Effect of Eye Acupuncture with Needle Retention Exercise on Postoperative Heart Rate Variability and Prognosis in Patients Undergoing Percutaneous Coronary Intervention: Postprint

Authors: Zhang Di, Li Hongpeng, Ma Jiang, Nie Qian, Sun Jianfeng, Wu Zhipeng, Zhang Hongcai, Zhao Jue, Zhang Di

Date: 2023-04-03T11:24:38+00:00

Abstract

Background: Heart rate variability (HRV) is a known non-invasive indicator for evaluating cardiac autonomic nervous function and is commonly used to assess the short-term prognosis of coronary artery disease. Percutaneous coronary intervention (PCI) is a commonly employed surgical procedure for coronary artery lesions; however, major adverse cardiovascular events (MACE) such as malignant arrhythmias and recurrent myocardial infarction frequently occur postoperatively. Although dual antiplatelet therapy (DAPT) can reduce the incidence of MACE to a certain extent, it is prone to gastrointestinal bleeding complications and cannot continuously and effectively improve PCI prognosis. Eye acupuncture can effectively reduce the duration and frequency of chest pain, while exercise therapy can enhance cardiac and vascular function; nevertheless, the application of combined eye acupuncture with needle-retained exercise following PCI remains to be explored. Objective: To investigate the effects of eye acupuncture with needle-retained exercise on heart rate variability and prognosis in CHD patients after PCI. Methods: Thirty-two low- to medium-risk CHD patients following PCI who presented at the Affiliated Hospital of Chengdu University of Traditional Chinese Medicine between September 2021 and August 2022 were selected as study subjects. They were randomly assigned in a 1:1 allocation ratio to either the eye acupuncture with needle-retained exercise group or the medication group. The eye acupuncture with needle-retained exercise group received eye acupuncture with needle-retained exercise in addition to dual antiplatelet therapy, whereas the medication group received only dual antiplatelet therapy; all subjects in both groups completed the 2-week intervention. The following data were collected from patients: (1) Baseline indicators: including gender, age, height, weight, blood pressure, respiratory rate,

time interval since intervention, education level, occupation, severity of coronary artery disease, and number of underlying diseases. (2) Primary indicators: 24-hour ambulatory electrocardiography was employed to evaluate heart rate variability (HRV) within 24 hours after PCI and on the day of completion of the 2-week intervention. Recorded parameters included the standard deviation of all normal sinus RR intervals (SDNN), the standard deviation of the averages of RR intervals in 5-minute segments over 24 hours (SDANN), the average of the standard deviations of RR intervals in each 5-minute segment over 24 hours (SDNN index), the square root of the mean squared differences of successive RR intervals (rMSSD), the percentage of successive RR intervals differing by >50 ms (PNN50), high frequency (HF), low frequency (LF), and the low frequency/high frequency ratio (LF/HF). MACE was utilized to assess prognosis at 2, 4, and 8 weeks post-intervention. Cardiac or all-cause death, malignant arrhythmias such as ventricular tachycardia and ventricular fibrillation, severe heart failure, recurrent myocardial infarction, repeat PCI, chest pain, and other conditions were documented through telephone and outpatient consultations. (3) Secondary indicators: C-reactive protein (CRP), N-terminal pro-brain natriuretic peptide (NT-proBNP), creatine kinase-MB (CK-MB), and high-sensitivity troponin I (hs-TnI). (4) Safety indicators: occurrence of complications including subcutaneous hematoma, skin lesions, muscle soreness, respiratory abnormalities, and stroke after PCI. All outcome indicators were measured within 24 hours after PCI and on the day of completion of the 2-week intervention. Results: After 2 weeks of treatment, there were no statistically significant differences between the two groups in LF/HF, SDNN, SDANN, SDNN index, LF, HF, RMSSD, or PNN50 ($P>0.05$). There were statistically significant differences between the two groups in LF/HF, SDNN, and SDANN levels ($P<0.05$). After 2 weeks, CRP in the medication group was higher than that in the eye acupuncture with needle-retained exercise group ($P<0.05$); there were no statistically significant differences between the two groups in NT-proBNP, CK-MB, or hs-TnI ($P>0.05$). The incidence of MACE and adverse reaction rate in the eye acupuncture with needle-retained exercise group were lower than those in the medication group ($P<0.05$). Conclusion: Eye acupuncture with needle-retained exercise is more effective than medication in improving heart rate variability in CHD patients after PCI, with lower MACE incidence and better short-term postoperative prognosis.

Full Text

Effect of Ocular Acupuncture Combined with Exercise Therapy on Postoperative Heart Rate Variability and Prognosis in Patients Undergoing Percutaneous Coronary Intervention

ZHANG Di[1]*, LI Hongpeng[2], MA Jiang[3], NIE Qian[4], SUN Jianfeng[1], WU Zhipeng[1], ZHANG Hongcai[4], ZHAO Jue[4]

[1]Department of Rehabilitation, Hospital of Chengdu University of Traditional Chinese Medicine, Chengdu 610072, China
[2]School of Medicine and Life Science, Chengdu University of Traditional Chinese Medicine, Chengdu 610075, China
[3]Rehabilitation Department, Southwest Hospital of Army Medical University, Chongqing 400038, China
[4]Department of Cardiology, Hospital of Chengdu University of Traditional Chinese Medicine, Chengdu 610072, China

Corresponding author: ZHANG Di, Attending Physician; E-mail: erinzd53@126.com

Funding: Sichuan Provincial Administration of Traditional Chinese Medicine Project (2020LC0081); Chengdu University of Traditional Chinese Medicine "Xinglin Scholar" Project (MPRC2021044); Hospital of Chengdu University of Traditional Chinese Medicine Research Project (20ZL02)

Abstract

Background: Heart rate variability (HRV) is a well-established non-invasive indicator of cardiac autonomic function commonly used to evaluate the short-term prognosis of coronary artery disease. Percutaneous coronary intervention (PCI) is a widely used surgical treatment for coronary artery disease; however, major adverse cardiovascular events (MACE) such as malignant arrhythmias and recurrent myocardial infarction frequently occur postoperatively. While dual antiplatelet therapy (DAPT) can reduce MACE to some extent, it is prone to gastrointestinal bleeding complications and cannot consistently improve long-term PCI outcomes. Ocular acupuncture effectively reduces the duration and frequency of chest pain, and exercise therapy enhances cardiac and vascular function. The application of combined ocular acupuncture and exercise therapy following PCI warrants further investigation.

Objective: To investigate the effect of ocular acupuncture combined with exercise therapy on HRV and prognosis in patients with coronary heart disease (CHD) after PCI.

Methods: Thirty-two moderate- to low-risk CHD patients who underwent PCI at the Hospital of Chengdu University of Traditional Chinese Medicine between September 2021 and August 2022 were enrolled. Participants were randomly assigned in a 1:1 ratio to either the ocular acupuncture with exercise group or the medication-only group. The ocular acupuncture with exercise group received combined therapy in addition to DAPT, while the medication group received DAPT alone. Both groups completed a 2-week intervention. Data collection included: (1) Baseline indicators: gender, age, height, weight, blood pressure, respiratory rate, interval between PCI and intervention, education level, occupation, coronary artery disease severity, and number of comorbidities. (2)

Primary indicators: HRV assessed via 24-hour Holter monitoring within 24 hours post-PCI and on the final day of the 2-week intervention, including standard deviation of all normal-to-normal RR intervals (SDNN), standard deviation of the average 5-minute RR intervals (SDANN), mean of the standard deviations of 5-minute RR intervals (SDNN index), root mean square of successive differences (rMSSD), percentage of adjacent RR intervals differing by >50 ms (pNN50), high frequency (HF), low frequency (LF), and LF/HF ratio. Prognosis was evaluated using MACE at 2, 4, and 8 weeks post-intervention, with cardiac or all-cause death, malignant arrhythmias (ventricular tachycardia/fibrillation), severe heart failure, recurrent myocardial infarction, repeat PCI, and chest pain recorded via telephone and outpatient follow-up. (3) Secondary indicators: C-reactive protein (CRP), N-terminal pro-B-type natriuretic peptide (NT-proBNP), creatine kinase-MB (CK-MB), and high-sensitivity troponin I (hs-TnI). (4) Safety indicators: post-PCI complications including subcutaneous hematoma, skin lesions, muscle soreness, respiratory abnormalities, and stroke. All outcome measures were assessed within 24 hours post-PCI and on the final day of the 2-week intervention.

Results: After 2 weeks, there were no significant differences between groups in LF/HF, SDNN, SDANN, SDNN index, LF, HF, rMSSD, or pNN50 ($P>0.05$). However, significant between-group differences were observed in LF/HF, SDNN, and SDANN levels ($P<0.05$). CRP levels were significantly lower in the ocular acupuncture with exercise group compared to the medication group ($P<0.05$), while NT-proBNP, CK-MB, and hs-TnI showed no significant differences ($P>0.05$). The ocular acupuncture with exercise group demonstrated significantly lower MACE incidence and adverse reaction rates compared to the medication group ($P<0.05$).

Conclusion: Ocular acupuncture combined with exercise therapy is more effective than medication alone in improving HRV, reducing MACE incidence, and enhancing short-term prognosis in CHD patients post-PCI.

Keywords: coronary disease; percutaneous coronary intervention; eye acupuncture therapy; ocular acupuncture combined with exercise therapy; heart rate variability; major adverse cardiovascular events; randomized controlled trial

Introduction

Coronary heart disease (CHD) remains the leading cause of cardiovascular mortality, posing a serious threat to public health [1]. The 2019 China Cardiovascular Health and Disease Report indicated a 1:30 ratio between CHD and overall cardiovascular disease patients in China [2]. Percutaneous coronary intervention (PCI) is an effective treatment for improving myocardial perfusion in CHD patients [3-6]; however, ischemia-reperfusion injury following PCI frequently leads to major adverse cardiovascular events (MACE) including malignant arrhythmias, recurrent myocardial infarction, repeat PCI, chest discomfort, and even

cardiac or all-cause death, resulting in poor prognosis [7-9].

Heart rate variability (HRV) serves as a non-invasive measure for evaluating cardiac autonomic function and is considered evidence of myocardial ischemia and arrhythmia [10-11]. Lower HRV indicates poorer prognosis [12]. Current standard post-PCI care involves dual antiplatelet therapy (DAPT) with aspirin and oral P2Y12 inhibitors to prevent thrombotic complications. However, premature discontinuation is associated with stent thrombosis and adverse outcomes including death [13], while long-term use increases bleeding risk without consistently improving PCI prognosis [14-15]. The optimal duration of postoperative pharmacotherapy remains controversial, necessitating better approaches to avoid stent thrombosis or bleeding events.

Ocular acupuncture combined with exercise therapy represents an emerging integrative rehabilitation approach. Ocular acupuncture is a micro-needle technique based on the "Eight Region Theory" of Traditional Chinese Medicine (TCM) meridian theory, involving needle insertion around the orbital margin to unblock meridians, activate blood circulation, relieve pain, and regulate organ function [16-17]. According to TCM meridian theory, periorbital tissues are closely related to organ function [18-19], and ocular acupuncture at the "upper jiao region" and "heart region" can effectively reduce angina duration and frequency in CHD patients [20]. Exercise therapy enhances cardiac and vascular function, reduces MACE incidence [21-27], and improves muscle strength, endurance, balance, coordination, and quality of life, earning Class I recommendation from the American Heart Association and European Society of Cardiology for cardiac rehabilitation [28-29].

Currently, ocular acupuncture with exercise is primarily applied in post-stroke rehabilitation and was promoted nationally by the State Administration of Traditional Chinese Medicine in 2018 as an appropriate TCM technique. However, its application in other domains requires further exploration. Based on these foundations, our research team conducted a randomized controlled trial to investigate the effects of ocular acupuncture combined with exercise therapy on HRV and prognosis in CHD patients post-PCI, aiming to develop a more effective and safer treatment to reduce MACE and complications while expanding cardiac rehabilitation options.

Methods

Study Population

We enrolled 32 moderate- to low-risk CHD patients who underwent PCI at the Hospital of Chengdu University of Traditional Chinese Medicine between September 2021 and August 2022. Inclusion criteria were: (1) confirmed diagnosis of stable angina, non-ST-elevation myocardial infarction, or ST-elevation myocardial infarction [30]; (2) age 45-80 years; (3) moderate- to low-risk status

post-PCI (risk stratification criteria in); (4) stable vital signs within 24 hours post-PCI. Exclusion criteria included: (1) unstable vital signs; (2) severe complications such as malignant tumors, heart failure, respiratory failure, or shock; (3) cognitive impairment or severe hearing/visual deficits; (4) severe hepatic, renal, or immune dysfunction; (5) pregnancy or lactation; (6) contraindications to acupuncture; (7) other conditions deemed unsuitable for exercise. All participants provided informed consent prior to enrollment.

Trial Design

This study employed computer-generated randomization with a 1:1 allocation ratio to assign participants to either the ocular acupuncture with exercise group (n=16) or the medication-only group (n=16). The study was approved by the Hospital Ethics Committee of Chengdu University of Traditional Chinese Medicine in July 2021 (2021KL-028) and registered with the Chinese Clinical Trial Registry (ChiCTR2100048960) in July 2021. The protocol followed the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines [31], and results were reported according to the Consolidated Standards of Reporting Trials (CONSORT) statement [32].

Randomization and Blinding

We used dynamic block randomization with web-based applications. Applicants sent a text message containing the participant's name initials, gender abbreviations, and birth date to the central randomization system, which automatically generated a random number and group assignment. Blinding was maintained through triple separation of researchers, operators, and statisticians. Researchers remained unaware of individual treatment assignments; operators implemented treatments according to the central randomization system; participants were unaware of treatment options; and statisticians were blinded to group allocation and treatment details throughout data collection and analysis. A separate investigator managed group allocation, stored the assignment scheme on a password-protected computer, and disclosed it only after treatment completion.

Interventions

Medication Group: Participants received standard perioperative and postoperative antiplatelet and anticoagulation therapy for 2 weeks according to the 2016 Chinese PCI Guidelines [33]. Baseline medications included: (1) Aspirin enteric-coated tablets: 100-300 mg orally 6 hours preoperatively, then 100 mg/d for 2 weeks postoperatively; (2) Clopidogrel bisulfate tablets: 300-600 mg orally >6 hours preoperatively, an additional 600 mg at 2-6 hours preoperatively, then 75 mg/d for 2 weeks postoperatively. Under guidance from cardiology specialists, additional antihypertensive, lipid-lowering, or glucose-lowering medications were administered as needed, with continued follow-up care after study completion.

Ocular Acupuncture with Exercise Group: In addition to the medication regimen, this group received 24-hour cardiac monitoring followed by a 2-week ocular acupuncture with exercise therapy protocol. Following the National Standard of the People's Republic of China for ocular acupuncture [34], specialized ocular acupuncture needles were inserted 2 mm outside the orbital margin at specific points: "upper jiao region" (ACU1) and "heart region" (ACU2) [Figure 1: see original paper]. The operator fixed the periorbital skin with the pressing hand, grasped the needle handle with forceps using the puncturing hand, and inserted the needle at approximately 15° along the skin from the acupoint origin to endpoint, reaching 5-8 mm into the dermal and subcutaneous tissue without deeper insertion. The needle handle was pressed to obtain "deqi" sensation and secured with adhesive tape. Exercise therapy commenced immediately, consisting of warm-up training, exercise training (aerobic, resistance, and flexibility exercises), and cool-down training, with detailed protocols in . After 60 minutes of exercise, needles were removed by gently rotating the handle with forceps and slowly withdrawing. The needle hole was pressed with a dry cotton ball for >30 seconds. Treatment was administered once daily for 60 minutes, 5 days per week for 2 weeks, with 2 rest days between weeks. Exercise intensity was adjusted in real-time based on patient sweating, respiration, pulse, and blood pressure responses.

Outcome Measures

Baseline Indicators: Gender, age, height, weight, blood pressure, respiratory rate, interval between PCI and intervention, education level, occupation, coronary artery disease severity, and number of comorbidities.

Primary Indicators: HRV was assessed using 24-hour Holter monitoring within 24 hours post-PCI and on the final intervention day. Parameters included: SDNN, SDANN, SDNN index, rMSSD, pNN50, HF, LF, and LF/HF ratio to evaluate cardiac autonomic function and post-PCI prognosis. MACE was assessed at 2, 4, and 8 weeks post-intervention via telephone and outpatient follow-up, recording cardiac or all-cause death, malignant arrhythmias (ventricular tachycardia/fibrillation), severe heart failure, recurrent myocardial infarction, repeat PCI, and chest pain.

Secondary Indicators: Fasting blood samples collected within 24 hours post-PCI and on the morning after intervention completion were analyzed for CRP, NT-proBNP, CK-MB, and hs-TnI to assess myocardial function.

Safety Indicators: Post-PCI complications including subcutaneous hematoma, skin lesions, muscle soreness, respiratory abnormalities, and stroke.

Statistical Analysis

One researcher collected all data using case report forms and recorded it in a dedicated Excel database, which was double-checked by a second researcher.

Paper and electronic data were stored at the Hospital of Chengdu University of Traditional Chinese Medicine and an independent network drive for ten years. Statistical analysis was performed using SPSS 23.0 software. Continuous variables were expressed as mean ± standard deviation ($\bar{x}\pm s$) and compared between groups using independent t-tests. Categorical variables were expressed as frequencies and compared using ^{2} tests. Multiple linear regression was used to explore correlations between MACE and HRV parameters. Mean differences or odds ratios with 95% confidence intervals were calculated. $P<0.05$ was considered statistically significant.

Results

Baseline Characteristics

Baseline data showed no significant differences between the two groups ($P>0.05$,).

HRV Comparison

At baseline, no significant differences existed between groups in SDNN, SDANN, SDNN index, rMSSD, pNN50, HF, LF, or LF/HF ($P>0.05$). After 2 weeks of treatment, there were no significant differences between groups in LF/HF, SDNN, SDANN, SDNN index, LF, HF, rMSSD, or pNN50 ($P>0.05$). However, significant between-group differences were observed in LF/HF, SDNN, and SDANN levels ($P<0.05$) .

Myocardial Function Comparison

Baseline levels of CRP, NT-proBNP, CK-MB, and hs-TnI showed no significant differences between groups ($P>0.05$). After 2 weeks, CRP levels were significantly higher in the medication group compared to the ocular acupuncture with exercise group ($P<0.05$), while NT-proBNP, CK-MB, and hs-TnI showed no significant differences ($P>0.05$) .

MACE and Adverse Event Rates

The ocular acupuncture with exercise group experienced 4 MACE cases: 2 cases of chest pain (at 2 weeks) and 2 cases of acute heart failure (at 4-week follow-up), plus 1 case of periorbital subcutaneous hematoma. The medication group experienced 12 MACE cases: 6 cases of chronic heart failure (2 at 2 weeks, 2 at 4 weeks), 5 cases of palpitations, 1 case of acute heart failure resulting in death (at 8-week follow-up), plus adverse reactions including abdominal distension, melena, nausea, and pulmonary infection (2 cases each). The ocular acupuncture with exercise group demonstrated significantly lower MACE incidence (25%) ($^2=2.41$, $P=0.016$) and adverse reaction rate (12.5%) ($^2=2.08$, $P=0.038$) compared to the medication group.

Correlation Between MACE Incidence and HRV

Binary logistic regression analysis with MACE incidence as the dependent variable and HRV parameters as independent variables revealed statistically significant effects: SDNN (B=-0.019, t=-3.72, P=0.002), SDANN (B=-0.019, t=-3.553, P=0.003), and LF/HF (B=-0.869, t=-2.225, P=0.043). SDNN (β=-0.705), SDANN (β=-0.689), and LF/HF (β=-0.511) were negatively correlated with MACE incidence .

Discussion

In the United States, approximately 60% of patients undergo post-PCI rehabilitation [35], with established efficacy and safety [36-38]. However, post-PCI rehabilitation in China remains in its infancy, with high rates of complications including acute coronary occlusion, no-reflow phenomenon, coronary perforation, stent thrombosis, stent dislodgement, bleeding, death, and stroke, making post-PCI rehabilitation imperative.

The ocular acupuncture with exercise therapy used in this study combines two components. Ocular acupuncture, developed by renowned acupuncturist Professor Peng Jingshan of Liaoning University of Traditional Chinese Medicine, is based on ancient Five-Ring and Eight-Region theories. It involves needling eight regions and thirteen points around the eyes to regulate organ function and meridian balance. According to TCM theory, "eye collaterals connect to the brain and regulate organs," and the *Taiping Huimin Heji Jufang* documents that "the eye has five rings corresponding to the five organs," illustrating the eye-organ relationship and TCM's holistic perspective. The *Longshu Pusa Yan Lun* Eight-Region theory states that "human eyes are like the two luminaries of heaven, the body's supreme treasure, gathering the essence of the five organs," reflecting TCM's holistic and syndrome-differentiation approach [39]. Exercise therapy emphasizes combining passive and active training to regulate neural activity, improve vascular endothelial function, enhance aerobic metabolism, increase exercise tolerance and cardiopulmonary function [40], improve muscle strength and proprioception, increase joint range of motion and stability, and promote motor and nerve repair [41-42], thereby reducing cardiovascular disease incidence. This core modern rehabilitation approach is widely used in musculoskeletal, endocrine, cardiovascular, cerebrovascular, and nervous system disorders.

Currently, ocular acupuncture with exercise is primarily used for post-stroke rehabilitation and various pain conditions. Our research team was inspired to explore its application in other fields through preliminary literature review. TCM meridian theory states that the Hand Shaoyin Heart Meridian connects to the heart system and belongs to the heart, while the heart system connects to the pericardium. The Hand Jueyin Pericardium Meridian can treat heart pain and restlessness, and the Hand Shaoyin Heart Meridian can also treat pericardium-

related disorders through the heart system. Branches, collaterals, and divergent meridians of the Hand Shaoyin Heart Meridian all reach the eye region, providing theoretical basis for treating heart-related conditions like restlessness, heart pain, diaphragm discomfort, syncope, jaundice, hypochondriac pain, and insomnia using periorbital acupoints. Liu et al. [43] used ocular acupuncture at the "heart region" and "upper jiao region" to significantly reduce angina duration, frequency, and blood TNF-α and CRP levels in CHD patients, achieving notable clinical efficacy. For arrhythmia treatment, ocular acupuncture can regulate heart rhythm within short periods with significant effects and low recurrence rates [44], confirming its therapeutic role in heart-related organ diseases. Exercise training upregulates cardioprotective factors (growth differentiation factor-15) and vascular endothelial nitric oxide synthase expression, increasing coronary endothelial nitric oxide levels, improving coronary endothelium-dependent vasodilation, regulating vascular tone, reducing peripheral vascular resistance, improving large artery compliance, relieving microvascular spasm, and slowing or inhibiting atherosclerosis progression to prevent CHD development [27,45-46]. Additionally, exercise training improves autonomic function, increases maximal oxygen uptake, reduces myocardial oxidative stress, prevents abnormal extracellular matrix collagen degradation and fibrosis, regulates myocardial contractility and tissue perfusion, and reduces rates of cardiac death, myocardial infarction, post-angioplasty angina, and restenosis, thereby preventing or even reversing myocardial remodeling while improving muscle strength, endurance, balance, coordination, quality of life, and long-term PCI rehabilitation outcomes [47-48]. Consequently, both the American and European cardiac societies recommend exercise therapy as Class I evidence for cardiac rehabilitation.

Our study found that after 2 weeks of intervention, the ocular acupuncture with exercise group showed increased HRV parameters (except HF) approaching normal ranges, while the medication group showed slight HRV decreases. Significant between-group differences in sympathetic function indicators (SDNN, SDANN) and autonomic balance (LF/HF) ($P<0.05$) were observed. The ocular acupuncture with exercise group demonstrated significantly lower MACE incidence (25%) compared to the medication group ($P<0.05$). Binary logistic regression revealed negative correlations between MACE incidence and SDNN, SDANN, and LF/HF ($P<0.05$). These findings indicate that ocular acupuncture with exercise is superior to medication alone in reducing post-PCI MACE incidence and improving prognosis, primarily by reducing sympathetic activity and promoting autonomic balance to regulate HRV.

HRV parameters, including frequency-domain measures (LF, HF, LF/HF) and time-domain measures (SDNN, SDANN, SDNN index, rMSSD, pNN50), reflect cardiac autonomic activity. SDNN, SDANN, and SDNN index are important sympathetic activity indicators; reductions primarily reflect increased sympathetic activity. RMSSD, pNN50, and HF primarily reflect vagal activity; decreases represent reduced vagal activity. LF is sensitive to both sympathetic and vagal activity, while LF/HF reflects sympathetic/vagal balance. Myocardial ischemia causes cardiac autonomic dysfunction with excessive sympathetic

excitation and significantly reduced vagal activity, leading to decreased HRV [49-50]. Standard post-PCI DAPT can increase HRV, particularly sympathetic function parameters like SDNN, SDANN, SDNN index, and LF [51-53], which are protective factors against MACE and reflect short-term post-PCI prognosis [54]. Although HRV significantly increases at 24 hours and 6 months post-PCI, with higher values at 6 months than at 24 hours [52], early transient autonomic dysfunction due to endothelial cell injury, thromboembolism, and PCI-induced inflammatory reactions causes a temporary HRV decline during the first postoperative week [55-56]. Our study found subnormal HRV parameters at baseline (within 24 hours post-PCI), indicating persistent sympathetic dominance and parasympathetic deficiency. After ocular acupuncture with exercise, increases in SDNN, SDANN, SDNN index, rMSSD, pNN50, LF, and LF/HF, along with decreased HF, and significant between-group differences in SDNN, SDANN, and LF/HF, demonstrate that ocular acupuncture with exercise more effectively influences autonomic activity than medication alone, significantly reducing MACE risk and sympathetic activity.

Beyond HRV effects, our study found that ocular acupuncture with exercise reduced elevated myocardial function marker levels, improving myocardial function to some degree. However, compared with medication, only CRP showed significant improvement ($P<0.05$), with no statistically significant differences in CK-MB, hs-TnI, or NT-proBNP ($P>0.05$). This may reflect different pathophysiological significance among cardiac markers. CK-MB, composed primarily of myocardial cells, rises 3-6 hours after acute myocardial infarction, peaks at 12-24 hours, and normalizes within 2-3 days, serving as the "gold standard" for diagnosing acute myocardial infarction. hs-TnI exists as a complex in myocardial cytoplasm; when myocardial injury occurs, hs-TnI dissociates and releases into the bloodstream [57], sensitively reflecting minor myocardial cell damage and serving as a crucial diagnostic criterion for myocardial tissue injury [58], recommended by European and American cardiovascular societies as the preferred cardiac injury marker [59-60]. NT-proBNP is synthesized and released in greater amounts with increased ventricular volume or pressure load, primarily used for diagnosing acute and chronic heart failure, playing an irreplaceable role in diagnosis, treatment, and efficacy assessment [61-62]. CRP is a myocardial cell injury marker [63-64] synthesized by hepatocytes during inflammation (such as microbial invasion or tissue injury) [65], closely related to acute-phase cardiovascular endothelial cell injury and serving as an independent and powerful predictor of cardiovascular events [66-68]. CRP begins rising within hours of inflammatory stimulation and normalizes as lesions resolve and tissue structure and function recover [69]. Studies show that significantly elevated CRP levels in post-PCI angina patients closely correlate with inflammatory response severity [70]. Based on these marker characteristics and our findings, ocular acupuncture with exercise demonstrates stronger anti-inflammatory effects than medication, effectively promoting myocardial injury repair and reducing ventricular volume/pressure load, with efficacy comparable to medication.

Although our study confirms that ocular acupuncture with exercise more effec-

tively regulates HRV and reduces MACE incidence with better prognosis than DAPT alone, several limitations exist. As a randomized controlled trial focusing on CHD patients undergoing PCI (including unstable angina, ST-elevation myocardial infarction, and non-ST-elevation myocardial infarction), the acute nature of included conditions precluded preoperative 24-hour Holter monitoring in most patients, particularly those undergoing emergency PCI. Therefore, we only compared post-PCI HRV parameters, MACE incidence, cardiac function markers, and adverse reactions between groups; differences between pre- and post-PCI treatment effects remain unclear. Future studies with stricter inclusion criteria recruiting elective PCI patients could address this gap. Additionally, although between-group CRP differences confirm the anti-inflammatory efficacy of ocular acupuncture with exercise, negative findings regarding myocardial injury repair and ventricular load reduction warrant attention. With increased sample sizes, these negative conclusions may change. Future research incorporating Doppler echocardiography, cardiac PET-CT, or cardiac MRI could provide more intuitive myocardial function indicators. Furthermore, our sample size limited correlation analysis to binary logistic regression; future studies with larger samples could employ multiple logistic regression to identify the most critical HRV parameters for MACE risk and further explore mechanisms underlying ocular acupuncture with exercise effects on autonomic function and myocardial function.

Conclusion

Ocular acupuncture combined with exercise therapy is more effective than dual antiplatelet therapy alone in regulating HRV, reducing MACE incidence, and improving prognosis in CHD patients post-PCI. These advantages relate to inhibiting sympathetic activity, enhancing vagal tone, maintaining autonomic balance, reducing myocardial inflammation, and promoting myocardial cell repair and functional improvement.

Author Contributions: ZHANG Di conceived the research direction, wrote the initial draft, and was responsible for quality control and final approval of the manuscript. LI Hongpeng and MA Jiang collected and organized case data. NIE Qian and SUN Jianfeng were responsible for patient diagnosis and treatment. WU Zhipeng performed statistical analysis. ZHANG Hongcai revised the manuscript. ZHAO Jue provided medication guidance and monitored vital signs. All authors approved the final manuscript.

Conflict of Interest: The authors declare no conflict of interest.

Date of Submission: November 16, 2022
Date of Revision: March 18, 2023

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Note: Figure translations are in progress. See original paper for figures.