Int J Clin Exp Med 2015;8(9):16463-16471
www.ijcem.com /ISSN:1940-5901/IJCEM0011198

Original Article

Effect of cardiac shock wave therapy on the microvolt T wave alternans of patients with coronary artery disease

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Received June 8, 2015; Accepted July 28, 2015; Epub September 15, 2015; Published September 30, 2015

Abstract: Objective: The aim of this study was to evaluate the effect of cardiac shock wave therapy (CSWT) on microvolt T wave alternans (MTWA) in patients with coronary artery disease (CAD). Methods: 87 patients with old myocardial infarction (OMI) were enrolled in this study. Sixty-two patients were randomized into the CSWT group, 32 patients into the regular treatment group (Group A) according to different shock wave procedure, and 30 into the expanding scope treatment group (Group B), and 25 patients were randomized into the control group (Group C). But the shock wave (SW) energy was only applied to the patients in the CSWT group and not to the patients in the control group. Three months was a treatment course, thus patients received a total of 9 CSWT treatment sessions. Results: Technetium-99m sestamibi myocardial perfusion, fluorine-18 fluorodeoxyglucose myocardial metabolism single-photon emission computed tomography (SPECT) were performed to identify segments of myocardial ischemia, myocardial viability, and microvolt T wave alternans (MTWA) before and after CSWT. After CSWT, the rehospitalization rates of CSWT group were lower than control group (P<0.05). The myocardial ischemic segments, metabolism abnormal segments, total radioactive score of perfusion imaging and metabolism imaging, MTWA, and MTWA/HR in CSWT group were reduced significantly (P<0.05). And the heart rate of maximum MTWA, exercise time were increased significantly (P<0.05). All of the parameters in the control group did not change significantly even worsen after the treatment (P>0.05). Conclusions: CSWT can reduce the MTWA value, improve the heart chronotropic function and increase the threshold of frequency which causes MTWA.

Keywords: Cardiac shock wave therapy, coronary artery disease, microvolt T wave alternans

Introduction

T wave alternans (TWA) refers to the occurrence of sinus rhythm, alternating changes beat to beat of the amplitude, morphology and even polarity of T wave on electrocardiogram (ECG), it is a sign of unstable cardiac electrical activity, it is a expression of non-uniform of ventricular repolarization, and it is easy to form unidirectional block and impulse reentry, and induce rapid ventricular arrhythmia. However, the T wave alternans which can be seen on the electrocardiogram is very rare. In recent years, with the development of advanced signal processing techniques, we can test microvolt T wave alternans (MTWA) in the normal exercise testing, MTWA which refers to the TWA which cannot be recorded by the normal ECG, unless through special ECG signal processing technique. Studies have shown that MTWA is an independent predictor of rapid ventricular arrhythmia and sudden cardiac death (SCD) [1-5]. Coronary artery disease (CAD) patients are the high-risk group of rapid ventricular arrhythmia and SCD, MTWA have significant value of prognosis assessment for CAD patients.

Extracorporal cardiac shock wave therapy (CSWT) is a non-invasive, safe, effective and new treatment for CAD [6-11], research in China and abroad showed that low-energy pulse waves produced by CSWT could induce a "cavitation effect" (micrometer-sized violent collapse of bubbles within and outside cells), which could exert a mechanical shear force on the myocardial tissue and vascular endothelial cell membranes [6, 9]. The CSWT was able to promote angiogenesis in ischemic myocardium, improve myocardial perfusion, and increase capillary density (about 10% of energy density

Table 1. Comparison of baseline characteristics of patients in three groups

Basic information	Group A (n = 32)	Group B (n = 30)	Control group (n = 25)	*P* value
Age (years)	68.31±8.72	65.67±8.33	66.24±8.14	NS
Male/female, n (%)	24 (75.0)	24 (80.0)	20 (80.0)	NS
	/8 (25.0)	/8 (25.0)	/5 (20.0)	NS
Time since last MI (years)	6.0 (5.0, 10.0)[a]	6.5 (5.0, 10.5)[a]	5.0 (4.5, 10.0)[a]	NS
History of smoking, n (%)	11 (34.4)	8 (26.7)	7 (28.0)	NS
BMI (kg/m^2)	23.49±1.53	24.04±2.00	23.01±1.65	NS
Hypertension, n (%)	21 (65.6)	18 (60.0)	16 (64.0)	NS
Diabetes, n (%)	13 (40.6)	15 (50.0)	11 (44.0)	NS
Hypercholesterolemia, n (%)	17 (53.1)	15 (50.0)	13 (52.0)	NS
Site of MI, n (%)				NS
Anterior wall	17 (53.1)	14 (46.7)	11 (44.0)	
Inferior wall	10 (31.3)	8 (26.7)	9 (36.0)	
Anterior + Inferior wall	2 (6.3)	3 (10.0)	2 (8.0)	
Anterior + strictly posterior wall	1 (3.1)	3 (10.0)	2 (8.0)	
Lateral wall	2 (6.3)	2 (6.7)	1 (4.0)	
NYHA class, n (%)				NS
Class I	4 (12.5)	6 (20.0)	5 (20.0)	
Class II	17 (53.1)	14 (46.7)	11 (44.0)	
Class III	11 (34.4)	10 (33.3)	9 (36.0)	
CCS angina scale, n (%)				
Class II	13 (40.6)	11 (36.7)	11 (44.0)	
Class III	19 (59.4)	19 (63.3)	14 (56.0)	
Standard medication for CHD				
AP [n (%)]	13 (40.6)	10 (33.3)	11 (44.0)	NS
ACEI/ARB [n (%)]	20 (62.5)	22 (73.3)	15 (60.0)	NS
ASP [n (%)]	24 (75.0)	18 (60.0)	19 (76.0)	NS
BB [n (%)]	23 (71.9)	24 (80.0)	17 (68.0)	NS
CCB [n (%)]	17 (53.1)	14 (46.7)	14 (56.0)	NS
S [n (%)]	22 (68.8)	19 (63.3)	17 (68.0)	NS
N [n (%)]	24 (75.0)	22 (73.3)	19 (76.0)	NS
D [n (%)]	12 (37.5)	9 (30.0)	10 (40.0)	NS

Note: BMI, Body Mass Index; NYHA, New York Heart Association; CCS, Canadian Cardiovascular Society; CHD, coronary heart disease; AP, antiplatelet agents; ACEI, angiotensin converting enzyme inhibitors; ARB, Angiotensin II receptor blockers; ASP, aspinrin; BB, β-blockers; CCB, calcium channel blockers; S, statins; N, Nitrate esters; [a]Median (Quartile), NS: $P>0.05$.

that used for urolithiasis) and accelerated the establishment of collateral circulation, thus improved myocardial ischemia by upregulating vascular endothelial growth factor (VEGF) and its receptor fms-like tyrosine 1 [7]. It is the third “Sword” of CAD treatment. The study reported the effect of CSWT on the MTWA of CAD patients for the first time.

Materials and methods

Object

The study enrolled 87 patients had been suffered from old MI, 68 males, 19 females, age from 43-80 (mean age was 66.80±8.41) with medical history 1-15 years. All of the enrolled patients had been admitted at our institute, department of Cardiology, the First Affiliated Hospital of Kunming Medical University from October 2008 to January 2011. Using randomized single-blind method according to random number table of patients entering the study, 62 patients were divided in the CSWT group, including 48 males, 14 females, age from 43-80 (mean age was 67.03±8.57), and divided 32 cases, including 24 males, 8 females, age from 47-80 (mean age was 68.31±8.72) into the regular treatment group (Group A, 9 spots treatment of each ischemia target region)

Table 2. Comparison of myocardial perfusion and metabolism of different time point before (pre) and after (post) treatment in three groups

Group	Time point	Ischemic segments	Abnormal metabolic segments	Total score of myocardial perfusion	Total score of myocardial metabolism
Group A	0 month	289 (53%)	243 (45%)	35.03±4.81	30.22±4.38
	3 month	245 (45%)*	172 (32%)*	30.09±3.79*	25.56±2.74*
(n = 32) (544 segments)	6 month	211 (39%)*,Δ	139 (26%)*,Δ	27.31±3.27*,Δ	23.53±2.69*,Δ
(n = 30) (510 segments)	12 month	199 (39%)*,Δ	132 (25%)*,Δ	26.53±3.32*,Δ	23.09±2.60*,Δ
Group B	0 month	242 (47%)	204 (40%)	32.63±5.49	28.60±4.22
(n = 30) (510 segments)	3 month	173 (34%)*,#	133 (26%)*,#	27.60±4.05*,#	23.97±3.09*,#
	6 month	136 (27%)*,Δ,#	92 (18%)*,Δ,#	24.23±2.64*,Δ,#	21.47±2.01*,Δ,#
	12 month	127 (25%)*,Δ,#	82 (16%)*,Δ,#	22.90±2.41*,Δ,#	20.67±1.75*,Δ,#
Group C	0 month	198 (47%)	160 (38%)	32.52±5.83	28.36±4.33
(n = 25) (425 segments)	3 month	222 (52%)	190 (45%)	33.80±5.80	29.64±4.82
(n = 24) (408 segments)	6 month	219 (54%)	186 (46%)	34.52±6.07	29.72±5.22
(n = 22) (374 segments)	12 month	214 (57%)*	183 (50%)*	37.08±5.18*	32.20±4.81*

Note: Comparison of 0 month within group, *P<0.05; comparison of 3 month within group, $^{\Delta}P$<0.05; compared with same time point of Group A, $^{\#}P$<0.05.

Table 3. Comparison of MTWA of different time point before (pre) and after (post) treatment in three groups

Group	Time point	Time of exercise (s)	HR (bpm)	MTWA (μV)	MTWA/HR
A	0 month	343.91±85.03	101.91±10.16	32.50 (22.25, 47.25)	0.32 (0.19, 0.48)
	3 month	438.81±78.68*	106.13±8.44*	25.00 (18.25, 37.25)*	0.25 (0.17, 0.37)*
	6 month	489.44±72.18*,Δ	108.09±7.28*	23.00 (16.25, 34.25)*	0.22 (0.15, 0.32)*
	12 month	558.41±67.67*,Δ,#	109.19±6.80*	20.00 (15.25, 30.25)	0.19 (0.14, 0.28)*
B	0 month	360.50±82.34	101.37±9.24	30.50 (24.50, 49.00)	0.30 (0.23, 0.52)
	3 month	469.13±94.28*	108.03±7.56*	23.50 (17.75, 39.25)*	0.22 (0.16, 0.38)*
	6 month	524.77±88.39*,Δ	110.10±6.69*	19.50 (15.75, 35.00)*	0.18 (0.14, 0.33)*
	12 month	576.73±89.80*,Δ,#	111.20±6.08*	18.00 (13.75, 30.75)*	0.16 (0.12, 0.29)*
C	0 month	351.64±94.42	103.16±10.02	35.00 (26.00, 47.50)	0.32 (0.23, 0.50)
	3 month	382.48±91.65	99.92±9.24	33.00 (23.00, 48.00)	0.32 (0.21, 0.53)
	6 month	363.16±95.48	101.84±9.20	33.00 (25.00, 49.00)	0.31 (0.23, 0.54)
	12 month	342.32±99.28	99.48±8.56	38.00 (29.50, 53.50)	0.35 (0.28, 0.59)

Note: Comparison of 0 month within group, *P<0.05, comparison of 3 month within group, $^{\Delta}P$<0.05, comparison of 6 month within group, $^{\#}P$<0.05.

according to different shock wave procedures, the rest 30 patients, including 24 males, 6 females, age from 43-79 (mean age was 65.67±8.33) into the expanding scope treatment group (Group B, 25 spots treatment of each ischemia target region), and 25 patients were divided into the control group (Group C, treated with the same procedures of 9 spots treatment of each ischemia target region but without the shock wave energy), including 20 males, 5 females, age from 48-79 (mean age was 66.24±8.14). Comparing age, gender, medical history of patients in three groups, the differences were no statistical significance (basic information of patients see **Table 1**). This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Kunming Medical University. Written informed consent was obtained from all participants.

Inclusion criteria

Related check-up, such as medical history inquiry, physical examination, ECG, markers of myocardial necrosis, at least once definite diagnosed as acute myocardial infarction (AMI), and course of myocardial infarction ≥3 months. AMI diagnostic criteria refer to the related guideline of Chinese Medical Association in 2010 [12].

All patients without coronary revascularization treatment indications, coronary revascularization operation failed, and patients refused to accept surgery, such as this kind of reasons, they cannot access to nationally and internationally recognized coronary revascularization treatment, such as thrombolysis, percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG). Patients still with chest pain, chest tightness while accepting standard drug therapy, poor exercise endurance and hospitalized with symptoms related to myocardial ischemia more than 3 times within 1 year.

Class II or above grading of angina pectoris by the Canadian Cardiovascular Society (CCS) Classification System. Class I to III, New York Heart Association (NYHA) classification of cardiac function. Sinus rhythm and heart rate between 40-120 bpm.

Exclusion criteria

Exclusion of AMI within 3 months; 2) underwent surgery of PCI or CABG; 3) underwent heart transplant surgery; 4) intracardiac thrombus; 5) atrial fibrillation; 6) Class IV, NYHA classification of cardiac function; 7) chronic obstructive pulmonary disease; 8) malignant tumor.

Identification of the myocardial ischemic and viable myocardium

Used Discovery VH Millennium SPECT of American General Electric Company (Discovery VH Millennium; General Electric, Fairfield, CT, USA), carried on 99mTc-MIBI and 18F-FDG myocardial SPECT image. Using the criteria recommend by American Heart Association (AHA), the left ventricle is divided into 17 segment, to analysis of myocardial perfusion and metabolism [13], to identify the myocardial viability. Isotope uptake of myocardial perfusion and metabolism were evaluated by semi-quantitative score index [14]: Normal = 1 point, sparse = 2 points, seriously sparse = 3 points, defect = 4 points. The criteria of SPECT to judge viable myocardium: uptake score 99mTc-MIBI and 18F-FDG ≤2 points, or uptake of 99mTc-MIBI sparse, however the score increased compare with 18F-FDG ≥1 point (myocardial perfusion seriously sparse or defect, but myocardial metabolism well, which means the perfusion and metabolism are mismatched). Non-viable myocardium: uptake of 99mTc-MIBI and 18F-FDG are severe sparse or defect, the score is 3 or 4 points. All radioactive scores of perfusion and metabolism imaging of 17 myocardial segments were added to obtain the total scores of perfusion and metabolic imaging of each patient, which reflected the level of myocardial perfusion and metabolism.

Time domain of MTWA

Used Marquette Case 8000 treadmill exercise analysis system of American GE Company (Marquette Case 8000, General Electric, USA) for testing which added T wave alternans analysis software in it. Adopted conventional 12 lead system, to get the 3 min supine ECG firstly, then carried exercise tolerance test using modified Bruce protocol to get the 3 min of seat ECG after the exercise, during the whole exercise tolerance test, MTWA analysis software processed the ECG signals for real time anti-baseline drift and signal filtering algorithm, automatically detect and exclude the interference of heart beats (ectopic beat and adjacent of heart beats), then made the average amount of correction gradually of ECG waveform, to carried on the dynamic time domain quantitative analysis of ST-T waveform area and calculated the value of T wave alternans [2].

CSWT

Based on the standard drug therapy and lifestyle intervention, to carried on the treatment by using the shock wave therapy system (Modulith SLC, Storz Medical, Taegerwilen, Switzerland), it was installed with a real-time ultrasound probe. Patients awake, rest quietly in the supine position, expose the chest, connected electrocardiogram monitoring, prepared the defibrillator and emergent medicine, to exactly located the target ischemic area by real-time ultrasound probe (99mTc-MIBI and 18F-FDG myocardial SPECT testing showed that there were viable myocardium of some myocardial ischemic segments), shock wave energy release relies on R wave triggered of real time surface ECG, to release during the absolute refractory period of electrical activity, wave energy was gradually increased, if the patients no chest pain or any other uncomfortable feels, can increase wave energy to 0.09 mJ/mm^2. The regular treatment group, 9 spots treatment of each ischemia target region (-1, 0, +1 pair combination), the expanding scope treatment group, 25 spots treatment of each ischemia target region (-2, -1, 0, +1, +2 pair combination), both of the two shock wave therapy scheme is the same, 200 shoots/spot, 3 times/week, the first, third and fifth day of first week of each month, 1 week treatment followed by three weeks rest, a course of 3 months, totally 9 times shock wave [9, 15, 16]. The control group, 9 spots treatment of each ischemia target region (-1, 0, +1 pair combination), treated with the same procedures but without the shock wave energy. During treatment, patients were closely monitored for vital signs and symptoms, found that any exceptions to be handled promptly. During followed-up, if the patient access to standard treatment of PCI/CABG, then quit from the study.

Follow-up

All of the objects of the study, during the 12-month follow-up, periodic telephone inquiries, out-patient follow-up and hospitalization were used. If the patient appear acute heart failure or the worsening of heart failure, angina pectoris happened frequently, myocardial infarction happened again, to assist by drug reinforcement, interventional therapy and other related interventions timely.

Statistical analysis

Using SPSS15.0 statistical analysis software, P<0.05 of all tests were considered to be statistically significant. Measurement data was expressed as mean ± standard deviation ($\overline{x}$±s), compared between groups within each subgroup were analyzed with ANOVA, pair comparison used Q value method to verify. Numeration data was expressed as ratio, comparison between groups use X^2 test, non-normal distribution data was expressed as median (quartile), compared between two groups used rank sum test, comparison between multiple groups use K-W test.

Results

Mortality rate, re-infarction rate and re-hospitalization rate

During the period while patients underwent CSWT treatment, no worsening of angina pectoris, no heart failure, no bleeding, no embolism, no malignant arrhythmias (such as ventricular tachycardia, ventricular fibrillation), no significant changes in blood pressure, heart rate and oxygen saturation. One patient with old extensive anterior wall MI in the regular treatment group (Group A) died from low potassium caused by acute diarrhea, then induced ventricular tachycardia, ventricular fibrillation at the 10-month follow-up. No death happened in the expanding scope treatment group (Group B). In the control group (Group C) one patient experienced a sudden cardiac death at the 10-month follow-up, caused by malignant ventricular arrhythmia (ventricular tachycardia, ventricular fibrillation), then cardiopulmonary arrest. One patient combined with diabetes repeatedly suffered from angina during the 5-month follow-up. The result of the coronary angiography indicated that there had the left trunk and three branch of coronary artery stenosis. The patient received the CABG. One patient experienced AMI at the 9-month follow-up, emergency treatment of CA + PCI, patients in Group A and B no re-infarction, compared the mortality and re-infarction rate of patients in three groups, the differences were no statistical significance (P>0.05). Totally, 26 patients re-hospitalized because of CAD during follow-up, 7 patients in Group A, 5 patients in Group B and 14 patients in Group C, compared the re-hospitalization rate between Group A and B, the differences were no statistical significance (P>0.05). However, the re-hospitalization rate of Group A, Group B and C, the differences have statistical significance (P<0.05).

Myocardial perfusion and metabolism

32 patients in the regular treatment group (Group A), totally 544 myocardial segments, 30 patients in the expanding scope treatment group (Group B), totally 510 myocardial segments, 25 patients in the control group (Group C), totally 425 myocardial segments. Pair comparison among three groups, myocardial ischemic segments, abnormal metabolic segments, total score of myocardial perfusion and metabolism in 0 month, the differences were no statistical significance (P>0.05). Followed-up to 3, 6, and 12 months, the above mentioned indicators of Group A and B significantly improved compared with data of 0 month (P<0.05) and the control group (P<0.05). Followed-up to 3, 6, and 12 months, compared at different time

points of same period with Group A, the above mentioned indicators of Group B improved (P<0.05). Followed-up to 0, 3, 6 and 12 months, pair comparison of the above mentioned indicator at different time points of Group C, except the indicators of 12 months were deteriorated compared with 0 month (P<0.05), compared the rest indicators, the differences were no statistical significance (P>0.05) (**Table 2**).

MTWA

Pair comparison of value of MTWA (μV), the frequency threshold means the heart rate of maximum MTWA (HR, bpm), exercise time (time, S), the ratio of MTWA and frequency threshold (MTWA/HR) in 0 month among three groups, the differences were no statistical significance (P>0.05). Followed-up to 3, 6, and 12 months, the above mentioned indicators of Group A and B significantly improved compared with data of 0 month (P<0.05) and same period of control group (P<0.05), the exercise time of patients increased constantly during the period of follow-up, pair comparison of patients in three groups at different time points, the differences have statistical significance (P<0.05), significantly increased in 12 month (P<0.05). However, compared with Group C, the above mentioned indicators of Group A and B in the same period improved significantly (P<0.05). Pair comparison of above mentioned indicators within Group C at different time points, the differences were no statistical significance (P>0.05) (**Table 3**).

Discussion

99mTc-MIBI and 18F-FDG myocardial SPECT to identify viable myocardium of patients after myocardial infarction have high specificity and sensitivity [17, 18]. 18F-FDG and 99mTc-MIBI myocardial SPECT reflects myocardial metabolism and blood perfusion respectively. When 99mTc-MIBI imaging shows reduction in perfused segments of blood flow, while the 18F-FDG imaging shows the corresponding segments have normal or relatively increased FDG uptake (perfusion and metabolism are mismatched), this indicates that the myocardium is ischemic but viable. On the contrary, in the segments with irreversible injury, both the blood flow perfusion and myocardial glucose utilization (FDG uptake reduced) are reduced simultaneously (per- fusion and metabolism are matched). This indicates that there is no survival of myocardial cells, but myocardial scarring and necrosis. If the radioactive distribution is uniform of blood perfusion and metabolism image, indicates it is normal [14].

In this study, it is the first time that the semi-quantitative evaluation of myocardial perfusion and metabolism based on 99mTc-MIBI and 18F-FDG dual-isotope SPECT imaging was used in all of the patients. We used the ischemic myocardial segments with some viability as the target area for the SW treatment in order to obtain the maximal efficacy of CSWT. The study showed that patients of Group A and B after CSWT treatment, the level of myocardial perfusion and metabolism in 3, 6, and 12 months improved significantly compared with patients in Group C. Patients in Group A and B, the level of myocardial perfusion and metabolism improved continuously after they received CSWT treatment, and the level of myocardial perfusion and metabolism in the 3-month follow-up was better than 0-month obviously (P<0.05), the level of myocardial perfusion and metabolism in 6-month follow-up was better than the 3-month follow-up obviously (P<0.05), and when follow-up to 12 months, the level of myocardial perfusion and metabolism was improved than 0, 3 month (P<0.05). It is showed that both of the two shock wave treatment scheme can improve the level of myocardial perfusion and metabolism effectively, and the effect can last at least 1 year. Followed-up to 3, 6, and 12 months, compared with the level of myocardial perfusion and metabolism of patients in Group A respectively, the level of myocardial perfusion and metabolism of patients in Group B improved significantly, the differences have statistical significance, it is showed that the expanding scope treatment group through expanding shock wave treatment of ischemia region and increasing wave energy per unit area (25 points ×200 shoots/spot = 5000 shoots), it can make more regeneration of capillary in the ischemia area, it was better to improve the myocardial perfusion and metabolism, the curative effect was better than the regular treatment group and can last at least 1 year. However, the level of myocardial perfusion and metabolism of the control group appeared the downward trend in a short time (within 6 months), but the differences were no statistical significance, inconsideration of the medication may have some influences on myocardial perfusion and metabolism in a short time, however, when follow-up to 12 month, myocardial perfusion and metabolism obviously reduced compared with 0 month (P<0.05), it is showed that compared with the patients who accepted shock wave energy treatment, the level of myocardial perfusion and metabolism of patients in control group appear the tendency of deterioration.

Study showed that MTWA occurred when myocardial ischemia and MTWA is an independent predictor of rapid ventricular arrhythmia and sudden cardiac death (SCD) [2-5], CAD patients are the high risk group of SCD. Myocardial ischemia in patients with coronary artery disease, the ventricular wall motion abnormality, myocardial fibrosis, sinus node dysfunction will cause chronotropic incompetence, expressed as cannot achieve the maximum heart rate (MHR) during the treadmill exercise test, and it was closely related with myocardial ischemia of coronary artery disease [19]. Myocardial ischemia of CAD patients influenced the function of ion channels of myocardial cell and the connection function of myocardium, it may cause the dropped of frequency threshold of TWA, suggested that CAD patients can detect TWA at a low heart rate. Therefore, the study tested the MTWA, frequency threshold (HR), MTWA/HR, time of exercise during the treadmill exercise stress test and it is the first time using the changes of above indicators before and after CSWT to evaluate exercise tolerance and malignant cardiac events and other prognosis.

Electrophysiological basis of TWA formed is that on the basis of transmural three myocardial layers repolarization formed T wave, appeared heterogeneity of inner, middle and outside three myocardial layers repolarization alternans, formed repolarization incomplete [Ca^{2+}] in the cell unable to complete the cycle, disrupt its steady-state led to calcium instant variable, and interference normal distribution of calcium ion, led to the action potential duration length alternation [19, 20]. Coupled with myocardial cell deficiency blood, conduction velocity of the action potential became slow, dispersion of refractory period increased, easy formed one-way block and reentry, laid a foundation for the occurrence of rapid ventricular arrhythmia. In addition, calcium influx increased through the cell membrane maybe the logic basis of TWA forming, activity of sympathetic nerve increased is the neural basis of TWA forming [21, 22]. The study showed patients of two shock wave treatment groups, MTWA value, HR, MTWA/HR, time of exercise after the shock wave treatment improved significantly compared with data pre-treatment, and the effect can last at least 1 year, and the time of exercise on different time points of Group A and B increased continuously, the differences have statistical significance, the above mentioned indicators improved related with the level of myocardial perfusion and the metabolism of patients post-treatment improved, thus improved the instability of electric activities of myocardial ischemia, reduced the myocardia dispersion of repolarization, increased the exercise physiology and tolerance of the patients at the same time. The above mentioned indicators of the control group not changed obviously in the follow-up, it is showed that the CAD patients who received the wave energy treatment, the probability of ventricular arrhythmia and SCD reduced significantly compared with the patients who have not accepted the wave energy treatment, the chronotropic response improved obviously, the frequency threshold which will cause TWA increased significantly, exercise tolerance increased significantly.

The result of study showed that during 12 months follow-up, patients in Group A and B no re-infarction. Compared the mortality and re-infarction rates among three groups, the differences were no statistical significance. This may have been due to the small sample size and the relatively short period of follow-up. A total of 26 patients suffered from rehospitalization due to myocardial ischemia related symptoms, 7 of them in Group A, 5 in Group B, 14 in the control group, compared the rehospitalization rates of Group A, Group B and Group C, the rehospitalization rates of Group A and B were lower than Group C, differences have statistical significance. It is showed that both of the two wave treatment scheme can improved the myocardial ischemia and related symptoms effectively, the rehospitalization rate reduced obviously, and patients who received wave energy treatment, the myocardial perfusion and the metabolism improved effectively, related symptoms of myocardial ischemia improved correspondingly, so that the rehospitalization rate significantly lower than the patients who have not accepted wave energy treatment.

In a word, although the study sample size was relatively small and the period of follow-up was relatively short, the results of our study showed that CSWT improved the myocardial perfusion and the metabolism of CAD patients, improved chronotropic response and increased the frequency threshold which will cause TWA and reduced the risk of sudden death of patients. CSWT is a non-invasive, safe, effective new therapeutic angiogenesis of coronary artery disease.

Disclosure of conflict of interest

None.

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