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ORIGINAL RESEARCH

Construction and Validation of Coronary CTA Health Education Program Based on Knowledge to Action Framework Combined with Teach-Back Method

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Introduction: The success of coronary CT angiography (CCTA) depends not only on the scan sequence parameters, but also on adequate preparation and active cooperation. At present, there are many reports about CCTA nursing and education, but there is no systematic and complete CCTA health education program.

Aim: Construct CCTA health education program and verify its effect.

Methods: Through literature research, evidence extraction and expert consultation, the CCTA health education program was constructed. 298 patients who underwent CCTA examination in the imaging department of our hospital were selected and randomly divided into the control group (148 cases) and the intervention group (150 cases) who were given the health education program based on KTA combined with feedback method. The effect was verified by comparing the CCTA knowledge self perception score, state anxiety score and examination duration between the two groups.

Results: 1. The CCTA health education program based on KTA joint feedback method is constructed. 2. The scheme shows significant differences in seven aspects such as CCTA knowledge self perception score.

Conclusion: The CCTA health education program constructed in this study can improve patients' self-awareness of CCTA knowledge and the success rate of one-time examination, increase satisfaction, ensure image quality, reduce patients' anxiety and tension, stabilize heart rate and heart rate, shorten examination time, and improve work efficiency.

Keywords: coronary artery, feedback method, health education, knowledge transformation theory, multi-slice spiral CT, nursing

Introduction

With the ongoing advancement of population aging and economic growth, both the incidence and mortality rates of cardiovascular diseases have been progressively increasing. A survey has revealed that heart disease is ranked among the top ten leading causes of death in the United States, with the proportion of deaths attributable to white individuals estimated at approximately 11.0%, black individuals at 9.7%, Hispanic individuals at 7.4%, and Asian individuals at 6.1%. Coronary heart disease (CHD) represents a substantial portion of these heart-related conditions.[1] In the United Kingdom, around 300 deaths per 100,000 individuals annually are attributed to CHD, with Scotland exhibiting the highest mortality rate from this disease.[2] In China, the population suffering from CHD is estimated to be about 330 million. According to 2019 statistics, the incidence rates have risen by 26.1% in men and 19% in women since 2008, leading to nearly 700,000 annual deaths due to CHD.[3] Furthermore, there is an observable trend of increasing incidence and mortality rates among younger age groups, establishing CHD as the leading cause of sudden death among young individuals.[4]

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Coronary angiography (CAG), which involves the insertion of a catheter into the peripheral artery under the guidance of Digital Subtraction Angiography is widely regarded as the "gold standard" for the diagnosis of CHD. Despite its status, the procedure is associated with extended examination durations and high costs, while its invasive nature introduces various risks, imposing significant physical and economic burdens on patients.[5] In contrast, coronary computed tomography angiography (CCTA) is an advanced imaging modality that employs multi-slice spiral CT to rapidly scan the cardiac region after the intravenous administration of a bolus injection of iodine contrast agent, followed by the reconstruction of the coronary artery image through post-processing techniques.[6] This approach is not only efficient and straightforward but has also gained widespread acceptance. It allows for the visualization of coronary artery calcification, the degree and severity of stenosis, and the condition of plaques along the vessel walls. CCTA demonstrates a sensitivity and specificity exceeding 90% in diagnosing coronary artery stenosis, coupled with an exceptionally high negative predictive value.[7] For patients suspected of having CHD or those with mild coronary artery disease who do not require interventional treatment, CCTA plays an especially pivotal role in screening.

The CCTA examination is influenced by a range of factors, including respiratory motion, limb movement artifacts, variations in heart rate and rhythm, swallowing, coughing, breath-holding maneuvers, scanning parameters, contrast agent extravasation, concentration, temperature, and flow rate.[8] Additionally, a lack of patient understanding regarding the procedure, the noise produced by the machine, and adverse reactions can induce tension and anxiety, which in turn may lead to alterations in heart rate, rhythm, and blood pressure.[9] Respiratory motion artifacts are commonly observed when patients fail to follow breath-holding instructions, while physical motion artifacts arise from patient tension during the scanning process.[10] Effective mitigation of these interferences requires comprehensive health education and targeted interventions. This highlights the significance of patient education in CCTA, which plays an essential role in ensuring both the success of the examination and the acquisition of high-quality images.[11] Although pre-examination health education has been receiving increasing attention, challenges remain, including incomplete content, insufficiently detailed guidance, and a predominance of one-way communication over more interactive approaches. Moreover, the time gap between scheduling and the actual examination can adversely affect patients' recall, thereby reducing the effectiveness of educational efforts.[12]

The Knowledge to Action Framework (KTA) was introduced by Professor Graham's research team in Canada in 2006 with the goal of facilitating the integration of research findings into clinical practice. This framework aims to engage policy makers, administrators, practitioners, researchers, patients, and the general public in the translation of knowledge and the reform of practices, thereby improving the quality of clinical care and patient health outcomes.[13] KTA is composed of two primary components: knowledge generation and knowledge application. The knowledge generation process encompasses three steps: knowledge consultation, knowledge integration, and knowledge production. The knowledge application phase, on the other hand, consists of seven steps: identifying problems and selecting the appropriate knowledge to address them, introducing knowledge into specific contexts, evaluating barriers, monitoring the application of knowledge, assessing the outcomes following its application, and ensuring the sustainability of knowledge use.[14] The teach-back method, also referred to as "feedback teaching", involves educators transmitting knowledge, which is then reiterated by the recipients in their own words. This allows educators to assess the understanding and retention of the information. Any misconceptions or errors are addressed and clarified by the educators until full comprehension is achieved.[15] The present study aimed to develop a CCTA health education program that integrates the KTA framework and teach-back method, with the program being implemented between the appointment and the examination. The objectives of this initiative were to enhance patients' understanding of CCTA-related knowledge, increase the success rate and satisfaction of first-time examinations, reduce patient anxiety, lower heart rate, improve cooperation during the examination, decrease the examination duration, and ensure the quality of the imaging.

Methods

Development of the KTA-Integrated Teach-Back Coronary CTA Health Education Program

Literature Review and Evaluation

Database searches were carried out using sources such as PubMed, Web of Science, Cochrane, Clinical Guidelines, the National Guideline Clearinghouse, CNKI, and Wanfang. The PICO strategy was employed in the search process.

Keywords were obtained through a combination of controlled vocabulary and free-text terms. The keywords included: coronary artery, coronary CT angiography, education, health education, nursing, and nursing research. The scope of the search encompassed relevant randomized controlled trials, guidelines, consensus statements, and systematic reviews published worldwide over the last two decades, including literature in both English and Chinese. A total of 456 articles were initially identified, from which 21 were retained after a comprehensive review. These included 16 randomized controlled trials, 3 clinical practice guidelines, 1 expert consensus, and 1 systematic review or meta-analysis derived from research literature. The evaluation and evidence extraction from the selected articles were conducted independently by two reviewers, with a third reviewer resolving any discrepancies.

Delphi Expert Consultation

In accordance with the knowledge transformation theory, relevant articles were selected through a systematic process of literature retrieval, screening, and quality assessment. Following the extraction and synthesis of evidence, a three-level health education framework for coronary CTA was preliminarily established.

The expert consultation form is structured into three sections: ① Introduction: This section outlines the research background, objectives, methods, and provides explanations for relevant terminology; ② General expert information: This part includes the expert's basic details, their familiarity with the research, and the basis for their judgment. Familiarity levels are assigned values using a Likert 5-point scale (1.0, 0.8, 0.6, 0.4, 0.2) corresponding to five categories: very familiar, relatively familiar, moderately familiar, somewhat unfamiliar, and unfamiliar. The judgment basis includes theoretical knowledge, practical experience, reference to domestic and international materials, and subjective perception, with corresponding impact values of 1.0, 0.8, and 0.6 for high, medium, and low impact, respectively. Values for theoretical knowledge (0.3, 0.2, 0.1), practical experience (0.5, 0.4, 0.3), reference to domestic and international materials (0.1, 0.1, 0.1), and subjective perception (0.1, 0.1, 0.1) are based on existing literature;[16] ③ Main questionnaire section: This part focuses on item content and importance assignment, where each item is rated using the Likert 5-point scale (ranging from unimportant to very important), with scores assigned from 1 to 5, and a column for expert suggestions is also included.[17]

Expert selection criteria: ① Substantial experience in the fields of imaging, health education, or nursing; ② A minimum of 10 years of relevant work experience in imaging; ③ A bachelor's degree or higher, with an intermediate title or above; ④ A genuine interest in the research topic and a willingness to participate. An expert inquiry form concerning the health education aspects of coronary CTA is issued to those who meet these criteria.

Item selection criteria: The enthusiasm of experts is reflected in the questionnaire response rate, with a rate exceeding 70% indicating strong engagement. The expert authority coefficient (Cr) is determined by averaging the experts' familiarity (Ca) and judgment criteria (Cs). A Cr value greater than 0.7 indicates high expert authority. The average importance assignment value reflects the consensus of expert opinions. The criteria for item selection include an average importance assignment value greater than 3.5 and a coefficient of variation less than 0.25. The Kendall concordance coefficient (W) is used to assess the degree of consensus among expert opinions, with values ranging from 0 to 1, typically fluctuating between 0.4 and 0.5.[18]

Validation of Health Education Programs

Sample Size

The objective of this study is to implement a coronary CTA health education program grounded in the knowledge transformation model and supplemented with the feedback method developed in the preliminary phase of clinical practice and to assess its effectiveness. Using a convenient sampling approach, a total of 300 patients who underwent coronary artery CTA at a hospital in Shanghai between May 1, 2021, and July 31, 2021, were selected. These patients were assigned to either the control or intervention group based on the parity of their appointment dates, with 150 patients in each group. The control group received the standard health education program, while the intervention group was provided with a health education program integrating the knowledge transformation model and feedback method.

Inclusion criteria: ① First-time recipients of coronary CTA; ② Aged 18 years or older, alert, and free from cognitive impairments; ③ Voluntarily agreed to participate in the study and signed the informed consent form. Exclusion criteria:

① Severe cardiac or renal insufficiency, acute myocardial infarction, serious arrhythmias, hyperthyroidism during treatment, or acute asthma; ② Patients with a documented history of severe allergic reactions to iodine contrast agents; ③ Individuals with communication impairments, such as difficulties in hearing or reading; ④ Individuals unable to hold their breath for various reasons; ⑤ Pregnant women.

Two cases from the control group were excluded from the statistical analysis due to incomplete or invalid data. Consequently, the final analysis included 150 cases from the intervention group and 148 cases from the control group.

Verification Method

Control group: The conventional health education program comprised the following components: ① Distribution of informed consent forms at the time of appointment, instructing patients to thoroughly read and complete medical and allergy histories, along with other required assessments, prior to the examination, with signatures obtained one day before the procedure; ② Routine education on the day of examination, including instructions on pre-examination precautions, administration of metoprolol for heart rates exceeding 90 beats/min, guidance on cooperation during the procedure, and breath-holding training on the examination bed; safety checks, including the removal of all metallic items; ③ Education regarding post-examination precautions.

Intervention group: A health education program tailored to coronary CTA was implemented based on the knowledge transformation theory in combination with the teach-back method (Table 1). The program involved: ① The formation of a health education team, comprising physicians, technicians, nurses, and customer service personnel, all of whom underwent comprehensive training; ② Health education timing combined with teach-back method: 20 min on appointment day, 30 min one day before examination, and 20 min on examination day for "assessment, explanation → questioning → repetition → evaluation" of relevant knowledge; ③ Pre-examination knowledge dissemination and preparation: Special preparations, such as heart rate and rhythm management, as well as breath-holding training; routine preparations, including fasting, procedural guidance, cooperation during the procedure, and emergency preparedness; ④ Assessment of iodine contrast media usage, explanation of possible adverse reactions, and warming of the contrast media to 37 °C; ⑤ Nursing care during the examination, including patient positioning, ECG gating and high-pressure injector setup and securement, ensuring patient comfort, privacy, and protection, coordinating breathing, and adhering to an individualized injection protocol with continuous monitoring; ⑥ Post-examination care, including observation, patient praise, hydration, education about potential delayed reactions, and corresponding management strategies; ⑦ Psychological support and environmental enhancement, featuring continuous psychological care, teaching relaxation and breathing techniques to alleviate anxiety, playing soothing music, and creating a comfortable atmosphere. Additionally, QR codes linking to relevant informational videos were displayed at ward and imaging department windows, with pertinent information continuously broadcasted on TV screens.

Measurement Indicators and Evaluation Tools

① General information questionnaire:[7] This instrument is based on a literature review and incorporates modifications to an earlier version of the questionnaire. It collects basic demographic and health-related data, including name, age, gender, cultural background, income, and medical history, among other factors.

② Self perception questionnaire of patients on CCTA knowledge:[7] This questionnaire was adapted from an existing tool[7] and revised according to practical insights. It consists of 20 items covering topics such as coronary heart disease, iodine contrast agents, factors influencing coronary artery examinations, and key considerations for

Table 1 Two Rounds of Expert Authority Coefficients

Round	Ca	Cs	Cr
First round	0.90	0.84	0.87
Second round	0.91	0.87	0.89

Note: expert judgment coefficient (Ca), familiarity degree (Cs) and authority coefficient (Cr).

preparing for CTA procedures. The format is multiple-choice with four possible responses: very clear, know, somewhat know, and do not know, corresponding to scores of 3, 2, 1, and 0, respectively. The total score is 60 points, with higher scores reflecting a better understanding of the material.[7] The questionnaire's clinical validity was assessed with 50 coronary CTA patients, yielding a Cronbach's alpha coefficient of 0.958, a KMO value of 0.825 ($P < 0.05$), and a Bartlett's test of sphericity result of 0.000. The test-retest reliability coefficient was found to be 0.892 ($P = 0.03$), confirming the tool's excellent reliability and validity.

③ State Anxiety (S-AI) questionnaire: initially developed by Cattell and Spielberger and subsequently modified by Li Wenli et al in 1995,[17] aims to assess an individual's immediate or recent experiences of fear, tension, anxiety, and neuroticism in a given situation or time frame. This instrument consists of 20 items in total. The items are categorized as follows: 1 point for "none at all", 2 points for "somewhat", 3 points for "moderately", and 4 points for "very obvious". Among these items, those numbered 1, 2, 5, 8, 10, 11, 15, 16, 19, and 20 are scored in reverse for positive emotions, while the remaining 10 items are scored in ascending order to measure negative emotions. A higher score reflects a greater level of anxiety at the assessed time or in the given situation. For example, for topic 1, "I feel calm", the patient chooses "very obvious" and scores it in reverse order as 1 point; In topic 3, "I am nervous", patients who choose "very obvious" will score 4 points in positive order.This questionnaire has been extensively utilized and is widely regarded for its reliability and validity.

④ Satisfaction questionnaire:[4] This questionnaire, which was revised by integrating a literature review with practical observations, consists of seven items: the nurses' lancing technique, the nursing staff as a whole, scanning technicians, bar service personnel, mastery of coronary CTA knowledge, the examination process, and the overall impression of the CT department. Each item is divided into four grades: "very satisfied, basically satisfied, average, dissatisfied", and the proportion of people in each grade of the two groups is counted. The less the proportion of "dissatisfied", the higher the satisfaction is. The Cronbach's alpha coefficient was 0.75, standardized to 0.759, with a KMO value of 0.634 and Bartlett's test of sphericity yielding a significance level of < 0.05, indicating strong reliability and validity.

⑤ Evaluation of image quality: In accordance with the established guidelines, two senior imaging physicians, who were fixed in their roles, independently assessed the image quality in a double-blind manner. Discrepancies between their evaluations were resolved through negotiation. Each coronary artery image was rated using a subjective scoring system and categorized into four grades: excellent (no artifacts, no visible noise, clear delineation of the vessel, good vessel brightness); good (mild artifacts, slight blurring around the vessel, good vessel brightness, diagnostic quality); fair (moderate artifacts, noticeable blurring around the vessel, fair vessel brightness, no significant diagnostic impact); and poor (severe artifacts, misalignment of the vessel, substantial blurring around the vessel, inability to distinguish the vessel from surrounding structures) (Figures 1–4).[19]

⑥ Success rate of one-time inspection: This refers to the proportion of individuals who successfully complete the inspection on the first attempt out of the total number of participants. The patient is positioned on the CT scan table, and adjustments are made based on heart rate, fluctuations in heart rate, and the patient's ability to cooperate with breath-holding. The scan technician and nurse continuously adjust the patient's condition until it is optimal. If the optimal state is achieved on the first attempt and the examination is completed successfully, the procedure is considered successful.[7]

⑦ Examination time: This refers to the total duration, in minutes, from the moment the patient enters the examination room until they leave after the procedure is completed.[7]

⑧ Heart rate: The finger clip pulse oximeter yuwell (specification and model: yx301) produced by Jiangsu Yuyue Medical Equipment Co., Ltd. It was used to measure the patient's heart rate in a calm state on the day of appointment (before intervention); The heart rate was measured the day before the examination, before the scan on the day of the examination, and during the scan (the average of three heart rates was taken after the intervention).

All measurement indicators were obtained by the designated medical staff involved in the study. The general information questionnaire was administered prior to the intervention.Self perception questionnaire of patients on CCTA knowledge, S-AI questionnaire, and heart rate were assessed both before and after the intervention. The success

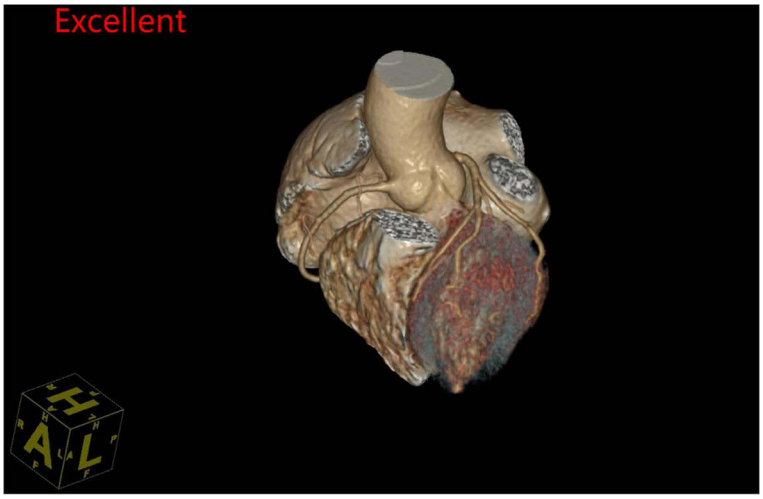

Figure 1 The reconstructed three-dimensional coronary artery images with excellent, good, average and poor image quality scores were added. As follows: Image quality score: excellent (no artifacts, no obvious noise, clear and recognizable blood vessels, good blood vessel brightness).

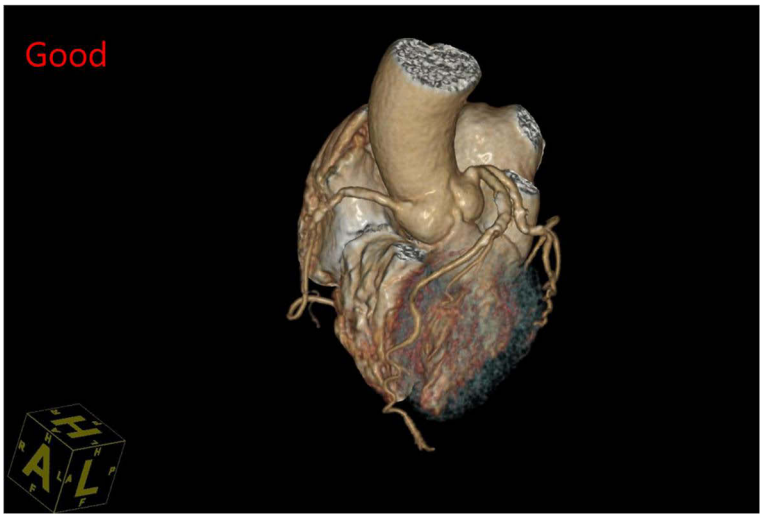

Figure 2 Image quality score: good (slight artifact, slight blur around blood vessels, good brightness of blood vessels, which can be diagnosed).

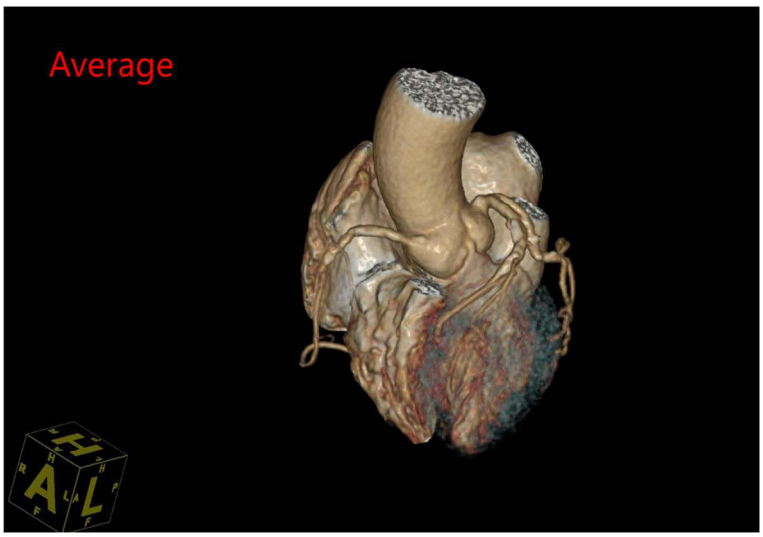

Figure 3 Image quality score: average (moderate artifact, obvious blurring around blood vessels, acceptable brightness of blood vessels, which does not affect the diagnosis).

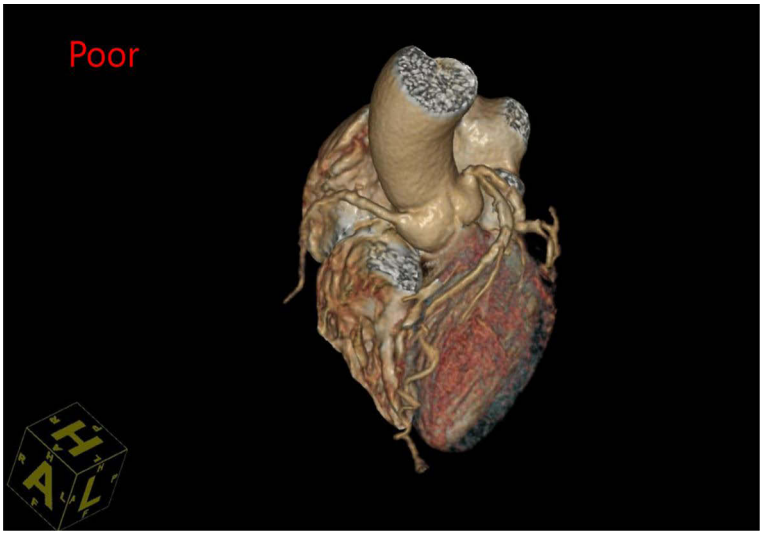

Figure 4 Image quality score: poor (serious artifact, obvious vascular dislocation, serious peripheral blur, inability to distinguish blood vessels from surrounding components, poor brightness of blood vessels, unable to evaluate).

rate of the one-time examination, examination duration, image quality, and patient satisfaction were evaluated following the intervention.

Data Analysis

Two staff members are responsible for data entry and sorting using Excel, with one assigned to data entry and the other to verification. Statistical analysis is performed using SPSS 25. Expert consultation statistics are described using percentages, means, and other relevant measures, while the degree of coordination among expert opinions is expressed using the Kendall coordination coefficient. Demographic data are described by frequency and percentage; The measurement data is described by the mean±standard deviation; Shapiro—Wilk test is used to test the normality of data. This study is a large sample data considering normal distribution. "CCTA knowledge self-perception, S-AI, heart rate, examination time" uses *t*-test; "One-time inspection success rate, image quality and satisfaction" uses chi-square test or Fisher exact probability test.

Ethical Considerations

This study was conducted in strict accordance with the Helsinki Declaration, adhering to the principles of voluntariness, confidentiality, and humanistic care. It received approval from the Ethics Committee of Tongji University Affiliated Oriental Hospital (Shanghai Oriental Hospital), ensuring compliance with the institution's medical regulations. Prior to the commencement of the study, the researcher provided a thorough explanation of the study's objectives and significance to the participants. Consent was obtained from both the participants and their families, and informed consent forms were duly signed. The study contained no harmful elements, did not infringe upon the participants' privacy, and was entered into voluntarily with full awareness of its purpose. Ethics Approval No.: [2024] Yen Audit No. (006).

Results

Results of the Expert Consultation

Basic information of experts: In accordance with the inclusion and exclusion criteria, a total of 15 experts from various fields, including imaging diagnosis, imaging technology, health education, and clinical nursing, were selected. All experts are affiliated with grade III class A hospitals in Shanghai, comprising 8 males and 7 females. The average age of the participants is 42.6 ± 5.03 years, with an average of 20.33 ± 6.21 years of professional experience. Regarding their professional titles, there are 2 chief physicians, 3 deputy chief physicians, 5 chief technicians, 1 deputy chief nurse, and 4 chief nurses. Concerning their academic qualifications, 3 hold doctoral degrees, 4 possess master's degrees, and 8 have bachelor's degrees.

The expert enthusiasm coefficient: A total of 30 questionnaires were distributed across two rounds of expert consultation, with a recovery rate exceeding 100%. The expert authority coefficient (Cr)[20] was ≥0.8 (Table 2). Expert opinion coordination:[20] The Kendall coordination coefficient (Kendall *W* value) ranged from 0.3 to 1 in the first round and from 0.4 to 1 in the second round (Table 3).

CCTA Health Education Program Based on KTA Combined with the Teach-Back Method

Through two rounds of expert consultation, a consensus was reached, resulting in a CCTA health education program based on knowledge transformation theory combined with the teach-back method. The program consists of three levels: 5 first-level items, 11 second-level items, and 31 third-level items. The main aspects include "assessment", "pre-examination knowledge and preparation", "contrast media adverse reactions and management", "examination cooperation", and "post-examination knowledge" (Table 1).

Results of the Application of Health Education Programs

Comparison of General Information Between the Two Coronary CTA Groups

Furthermore, no statistically significant difference was observed in the general information between the two patient groups ($P > 0.05$), and they were found to be comparable (Table 4).

Table 2 Degree of Coordination of Two Rounds of Expert Opinions

Parameters	First Round			Second Round		
	W	X^2	*P*	*W*	X^2	*P*
Primary indicators	0.356	151.679	<0.05	0.404	150.271	<0.05
Secondary indicators	0.386	368.465	<0.05	0.431	176.341	<0.05
Tertiary indicators	0.305	773.699	<0.05	0.436	512.013	<0.05

Table 3 Coronary CTA Health Education Program Based on Knowledge to Action Framework Combined with Teach-Back Method

Primary Item	Secondary Item	Third-Level Item
Estimate	Contraindication evaluation	1.To evaluate whether the patient has a history of severe allergic reaction to iodine contrast agent, hyperthyroidism attack, acute asthma, high fever > 38, severe irreversible cardiac and renal insufficiency and other absolute contraindications. 2. People with allergic history to other drugs and food, people with allergic constitution with mild allergic history to iodine contrast agent, poor control of hypertension and gout attack are all relative contraindications. 3. Whether diabetic patients take metformin or not; Whether to stop taking metformin for 48 h before the examination, and whether those who have not stopped taking metformin have issued renal function test results and whether there is no abnormality.
	Other aspects of evaluation	4.Whether the heart rate is too fast, arrhythmia, whether there is drug control. 5.Whether there is a long-term history of infusion or chemotherapy, venous conditions 6.The education level of patients and their families, whether they are accompanied by family members, and the emotional state of patients. Is this the first time for examination?

(*Continued*)

Table 3 (Continued).

Primary Item	Secondary Item	Third-Level Item
Relevant knowledge and preparation before inspection	Coronary CTA related knowledge	7.Definition, harmfulness and diagnostic means of coronary heart disease 8.The purpose, method, process and factors affecting the image quality of coronary CTA, the method of injecting iodine contrast agent into the vein of the right upper limb, the radiation safety of spiral CT and so on.
	Pre-inspection knowledge and preparation	9.You do not need to fast or fast for 1–2 h before the examination, and you can drink water without drinking preparation. 10.Routine medication does not need to be stopped, diabetes patients who take metformin need to stop metformin for 48 h, and renal function test results are normal if they do not stop taking metformin. 11.If there are patients with arrhythmia and frequent premature beats, contact a doctor to intervene the heart rhythm and heart rate in advance and keep the heart rate < 70–90 beats/min; It is better to take long-acting β -blockers the night before examination. 12.12–24 h before the check-up, avoid taking drugs, food, drinks, etc. that increase the heart rate, such as Viagra drugs, alcohol, coffee drinks, etc. Inform patients of the importance of good mentality and stable mood to stabilize heart rate, and the significance of stable heart rate to examination. 13.Tell them not to wear metal pendants on their chests, clothes with double breastings on their chests, and underwear with metal on them for women.
	Breathing and breath-holding skills training	14.Inform coronary CTA of the need for breath-holding cooperation, and different breath-holding training methods, breath-holding time and times of breath-holding during examination. 15.Breathe deeply and then hold your breath: take a deep breath with your nose after listening to the machine instruction, and hold your breath while your abdomen bulges. Listen to the machine instruction "You can breathe" and then relax your breathing. 16.Take a deep breath and hold your breath at the end of exhalation: breathe in through your nose and then exhale slowly through your mouth. Hold your breath at the end of exhalation, and your abdomen will relax and remain motionless at the same time. Listen to the machine instruction "You can breathe" and then relax your breathing. 17.Breathe calmly, hold your breath at the end of exhalation, keep your abdomen still, and listen to the machine instruction "You can breathe" before relaxing your breathing.
Adverse reaction of iodine contrast agent and its treatment	Possible adverse reactions during inspection.	18.Prompt for sneezing and coughing without other reasons during the injection of iodine contrast agent, and observe closely to find out in time, so as to be alert to allergies. 19.Nausea and vomiting may occur. Do not panic and lean to one side. Clean your mouth in time to prevent suffocation.
	Possible adverse reactions after the examination.	20.Rash, itching, throat tension, facial swelling, chest tightness and palpitation may occur and need to be reported in time. The medical staff will strengthen observation and find out and deal with them in time. 21.There is a possibility of local extravasation. Once it happens, do not be nervous. The medical care has a professional treatment method to deal with it in time, and its local area will gradually absorb and dissipate.

(*Continued*)

Table 3 (Continued).

Primary Item	Secondary Item	Third-Level Item
Cooperation in inspection	Body position coordination	22.Lie flat on your back on the machine tool and set a comfortable posture. Put your hands above your head on the pillows on both sides of your head. Do not press them under your head. It is better for you to be comfortable 23.It is necessary to unbutton the chest clothes and connect the ECG leads properly to observe the heart rate and rhythm while paying attention to protecting privacy. It is necessary to take nitroglycerin under the tongue to dilate the coronary artery to achieve better image effect.
	Possible discomfort during inspection and preventive treatment	24.Because the injection speed of contrast agent with high-pressure syringe is relatively fast, if there is severe pain during injection, the left hand will signal in time. 25.There may be transient fever, urinary incontinence and bitter taste in the mouth at the moment of drug injection, which belongs to the physiological reaction of iodine contrast agent. Do not panic. 26.If there are other discomfort, nausea and vomiting in the process, tilt your head to one side in time, and raise a small red flag with your left hand as a sign; Keep your body posture still without discomfort, and do not cough or swallow; Prevent the connecting tube from falling off, local swelling and motion artifacts.
Inspection end related knowledge	Matters needing attention at the end of inspection	27.It is instructed to rest and observe in the observation area for 20–30 min, eat slowly in moderation without discomfort, and drink more than 2000–3000mL within 24 h after examination. Those who are forbidden to drink water can promote the excretion of contrast media through intravenous rehydration. 28.After the observation and evaluation, there is no adverse reaction, and you can leave after pulling out the needle; Please press the needle hole for 5 ~ 10 min to evaluate its compliance. 29.Diabetic patients who take metformin continue to stop taking metformin hypoglycemic agents for 48 h; Do not drink alcohol and allergic seafood and other foods for three days.
	Adverse reactions and treatment	30.In case of dizziness and nausea: continue to rest and observe; Vomiting: do not panic, clean up the vomit in time, gargle and take a deep breath to relax, and take medicine according to the doctor's advice in severe cases; Skin allergy and itching such as rash and wheal: do not scratch and take medicine according to the doctor's advice; Mouth, lip, facial edema and suffocation: Do not be nervous, take oxygen, and take medicine according to the doctor's advice. 31.After 3–7 days, seek medical attention in time if skin itches, lumps and rubella appear; If the injection arm is found to be striped red and local pain, you can apply hot compress and contact the doctor by telephone in time; Late detection of elephants is relatively rare and generally not life-threatening. Please do not be nervous and contact the nearest doctor in time.

Following the intervention, both groups demonstrated an increase in the scores on patients' self perception score of CCTA knowledge (within-group comparison before and after the intervention)

The scores in the intervention group were notably higher than those in the control group (comparison between the two groups after the intervention). A reduction in state anxiety scores (S-AI) was observed in both groups after the intervention (within-group comparison before and after the intervention), with the intervention group exhibiting a significantly greater reduction than the control group (comparison between the two groups after the intervention).

Table 4 Comparison of General Information of Coronary CTA Subjects in the Two Groups (x^2±s) Cases (%)

Parameters	Group	Intervention Group	Control Group	X^2	*P*
Age		50.10±14.40	51.91±15.01	1.01	0.27
Gender	Male	91 (60.7%)	77 (52%)	2.26	0.13
	Female	59 (39.2%)	71 (48%)		
Occupation	Cadre	29 (19.3%)	17 (11.56%)	9.72	0.21
	Workers	59 (39.3%)	46 (31.3%)		
	Farmers	9 (6%)	19 (12.8%)		
	Farmers	53 (35.3%)	66 (44.6%)		
Marital status	Unmarried	16 (10.7%)	11 (7.4%)	7.22	0.07
	Married	124 (82.7%)	113 (76.4%)		
	Divorced	7 (4.7%)	16 (10.8%)		
	Widowed	3 (2%)	8 (5.4%)		
Educational level	Junior high school and below	51 (34.0%)	55 (37.2%)	0.39	0.82
	High school and junior college	55 (36.7%)	50 (33.8%)		
	University and above	44 (29.3%)	43 (29.1%)		
Type of medical insurance	Provincial medical insurance	5 (3.3%)	11 (7.4%)	6.47	0.09
	Municipal Medical Insurance	104 (63.9%)	92 (62.2%)		
	New Agricultural Cooperative	13 (8.7%)	23 (15.5%)		
	Self-funded	28 (18.7%)	22 (14.9%)		
Economic Income (Monthly)	Less than 2000 Yuan	16 (10.7%)	22 (14.9%)	1.19	0.55
	2000~5000 Yuan	73 (48.7%)	68 (45.9%)		
	Above 5000 Yuan	61 (40.7%)	58 (39.2%)		
Negative life events in the last year	No	135 (90%)	126 (85.1%)	1.62	0.20
	Yes	15 (10%)	22 (14.9%)		
Malignant tumor history	No	131 (87.3%)	120 (81.1%)	2.19	0.14
	Yes	19 (12.7%)	28 (18.9%)		
Previous history of hypertension diabetes	No	100 (66.7%)	83 (56.1%)	3.55	0.06
	Yes	50 (33.7%)	65 (43.9%)		

Regarding heart rate, a substantial decrease was recorded in the intervention group, while an increase was noted in the control group. A significant difference between the two groups was observed after the intervention ($P < 0.001$) (Table 5).

After the intervention, the intervention group experienced a significantly shorter examination time compared to the control group. Additionally, the success rate of a single examination was higher, and the image quality in the intervention group was superior to that in the control group (Table 6).

Table 5 Patients' Self Perception Score of CCTA Knowledge, State Anxiety Score and Heart Rate Between the Two Groups Before and After Intervention (x^2 ± s)

Variable	Group	Pre-Intervention	Post-Intervention	*t*	*P*
Self perception score of CCTA knowledge	Intervention group	11.30±7.66	51.14±7.71	–46.28	<0.001
	Control group	11.32±8.11	23.10±13.85	–18.41	<0.001
	t	0.027	–21.53	<0.001	
	P	0.98	<0.001		
S-AI	Intervention group	53.83±11.93	27.21±9.58	20.64	<0.001
	Control group	52.91±12.18	43.00±15.42	6.07	<0.001
	t	–0.660	10.60		
	P	0.510	<0.001		
Hr	Intervention group	78.36±9.79	72.50±9.70	9.87	<0.001
	Control group	76.6±12.22	80.86±13.40	–4.12	<0.001
	t	–1.34	6.17		
	P	0.18	<0.001		

Note: CTA refers to coronary angiography, S-AI refers to state anxiety score, Hr refers to heart rate.

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Table 6 Comparison of Examination Duration ($x^2 \pm s$), Success Rate of One-Time Examination and Image Quality (%) Between the Two Groups

Parameters	Classification	Intervention Group	Control Group	t/X^2	P
Length of examination (min)		5.0±0.98	7.99±1.58	18.85	<0.001
Success rate of one-time examination (%)	No	8 (5.3%)	36 (24.3%)	21.35	<0.001
	Yes	142 (94.7%)	112 (75.7%)		
Image quality	Excellent	132 (88%)	108 (73%)	43.63	<0.001
	Good	12 (8%)	15 (10.1%)		
	Fair	5 (3.3%)	18 (12.2%)		
	Poor	1 (0.7%)	7 (4.7%)		

Table 7 Comparison of Satisfaction Between Two Groups (%)

Parameters	Categorization	Intervention Group	Control Group	X^2	P
Nurses' Needle Laying Technique	Unsatisfactory	0	0	76.67	<0.001
	Average	1 (0.7%)	24 (6.2%)		
	Quite satisfied	7 (4.7%)	51 (34.5%)		
	Very satisfied	142 (94.7%)	73 (49.3%)		
Whole nursing staff	Unsatisfactory	0	2 (1.4%)	125.38*	<0.001
	Average	0	36 (24.3%)		
	Quite satisfied	11 (7.3%)	59 (39.9%)		
	Very satisfied	139 (92.7%)	51 (34.5%)		
Scanning technician	Unsatisfactory	0	0	97.15	<0.001
	Average	0	66 (44.6%)		
	Quite satisfied	47 (31.3%)	45 (30.4%)		
	Very satisfied	103 (68.7%)	37 (25%)		
Barman	Unsatisfactory	0	33 (22.3%)	149.66	<0.001
	Average	7 (4.7%)	74 (50%)		
	Quite satisfied	76 (51%)	31 (21.6%)		
	Very satisfied	61 (44.3%)	9 (6.1%)		
Knowledge of coronary CTA	Unsatisfactory	0	21 (14.2%)	188.73	<0.001
	Average	1 (4.7%)	87 (58.81%)		
	Quite satisfied	60 (40%)	36 (24.3%)		
	Very satisfied	89 (56.3%)	4 (2.7%)		
Coronary CTA examination procedure	Unsatisfactory	0	6 (4.1%)	158.61*	<0.001
	Average	0	70 (47.3%)		
	Quite satisfied	31 (20.7%)	43 (29.1%)		
	Very satisfied	119 (79.3%)	29 (19.6%)		
The overall impression of CT department	Unsatisfactory	0	1 (0.7%)	212.36*	<0.001
	Average	0	71 (48.6%)		
	Quite satisfied	44 (29.3%)	71 (48.6%)		
	Very satisfied	10.6 (70.7%)	5 (3.4%)		

Note: *Fisher precision method, with Pearson chi-square comparison. The reconstructed three-dimensional coronary artery images with excellent, good, average and poor image quality scores were added. As follows:

Comparison of satisfaction between the two groups: The overall patient satisfaction in the intervention group was significantly higher than in the control group (Table 7).

Discussion

Due to the high prevalence and significant impact of CHD, CCTA is recognized as a pivotal tool for the diagnosis of CHD, especially in early detection. Effective health education is indispensable for improving patient comprehension, reducing examination duration, enhancing the success rate of initial attempts, and ensuring superior image quality. As the

number of individuals requiring CCTA examinations continues to rise, the demand for comprehensive health education correspondingly increases. To date, neither domestic nor international studies have established a fully developed, individualized CCTA health education program, nor has the teach-back method been applied within the context of auxiliary examination departments for health education. The CCTA health education program proposed in this study, which integrates knowledge transformation theory with the teach-back approach, has undergone clinical validation and has been demonstrated to be effective.

Scientific and Reliability Analysis of the Program Constructed in This Study

Based on a review of domestic and international literature, expert consultations, and clinical practice, this study integrated knowledge transformation theory with feedback methods to ensure scientific rigor. During the protocol development, clinical experts from radiology departments across various tertiary hospitals in Shanghai were selected, including physicians, technicians, nurses, and health educators, all possessing extensive clinical experience. Both rounds of expert consultation achieved a 100% response rate, reflecting the high engagement of the experts. The authority coefficients were 0.87 and 0.89, respectively, demonstrating the high reliability and credibility of the expert opinions, which confirmed the validity of the consultation results. The mean importance scores for the items in both rounds exceeded 3.5, with all items in the second round scoring above 4. The coefficients of variation were less than 0.25 in both rounds, with the second round showing values below 0.2, and the ratios of perfect scores were greater than 0.2, indicating a high degree of consensus among the experts. Kendall's coefficient of concordance (W) ranged from 0.305 to 0.436 ($P < 0.05$), indicating statistical significance and strong coordination among expert opinions. In conclusion, considering the high level of expert engagement, authority, and consensus on the protocol, the scientific validity and reliability of the protocol were firmly established.

Practicality and Feasibility Analysis of the Constructed Program of This Study

This protocol effectively incorporated the four stages of the teach-back method into CCTA-related education. The interval between appointment scheduling and the examination was strategically utilized for health education: patients were encouraged to restate the educational content in their own words, facilitated by demonstrations from professional nurses and peer demonstrations among patients. This approach enhanced their understanding of relevant information and fostered better cooperation during the examination. Concerning the assessment content, both absolute and relative contraindications, heart rate, and additional evaluations were refined, while renal function assessments and physician approval for metformin users were included. When imparting health education, attention was given to addressing the common concerns of patients, such as fear of the examination, anxiety in unfamiliar settings, and worries about allergic reactions to iodine contrast agents. These negative emotions may trigger elevated secretion of epinephrine and norepinephrine, resulting in an increased heart rate and potential arrhythmias.[21] Consequently, early assessment and intervention for heart rate and rhythm were emphasized, considering the influence of emotions on heart rate and the success of the examination. Patients were also taught various relaxation techniques. Different methods for breathing and breath-holding training were introduced, including pre-recorded instructions for breath-holding aimed at preparing patients in advance to accommodate their individualized needs. Regarding adverse reactions to the contrast agent, the protocol expanded its focus beyond severe allergic reactions and extravasation, incorporating education on various adverse reaction management strategies. Additionally, it included guidance on recognizing allergic warning signs and handling "unprovoked coughing or sneezing" during scanning, as well as emphasizing education on delayed adverse reactions.[22] These elements underscore the practicality and feasibility of the protocol.

Enhanced CCTA Performance Achieved Through the Study's Protocol: Higher Success Rates, Shorter Examinations, and Quality Imaging in a Single Session

The success of CCTA examinations is influenced not only by technicians' scanning techniques and injection methods but also by pre-examination preparation, effective health education, nursing care, and the stabilization of heart rate and breath-holding.[23] First, the traditional vascular assessment was deemed insufficient. In the present protocol, following

intravenous placement, specific annotations were made on the examination form regarding vascular assessment to guide technicians and nurses in selecting optimal injection rates and enhancing observation, thereby ensuring patient safety during injection, minimizing the risk of extravasation, and improving first-time examination success rates. Second, this study's protocol effectively utilized the interval between appointment scheduling and the examination to implement health education through the teach-back method, which proved more effective than traditional, one-time pre-examination education in addressing the memory forgetting curve.[24] Third, due to patients' high medical expectations, misconceptions about the examination, and anxiety related to unfamiliar environments, large equipment, and drug side effects, which could potentially result in increased heart rate and rhythm instability,[25] this protocol employed a comprehensive health education approach through ward coordination. Multiple strategies, including cards, videos, questioning, demonstrations, family involvement, peer support, and group management, were integrated.[21,26–28] Various relaxation techniques and professional psychological counseling were also incorporated, not only stimulating patient interest and enhancing active learning but also ensuring an accurate understanding of the examination process and purpose while providing humanistic care. Fourth, under significant anxiety, sympathetic nervous system activation affects the endocrine system, leading to increased thyroid hormone and catecholamine secretion, which accelerates heart rate and increases heart rate variability, thereby compromising imaging clarity.[29] Traditional one-time pre-examination health education may exacerbate existing anxiety, while this protocol made use of the period from appointment scheduling to examination day for psychological counseling and comprehensive health education, addressing the underlying causes of anxiety and promoting emotional stability. Additionally, early medication interventions maintained heart rates below 70–90 beats/min, extending the isovolumic diastolic period and facilitating improved image acquisition. Fifth, to better meet patients' needs, diverse and targeted formats were implemented. Communication throughout the pre-examination period helped strengthen nurse-patient relationships, foster trust, alleviate tension and anxiety, and encourage patients to actively seek information and cooperate, thereby improving overall patient satisfaction. Sixth, the health education protocol was flexible, allowing for either group or one-on-one delivery,[30] and included "pre-recorded breath-holding training instructions" for various breathing techniques,[31] such as "breath-holding after deep inhalation, breath-holding after slow exhalation following deep inhalation, and breath-holding during quiet breathing".[32] To prevent excessive shoulder and thoracoabdominal movement during breathing, patients were instructed to maintain abdominal protrusion while holding their breath, ensuring sufficient separation between the abdominal aorta and the abdominal wall for optimal imaging.[33,34] Under professional guidance, patients were encouraged to demonstrate these techniques to one another, thus reducing nurses' workload, enhancing patient engagement, and ensuring mastery of breath-holding techniques. Furthermore, health education materials and videos were converted into QR code posters, enabling patients and their families to easily access information via mobile phones. In conclusion, well-prepared patients' active cooperation helped reduce examination time, ensured image quality, and improved both first-time examination success rates and work efficiency. Both the intervention and control groups demonstrated reduced S-AI scores post-intervention, with the intervention group showing significantly lower scores. The intervention group also exhibited decreased heart rates post-intervention, while the control group showed increased heart rates, possibly due to temporary pre-examination education inducing tension without sufficient processing time. Nevertheless, the control group's reduced S-AI scores post-intervention warrant further investigation.

Nurses and Technicians: Their Vital Dual Function as Researchers and Practitioners in CCTA Execution

The primary participants in this study consisted of nurses and technicians who, as researchers with the necessary scientific capabilities, developed a health education program informed by the principles of knowledge transformation theory. In their roles as practitioners, they provided tailored health education to patients through systematic assessments, employing a feedback mechanism for education, evaluation, and adjustment until the knowledge was successfully converted into proactive behaviors by the patients. Patients engaged in the study alongside the nurses and technicians, thereby fully demonstrating their involvement as research collaborators. During the intervention, nurses and technicians assumed a range of roles, including that of educators, psychotherapists, caregivers, and safety officers.

Their responsibilities encompassed health education, guidance in skill acquisition, patient monitoring and assessment, psychological care, first aid preparation, management of contrast agents, equipment operation and maintenance, formulation of scanning protocols, image acquisition and subsequent processing, radiation protection, and safeguarding patient privacy during the CCTA procedure. Each of these responsibilities played an essential role in ensuring patient safety, facilitating the smooth progression of the examination, and preserving the quality of the images obtained.

Conclusion

Drawing upon the principles of knowledge transformation theory, this study integrated an extensive body of both domestic and international literature with clinical cross-sectional research, utilizing a feedback approach. A health education and nursing program for coronary CTA was developed through the Delphi method, which demonstrated clinical effectiveness. The program is substantiated by a significant body of literature, rendering it both scientifically grounded and reliable, with its practicality and feasibility affirmed by experts. In clinical trials, the program notably enhanced the success rate of coronary artery CTA examinations, reduced the examination duration, and ensured the preservation of image quality. Furthermore, it alleviated patient anxiety, enhanced the patients' understanding of relevant knowledge, facilitated improved communication between nurses and patients, and considerably increased patient satisfaction.

Data Sharing Statement

The data are not available due to privacy or ethical restrictions.

Ethical Approval

This study adhered to the principles outlined in the Helsinki Declaration and was approved by the Science and Technology Ethics Committee of Oriental Hospital, affiliated with Tongji University (Shanghai Oriental Hospital) ([2024] Yan ShenNo. (006)). After being thoroughly informed about the study's objectives, procedures, and potential risks, all participants provided written consent by signing the informed consent form. Additionally, a code was utilized during the study in place of personal identifying information.

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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.

Disclosure

All the people involved in this study did not have any conflicts of interest.

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