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Original Article

Efficacy of rhBNP in heart failure with atrial fibrillation combined with poor conventional therapy response and recurrence risk factors

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Abstract: Objectives: To evaluate the efficacy of recombinant human brain natriuretic peptide (rhBNP) in patients with acute decompensated heart failure (ADHF) complicated with atrial fibrillation (AF) and poor response to conventional treatment. Methods: The study included 172 ADHF patients with AF who had poor response to conventional therapy and received rhBNP. Primary observations including changes in blood pressure, C-reactive protein (CRP), heart rate, blood urea nitrogen, oxygen saturation, creatinine, and N-terminal pro-brain natriuretic peptide (NT-proBNP) were monitored from admission to discharge. Secondary metrics included left ventricular ejection fraction (LVEF), left ventricular end-diastolic diameter (LVEDD), and left ventricular end-systolic diameter (LVESD) taken at the 3-month follow-up. AF recurrence was recorded, and logistic regression analyses were conducted. Results: After treatment with rhBNP, patients' heart rate and blood pressure decreased significantly, oxygen saturation improved, levels of NT-proBNP and CRP decreased, and indicators of renal function improved. At 3 months, LVEF increased and LVESD decreased. Overall, patients in the recurrence group were older, had lower BMI, and showed higher baseline NT-proBNP, CRP, and renal function-related parameters compared with the non-recurrence group. Multivariate analysis demonstrated that low BMI, as well as elevated baseline creatinine, CRP, blood urea nitrogen, and, NT-proBNP were independent risk factors for AF recurrence. Conclusions: rhBNP significantly improves hemodynamics, reduces inflammation, and ameliorates renal function in ADHF patients with AF who respond poorly to conventional therapy. Low BMI and elevated baseline NT-proBNP, CRP, creatinine, and blood urea nitrogen are independent predictors of AF recurrence.

Keywords: Recombinant human brain natriuretic peptide, acute decompensated heart failure, atrial fibrillation, inflammatory response, renal function

Introduction

Heart failure (HF) and atrial fibrillation (AF) represent prevalent cardiovascular disorders across the globe, and they frequently coexist and interact with each other. Epidemiological studies have shown that more than 30% of HF patients also have AF, while the incidence of HF in AF patients is significantly higher than in the general population. Patients with HF complicated by AF often present with more severe clinical symptoms, higher rates of hospitalization and mortality, and worse prognosis [1]. In clinical practice, conventional pharmacological treatments for acute decompensated heart failure (ADHF) primarily include diuretics, vasodilators, and inotropes, which aim to reduce volume overload and improve hemodynamics [2, 3]. In recent years, with the combined use of angiotensin receptor-neprilysin inhibitors (ARNI), sodium-glucose cotransporter 2 inhibitors (SGLT2i), β-blockers and mineralocorticoid receptor antagonists (MRA), the long-term outcomes of HF patients have improved [3, 4]. However, during the acute decompensated phase, a proportion of patients respond poorly to conventional therapy, underscoring the urgent need for new and more effective treatment strategies [5].

Natriuretic peptides are a class of endogenous hormones secreted by the heart, including atrial natriuretic peptide, brain natriuretic peptide (BNP), and C-type natriuretic peptide. BNP acti-

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vates the guanylate cyclase-cyclic guanosine monophosphate (cGMP) pathway by binding to natriuretic peptide receptor A (NPR-A) on target organ surfaces. This inhibits renin-angiotensin-aldosterone system (RAAS) activity, reduces sympathetic nervous system tone, promotes vasodilation, and enhances urinary sodium excretion [6]. In HF patients, BNP levels are usually elevated as a compensatory response to increased volume load [7]. However, research indicates that in HF patients, the biological activity of BNP is frequently compromised due to receptor downregulation and enhanced degradation pathways such as neutral endopeptidase [7, 8]. Recombinant human brain natriuretic peptide (rhBNP), as an exogenous BNP, can directly bind to receptors, circumventing the degradation and desensitization issues associated with endogenous peptides. It offers a supplementary therapeutic option for patients with inadequate response to conventional treatments, particularly those experiencing persistent volume overload and insufficient symptom relief [3, 9, 10].

The recurrence of AF remains a major challenge in clinical management. Although pharmacological therapy, electrical cardioversion, and catheter ablation can restore sinus rhythm, a considerable proportion of patients still experience recurrence. AF recurrence is associated not only with atrial electrophysiological remodeling but also with structural remodeling, inflammatory responses, ventricular dysfunction, neurohormonal activation, and electrolyte disturbances [11]. Previous studies have suggested that advanced age, hypertension, enlarged left atrial diameter, impaired cardiac function, elevated C-reactive protein (CRP), and renal dysfunction are potential risk factors for AF recurrence [12, 13]. To date, research focusing on the characteristics and risk factors of AF recurrence in patients with HF and AF receiving rhBNP is still insufficient.

To summarize, traditional treatment methods are still insufficient in the treatment of AF combined with HF. rhBNP may bring clinical benefits to ADHF patients who do not respond well to standard treatment. This study aims to evaluate the efficacy of rhBNP in patients who have a poor response to conventional treatment, as well as analyze the risk factors for atrial fibrillation recurrence. This study provides a new perspective and reference for the clinical diagnosis and treatment of these patients with AF combined with HF.

Methods

Patient selection

This was a single-center retrospective study. A total of 172 patients hospitalized for ADHF with AF at Anhui Provincial Thoracic Hospital between December 2022 and June 2025, who exhibited poor response to conventional therapy and subsequently received rhBNP, were included. All patients met the diagnostic criteria for ADHF and AF as defined in the Chinese guidelines. Upon admission, patients received conventional treatment, including diuretics, vasodilators, and/or inotropes, but showed inadequate therapeutic response [3, 14, 15]. This study was approved by the Ethics Committee of Anhui Provincial Thoracic Hospital.

Inclusion criteria: confirmed diagnosis of ADHF with AF; age ≥ 18 years; poor clinical response to standardized conventional therapy; and availability of complete admission, discharge, and follow-up clinical data. Exclusion criteria: systolic blood pressure < 90 mmHg; acute myocardial infarction or cardiogenic shock; severe hepatic or renal dysfunction; presence of malignancy; or incomplete clinical data.

Treatment

All patients received standard therapy for ADHF upon admission [3]. Basic treatment included intravenous loop diuretics to reduce volume overload and relieve dyspnea. Vasodilators or inotropic agents were administered as needed according to patients' hemodynamic status and clinical presentation, in order to improve cardiac function and tissue perfusion. In addition, since all patients had AF, they received anticoagulation therapy and rate control to reduce thromboembolic events and improve cardiac function, along with electrical cardioversion following radiofrequency ablation to restore sinus rhythm and enhance cardiac performance [15].

Because patients responded poorly to conventional therapy and their clinical symptoms were

insufficiently relieved, rhBNP (Chengdu Nordicon Biopharmaceutical Co., Ltd. National Drug Approval Number S20050033 0.5 mg/500 U per vial) was subsequently administered. The regimen consisted of continuous intravenous infusion, preceded, when necessary, by an intravenous loading dose of 1.5 μg/kg, followed by a maintenance infusion at 0.0075-0.01 μg/kg/min. During the treatment period, we closely monitored blood pressure, heart rate and urine output, and adjusted the dosage as appropriate. The total duration of treatment did not exceed 72 hours.

After discharge, all patients received guideline-directed medical therapy for HF, including ARNI, β-blockers, MRAs, and SGLT2i, and individualized adjustments were made based on blood pressure, renal function, and clinical tolerance to improve prognosis and reduce the risk of recurrence.

Data collection

Baseline data included demographic characteristics (age, gender, body mass index [BMI], etc.), comorbidities (diabetes, hypertension, chronic kidney disease, etc.), New York Heart Association (NYHA) functional classification, as well as admission oxygen saturation, heart rate, blood pressure, and body weight. Before and after treatment, patients' vital signs (systolic blood pressure, oxygen saturation, heart rate, diastolic blood pressure), cardiac function parameters (left ventricular end-systolic diameter [LVESD], left ventricular ejection fraction [LVEF], left ventricular end-diastolic diameter [LVEDD]), and laboratory test results (creatinine, NT-proBNP, CRP, and blood urea nitrogen) were recorded. Efficacy evaluation included changes in cardiac function and laboratory parameters at 3 months after discharge, as well as the recurrence of AF. In this study, 'poor response to conventional therapy' is defined as the persistence of at least two of the following manifestations 24 hours after administration of standard diuretics, vasodilators and/or positive inotropic agents: (1) Dyspnoea (no improvement or worsening in NYHA classification), orthopnoea, or persistent nocturnal paroxysmal dyspnoea; (2) Persistent pulmonary crackles, lower limb oedema, jugular venous distension (≥ 3 cm); (3) Weight loss < 1 kg/24 h, oxygen saturation < 90%, central venous pressure > 12 cmH_2O, or no reduction or increased NT-proBNP levels. All patients' characteristics were confirmed by assessment from at least two cardiovascular specialists [5, 16, 17].

Statistical analysis

Continuous variables were tested for normality prior to analysis, and all were normally distributed. Comparisons between the two groups were performed using independent-samples t tests, and comparisons of related parameters before and after treatment were conducted using paired t tests. Categorical variables are comparisons performed using the chi-square test or Fisher's exact test. AF recurrence was defined as the dependent variable; univariate logistic regression was first used to identify potential influencing factors, and variables with $P < 0.1$ were then entered into a multivariate logistic regression. $P < 0.05$ was considered statistically significant. All data were analyzed using SPSS 26.0.

Results

Baseline characteristics of all patients

As shown in **Table 1**, a total of 172 patients with ADHF and AF were included, comprising 99 males and 73 females. The average age was 72.24 years old, the average length of hospital stay was 9.66 days, and the average BMI index was 20.45. Among the enrolled patients, 64.53% were smokers, 56.40% had a history of alcohol consumption, and 22.67% reported having the habit of chewing betel nuts. In addition, 79 patients had diabetes, 75 had dyslipidemia, and 46 had a history of stroke.

Blood pressure, heart rate, and oxygen saturation at baseline and at discharge

We first analyzed the effects of rhBNP on heart rate, blood pressure, and oxygen saturation in all patients. As shown in **Table 2**, after rhBNP treatment, the heart rate of the patients at discharge was significantly lower than that at admission ($P = 0.001$). Both systolic and diastolic blood pressures showed a downward trend ($P < 0.001$). In addition, the oxygen saturation at discharge was significantly improved compared with the baseline level ($P < 0.001$).

Table 1. Baseline characteristics of all patients

Variables	n = 172
Age, mean ± SD	72.24 ± 11.79
Sex, n (%)	
Male	99 (57.56)
Female	73 (42.44)
Length of stay, mean ± SD	9.66 ± 5.65
BMI, mean ± SD	20.45 ± 2.39
Smoking, n (%)	
No	61 (35.47)
Yes	111 (64.53)
Alcohol consumption, n (%)	
No	75 (43.60)
Yes	97 (56.40)
Betel nut chewing, n (%)	
No	133 (77.33)
Yes	39 (22.67)
Diabetes mellitus, n (%)	
No	93 (54.07)
Yes	79 (45.93)
Dyslipidemia, n (%)	
No	97 (56.40)
Yes	75 (43.60)
History of stroke, n (%)	
No	126 (73.26)
Yes	46 (26.74)
24-hour urine volume, mL, mean ± SD	385.14 ± 92.65

Note: BMI, body mass index; SD, standard deviation.

Laboratory findings at baseline and at discharge

According to the data in **Table 3**, compared with the baseline, the NT-proBNP level at discharge was significantly decreased (P < 0.001). As an important and sensitive inflammatory marker, CRP was also significantly decreased at discharge compared with the baseline level (P < 0.001). The commonly used renal function indicators, serum creatinine and blood urea nitrogen, both decreased significantly after recombinant human brain natriuretic peptide treatment, suggesting an improvement in renal function (P < 0.001).

Cardiac function parameters at baseline and at 3-month follow-up

According to the data in **Table 4**, the patient's cardiac function improved significantly at 3 months. Specifically, it manifested as a significant increase in LVEF (P < 0.001), which reflected the enhancement of myocardial contractility. Meanwhile, LVESD significantly decreased (P = 0.004), indicating that the end-systolic volume of the heart was effectively improved. In contrast, LVEDD remained stable during the follow-up period, and no statistically significant difference was shown between its baseline value and the follow-up value (P = 0.272). These results indicate that rhBNP therapy improved the pumping function and systolic efficiency of the heart, while not having a significant impact on the structural dimensions at the end of diastolic movement.

Baseline characteristics in patients with and without AF recurrence

Patients were categorized into recurrence and non-recurrence groups based on the occurrence of atrial fibrillation recurrence during the three-month follow-up period. This enabled comparison of differences in baseline characteristics, treatment response, and prognosis between the two groups, thereby identifying independent predictors associated with recurrence. As presented in **Table 5**, 58 individuals experienced recurrence, whereas 114 did not. The recurrence group was characterized by older age (P = 0.007) and lower BMI (P < 0.001). Other variables, including sex, smoking and alcohol habits, betel nut use, comorbid conditions, and duration of hospitalization, showed no significant intergroup differences.

Blood pressure, heart rate, and oxygen saturation in patients with and without AF recurrence

Table 6 presents the comparisons of blood pressure, heart rate, and oxygen saturation at baseline and discharge between the two

Table 2. Heart rate, blood pressure, and oxygen saturation of all patients at baseline and at discharge

Variables	Baseline	At discharge	t	P
Heart rate	85.33 ± 7.01	82.66 ± 8.55	3.25	0.001
Systolic blood pressure	146.25 ± 17.74	133.72 ± 17.77	6.45	< 0.001
Diastolic blood pressure	95.51 ± 6.91	91.88 ± 7.37	4.31	< 0.001
Oxygen saturation	89.99 ± 1.88	96.30 ± 2.24	-27.69	< 0.001

Note: The discharge assessment point refers to the time at which a patient, having completed rhBNP therapy (lasting no longer than 72 hours) and with their condition stabilized, is prepared for discharge. During this period, the patient continues to receive standard heart failure treatment, with rhBNP administered as an adjunct therapy.

Table 3. NT-proBNP, C-reactive protein, and renal function parameters of all patients at baseline and at discharge

Variables	Baseline	At discharge	t	P
NT-proBNP	1802.67 ± 385.11	1452.68 ± 375.07	8.66	< 0.001
CRP	19.35 ± 7.56	12.72 ± 6.24	9.03	< 0.001
Serum creatinine	130.95 ± 20.63	99.27 ± 19.37	15.09	< 0.001
Blood urea nitrogen	10.13 ± 3.38	8.74 ± 2.40	4.29	< 0.001

Note: NT-proBNP, N-terminal pro-brain natriuretic peptide; CRP, C-reactive protein.

Table 4. Cardiac function parameters of all patients at baseline and at 3-month follow-up

Variables	Baseline	At 3-month follow-up	t	P
LVEF	37.45 ± 5.85	42.55 ± 6.25	-8.67	< 0.001
LVEDD	61.16 ± 5.80	60.45 ± 5.55	1.10	0.272
LVESD	49.55 ± 4.55	48.04 ± 5.15	2.93	0.004

Note: LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter.

groups. Results showed no significant differences in these parameters at baseline. At discharge, diastolic blood pressure and oxygen saturation were also comparable between the two groups. Whereas systolic pressure was significantly elevated in patients with recurrence compared to those without (P = 0.028).

Comparison of CRP, renal function, and cardiac function between patients with and without AF recurrence

As shown in **Table 7**, baseline NT-proBNP, CRP, serum creatinine, and blood urea nitrogen levels were significantly higher in the recurrence group compared with the non-recurrence group (P < 0.001). However, at discharge, no significant differences were observed between the two groups for these parameters. In addition, as presented in **Table 8**, there were no significant differences in LVEF, LVEDD, or LVESD between the recurrence and non-recurrence groups either at baseline or at the 3-month follow-up (P > 0.05).

Logistic regression analysis of AF recurrence

To further clarify potential factors influencing AF recurrence in patients with ADHF, logistic regression analysis was performed using baseline data. As shown in **Table 9**, univariate logistic regression revealed that age (OR = 1.04, P = 0.008), BMI (OR = 0.68, P < 0.001), baseline NT-proBNP (OR = 1.17, P < 0.001), CRP (OR = 1.16, P<0.001), serum creatinine (OR = 1.05, P < 0.001), and blood urea nitrogen (OR = 1.21, P < 0.001) were potential risk factors for AF recurrence. Further multivariate logistic regression analysis demonstrated that low BMI (OR = 0.68, P < 0.001), elevated baseline NT-proBNP (OR = 1.14, P = 0.033), elevated CRP (OR = 1.16, P < 0.001), elevated serum creatinine

Table 5. Comparison of baseline characteristics of patients with and without atrial fibrillation recurrence

Variables	Non-recurrent group (n = 114)	Recurrent group (n = 58)	Statistic	P
Age, mean ± SD	70.53 ± 11.76	75.62 ± 11.19	-2.73	0.007
Sex, n (%)			0.61	0.437
Male	68 (59.65)	31 (53.45)		
Female	46 (40.35)	27 (46.55)		
Length of stay, mean ± SD	9.55 ± 5.99	9.86 ± 4.96	-0.34	0.735
BMI, mean ± SD	21.09 ± 2.28	19.19 ± 2.09	5.30	< 0.001
Smoking, n (%)			0.28	0.597
No	42 (36.84)	19 (32.76)		
Yes	72 (63.16)	39 (67.24)		
Alcohol consumption, n (%)			0.18	0.675
No	51 (44.74)	24 (41.38)		
Yes	63 (55.26)	34 (58.62)		
Betel nut chewing, n (%)			1.47	0.225
No	85 (74.56)	48 (82.76)		
Yes	29 (25.44)	10 (17.24)		
Diabetes mellitus, n (%)			2.25	0.133
No	57 (50.00)	36 (62.07)		
Yes	57 (50.00)	22 (37.93)		
Dyslipidemia, n (%)			0.05	0.818
No	65 (57.02)	32 (55.17)		
Yes	49 (42.98)	26 (44.83)		
History of stroke, n (%)			1.64	0.201
No	80 (70.18)	46 (79.31)		
Yes	34 (29.82)	12 (20.69)		

Table 6. Comparison of heart rate, blood pressure, and oxygen saturation between patients with and without atrial fibrillation recurrence

Variables	Non-recurrent group (n = 114)	Recurrent group (n = 58)	t	P
Heart rate at baseline, mean ± SD	84.81 ± 7.11	86.34 ± 6.74	-1.36	0.174
Heart rate at discharge, mean ± SD	83.37 ± 8.61	81.26 ± 8.34	1.54	0.127
Systolic blood pressure at baseline, mean ± SD	144.97 ± 16.08	148.76 ± 20.54	-1.23	0.224
Systolic blood pressure at discharge, mean ± SD	131.60 ± 17.57	137.90 ± 17.57	-2.22	0.028
Diastolic blood pressure at baseline, mean ± SD	95.17 ± 7.04	96.19 ± 6.65	-0.92	0.360
Diastolic blood pressure at discharge, mean ± SD	91.38 ± 7.54	92.86 ± 6.98	-1.25	0.212
Oxygen saturation at baseline, mean ± SD	90.09 ± 1.86	89.81 ± 1.94	0.91	0.363
Oxygen saturation at discharge, mean ± SD	96.47 ± 2.18	95.97 ± 2.32	1.41	0.160

(OR = 1.05, P < 0.001), and elevated blood urea nitrogen (OR = 1.21, P = 0.010) were independent risk factors for AF recurrence (**Table 10**).

Discussion

The present study assessed the effectiveness of rhBNP in patients with ADHF complicated by AF who had poor response to conventional therapy and further explored the risk factors associated with AF recurrence. rhBNP effectively improved blood pressure levels, reduced inflammatory indicators, and enhanced renal function, and it increased the LVEF and reduced the LVESD. The results of logistic regression analysis showed that elevated BMI and base-

Table 7. Comparison of NT-proBNP, C-reactive protein, and renal function parameters between patients with and without atrial fibrillation recurrence

Variables	Non-recurrent group (n = 114)	Recurrent group (n = 58)	t	*P*
NT-proBNP at baseline, mean ± SD	1727.42 ± 332.02	1950.57 ± 439.09	-3.41	< 0.001
NT-proBNP at discharge, mean ± SD	1443.20 ± 383.57	1471.31 ± 360.32	-0.46	0.643
CRP at baseline, mean ± SD	17.00 ± 6.50	23.99 ± 7.40	-6.36	< 0.001
CRP at discharge, mean ± SD	12.49 ± 5.75	13.19 ± 7.13	-0.65	0.515
Serum creatinine at baseline, mean ± SD	124.80 ± 16.67	143.02 ± 22.40	-5.47	< 0.001
Serum creatinine at discharge, mean ± SD	98.27 ± 17.96	101.25 ± 21.92	-0.95	0.341
Blood urea nitrogen at baseline, mean ± SD	9.45 ± 3.12	11.48 ± 3.48	-3.89	< 0.001
Blood urea nitrogen at discharge, mean ± SD	8.90 ± 2.19	8.42 ± 2.76	1.15	0.251

Note: NT-proBNP, N-terminal pro-brain natriuretic peptide; CRP, C-reactive protein.

Table 8. Comparison of cardiac function parameters between patients with and without atrial fibrillation recurrence

Variables	Non-recurrent group (n = 114)	Recurrent group (n = 58)	t	P
LVEF at baseline, mean ± SD	36.93 ± 5.45	38.48 ± 6.49	-1.66	0.100
LVEF at 3-month follow-up, mean ± SD	42.54 ± 5.99	42.58 ± 6.80	-0.04	0.967
LVEDD at baseline, mean ± SD	61.25 ± 5.98	60.98 ± 5.47	0.29	0.772
LVEDD at 3-month follow-up, mean ± SD	60.61 ± 5.15	60.13 ± 6.29	0.54	0.590
LVESD at baseline, mean ± SD	49.78 ± 4.52	49.10 ± 4.63	0.92	0.357
LVESD at 3-month follow-up, mean ± SD	48.34 ± 4.70	47.44 ± 5.94	1.08	0.281

Note: LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter.

line NT-proBNP, CRP, serum creatinine and blood urea nitrogen were independent risk factors for AF recurrence.

The role of rhBNP in the treatment of HF is still controversial in clinical practice, and it is only considered as a second-line treatment option for ADHF [3, 18]. However, studies have shown that the drug can effectively improve cardiac function and myocardial inflammation in patients with HF, and reduce the incidence of AF after coronary artery bypass grafting [19, 20]. Our findings showed that in patients with ADHF and AF who responded poorly to conventional therapy, rhBNP reduced blood pressure and heart rate, while markedly improving oxygen saturation. This effect may be attributed to rhBNP binding to brain natriuretic peptide receptors, thereby promoting vasodilation, reducing ventricular filling pressure and peripheral resistance, and consequently alleviating dyspnea and pulmonary congestion in acute HF patients [21, 22]. Our results show that recombinant human brain natriuretic peptide can continue to exert stable hemodynamic benefits even in complex cases with atrial fibrillation. In addition, this study provides further support for the application of recombinant human brain natriuretic peptide in patients with heart failure who are not responsive to conventional treatment.

Previous studies have demonstrated that inflammatory responses and renal function play key roles in the HF and AF [23, 24]. Regarding inflammation and renal function, this study observed a significant reduction in NT-proBNP levels following rhBNP treatment, potentially attributable to the following mechanisms: rhBNP improves haemodynamics and reduces ventricular wall stress, thereby decreasing myocardial cell synthesis and release of NT-proBNP. Concurrently, its promotion of urinary sodium excretion and vasodilation helps alleviate preload and afterload on the heart, further reducing myocardial tension. Moreover, as a bio-

Table 9. Univariate logistic regression analysis of atrial fibrillation recurrence

Variables	β	P	OR (95% CI)
Age, mean ± SD	0.04	0.008	1.04 (1.01-1.07)
Sex, n (%)			
Male			1.00 (Reference)
Female	0.25	0.437	1.29 (0.68-2.44)
Length of stay, mean ± SD	0.01	0.734	1.01 (0.96-1.07)
BMI, mean ± SD	-0.39	< 0.001	0.68 (0.57-0.80)
Smoking, n (%)			
No			1.00 (Reference)
Yes	0.18	0.597	1.20 (0.61-2.33)
Alcohol consumption, n (%)			
No			1.00 (Reference)
Yes	0.14	0.675	1.15 (0.60-2.17)
Betel nut chewing, n (%)			
No			1.00 (Reference)
Yes	-0.49	0.228	0.61 (0.27-1.36)
Diabetes mellitus, n (%)			
No			1.00 (Reference)
Yes	-0.49	0.135	0.61 (0.32-1.16)
Dyslipidemia, n (%)			
No			1.00 (Reference)
Yes	0.07	0.818	1.08 (0.57-2.04)
History of stroke, n (%)			
No			1.00 (Reference)
Yes	-0.49	0.203	0.61 (0.29-1.30)
Heart rate at baseline	0.03	0.175	1.03 (0.99-1.08)
Systolic blood pressure at baseline	0.01	0.187	1.01 (0.99-1.03)
Diastolic blood pressure at baseline	0.02	0.358	1.02 (0.98-1.07)
Oxygen saturation at baseline	-0.08	0.361	0.92 (0.78-1.09)
NT-proBNP at baseline	0.16	< 0.001	1.17 (1.07-1.28)
CRP at baseline	0.15	< 0.001	1.16 (1.10-1.23)
Serum creatinine at baseline	0.05	< 0.001	1.05 (1.03-1.07)
Blood urea nitrogen at baseline	0.19	< 0.001	1.21 (1.09-1.35)
LVEF at baseline	0.05	0.102	1.05 (0.99-1.11)
LVEDD at baseline	-0.01	0.770	0.99 (0.94-1.05)
LVESD at baseline	-0.03	0.355	0.97 (0.90-1.04)

Note: OR, odds ratio; CI, confidence interval.

Table 10. Multivariate logistic regression analysis of atrial fibrillation recurrence

Variables	β	P	OR (95% CI)
BMI	-0.39	< 0.001	0.68 (0.55-0.83)
NT-proBNP at baseline	0.13	0.033	1.14 (1.01-1.29)
CRP at baseline	0.15	< 0.001	1.16 (1.07-1.26)
Serum creatinine at baseline	0.05	< 0.001	1.05 (1.03-1.08)
Blood urea nitrogen at baseline	0.19	0.010	1.21 (1.05-1.41)

Note: BMI, body mass index; NT-proBNP, N-terminal pro-brain natriuretic peptide; CRP, C-reactive protein.

marker reflecting the severity of heart failure, the reduction in NT-proBNP levels also indirectly indicates that rhBNP treatment improved patients' cardiac function status [25]. This work also showed that CRP levels were reduced after rhBNP treatment, suggesting a potential anti-inflammatory effect. This finding is consistent with prior research indicating that inflammation may accelerate electrophysiological remodeling, thereby promoting the occurrence and recurrence of AF [26]. rhBNP may alleviate inflammation by improving hemodynamic status and indirectly reducing the release of inflammatory mediators, which may explain the decrease of CRP level observed in this study [27]. In addition, our results showed that rhBNP significantly decreased blood urea nitrogen levels, indicating improved kidney function. Previous studies have reported that HF patients often develop varying degrees of renal impairment due to decreased cardiac output and renal hypoperfusion [28]. It has also been suggested that the natriuretic peptide system may improve renal function by dilating renal arterioles and promoting sodium excretion. The results of this study were consistent with the above observations, which further confirmed the renal protective effect of rhBNP in ADHF patients [29]. Moreover, this study demonstrated a significant increase in LVEF and a reduction in LVESD, although LVEDD showed no significant change. These results suggest that rhBNP may promote left ventricular reverse remodeling to some extent, thereby improving systolic function. Pre-

vious studies have noted that although elevated endogenous BNP represents a compensatory response in HF, reduced receptor sensitivity and enhanced degradation pathways limit its clinical efficacy [7, 30]. In contrast, exogenous rhBNP may effectively supplement natriuretic peptide activity and thereby improve cardiac function. Our study confirmed the improvement effect of rhBNP on cardiac function.

This study found that patients in the recurrence group were older, had lower BMI and exhibited higher baseline levels of NT-proBNP, CRP, creatinine, and blood urea nitrogen. Logistic regression analyses indicated that low BMI, as well as elevated inflammatory and renal function-related markers, were risk factors for AF recurrence. The observation is in agreement with prior studies. Askarinejad et al. recently reported that advanced age and elevated blood urea nitrogen were linked to an increased risk of AF recurrence [31]. A meta-analysis suggested that higher levels of CRP and IL-6 are important predictors of AF recurrence following radiofrequency ablation [32]. The present study confirmed these conclusions. We also highlighted that patients who showed insufficient improvement in inflammation and renal function after rhBNP treatment still faced a higher risk of recurrence. It is noteworthy that earlier studies identified high BMI as a risk factor for AF recurrence, but more recent research has suggested that the relationship between body weight/BMI and AF recurrence may not be linear, with both excessively high and excessively low BMI contributing to increased recurrence risk [33, 34]. This interpretation does not conflict with the present findings. In addition, LVEF, LVEDD, and LVESD did not differ significantly between the recurrence and non-recurrence groups, suggesting that the extent of ventricular remodeling improvement under rhBNP therapy may not be sufficient to differentiate recurrence risk. This aligns with previous reports that LVEF has limited predictive value for AF recurrence and suggests that inflammatory and renal function markers may be stronger predictors than cardiac functional indices.

The evidence generated by our work is of great significance for clinical decision-making. Firstly, for ADHF with poor treatment response, rhBNP as a supplementary treatment option can significantly improve hemodynamics, inflammatory response and renal function. This indicates that the drug has potential value in specific populations. Secondly, the results of routine laboratory tests such as CRP, NT-proBNP, creatinine and blood urea nitrogen can be used as important predictors of AF recurrence. Patients with low BMI and concurrent abnormalities in inflammatory and renal function should receive closer monitoring and more intensive interventions.

This study has several limitations. First, this was a retrospective analysis conducted at a single center with a modest sample size, which may restrict the external validity of the results. Second, the follow-up duration was only 3 months, making it inadequate to evaluate the long-term prognostic impact of rhBNP. Third, only CRP was measured as an inflammatory marker, without inclusion of a broader range of biomarkers, potentially underestimating the role of inflammation in AF recurrence. Finally, differences in drug dosage and treatment adherence among patients may also have influenced the results. We believe that the abovementioned notable points are the primary issues that need to be addressed in the subsequent research. If these problems are solved, it will undoubtedly further enhance the value of this work.

Conclusion

Our work indicates that rhBNP can effectively improve the hemodynamic status, inflammatory level and renal function of ADHF patients with AF who have a poor response to conventional treatment. After 3 months of treatment, LVEF was increased while LVESD was reduced. Further analysis indicated that low BMI and elevated baseline NT-proBNP, CRP, blood urea nitrogen and serum creatinine were independent risk factors for AF recurrence. Therefore, for such patients, rhBNP should be actively applied to alleviate acute symptoms, and closer monitoring and intervention targeting inflammation and renal function after discharge are warranted to reduce the risk of AF recurrence and improve long-term outcomes.

Disclosure of conflict of interest

None.

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