



Original Article

Application of 4R Crisis Management Combined with the Health Belief Model in the Prevention and Control of Venous Thromboembolism in Stroke Patients: A Randomized Controlled Trial



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Abstract

Background and objectives: Stroke patients have a high incidence of venous thromboembolism (VTE). Improving the prevention and control rates of VTE in stroke patients can enhance their quality of life. The aim of this study was to analyze the effect of 4R crisis management combined with the health belief model in the prevention and control of VTE in stroke patients.

Methods: A randomized controlled trial was conducted on 86 stroke patients in the neurosurgery department of a tertiary hospital in Wuhan. The control group was treated with the routine VTE prevention and control strategy, while the experimental group was treated with 4R crisis management combined with the health belief model. The primary outcome measures were the incidence rates of deep vein thrombosis and pulmonary thromboembolism, while the secondary outcome measures were the Short Form Health Belief Model Scale score, medical quality evaluation, and stroke patients' health behavior scale score. The statistical analysis methods included t-tests and non-parametric tests.

Results: After the intervention, the incidence rate of deep vein thrombosis in the control group was 14.6% (6/41), while in the experimental group it was 2.4% (1/41). The difference was statistically significant ($\chi^2 = 3.905$, $P = 0.048$). The incidence rates of pulmonary thromboembolism in both groups were 0%. The scores of all dimensions of the Short Form Health Belief Model Scale in the experimental group were higher than those in the control group, and the difference was statistically significant ($P < 0.05$, $P < 0.01$). The medical quality for each item showed that the experimental group performed better than the control group, with the difference being statistically significant ($P < 0.05$, $P < 0.01$). The scores on the stroke patients' health behavior scale in the experimental group were higher than in the control group, except for responsibility, tobacco, and alcohol ($P < 0.01$).

Keywords: 4R crisis management; Health belief model; Cerebral apoplexy; Venous thromboembolism; VTE; Health education; Randomized controlled trial; Deep vein thrombosis; Pulmonary thromboembolism.

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Conclusions: The application of 4R crisis management combined with the health belief model can effectively improve the health beliefs and health behaviors of stroke patients to prevent VTE, thereby reducing the incidence of VTE.

Introduction

Venous thromboembolism (VTE) includes deep vein thrombosis (DVT) and pulmonary thromboembolism (PE). It is a major complication affecting the quality of life of stroke patients.¹ Stroke patients are prone to VTE due to hemiplegia, the use of dehydrating agents, infection, and other reasons, with the incidence rate as high

as 20% to 42%.² Within three months after a stroke, the incidences of DVT and PE are 2.5% and 1.2%, respectively.³ Without any intervention, the incidence of DVT after stroke can be as high as 70%.⁴ Stroke patients complicated with VTE experience serious impacts, which not only delay their early recovery but also prolong the length of hospital stay, increase patient pain, and reduce the quality of medical care.⁵

The 4R crisis management theory was first proposed by Robert Heath. It divides crisis management into four stages: reduction, readiness, response, and recovery.⁶ This theory requires managers to divide emergency management into four sub-modules, including reducing the impact and influence of risks on the organization. The organization must make adequate preparations for risk response, deal with the risks that have already occurred scientifically, recover quickly after risks occur, and turn crises into opportunities.⁷ The 4R crisis management theory is a cyclic process of dynamic and effective improvement in organizational management. Each stage is independent but connected to the others, with timeliness and theoretical guidance.⁸ As a dynamic risk management framework, the 4R crisis management theory can optimize the nursing process through risk assessment, plan formulation, and multi-stage intervention. However, its practical value in the prevention and control of VTE in stroke patients has not been fully explored.⁹

The health belief model refers to enhancing patients' perception of disease threat, their cognition of behavioral benefits, and self-efficacy. It has been proven to effectively improve the self-management ability of patients with chronic diseases.¹⁰ The health belief model emphasizes psychology as its foundation and plays a role in promoting patients to adopt positive health behaviors. Studies have shown that the health belief model has a positive impact on improving compliance with tuberculosis medication,^{11,12} promoting health beliefs, and preventing osteoporosis. There are few reports on the application of the 4R crisis theory and the health belief model in the prevention and control of VTE in stroke patients. Therefore, this study aimed to explore the combined effect of 4R crisis management and the health belief model on stroke patients, providing valuable insights for clinical nursing practice.

Materials and methods

Study design

A randomized controlled trial was conducted by the neurosurgery department of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology from October 2022 to September 2023. The study was registered at the Chinese Clinical Trial Registry (ChiCTR2100045301).

Participants

Participants were recruited from October 2022, with follow-up ending in September 2023. Inclusion criteria were: (1) Cerebral stroke patients diagnosed for the first time by brain CT or MRI examination upon admission, with the diagnosis based on the Guideline for Cerebrovascular Disease Prevention and Treatment¹³; (2) Age ≥ 18 years old, hospital admission ≥ 48 h; (3) Clear consciousness; (4) Unilateral or bilateral muscle strength of both lower limbs $\geq$ grade 3; (5) Informed consent and voluntary participation in this study. Exclusion criteria were: (1) Illiterate, cognitive disorder, mental disorder, language disorder, blurred consciousness, and coma; (2) Patients who had been diagnosed with VTE or pathological fractures before admission; (3) Patients with severe acute or chronic diseases. Withdrawal criteria were: (1) Withdrawal dur-

ing the study; (2) No intervention was made according to the study protocol after inclusion.

Randomization and blinding

Eighty-six participants were randomly assigned to the intervention group ($n = 43$) or the control group ($n = 43$). Each participant was assigned a number from 1 to 86. A block randomization method in blocks of 4 at a 1:1 ratio was used to generate a sequence for the intervention and control groups. A random number table was used to randomly select the blocks and determine group assignments. The allocation was kept in sequentially numbered opaque envelopes. Blinding for both the researchers and the patients was not possible. Ultimately, 82 patients completed the entire study (Fig. 1).

Intervention and control groups

The control team consists of the department director, the responsible doctor, the head nurse of the ward, the full-time nurse, and the responsible nurse. The control group adopted conventional VTE prevention and control nursing strategies and health education methods. The responsible nurse implemented daily VTE prevention and control measures, provided oral education, and distributed VTE health education manuals to patients at key times during the hospitalization period, including admission, pre-operation, post-operation, and discharge. The content included VTE-related knowledge, contraindications, complications, and preventive measures. On top of the control group's strategies, the experimental group implemented the 4R crisis management combined with the health belief model for VTE prevention and control nursing in stroke patients.

Formation of the intervention team

The intervention team consists of the department director, the responsible doctor, the head nurse of the ward, the full-time nurse, and the responsible nurse. The department director is responsible for reviewing the plan. The responsible doctor is responsible for guiding and updating the VTE prevention and control strategy. The head nurse of the ward is responsible for formulating the 4R crisis management process and implementation plan, reviewing the content of the health belief model, and supervising the quality of VTE prevention and care measures under the joint model. The full-time nurse is responsible for the structured construction of the 4R crisis management process, formulating the content of the health belief model, and conducting training and reinforcement education. The responsible nurse is responsible for the comprehensive implementation of the 4R crisis management and health belief model and for providing feedback on the implementation of measures under the joint model.

Construction of the 4R crisis management model for VTE prevention in stroke patients

The experimental group adopted the 4R crisis management theory to manage VTE prevention and care for stroke patients, structuring VTE prevention and care into four stages: reduction, readiness, response, and recovery. The specific contents are as follows:

Reduction stage

Eliminate the hidden dangers of VTE occurrence, reduce the possibility and severity of VTE risk: (1) Improve the VTE risk early warning system to ensure that prevention measures are taken in advance: The nursing system uses the Caprini risk assessment scale. Stroke patients with a score of ≥ 3 will be automatically classified as high-risk individuals and marked in red on the nursing mobile

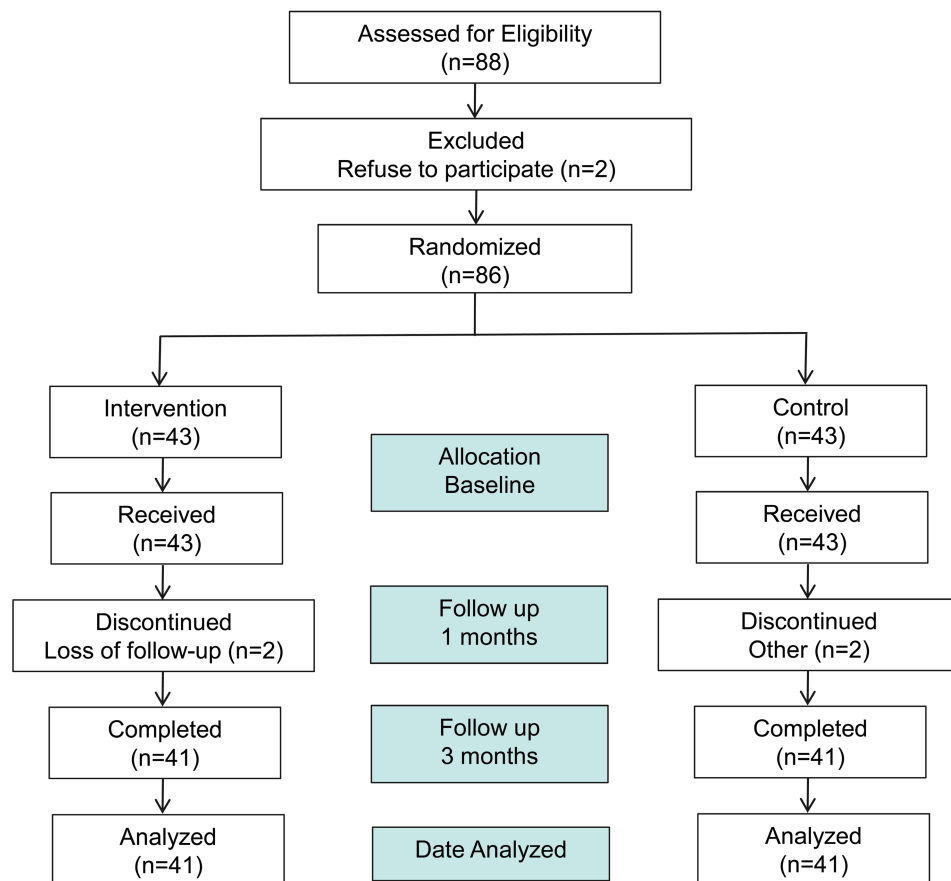


Fig. 1. Flow diagram of the study. All data were statistically analyzed using SPSS 26.0 software. When the measurement data met the normal distribution, they were expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$), and the t-test was used for comparison between groups, while repeated measures analysis of variance was used for comparison at different time points. When the data did not meet the normal distribution, non-parametric tests were used. Count data were expressed as the number of cases and rate (%), and the Chi-squared test was used for comparison between groups; rank data were analyzed using the rank sum test. $P < 0.05$ was considered statistically significant.

system page to alert nurses that these patients have a high risk of VTE, enabling preventive intervention. (2) Integrate with the medical electronic system to ensure preventive screening: When the Caprini score on the first nursing assessment form is ≥ 3 , it will automatically link to the homepage of the medical electronic system. After the doctor logs into the system and receives this information, they will selectively order venous compression ultrasound combined with D-dimer testing for risk screening based on the patient's condition.

Readiness stage

Enhance the response and preparedness of nursing staff to VTE risk in stroke patients: (1) Standardize preventive care: Members of the intervention team construct VTE prevention and care measures for stroke patients based on existing guidelines, consensus, and standards, as detailed in Table 1. (2) Nursing training: A dedicated nurse conducts weekly training for responsible nurses on VTE prevention and care for stroke patients. The training content includes early VTE risk identification in stroke patients, the timing of VTE risk assessment and re-evaluation, basic and mechanical preventive measures for VTE in stroke patients, etc. (3) Improve the VTE prevention and control nursing organizational system: A dedicated nurse is responsible for training and super-

vising responsible nurses to implement preventive measures. The dedicated nurses in the intervention team are selected from those with intermediate or higher professional titles, bachelor's degrees or above, and at least eight years of work experience, and have obtained provincial or national specialized nurse qualifications. A multidisciplinary team is formed, led by dedicated nurses and including responsible nurses, rehabilitation departments, nutrition departments, ultrasound departments, and vascular surgery departments. The dedicated nurse is responsible for overall coordination and communication to enhance the knowledge and skills of the prevention and control team members. (4) Regular screening and improving the sensitivity to VTE identification: For stroke patients who need to stay in bed in the early stage, nurses strictly measure leg circumference during bedside shift handovers. If limb swelling, abnormal leg circumference, chest pain without an obvious cause, or breathing difficulties are found, they immediately report to the doctor for relevant screening.

Response stage

For stroke patients who have already developed VTE, correct judgment should be made and timely nursing measures should be taken: (1) Multidisciplinary collaboration to enhance the ability to prevent and manage VTE: Collaborate with the rehabilitation department to

Table 1. Venous thromboembolism (VTE) prevention and control nursing measures and health education contents for stroke patients

Tertiary prevention	Prevention and control nursing rules	Content of health education	Information-based propaganda and education
Primary prevention	(1) Guide stroke patients to perform daily leg exercises such as isometric contractions of the quadriceps, straight leg raises, and ankle pump exercises (Fig. 2). For those with bilateral muscle strength of ≥ 3 , they should perform active exercises. For those with muscle strength of < 3 on either side or both sides, a combination of active and passive exercises should be adopted. Family members should supervise daily, with 20–30 sets each time and 10–15 times a day; (2) For hemiplegic patients, keep the affected limb elevated and warm, and avoid intravenous infusion on the affected side; (3) Nursing staff should monitor daily for VTE symptoms, limb range of motion, bleeding conditions, and skin conditions of the hemiplegic limb; (4) For stroke patients undergoing dehydration treatment, instruct them to drink plenty of water daily, 1,000–1,500 ml/d, to reduce blood viscosity, and consume more foods rich in fiber and high protein	(1) To educate the patients and their families about the standardized method, importance, and precautions of functional exercise, and to stop immediately in case of chest tightness, sweating, and other discomfort; (2) Educate patients and their families about the symptoms of VTE, and encourage family members and patients to self-examine symptoms and make accurate complaints; (3) Educating patients and their families about functional lying position, sleeping on air cushion beds, and wearing T-shoes to prevent foot drop	Graphics, text, and audio combined with a bedside presentation
Mechanical prophylaxis	(1) For stroke patients with limited mobility and no contraindications, intermittent pneumatic compression (IPC) treatment should be initiated upon admission (Fig. 3). During the use of IPC, nursing staff should closely monitor the tightness of the leg sleeves, increase rounds, and closely observe the patients' complaints and discomfort; (2) For patients who are temporarily unable to get out of bed, once their condition stabilizes, they should use a rehabilitation stationary bike for in-bed limb exercises (Fig. 3); (3) Encourage patients whose conditions have stabilized to get out of bed as soon as possible and use rehabilitation walking aids for bedside activities or standing and walking training	(1) Educate patients and their families on the purpose and significance of IPC treatment, as well as precautions during use. Instruct them to inform the medical staff immediately if they experience any discomfort; (2) Teach the correct usage of rehabilitation equipment; (1 = 3) Emphasize that patients must not use graduated compression stockings on their own	Combination of pictures, text, audio, and bedside oral education
Drug prophylaxis	(1) Low-dose anticoagulant drug therapy is contraindicated for patients with acute intracerebral hemorrhage; (2) For patients with acute ischemic stroke who have limited mobility and no contraindications, IPC combined with low-molecular-weight (LMW) heparin treatment should be initiated upon admission; (3) For patients with transient ischemic attack or mild stroke who are receiving dual antiplatelet therapy (DAPT), drug VTE prevention is not recommended; (4) For patients receiving oral anticoagulants for other indications, additional VTE drug prevention is not necessary	(1) For patients taking oral anticoagulant drugs, educate them about adverse reactions and precautions, including whether there are signs of excessive bleeding, such as bleeding symptoms in the gums, urethra, and digestive tract, and also avoid strenuous activities; (2) For patients receiving injection drug treatment, educate them that the injection site generally does not require a hot compress; if there is a hard lump accompanied by pain, inform the nurse to handle it accordingly	Combination of pictures, text, audio, and bedside oral education

correctly guide stroke patients on immobilization and limb range of motion, as well as the timing of activities, and instruct hemiplegic patients to perform passive movements correctly, for example, the ankle pump exercises (Fig. 2), the intermittent pneumatic compression (IPC) treatment and rehabilitation stationary bike exercises (Fig. 3); collaborate with the nutrition department to improve the nutritional status of stroke patients, enhance their immunity and resistance to infection; collaborate with the vascular surgery department to assess the severity of VTE and whether drug or surgical treatment is needed, and provide professional prevention and treatment guidance to avoid the development of more serious complica-

tions; collaborate with the radiology department to conduct efficient screening, perform bedside screening for stroke patients, accurately determine the location of VTE occurrence, and provide personalized education based on the type of thrombus. (2) Hierarchical reporting within the hospital to improve the efficiency of VTE management: When a patient develops VTE, the responsible nurse reports it to the dedicated nurse immediately, who then reports it to the head nurse, and the head nurse reports it to the responsible doctor. The VTE management process is implemented through the hospital's multi-disciplinary team process, achieving a closed-loop management of VTE by both medical and nursing staff.

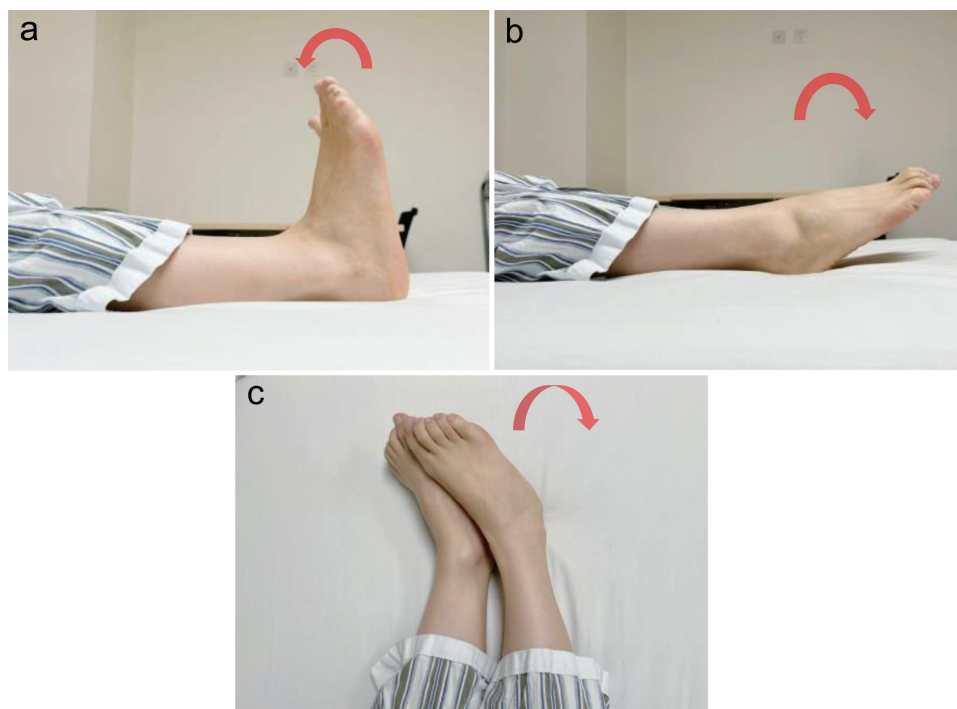


Fig. 2. Ankle pump exercises. (a) Dorsiflexion: Slowly pull the foot upward to maximal dorsiflexion, direct the toes toward the head, feel the stretch in the calf and hold for 3–5 seconds. (b) Plantar flexion: Gently press the toes downward, extending the ankle. Feel the stretch along the top of the foot and shin, and hold for 3–5 seconds. (c) Ankle circles: Starting from the ankle joint, slowly rotate the foot in a full circle. Perform 5–10 rotations in each direction, clockwise and counterclockwise. Repeat the sequence of dorsiflexion, plantar flexion, and circles. Perform 20–30 repetitions per set, 3–4 sets daily.



Fig. 3. Physical strategies for venous thromboembolism prevention. Intermittent pneumatic compression treatment (a–c) and rehabilitation stationary bike exercises (d) are recommended for postoperative bedridden, hemiplegic, or lower limb muscle strength less than level 3 patients. Once daily, for 20–30 minutes each time.

Recovery stage

After the occurrence and symptoms of VTE in stroke patients are controlled, organize nurses to summarize and review: (1) Personnel recovery: Organize personnel to reflect and summarize, discuss the omissions in each link and handling of VTE prevention and control nursing, and systematically summarize the implementation of the emergency response speed of nursing staff to high-risk VTE patients with stroke, the timeliness of information feedback, and the rationality of human resource allocation. (2) System recovery: Use root cause analysis, Plan/Do/Check/Act, and other methods for factor analysis, conduct a detailed analysis of the problems exposed in VTE prevention and control nursing, and propose targeted improvement plans to provide useful references for the corresponding deployment and adjustment of VTE prevention and control management plans for stroke patients.

Implementation of the health belief model

Based on the three aspects that influence health beliefs, namely susceptibility and severity of the disease, expectations of the effectiveness of behavior, and efficacy expectations, carry out health education on VTE prevention and control for stroke patients. (1) Strengthen the influence of health beliefs: Enhance the awareness of VTE prevention and control among patients and their families: Educate patients and their families about the incidence and complications of VTE, emphasizing its susceptibility and severity. At the same time, educate them on the benefits of implementing preventive measures to enhance patients' compliance with VTE prevention measures. Strengthen patients' confidence in VTE prevention and control: Based on patients' personality, behavior characteristics, and conditions, understand their level of VTE awareness, health belief level, and acceptance of health education, and provide individualized VTE prevention and control guidance and humanistic care for patients to enhance the positive beliefs of patients and their families in cooperating with the implementation of VTE prevention and control measures. Ensure the implementation of prevention measures: Members of the intervention team and family members jointly participate in the supervision of the implementation of VTE prevention measures for stroke patients: Establish a supervision form for the implementation of VTE prevention measures. Based on this form, the responsible nurse should actively inquire about the implementation of the prevention measures by patients and their families during the daily bedside shift handover based on the supervision form. Patients and their families conduct self-checks based on the supervision form, promoting mutual supervision between nurses and patients. Regular follow-up: The intervention team assesses the health belief level of patients weekly. When the health belief level of patients decreases, timely intervention is provided to restore their confidence in VTE prevention and control. (2) Formulation of health education content: The intervention team formulates the content of information-based health education on VTE prevention for stroke patients through literature review and searching authoritative online platforms, and uses various forms such as text, animation, charts, pictures, audio, and video. At different key time points during the hospitalization period of stroke patients, the information-based combined feedback method is used for focused education.¹⁴ The content of health education is shown in Table 1.

Outcome measurements

All questionnaires were distributed and collected on the second day of admission and the day before discharge. Among them, the incidence of VTE serves as the primary outcome measure; the rest are secondary outcomes.

Incidence of VTE

The incidence of VTE during the hospitalization of stroke patients was observed and recorded, including the incidence of DVT and PE.

Short Form Health Belief Model Scale (SFHBMS)

This scale was developed by the Chinese scholar Wan *et al.*¹⁵ based on the Champion Health Belief Model Scale, consisting of 20 items. It uses a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree", with scores of 1 to 5, respectively. The scale includes six dimensions: perceived susceptibility and severity of disease, health motivation, self-efficacy, and perceived benefits and barriers to health behaviors, with the "arriers" dimension scored in reverse. The higher the total score, the higher the corresponding level of health belief. The internal consistency reliability of this scale for stroke patients is 0.835.

Medical quality evaluation

The total length of hospital stay, the time of first getting out of bed, and the total time of getting out of bed for activities of stroke patients were collected.

Stroke patients' health behavior scale

This scale was compiled by Wan *et al.*,¹⁶ consisting of 25 items across six dimensions: exercise, medication, instructions, nutrition, responsibility, and smoking and drinking. Scores of 1, 2, 3, and 4 were assigned to "never, sometimes, often, and regularly", respectively. The smoking and drinking, and medication dimensions were scored in reverse. The higher the total score, the higher the level of health behavior. The total Cronbach's α coefficient of the scale is 0.878.

Statistical analysis

This study used the formula for calculating the sample size required for a two-sample mean comparison, with $\alpha = 0.05$, $\beta = 0.01$, $\delta/\sigma = 0.7$, $\mu 0.05/2 = 1.96$, $\mu 0.01 = 1.28$, $n1 = n2 = 2 \times [(\mu\alpha/2 + \mu\beta) \times \sigma / \delta]^2 + \mu\alpha^2/4$, resulting in $n1 = n2 \approx 80$. Considering potential issues such as follow-up dropouts and data loss during the study, the sample size was increased by 10%. The final sample size was determined to be 88. A total of 88 stroke patients were recruited in this study.

Results

Comparison of general data between the two groups

There were no statistically significant differences ($P > 0.05$) in gender, age, educational level, type of disease, and Caprini score at admission between the two groups of patients, as shown in Table 2.

Comparison of SFHBMS scores between the two groups

Compared with the pre-intervention state, the scores of each item on the SFHBMS scale for both groups increased, and the experimental group had higher scores than the control group. The differences were statistically significant ($P < 0.05$, $P < 0.01$), as shown in Table 3.

Comparison of medical quality evaluation between the two groups

After the intervention, the total number of days in the hospital and the time to first get out of bed in the experimental group were lower than those in the control group. The total time spent getting

Table 2. Comparison of general data between the two groups

Group	n	Gender (n)		Age (Mean ± SD)	Educational level (n)			Types of disease (n)		Caprini score at admission
		Male	Female		Junior high school	senior high school	College or above	Hemor- rhagic stroke	Ischemic stroke	
Experimental group	41	25	16	55.61 ± 7.96	18	20	3	20	21	3.71 ± 0.955
Control group	41	23	18	56.44 ± 7.03	20	16	5	22	19	3.80 ± 1.05
statistical magnitude		χ ² = 0.201		t = −0.500	Z = −0.154			χ ² = 0.195		t = −0.439
P		0.654		0.618	0.878			0.659		0.662

SD, standard deviation.

Table 3. Comparison of SFHBMS scores between the two groups

Group	n	Self-efficacy		Perceiving the benefits of healthy behaviors		Obstacles to perceiving healthy behaviors	
		Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
Control group	41	10.80 $\pm$ 1.66	11.29 $\pm$ 1.79	15.39 $\pm$ 1.07	16.54 $\pm$ 1.27	13.44 $\pm$ 1.05	15.63 $\pm$ 1.73
Experimental group	41	10.66 $\pm$ 1.35	12.10 $\pm$ 1.73	15.51 $\pm$ 1.34	17.39 $\pm$ 1.39	13.12 $\pm$ 1.33	16.71 $\pm$ 1.78
<i>t</i>		-0.437	2.069	0.455	2.902	-1.200	2.771
<i>p</i>		0.663	0.042	0.651	0.005	0.234	0.007

Group	n	Perception of disease susceptibility		Perceive the severity of the disease		Health dynamics	
		Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
Control group	41	6.34 $\pm$ 1.03	7.24 $\pm$ 1.04	8.95 $\pm$ 1.05	9.46 $\pm$ 1.23	16.46 $\pm$ 1.94	17.29 $\pm$ 1.44
Experimental group	41	6.24 $\pm$ 1.01	8.31 $\pm$ 0.79	9.29 $\pm$ 1.29	10.32 $\pm$ 1.31	16.22 $\pm$ 1.68	18.07 $\pm$ 1.66
<i>t</i>		-0.429	5.253	1.316	3.043	-0.609	2.274
<i>p</i>		0.669	<0.001	0.192	0.003	0.544	0.026

SFHBMS, Short Form Health Belief Model Scale.

out of bed was higher in the experimental group than in the control group. The differences were statistically significant ($P < 0.01$), as shown in Table 4.

Comparison of stroke patients' health behavior scale scores between the two groups

Compared with the pre-intervention state, the scores of each item on the Stroke Patients' Health Behavior Scale for both groups increased. The scores in the experimental group were higher than in the control group, except for responsibility, tobacco use, and

alcohol consumption. The differences were statistically significant ($P < 0.01$), as shown in Table 5.

Comparison of VTE incidence rates between the two groups

Both groups of patients developed DVT after the intervention. The incidence rate of DVT in the control group was 14.6% (6/41), while in the experimental group it was 2.4% (1/41). When comparing the two groups, the difference was statistically significant ($\chi^2 = 3.905$, $P = 0.048$). The incidence rates of PE in both the control group and the experimental group were 0%.

Table 4. Comparison of medical quality evaluation before and after intervention between the two groups

Group	n	Total days of hospitalization [Day, M (P25, P75)]	The time of the first attempt to get out of bed for activities [h, M (P25, P75)]	Total duration of activities performed away from bed [h, M (P25, P75)]
Control group	41	11(10.00, 12.00)	42(36.00, 48.00)	1.5(1.00, 2.00)
Experimental group	41	9(8.00, 11.00)	36(32.00, 42.00)	2(1.50, 2.50)
<i>t</i>		-4.138	-2.206	-3.234
<i>p</i>		<0.001	0.009	0.001

Table 5. Comparison of stroke patients' health behavior scale scores between the two groups

Group	n	Exercise		Take medicine		Instruction	
		Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
Control group	41	16.17 ± 1.59	19.15 ± 1.65	11.93 ± 1.10	13.29 ± 1.17	10.95 ± 1.22	12.05 ± 1.36
Experimental group	41	16.41 ± 1.97	21.46 ± 2.25	11.49 ± 1.58	14.15 ± 1.09	11.19 ± 1.74	13.56 ± 1.72
<i>t</i>		0.615	5.318	-1.456	3.430	0.736	4.420
<i>p</i>		0.54	<0.001	0.149	0.001	0.464	<0.001

Group	n	Nutrition		Responsibility		Tobacco and alcohol	
		Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
Control group	41	14.37 ± 1.39	18.85 ± 1.49	4.24 ± 0.94	4.78 ± 0.85	6.32 ± 0.82	7.07 ± 0.88
Experimental group	41	14.63 ± 1.24	20.80 ± 1.45	4.32 ± 0.96	5.07 ± 0.82	6.46 ± 0.98	7.32 ± 0.76
<i>t</i>		0.921	5.998	0.348	1.587	0.735	1.348
<i>p</i>		0.36	<0.001	0.729	0.117	0.465	0.181

Discussion

The Health Belief Model emphasizes the influence of strengthening patient' cognition to alter health behavior. Medical personnel can promote preventive health behaviors and implement health education through the Health Belief Model.¹⁷ This study showed that through 4R crisis management combined with Health Belief Model intervention, the scores of all dimensions of the health belief questionnaire in the experimental group were higher than those in the control group. In addition to responsibility, tobacco, and alcohol, the other four scores on the stroke patients' health behavior scale were higher than those of the control group. The reason for this is that the clinical manifestations of stroke patients with hemiplegia are mostly limb dysfunction, accompanied by varying degrees of psychological disorders, which seriously reduce the health belief, confidence, and motivation of stroke patients to carry out health behaviors.¹⁸ The Health Belief Model emphasizes the leading role of individual mental processes in adopting healthy behaviors. This study provides psychological support and positive disease education to improve the awareness of VTE and the importance of adopting healthy behaviors in stroke patients. It helps patients realize the susceptibility and severity of VTE through health education. Through the feedback-based health education method, patients can improve their health behavior autonomy to take basic preventive measures for VTE, give full play to their subjective initiative, and actively mobilize the self-efficacy of health behaviors. Through the cooperation and participation of family members, the family support of stroke patients can be enhanced, improving the efficacy of VTE prevention and management. 4R crisis management was adopted to strengthen the passive health behaviors of nursing staff for stroke patients, reinforce the normative implementation of VTE prevention and control measures by nursing staff, patients, and their families, form an organic linkage between nurses and patients, and realize the deepening of the Health Belief Model and the implementation of health behaviors.

The results of this study show that by adopting 4R crisis management combined with the Health Belief Model, the total hospitalization days and the time to first get out of bed in the experimental group were lower than those in the control group, while the

total duration of getting out of bed activities was higher than that in the control group. Previous studies have pointed out that the risk factors for VTE in stroke patients include lower limb weakness, consciousness disorders, the use of diuretics, infection, operation time, and lack of thrombosis prevention.^{19,20} The mastery of VTE prevention and control knowledge by nurses directly affects the quality of VTE care, suggesting that management levels should strengthen the training of VTE knowledge for nursing staff. At the same time, it is necessary to strengthen the functional exercise of patients' lower limbs and education on VTE prevention and control. This study has built a structured VTE prevention and control management process for stroke patients through 4R crisis management, and through the implementation of basic prevention and physical prevention measures, passive movements are implemented for those who cannot actively move. This effectively strengthens the self-discipline of stroke patients in performing standardized lower limb functional exercises, accelerates the time to first get out of bed, and increases the total duration of getting out of bed activities. Through the Health Belief Model, a proper diet is maintained to avoid the occurrence of other infectious complications, which indirectly promotes the rehabilitation process of patients, shortens the hospitalization period, and improves the quality of nursing. Gao *et al.*²¹ have shown good application effects of nursing based on the information platform in the prevention of VTE in patients with hip fractures. This study has enhanced the awareness of VTE diseases and the compliance of healthy behaviors among stroke patients through the combination of information-based health education paths, thereby improving the efficiency and accuracy of VTE prevention by medical staff, and ultimately enhancing the management level of VTE prevention and control by nursing staff and the quality of nursing.

The 4R crisis management, as a mature mechanism for effectively controlling risks and conducting preventive measures, adopts predictive, continuous, dynamic, and systematic management for the prevention and control of VTE in stroke patients through feed-forward control, process control, and feedback control. Khalil *et al.*²² significantly improved prostate cancer knowledge, health beliefs, and preventive health practices in adult and elderly men through educational interventions based on the Health Belief Mod-

el. Matlabi *et al.*²³ had a significant impact on the training of breast cancer screening behavior in female healthy volunteers through the Health Belief Model. The results of this study showed that the incidence of DVT in the intervention group of stroke patients was significantly lower than that in the control group after the intervention, while there was no significant difference in the incidence of PE. The reason for this is that 4R crisis management reduces the threshold of VTE prevention risk for stroke patients by shortening the stage, enhances the nurses' attention and alertness to VTE prevention, improves the nurses' ability to identify and prevent VTE at an early stage through the preparatory stage, strengthens the patients' cognitive level of VTE prevention through the Health Belief Model, and improves the prevention ability of VTE for nurses and patients through multidisciplinary collaboration and multi-dimensional efforts. Previous studies have shown that early prevention intervention in high-risk populations of VTE can reduce the relative risk of DVT by 84% and the incidence of PE by 55%.²⁴ Stroke patients are a high-risk population for VTE, and it is more important to emphasize that healthcare providers implement diversified and individualized health education for them, encourage patients to participate in self-care management and rehabilitation exercises in coordination, and increase the initiative of stroke patients in preventing VTE. This is of great significance for promoting patient safety. Patients with good disease knowledge are more likely to form correct disease prevention attitudes.²⁵ It is suggested that medical staff strengthen the influence of health education, through diversified health education models, to make the dissemination range of VTE prevention knowledge for stroke patients wider and the dissemination methods more convenient, promote the combination of knowledge, belief, and action in VTE prevention, and improve the cognitive level, belief level, and action effectiveness.

Strengths and limitations

This study introduces an innovative approach to the prevention and treatment of VTE in stroke patients, thereby enriching the clinical practice toolkit for healthcare professionals. However, several limitations should be acknowledged. Firstly, the relatively small sample size and insufficient representativeness may limit the generalizability of our findings. Secondly, the intervention period did not extend to the patients' discharge, which could have influenced the long-term outcomes. Additionally, the baseline investigation of stroke patients in this study was somewhat limited, as it did not account for all relevant factors influencing the occurrence of VTE. This may lead to deviations in the research results. Overall, while this study offers valuable insights, addressing these limitations in subsequent research will be crucial for further validating our findings and improving clinical practice.

Conclusions

The application of 4R crisis management combined with the health belief model could effectively improve the health beliefs and behaviors of VTE prevention and control in stroke patients. It could also improve the quality of nursing and reduce the incidence of VTE. Future research may build on these findings to further explore the long-term effects and refine the intervention methods.

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Conflict of interest

GY has been an Executive Associate Editor and YZ has been an Editorial Board Member of *Neurosurgical Subspecialties* since August 2024. The authors declare that they have no other conflict of interest in this study.

Author contributions

Conceptualization (PW, XY, DL, GY, YZ), methodology (PW, XY, YZ), validation (PW, XY, DL, YZ), supervision (PW, DL, GY, YZ), writing original draft (PW, XY, BL), review & editing (PW, XY, YZ), data collection (XY), data analysis (XY, BL, YW), review (YY), project administration (GY, YZ), and funding acquisition (YZ). All authors have approved the final version and publication of the manuscript.

Ethical statement

This study complies with the requirements of the Declaration of Helsinki (as revised in 2024). Ethical approval to conduct the study was granted by the Research and Ethical Committee of Union Hospital affiliated with Tongji Medical College of Huazhong University of Science and Technology. The approval record number is 2021-0125. All participants gave their informed consent. The study was registered at the Chinese Clinical Trial Registry (ChiCTR2100045301).

Data sharing statement

Due to the sensitive nature of the questions asked in this study, survey respondents were assured that raw data would remain confidential and would not be shared.

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