpretation ability throughout the course, extensively increase their mastery of theoretical knowledge and application of operational techniques, and enhance their learning enthusiasm and interest [23].

Furthermore, ultrasound simulation training is entirely student-centered and can be studied and learned in different courses according to the needs of trainees. It is also possible to perform repeated ultrasound exercises without being associated with the creation of medical disputes, and as the operator is emotionally unaffected by patient-related effects, they can practice in a relaxed state of mind [24]. A study had shown that medical simulation training can help improve the performance of clinical physicians and nurses, enhance communication skills and professional skills, and enhance team cohesion [25]. It was found in this study that trainees who participate in the ultrasonic simulation nursing training mode have higher teaching satisfaction rates; this may be because trainees can obtain sound practical experience and emotional stimulation using ultrasound simulation while obtaining positive feedback in teaching, thus strengthening their operational abilities and learning interests [26]. A double-blind parallel-group block-randomized controlled experiment revealed that compared with traditional ultrasound, ultrasound simulation training significantly improved medical trainees' ultrasound skills and interest in learning [27].

The results of this study show that ultrasound simulation teaching has significant advantages in improving nurses' theoretical knowledge, skill level and learning satisfaction. Compared with traditional teaching models, ultrasound simulation teaching can provide nurses with a more standardized and personalized learning experience, helping them better master ultrasound operation skills. In this study, the theoretical knowledge and skill scores of nurses who received ultrasound simulation teaching were significantly higher than those of nurses who received traditional teaching. This is consistent with the results of other related studies. For example, Eroglu O [28] found that ultrasound simulation teaching can increase medical students' ultrasound theoretical knowledge scores by 10% and skill scores by 8%. Hani S [29] also found that ultrasound simulation teaching can significantly improve nurses' ultrasound operation skill level. In this study, the learning satisfaction of nurses who received ultrasound simulation teaching was significantly higher than that of nurses who received traditional teaching. This may be because ultrasound simulation teaching can provide a more vivid and intuitive learning experience and increase learners' interest and enthusiasm. Miller GT [30] also found that ultrasound simulation teaching can significantly improve medical students' learning satisfaction. Comparative results between this study and other related studies indicate that ultrasound simulation teaching is an effective and feasible teaching model that can significantly improve nurses' ultrasound theoretical knowledge, skill level, and learning satisfaction. In the future, ultrasound simulation teaching can be applied to more medical education fields to improve the quality and effect of medical education.

Given the fundamental differences between traditional intraoperative ultrasound and laparoscopic ultrasound in terms of probes, scanning methods, and perspectives, the training of physicians and nurses based on tradition and structure is neither sufficient to enable nurses to master laparoscopic ultrasound scanning techniques nor appropriate to meet clinical needs [31]. Against this backdrop, ultrasonic simulation technology has become increasingly respected. Experience with ultrasound simulation is currently gained through supervised clinical practice, which, in turn, is challenged by patient availability and risk. Prior simulation training and subsequent evaluation are beneficial for ensuring and improving competence prior to performing procedures on patients. Hempel et al. pointed out that there are currently a large number of ultrasound simulators that can replace ultrasound examinations on patients, and the learning effect on simulators is significant. The earlier one learns skills such as ultrasound-guided vascular puncture in ultrasound simulators, the safer it will be in clinical applications in the future [32]. However, ultrasound simulation training has the characteristic of high cost. Post et al.'s study suggests that trainees can reach the level of general abdominal ultrasound examination within 3 h of training in an

ultrasound simulator, but the average cost of training one trainee is estimated to be $638 [33].

Nevertheless, ultrasonic simulation training has some limitations. First, due to limitations in time and energy, we did not conduct a pilot study; and only a few samples were included in this study, which may lead to some limitations in the extrapolation of our conclusions. Second, the limited case base at this stage may not be able to provide effective help to trainees at an advanced stage. In addition, there are other problems that arise from the fact that the operating nurse does not have a degree in ultrasound and only receives ultrasound training. In response to this, future studies should be conducted involving more departments and at more hospital levels to demonstrate the effectiveness of ultrasound simulation in nursing teaching. Moreover, various training methods can be combined according to the level and ability of the trainees to improve the quality of ultrasound training [34].

Conclusion

In summary, ultrasound simulation training has more obvious advantages than traditional teaching in ICU nursing education. By providing standardized training, instructors can better understand students' abilities and conduct personalized training, thereby improving the quality of clinical nursing teaching. Therefore, it is recommended to introduce ultrasound simulation training into the ultrasound training of ICU nurses. In addition, if the case database in the background of the training system can be improved regularly, graded training will be even more helpful for improving the skills of trainees. While this study demonstrates these benefits, further research is needed to directly evaluate ultrasound simulations The impact of training on trainee skill development.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-06968-4.

Supplementary Material 1

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Author contributions
SYL and GC conceived of the study, and WJ and ZP participated in its design and data analysis and LZ was responsible for statistics. All authors helped to draft the manuscript, read and approved the final manuscript.

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

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of China-Japan Friendship Hospital. We obtained signed informed consent from the participants in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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