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Original Article

Therapeutic efficacy of combined esmolol and carvedilol treatment for myocardial ischemia in patients with coronary heart disease

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Abstract: Objective: To evaluate the effects of esmolol plus carvedilol in treating myocardial ischemia in coronary heart disease (CHD), with a focus on blood pressure (BP), heart rate (HR), and safety. Methods: A total of 120 patients with CHD-related myocardial ischemia admitted to our hospital between January 2022 and January 2023 were enrolled. Among them, 60 patients were treated with carvedilol monotherapy (control group), and the other 60 cases received esmolol in combination with carvedilol (research group). Therapeutic efficacy, BP, HR, premature beat counts, dynamic electrocardiogram parameters (duration and frequency of ST-segment depression), cardiac function indicators (left ventricular end-diastolic dimension [LVEDD], left ventricular posterior wall thickness [LVPWT], left ventricular septal thickness [LVST], left ventricular ejection fraction [LVEF]), and biochemical indicators (N-terminal pro-B-type natriuretic peptide [NT-proBNP], superoxide dismutase [SOD]) were assessed. Safety profiles, including nausea and vomiting, hypotension, and drowsiness, were recorded. Furthermore, factors influencing therapeutic efficacy were analyzed. Results: Compared with the control group, patients in the research group exhibited significantly lower BP (systolic: (105.27±7.72) mmHg vs. (113.78±11.46) mmHg; diastolic: (64.98±4.81) mmHg vs. (71.35±7.76) mmHg and HR (67.90±5.63) bpm vs. (85.67±7.35) bpm). In addition, post-treatment premature beat counts (premature ventricular contraction count: (71.15±26.02) times/24 h vs. (253.67±78.62) times/24 h; premature atrial contraction count: (105.35±41.38) times/24 h vs. (279.53±59.30) times/24 h; junctional premature contraction count: (73.85±30.65) times/24 h vs. (153.58±40.07) times/24 h) were notably reduced in the research group. The duration ((22.90±3.43) min vs. (54.50±4.34) min) and frequency ((7.25±1.97) times vs. (12.47±3.33) times), of ST-segment depression were significantly decreased in the research group. Moreover, LVEDD ((42.05±4.21) mm vs. (46.48±3.98) mm), LVPWT ((9.23±2.25) mm vs. (11.18±2.59) mm), LVST ((8.72±2.48) mm vs. (10.30±2.71) mm), and NT-proBNP ((310.63±32.83) pg/mL vs. (403.87±40.51) pg/mL) were significantly reduced in the research group, whereas LVEF ((59.63±6.77)% vs. (53.73±5.04)%) and SOD ((112.72±10.12) U/mL vs. (90.60±9.85) U/mL) were significantly increased. The overall incidence of adverse events was lower in the research group. Multivariate analysis identified HR (OR=4.592, 95% CI: 1.289-16.366, P=0.019), LVEF (OR=0.290, 95% CI: 0.086-0.976, P=0.046), and NT-proBNP (OR=3.729, 95% CI: 1.124-12.371, P=0.031) as independent factors influencing therapeutic efficacy. Conclusions: Esmolol combined with carvedilol demonstrates superior efficacy and safety compared with carvedilol monotherapy in patients with myocardial ischemia secondary to CHD.

Keywords: Esmolol, carvedilol, myocardial ischemia of coronary heart disease, blood pressure, heart rate, safety

Introduction

Myocardial ischemia (MI) is a common pathological state that is particularly prevalent in patients with coronary heart disease (CHD). It is primarily caused by insufficient coronary blood flow due to the narrowing of coronary arteries, resulting in an imbalance between myocardial oxygen supply and demand [1, 2]. Although many patients with CHD-related MI may remain asymptomatic in daily life, this does not make MI a benign condition [3]. On the contrary, MI is a progressive and insidious process that can gradually impair the myocardium. Without timely and effective intervention, this damage may ultimately lead to severe consequences [4]. For example, MI may precipitate acute myocardial infarction or even sudden cardiac death, which

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usually occurs abruptly and is associated with a poor prognosis [5]. Therefore, early identification and appropriate treatment of MI are crucial for preventing disease deterioration in CHD patients [1]. In the early stages, treatment strategies for MI primarily focus on alleviating symptoms [6]. However, with advances in clinical research, consensus has been made that greater emphasis should be placed on reducing ischemic burden and improving underlying myocardial perfusion [7]. Accordingly, reducing the total ischemic load has become a key therapeutic goal, which can effectively lower mortality and improve overall treatment outcomes [8].

Carvedilol is widely used in the clinical treatment of MI due to its multiple pharmacological properties [9]. Carvedilol exerts vasodilatory effects that reduce cardiac burden and improve myocardial perfusion [10]. In addition, it can modulate calcium influx in cardiomyocytes, thereby decreasing myocardial excitability and contractility, which in turn reduces myocardial oxygen consumption [11]. Through these mechanisms, carvedilol can alleviate ischemia-related symptoms, such as angina pectoris, to a certain extent, contributing to enhanced quality of life and reduced complications [12, 13]. However, despite these benefits, carvedilol monotherapy may have a relatively slow onset of action, and its long-term use may be associated with certain adverse effects [14]. Consequently, combination therapy has been increasingly considered to enhance therapeutic efficacy in MI [15]. For instance, in a rat model of MI-induced heart failure, carvedilol combined with photo-biomodulation therapy significantly attenuated myocardial inflammation and oxidative stress, inhibited myocardial hypertrophy, and improved left ventricular function [16].

Esmolol, a selective β_1-adrenergic receptor blocker, is characterized by its rapid onset and short half-life. It can quickly reduce myocardial contractility and heart rate, thereby restoring the balance between myocardial oxygen supply and demand. Furthermore, its rapid metabolism contributes to a favorable safety profile [18]. Previous studies have demonstrated that esmolol provides effective myocardial protection under ischemic conditions. For example, oxygenated esmolol cardioplegia has demonstrated improved myocardial protection during prolonged normothermic ischemia in animal models [19]. In addition, esmolol has been widely used for rapid ventricular rate control in patients with atrial fibrillation due to its fast onset of action, while other β-blockers such as atenolol, metoprolol, or carvedilol are often employed for long-term management [17]. These findings suggest that esmolol may offer complementary advantages when combined with carvedilol.

This study aimed to evaluate the effects of esmolol combined with carvedilol in treating myocardial ischemia in CHD, with a focus on blood pressure (BP), heart rate (HR), and safety.

Materials and methods

Patient selection

This retrospective study included 120 patients with MI secondary to CHD who were treated at the Department of Cardiology, Beijing Luhe Hospital, Capital Medical University, between January 2022 and January 2023. Among them, 60 patients received carvedilol monotherapy (control group), while the other 60 patients received esmolol combined with carvedilol (research group). This study was approved by the Ethics Committee of Beijing Luhe Hospital, Capital Medical University. The patient screening process is illustrated in **Figure 1**.

Inclusion criteria: clinically confirmed diagnosis of CHD with MI; age between 18 and 80 years; first-time treatment for the condition; no use of β-blockers (including esmolol, carvedilol, or other β-blockers) within 3 months before treatment initiation; no known hypersensitivity to the study medications; normal hepatic and renal function (alanine transaminase [ALT] and aspartate aminotransferase [AST] <2 times the upper limit of normal value; serum creatinine (Cr) <133 μmol/L, or estimated glomerular filtration rate (eGFR) ≥60 mL/min/1.73 m^2); and complete medical data.

Exclusion criteria: hemodynamic instability or severe arrhythmia; acute myocardial infarction or unstable angina within the past month; percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) within the

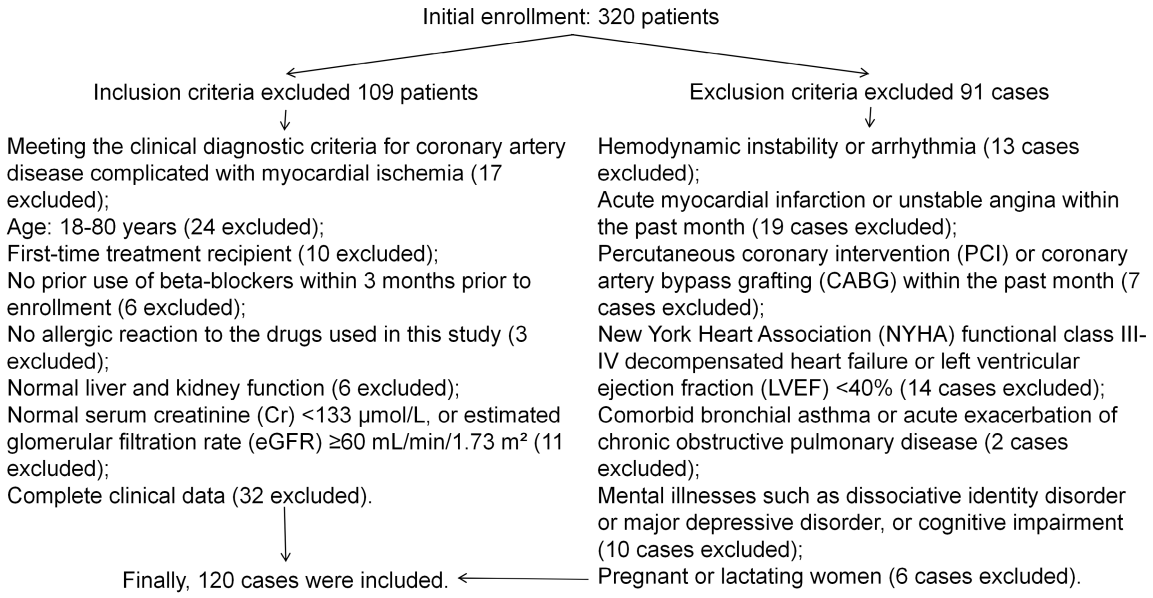

Figure 1. Study flowchart.

past month; decompensated heart failure (New York Heart Association [NYHA] class III-IV, or left ventricular (LV) ejection fraction (LVEF) <40%; acute exacerbations of bronchial asthma or chronic obstructive pulmonary disease; mental illness (e.g., schizophrenia and severe depression) or cognitive dysfunction; or pregnancy or lactation.

Treatment methods

Patients in the control group received carvedilol tablets (Fu'an Pharmaceutical Group Ningbo Tianheng Pharmaceutical Co., Ltd.; approval number: H20052428) at a dose of 10 mg once daily for 8 weeks.

Patients in the research group was treated with esmolol in addition to carvedilol. Esmolol hydrochloride injection (Qilu Pharmaceutical Co., Ltd.; approval number: H19991059) was administered intravenously at a loading dose of 0.5 mg/(kg•min) over 1 minute, followed by a continuous infusion at 0.05 mg/kg/min for 4 minutes, with the aim of maintaining HR within 60-80 beats per minute. Typically, the entire infusion was completed in less than 10 minutes. Patients were closely monitored during administration. Subsequently, carvedilol was initiated at the same dosage and regimen as in the control group. The total treatment duration was 8 weeks.

Treatment allocation was based on patient preference after full disclosure of the advantages and disadvantages of each regimen.

Data extraction

Clinical data were retrieved from the hospital's medical record system. The following parameters were collected for comparative analysis: therapeutic efficacy, BP (systolic/diastolic BP), HR, premature beat counts, ambulatory electrocardiographic parameters (duration and frequency of ST-segment depression), cardiac function indices (left ventricular end-diastolic dimension [LVEDD], left ventricular posterior wall thickness [LVPWT], left ventricular septal thickness [LVST], and LVEF), biochemical markers (N-terminal pro-B-type natriuretic peptide [NT-proBNP], and superoxide dismutase [SOD]), and safety outcomes (nausea and vomiting, hypotension, and somnolence).

Outcome measures

Therapeutic efficacy: Therapeutic efficacy was evaluated after 8 weeks of treatment. Cure: complete normalization of ST-segment changes on electrocardiography (ECG), complete resolution of clinical symptoms, and normalization of HR and BP; Marked effectiveness: near normalization of ST-segment changes, complete resolution of clinical symptoms, and a sig-

nificant reduction in HR and BP with a trend toward normalization; Effectiveness: ≥50% improvement in ST-segment depression, with obvious improvement in clinical symptoms and partial reduction in HR and BP; Ineffectiveness: failure to meet any of the above criteria. Total effectiveness rate = (cured cases + marked effectiveness cases + effective cases)/total number of cases * 100%.

BP and HR: BP (systolic and diastolic) and HR were recorded before treatment initiation and after 8 weeks of intervention.

ECG parameters: The duration and frequency of ST-segment depression were recorded using ambulatory ECG (a01; Shanghai Jumu Medical Equipment Co., Ltd.) before treatment and after 8 weeks of treatment.

Premature beat counts: Premature ventricular contraction (PVC), premature atrial contraction (PAC), and junctional premature beat (JPB) were recorded using ambulatory ECG before and after 8 weeks of treatment.

Cardiac function indices: LVEDD, LVPWT, LVST, and LVEF were measured using color Doppler echocardiography (Philips EPIQ5, Beijing AMY Technology Development Co., Ltd.) at baseline and after 8 weeks of treatment.

Biochemical markers: NT-proBNP and SOD levels were measured at baseline and after 8 weeks of treatment using an automated blood biochemistry analyzer (Shanghai Yuyan Instruments Co., Ltd.).

Safety profile: The incidence of adverse events, including nausea and vomiting, hypotension, and drowsiness, was evaluated throughout the 8-week treatment period.

The primary endpoints were therapeutic effectiveness, BP, HR, premature beats, and safety. EGC parameters, cardiac function indices, and biochemical markers were used throughout as secondary measures.

Statistical analysis

All data analyses were conducted using SPSS 22.0 software. Measurement data were expressed as mean ± standard deviation (SD) or median (interquartile range) [M (Q1, Q3)], as appropriate. Inter-group comparisons were performed using independent samples t-test (parametric data with normal distribution) or the Mann-Whitney U test (non-parametric data). Intra-group comparisons before and after treatment were performed using the paired t-test or the Wilcoxon signed-rank test. Categorical variables were expressed as counts/percentages and were compared using the chi-square (χ^2) tests. Univariate and multivariate binary Logistic regression analyses were performed to identify independent factors associated with therapeutic efficacy. A two-tailed $P<0.05$ was considered statistically significant.

Results

Baseline data

No significant differences were observed between the two groups in terms of age, disease course, body weight, sex distribution, or comorbidities (all $P>0.05$; **Table 1**), indicating good baseline comparability.

Therapeutic efficacy

As shown in **Table 2**, the research group demonstrated a significantly higher effectiveness rate compared with the control group (90% vs. 75%; $P<0.05$).

BP and HR

Baseline systolic/diastolic BP and HR were comparable between the two groups ($P>0.05$). After treatment, both groups demonstrated significant reductions in BP and HR (all $P<0.001$). Moreover, the reductions in systolic and diastolic BP, and HR were significantly greater in the research group compared with the control group ($P<0.05$; **Table 3**).

Premature beat counts

There were no significant differences in baseline PVC, PAC, and JPB between the two groups ($P>0.05$). After treatment, all parameters were significantly reduced in both groups, with more pronounced reductions in the research group (all $P<0.05$; **Table 4**).

Electrocardiographic indicators

No remarkable between-group differences were observed in the duration or frequency of ST-segment depression before treatment (P>

Table 1. Comparison of baseline data between the two groups

	Research group (n=60)	Control group (n=60)	χ^2/Z	P
Age (year)	67.00 (60.25, 74.00)	69.50 (59.00, 75.00)	-0.654	0.513
Course of disease (year)	3.00 (2.00, 4.00)	3.00 (2.00, 4.00)	-0.625	0.532
Weight (kg)	63.00 (55.00, 72.75)	62.50 (51.25, 71.00)	-0.454	0.650
Sex			0.341	0.906
Male	19 (31.67)	24 (40.00)		
Female	41 (68.33)	36 (60.00)		
Complicated with other diseases			0.677	0.984
Combined diabetes	10 (16.67)	12 (20.00)		
Hyperlipidemia	8 (13.33)	6 (10.00)		
Hypertension	8 (13.33)	7 (11.67)		
Ischemic cardiomyopathy	15 (25.00)	16 (26.67)		
Heart failure	7 (11.67)	8 (13.33)		
Chronic cardiac insufficiency	12 (20.00)	11 (18.33)		

Table 2. Comparison of treatment efficacy between the two groups

	Research group (n=60)	Control group (n=60)	χ^2	P
Cure	16 (26.67)	12 (20.00)		
Marked effectiveness	18 (30.00)	15 (25.00)		
Effectiveness	20 (33.33)	18 (30.00)		
Ineffectiveness	6 (10.00)	15 (25.00)		
Overall effectiveness rate	54 (90.00)	45 (75.00)	4.675	0.031

Table 3. Comparison of blood pressure and heart rate between the two groups

		Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)		Heart rate (beats/min)	
		Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Research group	60	157.83±11.73	105.27±7.72	95.88±6.38	64.98±4.81	97.48±8.46	67.90±5.63
Control group	60	159.55±11.66	113.78±11.46	95.47±7.13	71.35±7.76	97.32±7.40	85.67±7.35
t	-	0.806	4.771	0.332	5.404	0.110	14.867
P	-	0.422	<0.001	0.741	<0.001	0.912	<0.001

0.05). After treatment, both the duration and frequency of ST-segment depression were significantly reduced in each group, with greater improvements in the research group compared to the control group (all P<0.05; **Figure 2**).

Cardiac function indices

Baseline levels of LVEDD, LVPWT, LVST and LVEF were comparable between the two groups (all P>0.05). After treatment, LVEDD, LVPWT, and LVST were significantly decreased in both groups, while LVEF significantly increased (all P<0.05). Notably, the combination group showed significantly greater improvements in these cardiac function parameters compared with the control group (all P<0.05; **Figure 3**).

Biochemical markers

No obvious differences were observed between the two groups in terms of NT-proBNP and SOD levels at baseline (all P>0.05). After treatment, NT-proBNP levels decreased significantly, whereas SOD levels increased in both groups (all P<0.05). Compared with the control group, the combination group exhibited significantly lower NT-proBNP levels and higher SOD levels (both P<0.05; **Figure 4**).

Table 4. Comparison of premature beat counts between the two groups

	Research group (n=60)	Control group (n=60)	t	P
Premature ventricular contraction count				
Pre-treatment	456.75±67.17	445.52±72.12	0.883	0.379
Post-treatment	71.15±26.02***	253.67±78.62**	17.072	<0.001
t	41.465	13.929		
P	<0.001	<0.001		
Premature atrial contraction count				
Pre-treatment	516.27±92.26	507.18±49.26	0.673	0.502
Post-treatment	105.35±41.38***	279.53±59.30**	18.658	<0.001
t	31.479	22.874	t	31.479
P	<0.001	<0.001	P	<0.001
Junctional premature contraction count				
Pre-treatment	195.65±48.59	185.10±47.71	1.200	0.233
Post-treatment	73.85±30.65***	153.58±40.07**	12.242	<0.001
t	16.423	3.919		
P	<0.001	<0.001		

Note: ***P<0.001, **P<0.01 vs. the pre-treatment value.

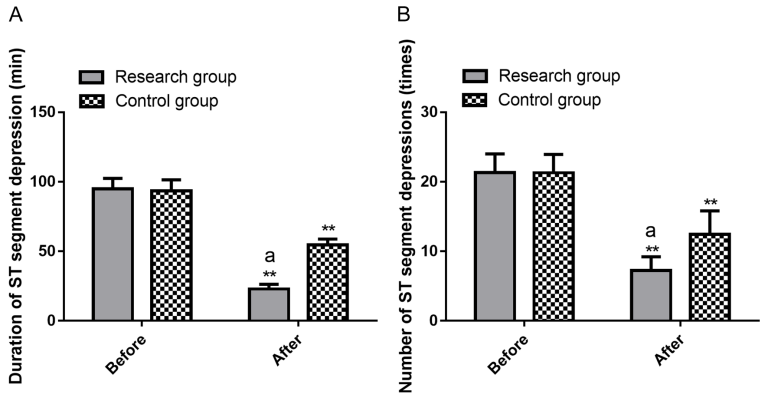

Figure 2. Comparison of duration (A) and frequency (B) of ST-segment depression between the two groups before and after treatment. Note: **P<0.01 vs. pre-treatment; [a]P<0.05 vs. control group.

Safety profile

The overall incidence of adverse events, primarily nausea and vomiting, hypotension, and drowsiness, was 3.33% in the research group, significantly lower than 18.33% in the control group (P<0.05; **Table 5**).

Factors associated with therapeutic efficacy

Univariate analysis revealed that age, diabetes, HR, LVEDD, NT-proBNP, and medication regimen were strongly associated with therapeutic efficacy (all P<0.05), whereas other variables showed no significant associations (**Table 6**).

Further multivariate logistic regression analysis identified HR (OR=4.592, 95% CI: 1.289-16.366, P=0.019), LVEF (OR=0.290, 95% CI: 0.086-0.976, P=0.046), and NT-proBNP (OR=3.729, 95% CI: 1.124-12.371, P=0.031) as independent factors associated with therapeutic efficacy (all P<0.05).

Specifically, patients with HR ≥97 beats/min had a 4.592-fold higher risk of ineffective treatment compared with those with HR <97 beats/min; patients with LVEF ≥47% had a significantly lower risk of treatment failure (OR=0.290) compared with patients with LVEF <47%; NT-proBNP ≥486 pg/mL was associated with a 3.729-fold elevated risk of treatment failure compared to NT-proBNP <486 pg/mL (**Table 7**).

Discussion

Coronary heart disease (CHD) is a common cardiovascular disease, particularly among middle-aged and elderly populations. It is primarily caused by coronary atherosclerosis and stenosis [20]. In many patients, the initial symptoms are subtle or nonspecific and may overlap with

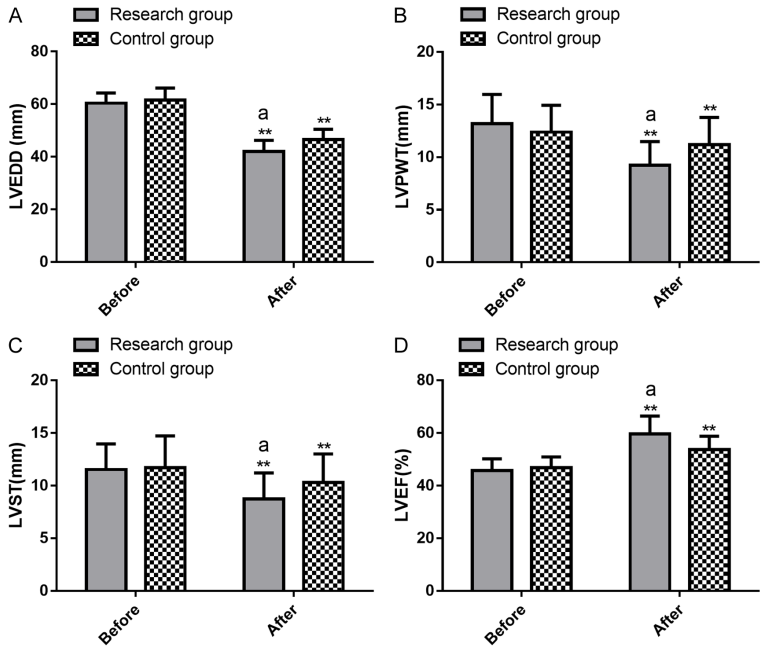

Figure 3. Comparison of cardiac function indices between the two groups before and after treatment. A: LVEDD; B: LVPWT; C: LVST; D: LVEF. Note: **P<0.01 vs. pre-treatment; aP<0.05 vs. control group. LVEDD, left ventricular end-diastolic dimension; LVPWT, left ventricular posterior wall thickness; LVST, left ventricular septal thickness; LVEF, left ventricular ejection fraction.

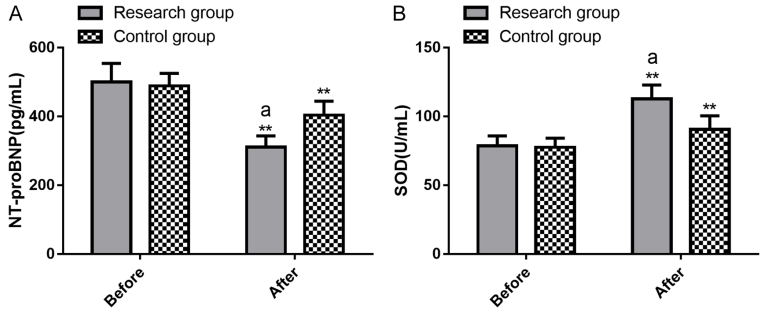

Figure 4. Comparison of biochemical markers between the two groups before and after treatment. A: NT-proBNP; B: SOD. Note: **P<0.01 vs. pre-treatment; aP<0.05 vs. control group. NT-proBNP, N-terminal pro-B-type natriuretic peptide; SOD, superoxide dismutase.

Table 5. Comparison of safety profile between the two groups

	Research group (n=60)	Control group (n=60)	X^2	P
Nausea and vomiting	1 (1.67)	2 (3.33)		
Hypotension	0 (0.00)	4 (6.67)		
Drowsiness	1 (1.67)	5 (8.33)		
Total	2 (3.33)	11 (18.33)	6.988	0.001

other clinical presentations, making timely detection challenging [21]. In the event of disease progression, patients may experience severe complications, such as acute myocardial infarction, heart failure, and even sudden cardiac death [22]. Hence, early prevention, timely diagnosis, and effective management of CHD is crucial. Preventive strategies include lifestyle modification, regular medical screening, and optimized pharmacological intervention in patients diagnosed with CHD [23].

Carvedilol has shown remarkable efficacy in the treatment of MI, primarily through reducing myocardial oxygen consumption by decreasing HR, myocardial contractility, and total peripheral vascular resistance, thereby relieving MI symptoms and improving patient outcomes [24]. Esmolol, another β-blocker, is characterized by fast onset of action and short half-life, allowing flexible personalized dose adjustment with a favorable safety profile [25]. Previous studies have shown that esmolol effectively reduces HR and BP in MI patients, thereby reducing the rate-pressure product and myocardial oxygen demand [26]. In addition to β-blockade, other pharmacological agents, such as propofol, have been demonstrated to exert cardioprotective effect through distinct intracellular signaling pathways [27]. These findings suggest that myocardial protection may involve multiple molecular mechanisms, and the beneficial effects observed with esmolol-carvedilol combination may extend beyond simple hemodynamic modulation.

In this study, we observed that systolic BP, diastolic BP, and HR were significantly lower in the

Table 6. Univariate analysis of factors associated with treatment efficacy

Indicators	Ineffective group (n=21)	Effective group (n=99)	X^2	P
Age (years)			6.549	0.011
<68 (n=59)	5 (23.81)	54 (54.55)		
≥68 (n=61)	16 (76.19)	45 (45.45)		
Disease course (years)			0.220	0.639
<3 (n=46)	9 (42.86)	37 (37.37)		
≥3 (n=74)	12 (57.14)	62 (62.63)		
Weight (kg)			0.691	0.406
<63 (n=78)	12 (57.14)	66 (66.67)		
≥63 (n=42)	9 (42.86)	33 (33.33)		
Sex			1.538	0.215
Male (n=43)	10 (47.62)	33 (33.33)		
Female (n=77)	11 (52.38)	66 (66.67)		
Comorbid diabetes (n=53)	14 (66.67)	39 (39.39)	5.226	0.022
Comorbid hyperlipidaemia (n=40)	8 (38.10)	32 (32.32)	0.260	0.610
Comorbid hypertension (n=27)	6 (28.57)	21 (21.21)	0.538	0.463
Systolic blood pressure (mmHg)			0.903	0.342
<159 (n=57)	8 (38.10)	49 (49.49)		
≥159 (n=63)	13 (61.90)	50 (50.51)		
Diastolic blood pressure (mmHg)			0.047	0.828
<95 (n=54)	9 (42.86)	45 (45.45)		
≥95 (n=66)	12 (57.14)	54 (54.55)		
Heart rate (beats/min)			5.343	0.021
<97 (n=56)	5 (23.81)	51 (51.52)		
≥97 (n=64)	16 (76.19)	48 (48.48)		
Premature ventricular contraction count (times/24 h)			0.405	0.524
<448 (n=59)	9 (42.86)	50 (50.51)		
≥448 (n=61)	12 (57.14)	49 (49.49)		
Premature atrial contraction count (times/24 h)			0.058	0.810
<507 (n=60)	10 (47.62)	50 (50.51)		
≥507 (n=60)	11 (52.38)	49 (49.49)		
Junctional premature contraction count (times/24 h)			1.248	0.264
<186 (n=59)	8 (38.10)	51 (51.52)		
≥186 (n=61)	13 (61.90)	48 (48.48)		
Duration of ST segment depression (min)			1.037	0.309
<94 (n=52)	7 (33.33)	45 (45.45)		
≥94 (n=68)	14 (66.67)	54 (54.55)		
Number of ST segment depressions (times)			0.354	0.552
<21 (n=41)	6 (28.57)	35 (35.35)		
≥21 (n=79)	15 (71.43)	64 (64.65)		
LVEDD (mm)			0.038	0.845
<60 (n=48)	8 (38.10)	40 (40.40)		
≥60 (n=72)	13 (61.90)	59 (59.60)		
LVPWT (mm)			0.220	0.639
<13 (n=57)	9 (42.86)	48 (48.48)		
≥13 (n=63)	12 (57.14)	51 (51.52)		

LVST (mm)			0.005	0.943
<12 (n=58)	10 (47.62)	48 (48.48)		
≥12 (n=62)	11 (52.38)	51 (51.52)		
LVEF (%)			5.437	0.020
<47 (n=58)	15 (71.43)	43 (43.43)		
≥47 (n=62)	6 (28.57)	56 (56.57)		
NT-proBNP (pg/mL)			6.130	0.013
<486 (n=58)	5 (23.81)	53 (53.54)		
≥486 (n=62)	16 (76.19)	46 (46.46)		
SOD (U/mL)			0.334	0.563
<78 (n=56)	11 (52.38)	45 (45.45)		
≥78 (n=64)	10 (47.62)	54 (54.55)		
Medication regimen			4.675	0.031
Carvedilol (n=60)	15 (71.43)	45 (45.45)		
Esmolol + Carvedilol (n=60)	6 (28.57)	54 (54.55)		

Note: LVEDD, left ventricular end-diastolic dimension; LVPWT, left ventricular posterior wall thickness; LVST, left ventricular septal thickness; LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide; SOD, superoxide dismutase.

Table 7. Multivariate analysis of factors associated with treatment efficacy

Indicators	B	Standard error	Wald	P	OR	95% CI
Age (years)	0.773	0.616	1.574	0.210	2.166	0.647-7.249
Comorbid diabetes	1.127	0.586	3.700	0.054	3.086	0.979-9.729
Heart rate (beats/min)	1.524	0.648	5.527	0.019	4.592	1.289-16.366
LVEF (%)	-1.237	0.618	3.999	0.046	0.290	0.086-0.976
NT-proBNP (pg/mL)	1.316	0.612	4.628	0.031	3.729	1.124-12.371
Medication regimen	-0.527	0.610	0.745	0.388	0.591	0.179-1.953

Note: LVEF, left ventricular ejection fraction; NT-proBNP, N-terminal pro-B-type natriuretic peptide.

research group compared to the control group. This suggests that combined therapy provides more effective hemodynamic control, thereby reducing myocardial oxygen consumption and improving myocardial tolerance to hypoxia. Restoration of the balance between oxygen supply and demand is a key mechanism underlying the improvement of ischemic myocardial function. The rapid action of esmolol likely contributes to early HR control, while carvedilol provides sustained β-blockade and vasodilatory effects, resulting in a complementary and synergistic therapeutic effect [28].

Previous evidence suggests that the administration of carvedilol, a novel β-blocker with vasodilatory effects, in patients with exertional angina is effective in improving the frequency of ST-segment depression without an excessive decrease in nocturnal HR and without exacerbation of nocturnal myocardial ischemic episodes, suggesting that the mode of action of this drug appears to be based not only on β-blocking but also on vasodilatory effects [29].

Furthermore, the combination group exhibited significantly lower counts of PVC, PAC, and JPB compared with the control group. This suggests that combined medication is effective in suppressing myocardial ectopic activity. The short half-life of esmolol allows rapid achievement and adjustment of therapeutic plasma concentrations, facilitating precise regulation of myocardial electrophysiological activity. When combined with carvedilol, this may enhance the suppression of abnormal automaticity and excitability, thereby reducing the incidence of arrhythmias.

Consistently, both the duration and frequency of ST-segment depressions were significantly lower in the research group after treatment.

This effect may be attributed to the rapid attenuation of tachycardia and myocardial oxygen demand, thereby alleviating MI symptoms [30]. Previous studies have also demonstrated that carvedilol improves ST-segment changes and reduces ischemic episodes, partly through its combined β-blocking and vasodilatory effects [29].

In terms of cardiac function, our results showed that LVEDD, LVPWT, and LVST were significantly decreased, while LVEF was increased in the research group compared with the control group, aligning with previous reports indicating that carvedilol improves ventricular remodeling and cardiac function [31]. The enhanced effects observed with combined therapy may be explained by the rapid hemodynamic stabilization provided by esmolol, which reduces myocardial workload and facilitates recovery of myocardial contractility, while carvedilol contributes to long-term structural and functional improvement [32].

Regarding biochemical markers, post-treatment NT-proBNP levels were significantly lower and SOD levels were higher in the research group compared with the control group. MI in CHD has been shown to induce cardiomyocyte apoptosis and increased ventricular wall stress, resulting in elevated B-type natriuretic peptide (BNP) and its cleavage product NT-proBNP, which circulates in the bloodstream, with its levels reflecting the severity of cardiac dysfunction [33]. Meanwhile, MI increases oxidative stress, depletes superoxide dismutase (SOD), and promotes lipid peroxidation, further impairing myocardial function [34]. These results suggest that carvedilol, may have limited effect on neurohormonal and oxidative stress pathways. Esmolol, through rapid heart rate control and reduction of myocardial oxygen demand, may complement carvedilol by attenuating myocardial stress and oxidative injury, ultimately lowering ventricular wall tension and NT-proBNP levels [35].

Safety results showed a lower total incidence of adverse events in the research group compared with the control group (3.33% vs. 18.33%), indicating that esmolol combined with carvedilol is well tolerated in the treatment of MI secondary to CHD. This combination can effectively regulate cardiovascular function, not only improving myocardial contractility but also by optimizing hemodynamic stability and vascular tone, thereby enhancing myocardial perfusion and tolerance to ischemia.

Finally, elevated baseline HR (≥97 beats/min), reduced LVEF (<47%), and high NT-proBNP (≥486 pg/mL) were identified as independent contributors to poor efficacy in patients with MI and CHD. Increased baseline HR may reflect sympathetic nerve overactivation and β-adrenergic receptor down-regulation, aggravating MI and complicating treatment [36]. Reduced LVEF indicates impaired myocardial contractile reserve and microcirculatory perfusion, which can limit the response to therapy [37]. Elevated NT-proBNP reflects increased ventricular wall stress and ongoing ventricular remodeling in CHD patients, heightening the risk of treatment ineffectiveness [38].

Several limitations in this study should be acknowledged. First, the cases were all from one single center, which may restrict the generalizability of the results. Future multicenter studies are warranted. Second, due to the retrospective design, clinical parameters were analyzed only at baseline and after 8 weeks of treatment. More detailed temporal assessments (e.g., at 2 weeks and 1 month) should be incorporated in prospective studies to better characterize the short-term dynamics of treatment response. Third, treatment allocation was not randomized, which may introduce potential selection bias. Finally, the underlying mechanism of the observed benefits from combined esmolol-carvedilol treatment were not thoroughly discussed. Further experimental research should be supplemented to further explore the potential molecular pathways involved.

Conclusion

Esmolol combined with carvedilol demonstrates significant clinical advantages in the treatment of CHD-induced MI. This combination therapy improves therapeutic efficacy, reduces premature beat counts, lowers BP and HR, ameliorates electrocardiographic abnormalities, improves cardiac function and biochemical markers, while maintaining a good safety profile. Additionally, increased baseline HR, reduced LVEF, and increased NT-proBNP levels may serve as important predictors of poor treatment response in patients

with MI and CHD. These findings provide valuable evidence for individualized treatment strategies and may help optimize clinical decision-making to maximize patient outcomes.

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Disclosure of conflict of interest

None.

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