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An retrospective study on the effects of deep learning model-based optimization emergency nursing on treatment compliance and curative effect of patients with acute left heart failure

Qian Dai[1†], Jing Huang[1†], Hui Huang[1*] and Lin Song[1*]

Abstract

Background Based on explainable DenseNet model, the therapeutic effects of optimization nursing on patients with acute left heart failure (ALHF) and its application values were discussed.

Method In this study, 96 patients with ALHF in the emergency department of the Affiliated Hospital of Xuzhou Medical University were selected. According to different nursing methods, they were divided into conventional group and optimization group. Activity of daily living (ADL) scale was used to evaluate ADL of patients 6 months after discharge. Self-rating anxiety scale (SAS) and self-rating depression scale (SDS) were employed to assess patients' psychological state. 45 min improvement rate, 60 min show efficiency, rescue success rate, and transfer rate were used to assess the effect of first aid. Likert 5-level scoring method was adopted to evaluate nursing satisfaction.

Results The optimization group showed shorter durations for first aid, hospitalization, electrocardiography, vein channel establishment, and blood collection compared to the conventional group. However, their SBP, DBP, and HR were inferior. On the other hand, LVEF and FS were significantly better in the optimization group. After nursing intervention, SAS and SDS scores were lower in the optimization group. Additionally, the optimization group had higher 45-minute improvement rates, 60-minute show efficiency, rescue success, and transfer rates. They also performed better in 6-minute walking distance and ADL scores 6 months post-discharge. The optimization group had better compliance, total effective rates, and satisfaction than the conventional group.

Conclusion It was demonstrated that explainable DenseNet model had application values in the diagnosis of ALHF. Optimization emergency method could effectively shorten the duration of first aid, relieve anxiety, and other adverse

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emotions, and improve rescue success rate and short-term efficacy. Nursing intervention has a positive impact on the total effective efficiency and patient satisfaction.

Keywords Deep learning model, Emergency nursing, Treatment compliance, Acute left heart failure

Introduction

Acute left heart failure (ALHF) is a common critical condition characterized by acute cardiac dysfunction leading to pulmonary congestion and acute respiratory distress [1, 2]. Due to its high mortality and recurrence rates, treatment and nursing strategies for ALHF have been a focus of clinical research. Despite advancements in modern medical technologies and pharmacological treatments, treatment compliance remains a crucial factor influencing patient prognosis and therapeutic efficacy [3].

Emergency nursing plays a critical role in the management of acute left heart failure. Effective emergency nursing not only promptly alleviates patient symptoms but also significantly improves their quality of life and treatment compliance [4]. However, traditional emergency nursing approaches have limitations in terms of personalization, precision, and timeliness. In recent years, with the rapid development of artificial intelligence (AI) technologies, deep learning models have been increasingly applied in the medical field, demonstrating tremendous potential. Particularly, optimization techniques based on interpretable deep learning models have provided new insights and methods for emergency nursing. Numerous studies [5, 6] have shown that interpretable deep learning models play an important role in early diagnosis and risk assessment of heart failure. By analyzing electronic health records (EHRs), biomarkers, and electrocardiogram data, AI can rapidly identify high-risk patients and predict acute events. These models have enhanced the recognition of heart failure in emergency settings and shortened diagnosis times. Deep learning models can process vast amounts of complex medical data to extract valuable information used in optimizing nursing strategies. For instance, researchers have developed decision support systems based on deep learning that provide personalized nursing recommendations based on real-time data, thereby enhancing the precision of nursing interventions [7]. The application of these systems in emergency nursing helps adjust treatment plans promptly and reduce the occurrence of complications. The application of interpretable AI models addresses the "black box" issue of traditional deep learning models in the medical field, enabling healthcare providers to understand the rationale behind model decisions. This not only enhances clinical trust but also improves the effectiveness of nursing interventions [8]. For example, through interpretable AI models, healthcare providers can understand which factors significantly impact patient treatment compliance and short-term efficacy, allowing for targeted nursing interventions. Several clinical studies and trials have begun exploring the specific effects of AI-optimized emergency nursing on ALHF patients. Comparative studies between traditional nursing models and AI-optimized nursing models have shown [9] significant advantages in improving treatment compliance, reducing hospitalization times, and enhancing patient outcomes. These research findings highlight the broad prospects of AI technology in emergency nursing and warrant further promotion and application.

This study aims to investigate the impact of AI-optimized emergency nursing, based on interpretable deep learning models, on treatment compliance and short-term efficacy in patients with acute left heart failure. By integrating advanced deep learning models into emergency nursing, we aim to achieve more efficient and precise nursing interventions, thereby improving treatment compliance and enhancing short-term efficacy in patients. The results of this study will provide new theoretical insights and practical guidance for clinical nursing of acute left heart failure, while also serving as a reference for optimizing nursing strategies for other acute diseases.

Materials and methods

Research objects and grouping

A retrospective analysis was used in this study, 96 ALHF patients admitted to emergency department at The Affiliated Hospital of Xuzhou Medical University between February, 2021 and May, 2022 were selected and performed with first aid. There were 54 males (56.25%) and 42 females (43.75%) aged between 53 and 87 with the average of 66.03 ± 5.97.

The inclusion criteria were as follows.

A. Patients who met the diagnostic criteria for ALHF [16].
B. Patients with III to IV New York Heart Association (NYHA) heart function levels.
C. Patients with clear cause of disease.
D. Patients with good compliance with treatment and nursing.
E. The age range of patients included in this study is 50–100 years old.

The exclusion criteria were as follows.

A. Pregnant or breast feeding women.

B. Patients with mental disease, infectious disease, and liver and kidney diseases.
C. Patients with cerebral hemorrhage.
D. Patients with congenital heart disease (Congenital heart disease is the most common congenital malformation, but it only occurs in heart organs.)
E. Patients with multiple organ failure (Multiple organ failure refers to the clinical syndrome of simultaneous or continuous failure of two or more organs. Multiple organ failure may include the heart, but when there is only one organ, it is not included in the criteria of multiple organ failure.)
F. Patients with end-stage disease of chronic heart failure.
G. Patients allergic to emergency treatment drugs.

The procedures of the experiment had been approved by Ethics Committee of The Affiliated Hospital of Xuzhou Medical University. All included research objects had signed informed consent forms.

96 included ALHF patients were randomly enrolled into conventional (45 cases performed with routine nursing) and optimization groups (51 cases undergoing optimization emergency nursing) according to different nursing methods.

Echocardiogram examination method

Patients were instructed to take left lateral position. After a 10-min rest, Philips color Doppler ultrasonic instrument was utilized for the examination. Then, left ventricular posterior wall radial line, interventricular septum, aorta, right ventricle, left ventricle, left atrial root, apical five-chamber surface, apical four-chamber surface, papillary muscle short axial view, and parasternal long axial view were measured. Single plane method was adopted to measure left ventricular ejection fraction (LVEF) of apical four-chamber surface and color Doppler blood flow imaging was used to detect apical five-chamber surface and apical four-chamber surface. After that, left ventricular blood flow spectrum of mitral valve orifice was detected, wave crest A and the velocity and deceleration time of wave crest E were measured, and the velocity of aortic flow was calculated to obtain the blood flow spectrum of aorta and mitral valve. Finally, Tei index was calculated.

Explainable DenseNet model-based processing methods for echocardiograms

DenseNet model mainly consisted of Dense and transition layer. In the transition layer, dimensionality reduction was performed through a convolution layer and a pooling layer. The convolution kernel of the convolution layer was 1×1 and the pooling kernel of the pooling layer was 2×2. Mean-pooling was carried out [17]. Dense module was responsible for the dense connection between layers and each layer in Dense module was connected to all preceding layers. Hence, the input of this layer included the features of all preceding layers. The non-linear transformation equation of DenseNet model was expressed as Eq. (1) below.

$$Y_l = A_l\left[Y_0, Y_1, \cdots Y_{i-1}\right] \quad (1)$$

In Eq. (1), Y_l, A_l, and Y_o, Y_1, ...Y_{i-1} represented the current layer, the operation between layers, and the input of the previous layer, respectively. The collected original cardiac echocardiographic images were converted from DICOM format to PNG format. After that, DenseNet model network was used for image classification, localization, and segmentation.

The employed operating system and hardware devices included Linux system (Ubuntu 18.04), processor (Intel(R) Xeon(R) CPU E3-1230 v3 @ 3.40 GHz×8), random asccess memory (RAM) (24.0 GB), discrete graphics card (Ge Force GTX Titan X), and development tools (MATLAB R2015b and Tensor Flow and Keras frameworks).

Emergency treatment methods for ALHF patients

The specific emergency treatment methods for ALHF patients were as follows

A. ALHF patients should be seated as much as possible so that legs dropped naturally to avoid venous return.
B. Nasal cannula was used to perform high-flow oxygen supply. Patients with severe disease should undergo pressurized mask oxygen inhalation.
C. Patients were treated with neuroleptics through intravenous drip. In the research, 5 to 10 mg morphine was used as the main neuroleptics to reduce cardiac load. The dose of neuroleptics should be appropriately reduced for elder patients.
D. 20 to 40 mg furosemide was administered intravenously to dilate veins and facilitate diuresis.
E. Phentolamine, nitroglycerin, or sodium nitroprusside was administered intravenously to dilate blood vessels. According to the disease conditions among different patients and biochemical indications, medication and dose were adjusted accordingly.

Nursing methods for different groups

ALHF patients in conventional group were performed with routine nursing as follows.

A. Vein channel was established immediately after admission. All vital signs and conscious state of patients were observed. Besides, cardiac monitoring was carried out.

B. Drug was administered according to the doctor's advice.
C. Psychological comfort was provided for patients.
D. Patients were assisted to take appropriate position.
E. Tidy environment and clean air were maintained in ward and room temperature was kept about at 25 °C.

On the basis of conventional nursing care, the optimization group of ALHF patients received the following enhanced nursing interventions.

A. Nursing skill training

All nursing staff should receive ALHF nursing and first aid-related knowledge and skill training to improve their proficiency in first aid operation and nursing efficiency.

B. Selection of reception tools

After receiving emergency notice, appropriate reception tools were selected in receiving room according to patients' status. Wheelchair placement was adopted for patients with suspected ALHF to reduce the amount of venous blood return, increase vital lung capacity, and relieve dyspnea. Patients with shock should immediately take horizontal position so as not to aggravate shock [10].

C. Supply nursing

ALHF patients were performed with oxygen inhalation with the flow of 4 L/min immediately after admission. Meanwhile, they underwent cardiac monitoring. Once the disease was improved, the dose of oxygen was adjusted to 2 L/min.

D. Vein channel establishment and drug administration

Vein channel was established with a indwelling venous catheter immediately after admission. According to the clinician's requirement, furosemide and other drugs were administered.

E. Psychological intervention

Intensive psychological comfort was performed on all patients. Patients and their family members were emotionally supported and encouraged to eliminate nervousness and fear.

F. Change in body posture

According to patients' needs and rehabilitation, reasonable and comfortable posture were taken.

G. Observation and adjustment of physiological indicators

After drug administration in accordance with the clinician's advice, the change in physiological indicators was closely observed and dripping rate and dose should be adjusted in time.

H. Patient transfer

When the disease among ALHF patients became stable, nursing staff made a work handover with relevant departments and then dealt with transfer-related affairs. Patients should be lifted and placed gently. During the transfer, first-aid medicine and equipment should be carried and the changes in disease needed to be closely observed. Abnormalities should be treated reasonably in time.

I. Continuing nursing

After the transfer into ward, first-aid nursing staff should make an all-round work handover with nursing staff at department. In addition, the patients' condition and nursing progression should be visited regularly and ward nursing staff should be assisted to perform nursing intervention.

J. Diet

Patients and their family members were told to eat light, low-sodium, and digestible food rather than stimulating, fried, and greasy food. Besides, they should follow the principle of "eat less but more times". Smoking, alcohol drinking, and other adverse living habits and behaviors should be prohibited.

Observation indicators

The general clinical data (age and gender), etiologies, and the time of electrocardiography, vein channel establishment, first aid, and hospitalization on patients in two groups were counted. NYHA was employed for cardiac function grading. The changes in diastolic blood pressure (DBP), systolic blood pressure (SBP), and heart rate (HR) of patients in two groups before and after nursing intervention were counted. What's more, activity of daily living (ADL) scale [11] was used to evaluate ADL of patients 6 months after discharge. The full score was 100 points. A higher ADL score indicated stronger self-care ability. Self-rating anxiety scale (SAS) and self-rating depression scale (SDS) were employed to assess patients' psychological state after nursing. SDS score below 53 suggested that patients didn't suffer from depression. SDS score between 53 and 62, between 63 and 72, and above 72 represented mild depression, moderate depression, and severe depression, respectively [12]. SAS score below 50 demonstrated that patients didn't suffer from anxiety. SAS score between 50 and 59, between 60 and 69, and between 70 and 79 referred to mild anxiety, moderate anxiety, and severe anxiety, respectively [13].

45 min improvement rate, 60 min show efficiency, rescue success rate, and transfer rate were adopted to assess the first-aid effects of different nursing methods. Improvement referred to the significant improvement of dyspnea among patients. Nonetheless, patients still couldn't lie flat. Dry and wet rales in two lungs reduced or disappeared. Besides, HR was less than 120 times/min, respiratory frequency was less than 25 times/min, and artery pressure reduced by 30% and above. Show efficiency referred to the alleviation of severe dyspnea among patients. They were able to lie flat with stable blood pressure, HR, and other vital signs.

Likert 5-level scoring method [14] was employed to evaluate nursing satisfaction. The score between 21 and 30, between 11 and 20, and below 10 represented very satisfied, satisfied, and dissatisfied, respectively. The calculation method for total satisfaction rate was displayed in Eq. (2) as follows.

$$TSR = \frac{Vs + S}{Tn} \times 100\% \tag{2}$$

In Eq. (2), *TSR*, V_s, *S*, and T_n denoted total satisfaction rate, the number of people being very satisfied, the number of people who were satisfied, and total number of cases, respectively.

Assessment and compliance and efficacy in two groups

Treatment compliance of two groups were compared. The assessment criteria for compliance were as follows.

A. Complete compliance

According to the clinician's guidance, patients received treatment and took medicine.

B. Partial compliance

In partial accordance with the clinician's advice, patients took medicine. The times and dose of medication varied from person to person.

C. Noncompliance

Patients took medicine, stopped taking medicine, or took medicine intermittently without following the clinician's advice. The calculation method for total compliance rate was shown in Eq. (3) below.

$$TCR = \frac{Ed + Pd}{Tn} \times 100\% \tag{3}$$

In Eq. (3), *TCR*, E_d, P_d, and T_n represented total compliance rate, the number of people with complete compliance, the number of people with partial compliance, and total number of cases, respectively.

The efficacy of nursing in patients was evaluated in the methods section of reference [24]. The specific evaluation indicators were as follows.

A. The clinical symptoms and vital signs were apparently improved. If cardiac function level was improved by 2 levels or above after the nursing, the nursing showed efficiency.
B. The clinical symptoms and vital signs were relieved. If cardiac function level was improved by 1 level after the nursing, the nursing was valid.
C. The clinical symptoms and vital signs were aggravated or patients died without the change in cardiac function level after the nursing, which demonstrated that the nursing was invalid.

The calculation method for overall effective rate was presented in Eq. (4) below.

$$OE = \frac{E + e}{Tn} \times 100\% \tag{4}$$

In Eq. (4), *OE*, *E*, *e*, and T_n referred to overall efficiency, the number of people showing efficiency, the number of effective people, and total number of cases, respectively.

Tei index

The Tei index, also known as the myocardial performance index (MPI), is a comprehensive indicator used to assess both systolic and diastolic cardiac functions. The method for calculating the Tei index is as follows:

- (1) Data collection

Use echocardiography to measure the following cardiac functional parameters: isovolumic contraction time (IVCT), isovolumic relaxation time (IVRT), and ejection time (ET). The Tei index is calculated using the equation:

$$Tei\ index = \frac{IVCT + IVRT}{ET} \tag{5}$$

Where, isovolumic contraction time (IVCT): the time from mitral valve closure to aortic valve opening;

Isovolumic relaxation time (IVRT): the time from aortic valve closure to mitral valve opening;

Table 1 Comparison of basic data between two groups

Factors	Conventional group ($n=45$)	Optimization group ($n=51$)	χ^2/t value	*P* value
Male [cases (%)]	24 (53.33)	30 (58.82)	0.754	0.082
Female [cases (%)]	21 (46.67)	21 (41.18)		
Age (years old)	66.77 ± 6.54	65.56 ± 5.93	0.252	0.073
Different etiology			0.891	0.061
Coronary artery disease (%)	15(33.33)	18(35.29)		
Hypertension (%)	12(26.67)	13(25.49)		
Arrhythmias (%)	8(17.78)	9(17.65)		
Rheumatic heart disease (%)	5(11.11)	6(11.76)		
Dilated cardiomyopathy (DCM) (%)	3(6.67)	3(5.88)		
Valvular disease (%)	2(4.44)	2(3.92)		
Cardiac functional levels			0.305	0.065
II	8(17.78)	10(19.61)		
III	27(60.0)	31(60.78)		
IV	10(22.22)	10(19.61)		

Note: The sex ratio, average age, etiology and cardiac function level of patients in routine group and optimization group were tested by chi-square test. The chi-square values were 0.754, 0.252, 0.891 and 0.305, respectively, and there was no statistical significance. These variables are homogeneous

Fig. 1 Echocardiogrames of ALHF patients. **A** The initial echocardiogram of ALHF patients. **B** The echocardiogram processed by the explainable DenseNet model. **C** Left ventricular image segmented by the explainable DenseNet model and delineated by doctors)

Ejection time (ET): the time from aortic valve opening to closure.

The above time parameters were measured and recorded by echocardiography. The measured values of IVCT, IVRT, and ET were substituted into the equation to calculate the Tei index. The higher the Tei index, the worse the systolic and diastolic function of the heart.

Statistical methods

SPSS22.0 was employed for data statistical analysis. Measurement data were denoted by mean±standard deviation (±s). Enumeration data were represented by percentage (%). conforming to normal distribution and homogeneity of variance were analyzed with t test and the differences between groups were analyzed. Data that didn't conform to normal distribution or homogeneity of variance were analyzed with nonparameter test or precision probability test. Enumeration data were analyzed with chi-square test. $P<0.05$ suggested that the difference revealed statistical significance. Effectiveness analysis is mainly to help determine the sample size needed for the experiment under the specified significance conditions and evaluate the statistical effectiveness of the experimental design. Through the effectiveness analysis, we can also give the reliability of the experimental conclusion under the existing sample size. In effectiveness analysis, we need to pay attention to four statistics: sample size, effect size, significance level, and power.

Results

Comparison of the basic data between two groups

Gender ratio and average age of patients in conventional and optimization groups were compared and analyzed (Table 1). The comparisons of gender ratio, average age, etiology, and cardiac functional levels between the two groups showed no statistically significant differences ($P>0.05$). The validity value obtained by t-test is 0.8931, which confirms the statistical validity of this experimental design.

Analysis of the processing of echocardiograms of ALHF patients based on explainable DenseNet model

The echocardiograms of ALHF patients were shown in Fig. 1. After being processed by the explainable DenseNet model, the quality of echocardiograms was apparently improved and the result of left ventricular segmentation

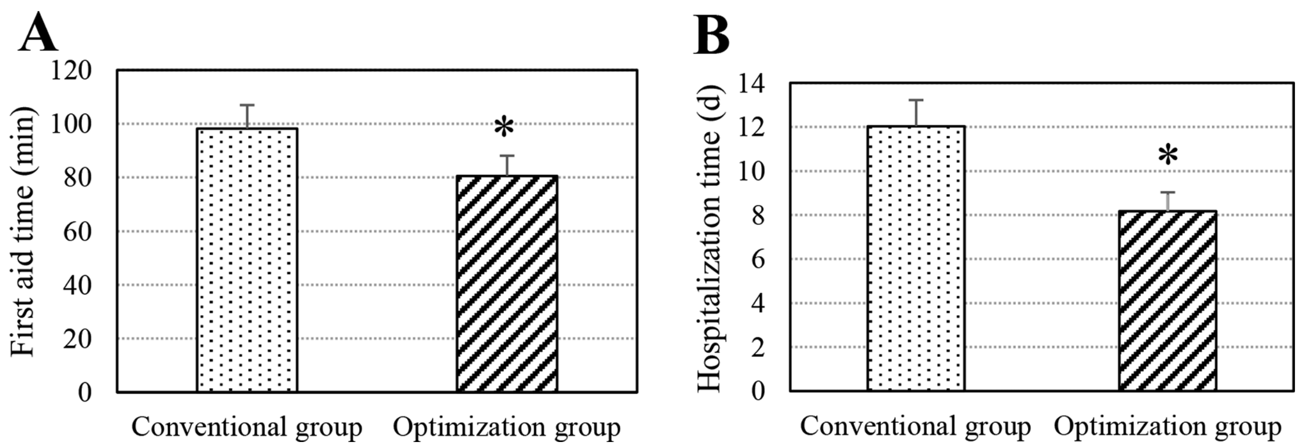

Fig. 2 Comparison of the duration of first aid and the duration of hospitalization between two groups. (* suggested that the comparison with conventional group revealed statistical difference ($P<0.05$))

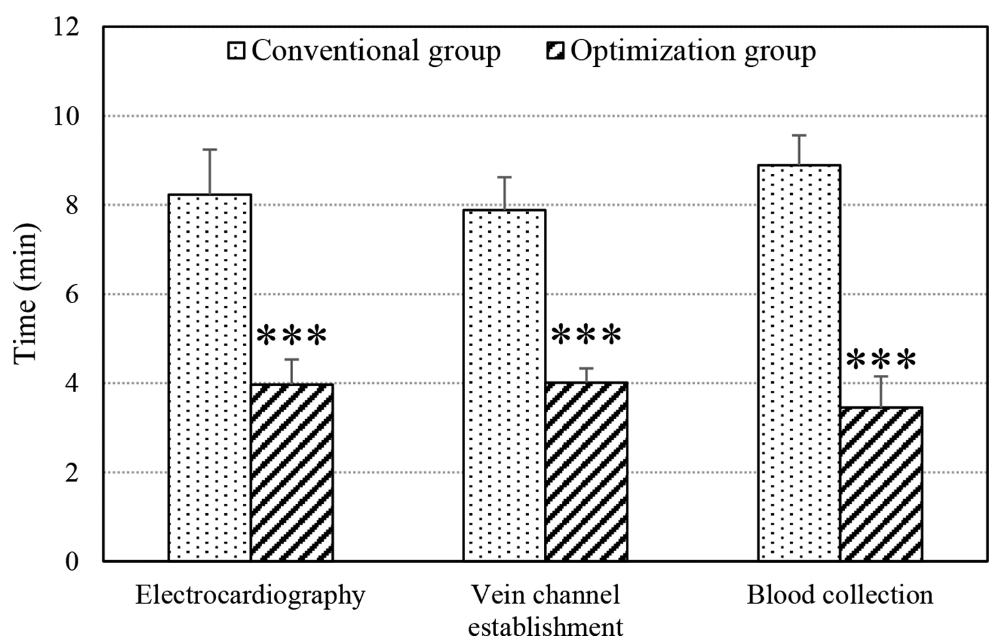

Fig. 3 Comparison of the duration of first aid between two groups. (*** suggested that the comparison with conventional group indicated extremely significant difference ($P<0.001$))

(red area) was similar to that of manual delineation (green area). The echocardiograms of ALHF patients showed mild abnormal or normal left ventricular systolic function and diastolic dysfunction.

Comparison of the duration of first aid and hospitalization between two groups

The duration of first aid and hospitalization between two groups were compared and analyzed (Fig. 2A and B). As illustrated in Fig. 2A, the duration of first aid in conventional and optimization groups amounted to 98.19±8.76 min and 80.54±7.56 min, respectively. The duration of first aid in the latter group was notably shortened versus that in the former one. The comparison of average duration of first aid in two groups suggested statistical difference ($P<0.05$). As presented in Fig. 2B, the duration of hospitalization in conventional and optimization groups were 12.03±1.19d and 8.17±0.86d, respectively. The duration of hospitalization in the latter group was apparently shortened versus that in the former one ($P<0.05$).

Comparison of the duration of first aid between two groups

The time of electrocardiography, vein channel establishment, and blood collection of conventional and optimization groups during first aid were counted and analyzed (Fig. 3). The time of electrocardiography, vein channel establishment, and blood collection in conventional and optimization groups amounted to 8.23±1.01 min vs. 3.97±0.56 min, 7.88±0.74 min vs. 4.01±0.32 min, and 8.89±0.67 min vs. 3.45±0.70 min, respectively. The time of electrocardiography, vein channel establishment, and blood collection in the latter group were notably shortened versus those in the former one. Extremely significant differences were detected ($P<0.001$).

Comparison of the changes in blood pressure and HR between two groups before and after nursing

The changes in blood pressure of two groups before and after nursing were compared (Fig. 4). No statistical difference was detected in SBP and DBP between two groups before nursing ($P>0.05$). After different nursing interventions, SBP and DBP of two groups both apparently declined versus those before nursing intervention (18.15±1.86 kPa and 10.22±1.24 kPa in optimization group) ($P<0.05$). In addition, SBP and DBP of optimization group were notably inferior to those of conventional group (22.03±2.01 kPa and 12.76±1.51 kPa). Statistical difference was detected ($P<0.05$).

The changes in HR of two groups before and after nursing were compared (Fig. 5). Before nursing intervention, no statistical difference was detected in HR between two groups ($P>0.05$). After different nursing interventions, HR of two groups both dramatically declined versus those before nursing. Statistical difference was detected in HR of conventional and optimization groups before and after nursing ($P<0.05$) ($P<0.01$). After nursing intervention, HR of the latter group was remarkably inferior to that of the former one ($P<0.05$). After nursing intervention, the heart rate in the optimization group was significantly lower than that in the Conventional group ($P<0.05$).

Comparison of cardiac function indicators between two groups before and after nursing

The changes in left ventricular ejection fraction (LVEF) and fractional shortening (FS) of two groups before and after nursing intervention were illustrated in Fig. 6A and B. Before nursing intervention, no statistical differences were detected in average LVEF and FS values between two groups ($P>0.05$). LVEF and FS of two groups increased after nursing. LVEF of conventional and optimization groups amounted to 38.54±0.69% and 43.29±3.31%, respectively. There were statistical differences in LVEF between two groups before and after nursing ($P<0.05$). Average LVEF of optimization group was apparently superior to that of conventional group ($P<0.05$). As illustrated in Fig. 6B, FS of conventional and optimization groups amounted to 21.59±2.61% and 27.32±2.97%, respectively. There were remarkable differences in FS of two groups before and after nursing ($P<0.01$). Average FS of optimization group was notably superior to that of conventional group ($P<0.05$).

Comparison of psychological state scores between two groups after nursing

SAS and SDS scores of two groups after nursing intervention were compared (Fig. 7A and B). As displayed in Fig. 7A, SAS scores for conventional and optimization groups amounted to 55.26±5.43 points and 30.36±3.81 points, respectively. SAS score for the latter group was apparently inferior to that for the former one ($P<0.001$). After nursing intervention, SDS scores for conventional and optimization groups amounted to 55.74±4.87 points and 31.05±3.48 points, respectively. SDS score for theoptimization group was notably inferior to that for the conventional group ($P<0.001$) (Fig. 7B).

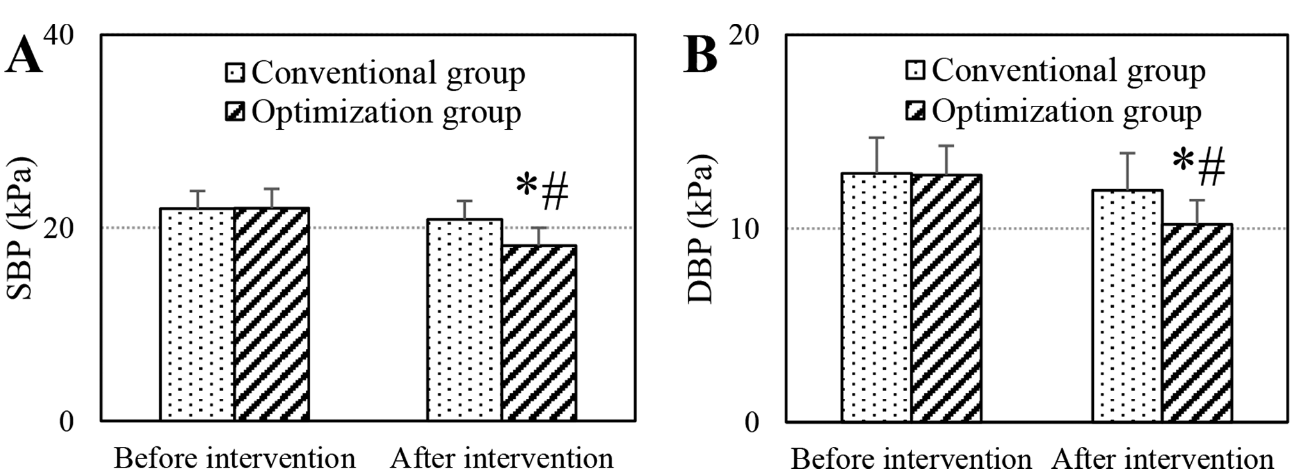

Fig. 4 Comparison of blood pressure between two groups before and after nursing. **A**: Comparison of SBP before and after nursing. **B**. Comparison of DBP before and after nursing. * suggested that the comparison with conventional group revealed statistical difference ($P<0.05$). # indicated that the comparison with SBP and DBP before nursing revealed statistical difference)

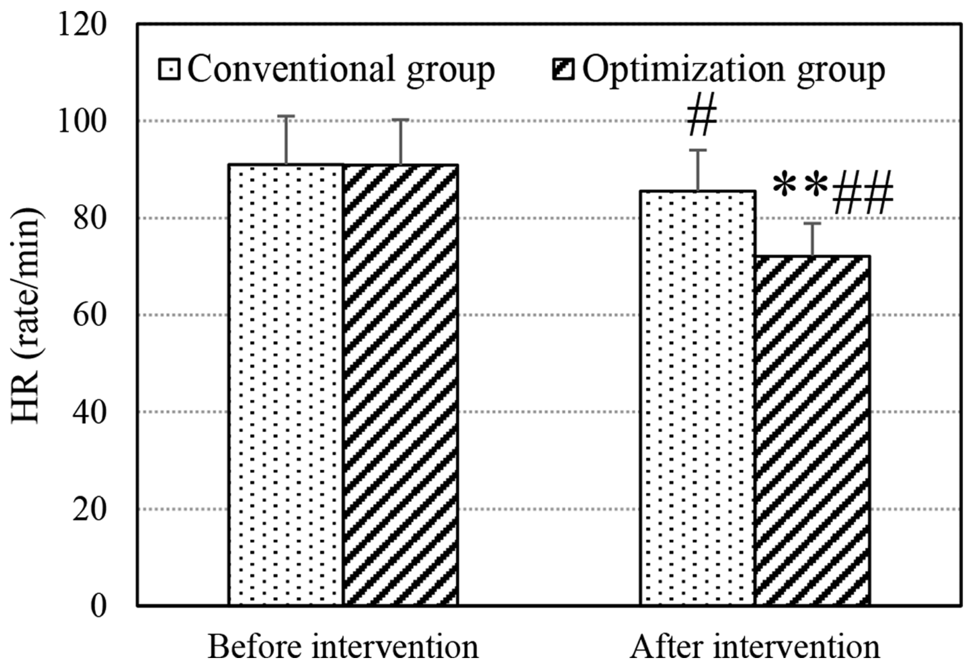

Fig. 5 Comparison of HR between two groups before and after nursing. (** indicated that the comparison with conventional group revealed significant difference ($P<0.01$). # suggested that the comparison with HR before nursing revealed statistical significance ($P<0.05$). ## demonstrated that the comparison with HR before nursing indicated significant difference ($P<0.01$))

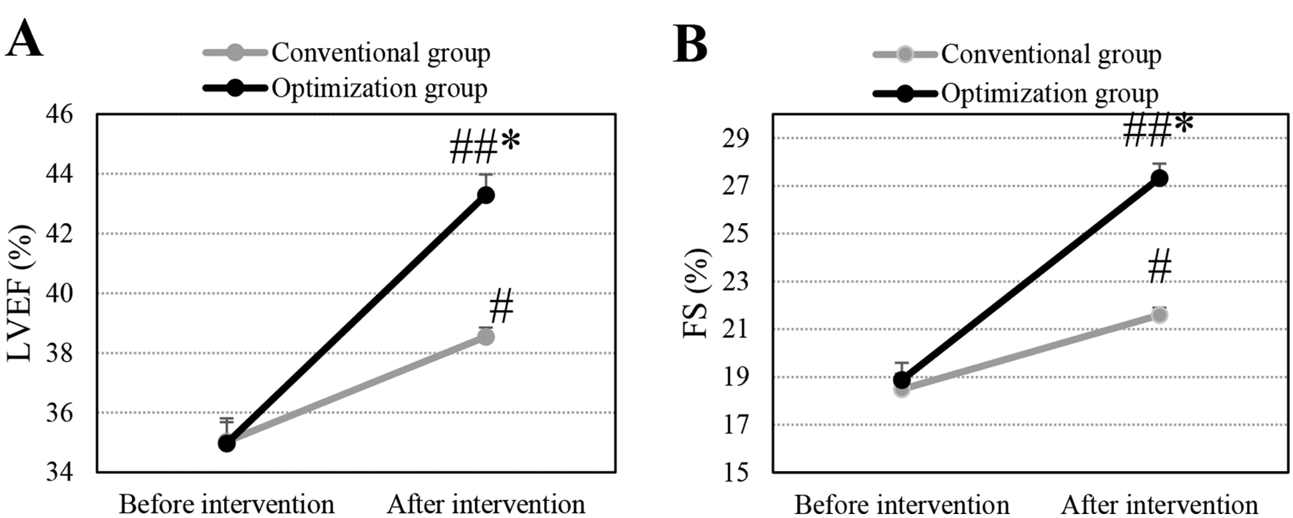

Fig. 6 **A** Comparison of LVEF and FS between two groups before and after nursing. (Note: A:LVEF; **B** FS; * indicated that the comparison with conventional group revealed statistical difference ($P<0.05$). # suggested that the comparison with LVEF before nursing revealed statistical difference. ## demonstrated that the comparison with LVEF before nursing indicated significant difference ($P<0.01$))

Comparison of efficacy of first aid between two groups after nursing

45 min improvement rate, 60 min show efficiency, rescue success rate, and transfer rate of two groups after nursing were compared and analyzed (Fig. 8). The above rates of conventional and optimization groups after nursing amounted to 46.67% (21 cases) vs. 78.43% (40 cases), 51.11% (23 cases) vs. 86.27% (44 cases), 57.78% (26 cases) vs. 88.24% (45 cases), and 62.22% (28 cases) vs. 92.16% (47 cases), respectively. The results indicate that the optimization group exhibited significantly lower rates of improvement at 45 min, effectiveness at 60 min, success in rescue, and transfer rates compared to the conventional group ($P<0.01$).

Comparison of 6 min walking distance and ADL scores 6 months after discharge between two groups after nursing intervention

6 min walking distance and ADL scores 6 months after discharge of conventional and optimization groups

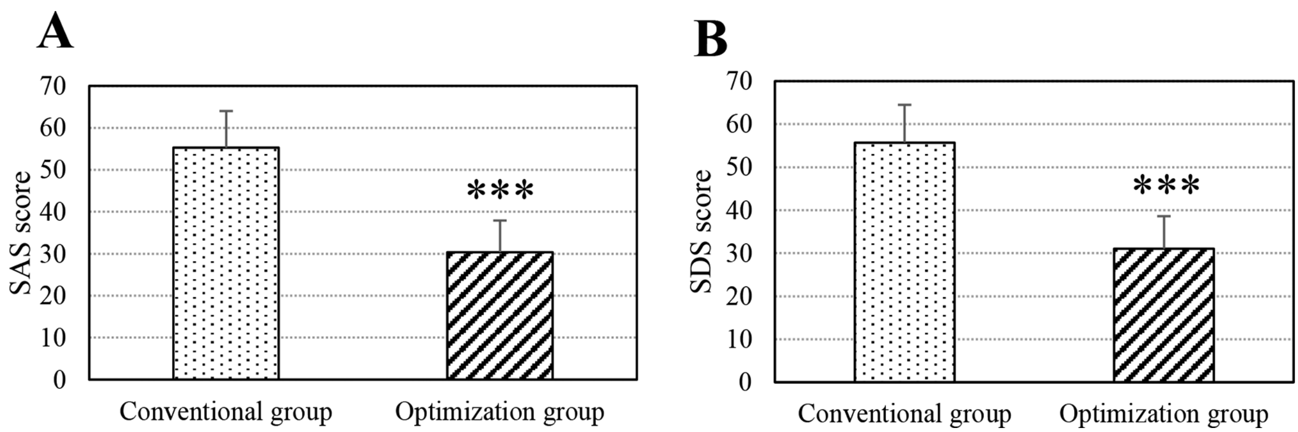

Fig. 7 Comparison of SAS and SDS scores for two groups after nursing. (Note: **A** SAS; **B** SDS; *** suggested that the comparison with conventional group indicated extremely significant difference ($P<0.001$))

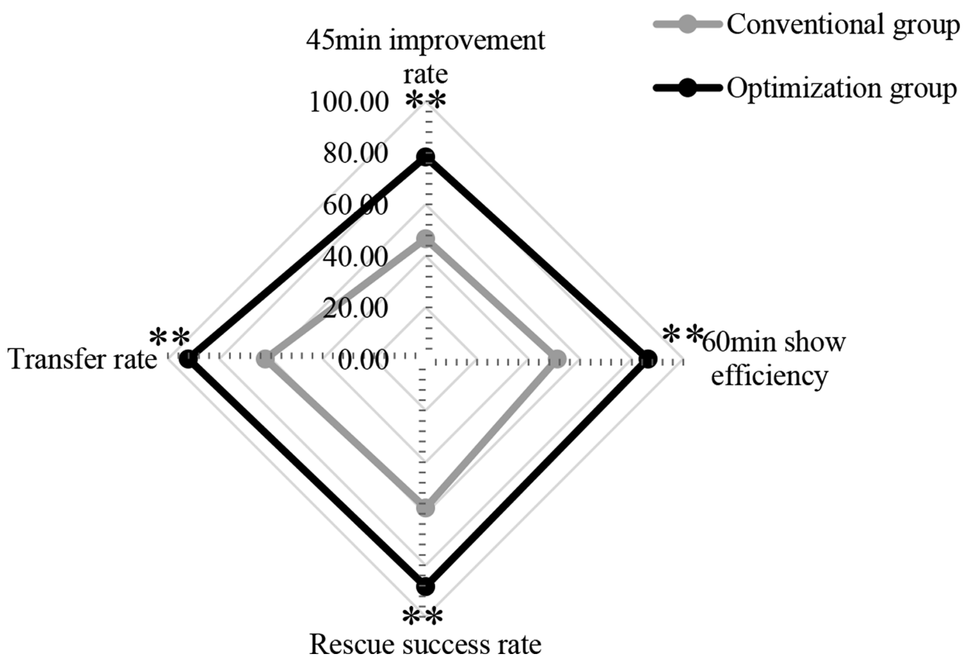

Fig. 8 Comparison of efficacy of first aid between groups after nursing. (** suggested that the comparison with conventional group indicated significant difference ($P<0.01$))

after nursing intervention were compared and analyzed (Fig. 9A and B). 6 min walking distance of two groups amounted to 342.19±33.81 m and 418.83±44.39 m, respectively. Apparently, 6 min walking distance of the latter group was longer than that of the former one ($P<0.001$). As illustrated in Fig. 9B, ADL scores for conventional and optimization groups 6 months after discharge amounted to 43.71±4.57 points and 60.09±5.19 points, respectively. The ADL score of the optimization group was significantly better than that of the conventional group ($P<0.01$).

Comparison of nursing compliance between two groups

The statistical results of nursing compliance in two groups were displayed in Fig. 10. During nursing intervention, the number of patients with complete compliance, partial compliance, and noncompliance in conventional and optimization groups amounted to 10 cases (22.22%) vs. 27 cases (52.94%), 18 cases (40.00%) vs. 20 cases (39.22%), and 17 cases (37.78%) vs. 4 cases (7.84%), respectively.

The proportion of patients with complete compliance in the latter group was notably superior to that in the former one ($P<0.01$), while the proportion of patients with noncompliance was apparently inferior to that in the former one ($P<0.01$). The total compliance rate in the

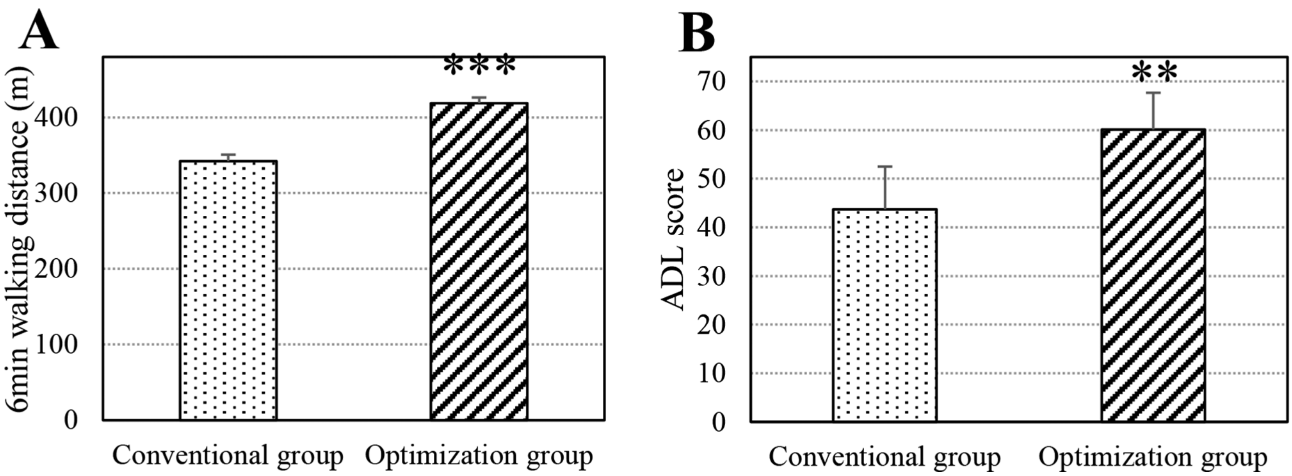

Fig. 9 Comparison of 6 min walking distance and ADL scores between two groups after nursing. (Note: A: 6 min walking distance; B:ADL scores; *** suggested that the comparison with conventional group indicated extremely significant difference ($P<0.001$))

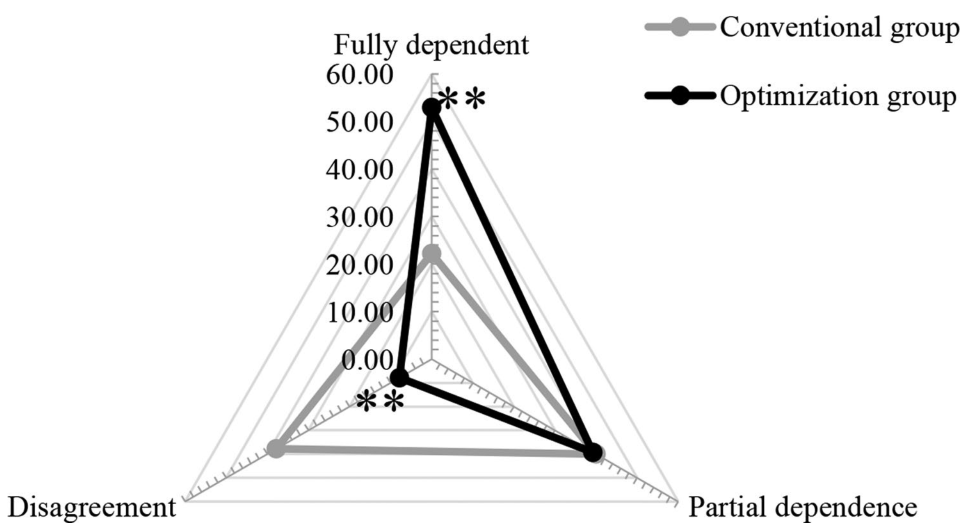

Fig. 10 Comparison of nursing compliance between two groups. (** suggested that the comparison with conventional group indicated significant difference ($P<0.01$))

optimization group (47 cases, 92.16%) was significantly higher than that in the conventional group (28 cases, 62.22%) ($P<0.01$).

Comparison of nursing efficacy between two groups

As illustrated in Fig. 11, the efficacy of different nursing methods in patients was compared. After nursing, the number of effective patients in optimization and conventional groups amounted to 32 (62.75%) and 12 (26.67%), respectively ($P<0.01$). The proportions of efficient and invalid patients in conventional group were both superior to those in optimization group ($P<0.01$). According to the further comparison and analysis of OE in two groups, OE in conventional and optimization groups amounted to 75.56% (34 cases) and 96.08% (49 cases), respectively. OE in the optimization group were superior to those in the conventional group ($P<0.01$).

Comparison of nursing satisfaction between two groups

The statistical results of nursing satisfaction with different nursing methods were displayed in Fig. 12. The proportions of patients who were very satisfied in optimization and conventional groups after nursing amounted to 88.24% (45 cases) and 62.22% (28 cases), respectively ($P<0.01$). The proportion of patients who were dissatisfied in conventional group was superior to that in optimization group ($P<0.01$). Overall satisfaction rate of conventional and optimization groups amounted to 80.00% (36 cases) and 98.04% (50 cases), respectively. After nursing, overall satisfaction of the latter group was superior to that of the former one ($P<0.01$). The overall satisfaction in the optimization group was superior to that in the conventional group ($P<0.01$).

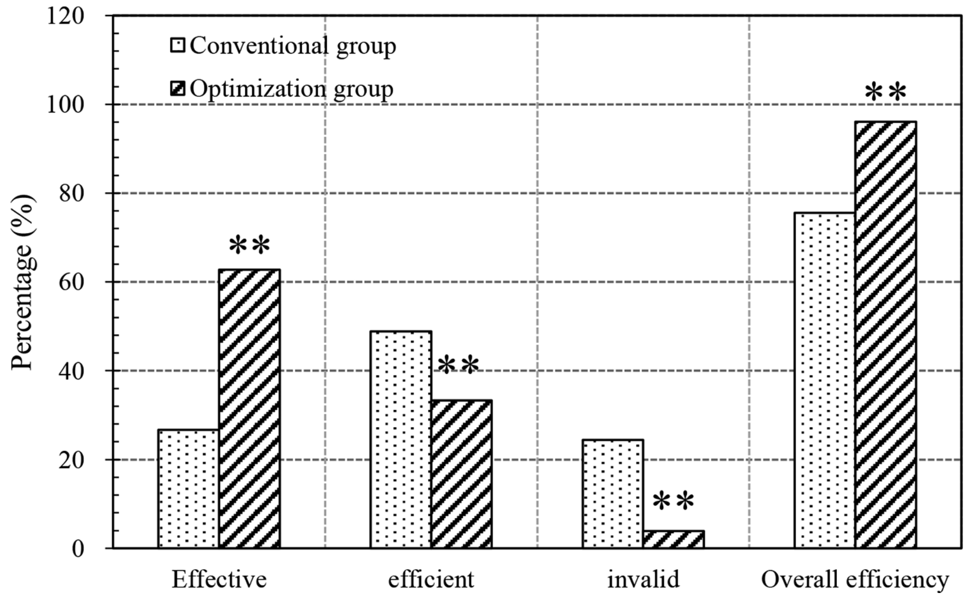

Fig. 11 Comparison of nursing efficacy between two groups. (** suggested that the comparison with conventional group indicated significant difference ($P<0.01$))

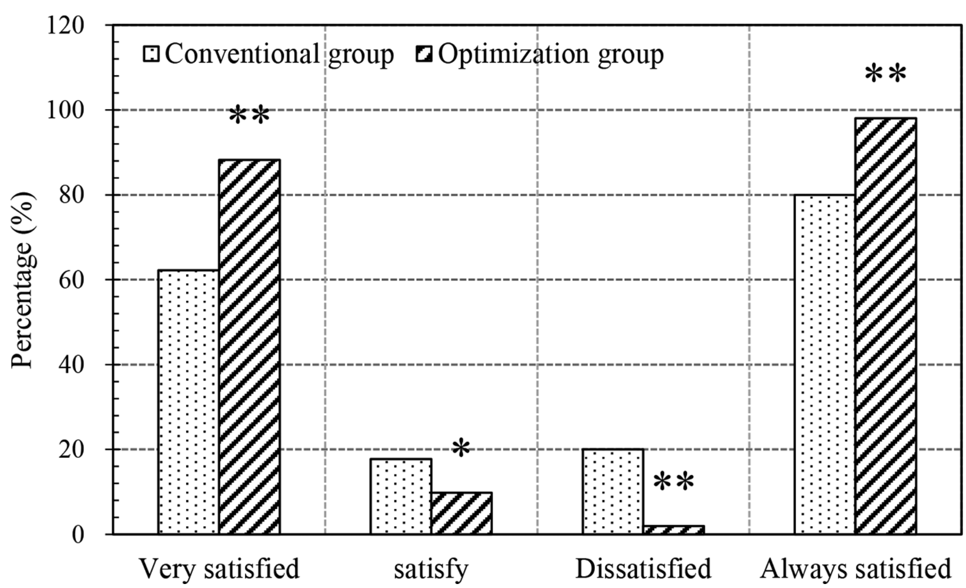

Fig. 12 Comparison of nursing satisfaction between two groups. (* demonstrated that the comparison with conventional group indicated statistical difference ($P<0.05$). ** suggested that the comparison with conventional group indicated significant difference ($P<0.01$))

Discussion

The fatality of ALHF is extremely high. It is featured with rapid occurrence and severe symptoms. Because of short duration of first aid for ALHF patients, the delay in effective and timely treatment for patients have a serious impact on patients' life and health [15]. During the rescue for ALHF patients, reasonable, standard, and normalized nursing method can help patients alleviate their disease condition. The implementation of emergency treatment is of great significance for rescue success rate and prognosis [16]. Routine nursing methods have the shortcomings of non-standard nursing measures and unclear nursing goals. In addition, the difference in professional abilities among nursing staff leads to the difference in therapeutic effects on patients. The emergency nursing for ALHF patients should be predictable, ordered, and divided [17]. According to patients' conditions, nursing staff perform appropriate treatment, such as oxygen inhalation, cardiopulmonary resuscitation, and vein channel establishment. Meanwhile, they get prepared for surgical operation [18, 19]. At present, salvage bed is the main clinical reception tool for ALHF patients. However, patients' heads can be elevated with the maximum angle between 70 and 80° on salvage bed. In this case, dyspnea can't be effectively alleviated. Even worse, dyspnea may causes falling out of bed [20, 21]. This study, based on an interpretable DenseNet model, explores the therapeutic effects of optimized nursing care on patients with acute left heart failure (ALHF). By comparing changes in various physiological and psychological indicators between the Conventional and Optimization groups, we found that optimized nursing care significantly outperformed conventional care in multiple aspects.

According to the results after nursing, the duration of first aid and hospitalization in optimization group was apparently shortened versus that in conventional group ($P<0.05$), which suggested that optimization nursing method could remarkably shorten the duration of first aid and hospitalization among ALHF patients. The finding was similar to the research outcomes obtained by Krzesinski et al. (2021) [22] and Lipinski et al. (2018) [23]. It was demonstrated that optimization nursing reduced the severity of ALHF at risk period, which might be caused by the enhanced nursing proficiency and predictability of rescue, the improvement of the timeliness of nursing measures, and the shortened rescue duration after the rigorous training for nursing staff. In addition, nursing measures were optimized to reduce the incidence of adverse events during the transfer. Consequently, the duration of first aid and hospitalization among ALHF patients was shortened.

According to the research results, the time of electrocardiography, vein channel establishment, and blood collection in optimization group was apparently shortened versus that in conventional group ($P<0.001$), which indicated that optimization nursing measures shortened rescue duration because wheelchair was used for reception to improve patient comfort and reduce oxygen consumption. As a result, more rescue time was saved for patients. What's more, nursing staff worked more efficiently. Hence, the rescue duration during the entire nursing was remarkably shortened. Optimized nursing care can effectively control blood pressure and heart rate in patients with ALHF, thereby improving cardiac function. This improvement may be attributed to a more comprehensive and personalized care approach in optimization, which includes attention to patients' daily activities and psychological states [24, 25].

It was shown that SBP and DBP of two groups both declined notably after different nursing interventions. SBP, DBP, and HR in optimization group were apparently inferior to those in conventional group, while LVEF and FS were both dramatically superior to those in the latter one. The above research findings revealed that optimization nursing method could effectively reduce blood pressure and HR and alleviate cardiac function level, which was similar to the current research outcome. According to the current research outcome, most patients suffer from anxiety and other negative emotions [26, 27]. Long-term anxiety and depression result in endocrine dyscrasia and eventually have a notable impact on recovery and prognosis [8, 28]. The optimized emergency nursing protocols can swiftly provide efficient treatment measures during critical moments after patient admission, enhancing emergency response efficiency, rescue success rates, and lowering the risk of mortality [29]. Improved psychological health may be associated with emotional support and psychological interventions provided in optimized care, which are crucial for the overall recovery of ALHF patients [30, 31].

It was demonstrated that SAS and SDS scores for optimization group were both remarkably superior to those for conventional group after nursing intervention ($P<0.001$), which suggested that optimization nursing method effectively alleviated patients' adverse emotions based on intensive psychological nursing for them and their family members. In addition, it was suggested that optimization nursing method improved 45 min improvement rate, 60 min show efficiency, rescue success rate, and transfer rate among ALHF patients.This may be that the optimized emergency care scheme can provide effective treatment measures quickly, thus improving the success rate of rescue. In addition, it also improves patients' compliance and satisfaction. Based on the analysis of the above results, optimized nursing plays a positive role in improving the nursing efficiency, and also gives care to patients' psychology, thus improving patients' compliance and satisfaction. Obviously, the optimized nursing is more effective than the conventional nursing methods.

As medical technology advances and nursing philosophies evolve, the importance of optimizing emergency care strategies for ALHF patients will become increasingly prominent [32]. Future research should continue to explore and validate new nursing methods and technologies to continually improve the effectiveness of emergency care, ultimately aiming to reduce mortality rates and enhance quality of life for ALHF patients. Subsequent studies could further investigate the specific mechanisms of DenseNet model-optimized nursing interventions, including their impact on cardiac function and psychological well-being. Through further research and refinement, optimized nursing strategies are poised to become a crucial component of acute left heart failure patient management, enhancing treatment compliance and overall therapeutic efficacy.

In conclusion, the nursing approach optimized with interpretable DenseNet models demonstrates significant superiority over conventional care in improving physiological indicators, psychological status, and emergency response outcomes in acute left heart failure patients.

Optimized nursing not only enhances patients' cardiac function in the short term but also improves their long-term quality of life and psychological well-being. This study provides novel insights and methodologies for clinical nursing of ALHF patients and offers valuable references for future research and nursing practices.

Conclusions

Based on the explainable DenseNet model, the therapeutic effect and application values of optimization emergency nursing for ALHF patients were investigated. It was demonstrated that the quality of echocardiograms was dramatically improved after being processed by the explainable DenseNet model. optimization nursing method could effectively improve patients' nursing compliance and satisfaction, reduce blood pressure, HR, and anxiety and other adverse emotions, and enhance short-term nursing effects. After nursing intervention, the total compliance rate of the optimization group was significantly better than that of the routine group, and the total efficiency and satisfaction of the optimization group were better than that of the routine group. However, there are still some shortcomings in the research. Only short-term effect of optimization nursing method was assessed without the observation on its long-term efficacy. In follow-up research, the duration of follow-up visit should be further extended to observe its long-term efficacy in ALHF patients. In conclusion, the research findings provided referable clinical basis for the diagnosis and emergency nursing for ALHF patients.

Abbreviations

ALHF	Acute left heart failure
AHF	Acute heart failure
DBP	Diastolic blood pressure
SBP	Systolic blood pressure
HR	Heart rate
LVEF	Left ventricular ejection fraction
FS	Fractional shortening
ADL	Activity of daily living
SDS	Self-rating depression scale
SAS	Self-rating anxiety scale

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Author contributions

Qian Dai and Jing Huang are co-1st author of this paper. Hui Huang and Lin Song are both corresponding authors. Q and J collected and analyzed the materials and were the main contributors to writing the manuscript. Q , J and H made methods and explanations, and reviewed and revised the manuscript. H and S analyzed and verified, and all authors read and approved the final draft.

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Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

The procedures of the experiment had been approved by Ethics Committee of The Affiliated Hospital of Xuzhou Medical University. All included research objects had signed informed consent forms.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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