

Application Effect of Enhanced External Counterpulsation in Patients with Chronic Heart Failure Comorbid with Type 2 Diabetes Mellitus

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Abstract: *Objective:* To analyze the effects of enhanced external counterpulsation on cardiac function, blood glucose, and exercise tolerance in patients with chronic heart failure comorbid with type 2 diabetes mellitus, and to evaluate the application efficacy of this therapy in this population. *Methods:* From August 2025 to October 2026, patients with chronic heart failure and diabetes admitted to our hospital were enrolled and randomly divided into a control group ($n = 75$) and an observation group ($n = 75$) using a random number table method. The control group received standard medication and routine health education, while the observation group received additional external counterpulsation therapy, 30 minutes per session, twice daily, 6 hours per week, for a total of 6 weeks, accumulating one course of counterpulsation with a total duration of 36 hours. *Results:* In terms of cardiac function indicators, after one course of treatment and at 3 months, the observation group showed higher left ventricular ejection fraction (LVEF) and lower left ventricular enddiastolic diameter (LVEDD) and Nterminal proBtype natriuretic peptide (NTproBNP) compared with the control group ($P < 0.05$). For exercise tolerance, the 6minute walk test (6MWT) distance, anaerobic threshold (AT), and maximal metabolic equivalent (METs) were all higher in the observation group than in the control group ($P < 0.05$). Regarding glycemic control, fasting plasma glucose (FPG), 2hour postprandial glucose (2hPG), and glycated hemoglobin (HbA1c) were all lower in the observation group ($P < 0.05$). *Conclusion:* External counterpulsation therapy in patients with chronic heart failure and type 2 diabetes mellitus can improve cardiac function, enhance exercise tolerance, and ameliorate glycemic levels, representing a nonpharmacological treatment modality worthy of broader clinical promotion.

Keywords: Chronic heart failure; Type 2 diabetes mellitus; Enhanced external counterpulsation

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1. Introduction

Chronic heart failure (CHF) is a complex clinical syndrome resulting from abnormal changes in cardiac

structure and/or function due to various causes, leading to impaired ventricular systolic and/or diastolic function, and represents the terminal stage of all cardiac diseases ^[1-2]. Diabetes mellitus (DM) is a chronic metabolic disorder characterized by impaired glucose homeostasis, among which type 2 diabetes mellitus (T2DM) is the most common type in the Chinese population, accounting for more than 90% of diabetic patients in China ^[3]. Numerous studies have shown that the prevalence of diabetes is higher in CHF patients than in the general population, and CHF significantly affects the prognosis of diabetic patients. Compared with T2DM patients without CHF, those with comorbid CHF present with more pronounced clinical symptoms and signs, worse New York Heart Association (NYHA) functional class, poorer quality of life, and worse prognosis ^[4-6]. This highly intertwined coexistence significantly increases hospitalization rates, mortality, and healthcare burden, necessitating multidisciplinary collaboration, early screening, and comprehensive management to improve clinical outcomes ^[7-8]. How to reduce mortality and improve long-term quality of life in patients with CHF and comorbid diabetes through effective therapeutic strategies has become a clinical focus and hotspot. This study aimed to observe the changes in cardiac function, blood glucose, and exercise tolerance in patients with CHF and T2DM after treatment with enhanced external counterpulsation (EECP), to analyze the efficacy of EECP in this population, and to provide a new non-pharmacological intervention option for the treatment of patients with CHF and T2DM, thereby expanding traditional therapy toward a more diversified approach.

2. Materials and methods

2.1. General information

2.1.1. Study participants

This study was approved by the Ethics Committee of our hospital, and all patients provided signed informed consent. A total of 150 patients with chronic heart failure and comorbid diabetes mellitus admitted to the Department of Cardiology of Lvliang People's Hospital from August 2025 to October 2026 were enrolled. Patients were randomly divided into a control group ($n = 75$) and an observation group ($n = 75$) using a random number table method. General clinical data of both groups, including sex, age, body mass index, and smoking history, were recorded and analyzed. There were no significant differences in baseline characteristics between the two groups ($P > 0.05$), as shown in **Table 1**.

Inclusion criteria: met the diagnostic criteria for CHF and T2DM according to the 2024 Chinese Guidelines for the Diagnosis and Treatment of Heart Failure and the Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes; NYHA functional class II–III; age between 40 and 65 years, regardless of sex; hemodynamically stable; normal audiovisual function; and able to complete outofhospital followup via telephone or WeChat. Exclusion criteria: significant hemodynamic fluctuations; severe heart failure in the acute phase or acute exacerbation; complicated by severe arrhythmias or uncontrolled hypertension; aortic aneurysm; mean pulmonary artery pressure (mPAP) > 50 mmHg; recent use of anticoagulants; congenital heart disease; deep vein thrombosis (DVT) or presence of infectious foci in the lower extremities; lower limb deformities; pregnancy; refusal to participate or inability to cooperate. Termination/withdrawal criteria: occurrence of serious cardiovascular adverse events during counterpulsation therapy; judged by the investigator as needing termination; voluntary withdrawal by the participant; loss to followup or inability to complete the required counterpulsation treatment.

Table 1. Baseline characteristics analysis

Group	n	Gender (%)		Age (years)		BMI (kg/m ²)		Smoking history (%)	
		Male	Female	Range	Mean	Range	Mean	Yes	No
Control group	75	44 (58.67)	31 (41.33)	4165	60.61 ± 7.51	18.837.7	26.48 ± 2.11	38 (50.67)	37 (49.33)
Observation group	75	46 (61.33)	29 (38.67)	4065	60.72 ± 7.62	18.637.9	26.51 ± 2.19	36 (48.00)	39 (52.00)
χ^2/t value	–	0.1111		0.0890		0.0854		0.1067	
<i>P</i> value	–	0.7389		0.9292		0.9320		0.7439	

2.2. Methods

Both groups received conventional pharmacotherapy recommended by clinical guidelines, including SGLT2 inhibitors (dapagliflozin), ACEI, betablockers, mineralocorticoid receptor antagonists (spironolactone), cardiostimulant agents, metformin, and other medications.

Educational booklets on heart failure and glycemic management were developed and distributed free of charge to enrolled patients. The main content included guidance on calculating fluid intake and output, recognizing and managing symptoms, monitoring blood glucose, regulating BMI, daily exercise and dietary recommendations, and rational medication use. Disease-related knowledge was disseminated through patient education lectures, popular science videos, WeChat group communications, and online conferences. Regular telephone followups were conducted to minimize patient attrition.

The observation group additionally received enhanced external counterpulsation (EECP) using a PECP/TI device (Chongqing Pusikang Technology Development Co., Ltd.). The treatment protocol consisted of 30 minutes per session, twice daily, 6 hours per week, for a total of 6 weeks, completing one full course of counterpulsation with a cumulative duration of 36 hours. The procedure was as follows:

- (1) ECG leads were attached and secured.
- (2) The device was calibrated, the ECG input function was activated, and changes in ECG and exhaust waveforms were monitored on the display screen.
- (3) Pneumatic cuffs were wrapped around the calves, thighs, and buttocks.
- (4) The counterpulsation pump was activated, and the counterpulsation pressure was set at 0.025–0.035 Pa, gradually increased from low to high. During the procedure, patients' treatment responses were closely monitored, with continuous surveillance of blood pressure, ECG, and other parameters, while pressure and timing settings were adjusted as needed. Adverse reactions such as dizziness and lowerlimb soreness were observed throughout the EECP sessions.

2.3. Observation indicators

Cardiac function, exercise tolerance, and glycemic parameters were compared between the two groups before treatment, after one course of treatment, and at 3 months posttreatment.

- (1) Cardiac function indicators: left ventricular ejection fraction (LVEF), left ventricular enddiastolic diameter (LVEDD), and Nterminal proBtype natriuretic peptide (NTproBNP).
- (2) Exercise tolerance indicators: 6minute walk test (6MWT) distance, anaerobic threshold (AT), and maximal metabolic equivalent (METs).
- (3) Glycemic indicators: fasting plasma glucose (FPG), 2hour postprandial plasma glucose (2hPG), and

glycated hemoglobin (HbA1c).

2.4. Statistical analysis

Data were processed using SPSS version 25.0. Continuous variables are expressed as mean $\pm$ standard deviation (SD) and were compared using the *t* test. Categorical variables are presented as frequencies (percentages) and were analyzed using the chisquare test. A *P* value of < 0.05 was considered statistically significant.

3. Results

3.1. Cardiac function

At the time points of one treatment course and 3 months posttreatment, the observation group demonstrated superior cardiac function indicators compared to the control group ($P < 0.05$). See **Table 2**.

Table 2. Cardiac function indicators (mean $\pm$ SD)

Group	LVEF (%)			LVEDD (mm)			NTProBNP (pg/ml)		
	Before treatment	After 1 course	After 3 months	Before treatment	After 1 course	After 3 months	Before treatment	After 1 course	After 3 months
Control group (n=75)	46.19 $\pm$ 5.38	47.35 $\pm$ 5.71	48.92 $\pm$ 5.75	57.95 $\pm$ 5.15	57.41 $\pm$ 5.24	56.01 $\pm$ 5.33	1989.52 $\pm$ 22.42	1846.22 $\pm$ 19.36	1815.44 $\pm$ 16.51
Observation group (n=75)	46.22 $\pm$ 5.42	51.31 $\pm$ 5.84	53.46 $\pm$ 5.96	57.96 $\pm$ 5.17	55.03 $\pm$ 5.06	53.79 $\pm$ 4.98	1989.61 $\pm$ 22.38	1460.88 $\pm$ 15.47	1204.51 $\pm$ 13.28
<i>t</i>	0.0340	4.1989	4.7476	0.0119	2.8296	2.6357	0.0246	134.6618	249.7058
<i>P</i>	0.9729	<0.01	<0.01	0.9905	<0.01	<0.01	0.9804	<0.01	<0.01

3.2. Exercise endurance

At the time points of one treatment course and three months, the observation group showed higher exercise endurance indicators than the control group ($P < 0.05$). As shown in **Table 3**.

Table 3. Exercise endurance indicators (mean $\pm$ SD)

Group	6MWT (m)			AT (mL/kg·min)			METS		
	Before treatment	1 course	3 months	Before treatment	1 course	3 months	Before treatment	1 course	3 months
Control group (n=75)	331.88 $\pm$ 8.25	342.51 $\pm$ 10.15	348.21 $\pm$ 14.25	9.49 $\pm$ 0.89	9.91 $\pm$ 1.02	9.86 $\pm$ 1.41	4.75 $\pm$ 0.68	4.83 $\pm$ 0.81	4.91 $\pm$ 0.96
Observation group (n=75)	331.92 $\pm$ 8.33	377.68 $\pm$ 11.85	402.69 $\pm$ 15.16	9.47 $\pm$ 0.91	10.88 $\pm$ 1.25	11.38 $\pm$ 1.62	4.79 $\pm$ 0.71	5.42 $\pm$ 0.96	5.97 $\pm$ 0.99
<i>t</i>	0.0295	19.5210	22.6767	0.1361	5.2068	6.1292	0.3524	4.0679	6.6568
<i>P</i>	0.9765	<0.01	<0.01	0.8919	<0.01	<0.01	0.7251	<0.01	<0.01

3.3. Blood glucose

At time points including after one course of treatment and at 3 months, blood glucose levels in the observation group were lower than those in the control group ($P < 0.05$), as shown in **Table 4**.

Table 4. Blood glucose indicators (mean $\pm$ SD).

Group	FPG (mmol/L)			2hPG (mmol/L)			HbA1c (%)		
	Before treatment	1 course	3 months	Before treatment	1 course	3 months	Before treatment	1 course	3 months
Control group (n=75)	8.48 $\pm$ 0.68	7.96 $\pm$ 0.58	7.81 $\pm$ 0.53	11.39 $\pm$ 1.02	10.48 $\pm$ 0.89	10.05 $\pm$ 0.81	7.85 $\pm$ 0.76	7.49 $\pm$ 0.53	7.29 $\pm$ 0.49
Observation group (n=75)	8.51 $\pm$ 0.71	7.06 $\pm$ 0.55	6.22 $\pm$ 0.47	11.37 $\pm$ 1.08	9.26 $\pm$ 0.73	8.39 $\pm$ 0.66	7.82 $\pm$ 0.78	7.08 $\pm$ 0.48	6.78 $\pm$ 0.35
<i>t</i>	0.2643	9.7512	19.4385	0.1166	9.1787	13.7590	0.2386	4.9657	7.3348
<i>P</i>	0.7919	<0.01	<0.01	0.9073	<0.01	<0.01	0.8118	<0.01	<0.01

4. Discussion

Chronic heart failure (CHF) represents the terminal stage of cardiovascular disease and ranks as the second most common cardiovascular complication in diabetes mellitus. In patients with CHF, excessive activation of the reninangiotensinaldosterone system and reduced activity of the natriuretic peptide system can both impair insulin secretion. As cardiac function deteriorates, physical activity limitation and cachexia in CHF patients lead to reduced muscle mass, which further exacerbates insulin resistance. Diabetes mellitus is an independent risk factor for heart failure; approximately 25% of patients with chronic heart failure have coexisting type 2 diabetes mellitus (T2DM), and over 40% of T2DM patients are repeatedly hospitalized due to worsening heart failure. Moreover, T2DM also increases the risk of heart failure-related complications, including death^[911]. In addition, T2DM can accelerate the progression of heart failure through multiple mechanisms (e.g., myocardial metabolic disorders, microangiopathy, chronic inflammation, etc.). The two conditions mutually reinforce each other, forming a vicious cycle. Compared with patients with CHF alone or T2DM alone, the comorbid state significantly increases the risk of major adverse cardiovascular events and elevates hospital readmission rates. Furthermore, in patients with both conditions, longterm and large fluctuations in blood glucose levels, along with persistently impaired mitochondrial function in cardiomyocytes and suppressed myocardial energy metabolism, lead to progressive deterioration of systolic and diastolic function. The circulatory disturbances resulting from worsening CHF further interfere with systemic glucolipid metabolism, widening glycemic fluctuations and consequently compromising the therapeutic effects of both antiheartfailure and hypoglycemic treatments, thereby increasing the clinical complexity of management.

Enhanced external counterpulsation (EECP) is a noninvasive external assisted circulatory device that has demonstrated therapeutic efficacy in conditions such as angina pectoris and ischemic heart failure. By sequentially compressing the calves, thighs, and buttocks, EECP increases diastolic blood perfusion to the heart and other vital organs, augments coronary blood flow, and improves myocardial oxygen supply; it also reduces cardiac afterload, increases cardiac output, and improves cardiac function^[12]. In effect, EECP mimics the hemodynamic changes induced by intraaortic balloon counterpulsation. Beyond the immediate hemodynamic effects mentioned above, EECP promotes the opening of collateral circulation and ameliorates myocardial ischemia and hypoxia; it also modulates systemic shear stress, promotes the release of nitric oxide (NO), increases NO bioavailability, and maintains normal vascular endothelial function^[13]. Compared with invasive circulatory assist techniques, EECP offers advantages of high safety and minimal invasiveness, making it suitable for repeated application in the treatment of CHF patients. This aligns well

with the longterm rehabilitation needs of CHF patients with coexisting T2DM, while avoiding the risks of infection, vascular injury, and other complications associated with invasive procedures. At the same time, EECF provides sustained hemodynamic modulation, which is conducive to improving peripheral tissue microcirculatory perfusion and enhancing insulin sensitivity, thereby breaking the vicious cycle in which heart failure and diabetes mutually exacerbate each other. This offers a novel therapeutic avenue for the comprehensive management of patients with comorbid conditions.

5. Conclusion

In summary, external counterpulsation therapy represents a safe, stable, and efficacious treatment option for patients with CHF and coexisting T2DM. It can improve cardiac function, enhance exercise tolerance, and ameliorate glycemic control, and thus merits wider adoption as a nonpharmacological therapeutic modality.

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Disclosure statement

The authors declare no conflict of interest.

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