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Effect of Individualized Cardiac Rehabilitation on Cardiac Function, Time Consumption, and Quality of Life in Patients After CABG

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ABSTRACT

Background: To investigate the effect of individualized cardiac rehabilitation (CR) on cardiac function, time consumption, and quality of life (QoL) in post-CABG patients.

Methods: Two different CR strategy: basic rehabilitation and individualized rehabilitation was designed. The patients were screened and randomized into the two groups: the basic rehabilitation group (BRG) and individualized rehabilitation group (IRG). Data, such as clinical characteristics, LVEF, 6MWD (6-min walk distance), BNP, LVEDD (left ventricular end diastolic dimension), SF-36 score, and time consumption were collected and recorded.

Results: There was no difference between the IRG and BRG patients in the clinical characteristics. The 6MWD and LVEF on post-op significantly were higher, while BNP and LVEDD significantly was lower in the IRG than in BRG. The time to first out-of-bed activity, ICU stay time, and post-op hospital stay time of the IRG in post-op was significantly shorter than BRG. The IRG patients scored significantly higher on the SF-36.

Conclusion: Individualized CR is safe and can reduce the time consumption and improve the cardiac function and QoL of patients undergoing CABG.

INTRODUCTION

Coronary atherosclerotic heart disease (CHD) is a leading cause of mortality worldwide [Zhang 2020]. In China, the morbidity and mortality of CHD has continued rising [China 2020]. The ESC guidelines show that the high morbidity and mortality of CHD brings serious burden to society [Task Force 2013]. Coronary artery bypass grafting (CABG) is a major treatment method for patients with CHD [Abu Daya 2017]. Many complications, such as pain, atelectasis, delirium, anxiety and depression, were noted in patients after CABG. The complications may cause physical and psychological trauma, affect postoperative rehabilitation, and cause an economic burden to the family and society [Huang 2008; Simon 2018]. Therefore, improving quality of life (QoL) and promoting the rehabilitation of patients after CABG is very important.

Cardiac rehabilitation (CR) originated in the 1950s, aiming to improve function and reduce risk [Servey 2016]. CR is a comprehensive method that involves multiple therapies, with exercise training as the core part [Dibben 2021; Rauch 2016; Stefanakis 2021]. CR based on systematic evaluation is demonstrated to be safe [Dibben 2021]. Despite the fact that CR has received a lot of attention and is recommended, it has not been widely accepted and applied [Kotseva 2018]. In recent years, some studies on CR after CABG have been reported, but there still are some deficiencies in these studies, such as single exercise form, lack of individualized exercise program, etc. [Rengo 2021; Reer 2021]. In the present study, we formulated an individualized CR strategy and investigated the effect of individualized CR on cardiac function, time consumption, and QoL in patients after CABG.

MATERIALS AND METHODS

Patients: Study patients were diagnosed with CHD and scheduled for CABG in The Affiliated Changzhou Second People's Hospital of Nanjing Medical University between January 2018 and June 2021. All patients were screened based on established criteria. The inclusion criteria: 1. 18-70 years old; 2. cardiac function classification (NYHA): I-III; 3. no myocardial infarction occurred within one week; 4. no serious dysfunction of important organs, such as lung, liver, and kidney; 5. sound limb function; 6. voluntary participation. Exclusion criteria: 1. Patient also had another cardiac disease that required operation, such as valve lesions, macroangiopathy, ventricular aneurysm, etc; 2. emergency CABG or re-operation; 3. unstable angina pectoris; 4. The patient was unable or unwilling to cooperate.

Eighty patients were included in the study and randomly divided into two groups: the basic rehabilitation group (BRG) and individualized rehabilitation group (IRG). (Figure 1) The patients in different groups were placed in different wards.

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Table 1. The cardiac rehabilitation strategy of patients in the individualized rehabilitation group

		Evaluation before exercise (Start exercising only when meet all the following conditions)	Exercise methods and frequency	Evaluation during exercise (Exercising is inappropriate if any of the following conditions are not met)	Adjust exercise (Methods and frequency)
Pre-extubation of the endotracheal tube	Awake period	Patient cooperation; dry wound dressing; the tube is well-fixed, MAP 65-110 mmHg; HR 50-130bpm; RR 12-30 bpm; SpO_2 >90%; BG <18mmol/L; pain score <4 points; limb muscle strength ≥3grade; no ventilator resistance; no malignant arrhythmia	**Aerobic exercise:** static flexion and extension of elbows and wrists; ankle dorsiflexion 40°-50°, hold >3s; ankle plantar flexion 20°-30°, hold >3s; ankle inversion and eversion. **Per time:** 15-20 sets* 1 rep; per day: 2-3times. **Resistance exercise:** straight leg raise, at least 30cm above the bed, hold >3s. Per time: 15-20 sets* 1rep; per day: 2-3times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13 points; pain score <6 points; no ventilator resistance; no adverse event; patient cooperation	**Inappropriate:** Decrease 5-10 sets next time; **Appropriate:** Increase 5 sets next time.
Post-extubation of the endotracheal tube	Day 1	Patient cooperation; dry wound dressing; the tube is well-fixed; MAP 65-110 mmHg; HR 50-130 bpm; RR 12-30 npm; SpO_2 >90%; BG <18 mmol/L; pain score <4 points; limb muscle strength ≥3grade; no malignant arrhythmia	**Self-care activity:** Take food, wipe face, wash hands, and use bedpan in bed; **Breath training:** Exercise with a breath trainer. Per time: 5-10 min; per day: 2 times.; **Aerobic exercise:** Sit beside the bed with the help of the nurse. Per time: 5-10 min; per day: 2 times.; **Resistance exercise:** Passive and active treadmill exercise in bed. **Per time:** 5-10 min; Per day: 2 times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13points; pain score <6points; no adverse event; patient cooperation	**Inappropriate:** Decrease 5 min next time; decrease 5 min per time or 1 time next day. **Appropriate:** Increase 5 min next time; increase 5 min per time or 1 times next day.
	Day 2	Patient cooperation; dry wound dressing; the tube is well-fixed; MAP 65-110 mmHg; HR 50-130 bpm; RR 12-30 npm; SpO_2 >90%; BG <18 mmol/L; pain score <4 points; limb muscle strength ≥4grade; no malignant arrhythmia	**Self-care activity:** take food, scrub body, and clean up in bed.; **Breath training:** Exercise with a breath trainer. Per time: 10-15 min; per day: 2 times.; **Aerobic exercise:** Sit up on your own; stand, mark time, and try to walk beside the bed with the help of nurse. Per time: 10-15 min; per day: 2 times.; **Resistance exercise:** Passive and active treadmill exercise in bed. **Per time:** 10-15 min; Per day: 2 times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13points; pain score <6points; no adverse event; patient cooperation	**Inappropriate:** Decrease 5-10 min next time; decrease 5-10 min per time or 1 time next day. **Appropriate:** Increase 5-10 min next time; increase 5-10 min per time or 1-2 times next day.

This study was reviewed and approved by the Research Ethics Committee of The Affiliated Changzhou Second People's Hospital of Nanjing Medical University. Written informed consent was obtained before patients were enrolled in the study.

CR strategy – patients in the BRG. 1. Routine health education, such as admission education, diet guidance, preoperative education, postoperative education, and discharge education. 2. Routine rehabilitation guidance: In the preoperative stage, patients were instructed with a breathing exercise, using abdominal respiration and half-closed lip respiration. In the postoperative stage, patients were instructed with a limb flexion and extension exercise, ankle pump exercise, and out-of-bed activity (after ECG monitoring was stopped).

CR strategy – patients in the IRG. In addition to the CR strategy in BRG, patients in the IRG received an individualized CR strategy based on aerobic and resistance exercises. In the postoperative stage, the individualized CR strategy was divided into two parts: pre-extubation of the endotracheal tube and post-extubation of the endotracheal tube. (Table 1) Before and during exercise, the specialist nurse would dynamically evaluate the patients and determine the CR plan of the patients, according to the evaluation results (Table 1). Rating

Post-extubation of the endotracheal tube	Day 3	Patient cooperation; dry wound dressing; the tube is well-fixed; MAP 65-110 mmHg; HR 50-130 bpm; RR 12-30 npm; SpO_2 >90%; BG <18 mmol/L; pain score <4 points; limb muscle strength ≥4grade; no malignant arrhythmia	**Self-care activity:** take food, sit up, get out of bed, and wash.; **Breath training:** Exercise with a breath trainer. Per time: 10-15 min; per day: 2-3 times.; **Aerobic exercise:** Warm-up, walk in ward with the help of nurse, relaxation exercise. Per time: 15-20 min; per day: 2 times.; **Resistance exercise:** Active treadmill exercise in bed. **Per time:** 15-20 min; per day: 2 times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13points; pain score <6points; no adverse event; patient cooperation	**Inappropriate:** Decrease 5-10 min next time; decrease 5-10 min per time or 1 time next day. **Appropriate:** Increase 5-10 min next time; increase 5-10 min per time or 1-2 times next day.
	Day 4	Patient cooperation; dry wound dressing; the tube is well-fixed; MAP 65-110 mmHg; HR 50-130 bpm; RR 12-30 npm; SpO_2 >90%; BG <18 mmol/L; pain score <4 points; limb muscle strength ≥5grade; no malignant arrhythmia	**Self-care activity:** Take food, get out of bed and wash, go to the toilet.; **Breath training:** Exercise with a breath trainer. Per time: 10-15 min; per day: 2-3 times.; **Aerobic exercise:** Warm-up, walk in ward, relaxation exercise. **Per time:** 20-30 min; per day: 2-3 times.; **Resistance exercise:** Active treadmill exercise in bed. Per time: 15-30 min; per day: 2-3 times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13points; pain score <6points; no adverse event; patient cooperation	**Inappropriate:** Decrease 5-10 min next time; decrease 5-10 min per time or 1 time next day. **Appropriate:** Increase 5-10 min next time; increase 5-10 min per time or 1-2 times next day.
	Day 5	Patient cooperation; dry wound dressing; the tube is well-fixed; MAP 65-110 mmHg; HR 50-130 bpm; RR 12-30 npm; SpO_2 >90%; BG <18 mmol/L; pain score <4 points; limb muscle strength ≥5grade; no malignant arrhythmia	**Self-care activity:** Daily self-care activities.; **Breath training:** Exercise with a breath trainer. Per time: 10-15 min; per day: 3 times.; **Aerobic exercise:** Warm-up, walk in ward, up and down stairs once (1/2 floor), relaxation exercise. **Per time:** 30-40 min; per day: 2-3 times.; **Resistance exercise:** Active treadmill exercise in bed. Per time: 20-30 min; per day: 2-3 times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13points; pain score <6points; no adverse event; patient cooperation	**Inappropriate:** Decrease 5-10 min next time; decrease 5-10 min per time or 1 time next day. **Appropriate:** Increase 5-10 min next time; increase 5-10 min per time or 1-2 times next day.
	Day 6	Patient cooperation; dry wound dressing; the tube is well-fixed; MAP 65-110 mmHg; HR 50-130 bpm; RR 12-30 npm; SpO_2 >90%; BG <18 mmol/L; pain score <4 points; limb muscle strength ≥5grade; no malignant arrhythmia	**Self-care activity:** Daily self-care activities.; **Aerobic exercise:** Warm-up, walk in ward, up and down stairs once (1 floor), relaxation exercise. **Per time:** 30-40 min; per day: 3-4 times.	SBP <180 mmHg; DBP <110 mmHg; increased HR ≤20 bpm; RR 12-40 bpm; SpO_2 >88%; RPE ≤13points; pain score <6points; no adverse event; patient cooperation	**Inappropriate:** Decrease 5-10 min next time; decrease 5-10 min per time or 1 time next day. **Appropriate:** Increase 5-10 min next time; increase 5-10 min per time or 1-2 times next day.

MAP, mean arterial pressure; HR, heart rate; RR, respiratory rate; BG, blood glucose; SBP, systolic pressure; DBP, diastolic pressure; RPE, rating of perceived exertion

of perceived exertion (RPE) was used to assess the patient's level of exertion [Borg 1982].

Data collection: The data were collected and recorded in pre-operation (pre-op) and post-operation (post-op). The data were listed: 1. Clinical characteristics of the patients, such as sex, age, NYHA classification, diabetes, hypertension, smoking, and so on. 2. Left ventricular ejection fraction (LVEF), left ventricular end diastolic dimension (LVEDD), brain natriuretic peptide (BNP), the time to first out-of-bed activity, ICU stay time, post-operation hospital stay time (post-op HS). 3. The 6-min walk test (6MWT) was used to evaluate the patients' ability to carry out activities of daily living [Fiorina 2007]. The test was carried out as recommended in the American Thoracic Society guidelines [Argyropoulos 2002], and the 6-min walk distance (6WMD) was recorded. 4. The Medical Outcomes Study 36-Item Short Form (SF-36) health survey was used to evaluate the QoL of patients [Ware 1992]. Eight multiple-item subscales are included in the SF-36

Table 2. Clinical characteristics of the patients

Clinical characteristics	Number of patients	% of total
Age[a]	61.94±9.14	
Sex		
Male	64	80
Female	16	20
NYHA classification[a]	2.28±0.45	
BMI[a]	25.17±2.76	
Diabetes		
With	39	49
Without	41	51
Hypertension		
With	63	79
Without	17	21
Smoking		
Yes	33	41
No	47	59
CABG		
On-pump	8	10
Off-pump	72	90
Number of bypass grafts[a]	2.99±0.89	
Cardiovascular adverse events	0	0

[a]mean ± SD

Table 3. Clinical characteristics of the patients in IRG and BRG

Clinical characteristics	IRG	BRG	*P*-value
Age	60.53±9.88	63.35±8.33	0.171
Sex	-	-	0.576
Male	31	33	
Female	9	7	
NYHA classification	2.25±0.44	2.30±0.46	0.622
BMI	25.70±2.76	24.65±2.72	0.092
Diabetes	-	-	0.502
With	18	21	
Without	22	19	
Hypertension	-	-	0.412
With	33	30	
Without	7	10	
Smoking	-	-	0.820
Yes	16	17	
No	24	23	
CABG	-	-	0.456
On-pump	3	5	
Off-pump	37	35	
Number of bypass grafts	3.08±0.99	2.90±0.78	0.384

questionnaire; it contains physical function (SF), role limitations due to physical problems (RP), body pain (BP), general health (GH), vitality (VT), social functioning (SF), role limitations due to emotional problems (RE), and mental health (MH) [Ware 1992]. Each subscale score ranges from 0 to 100 and higher score indicates better QoL.

Data analysis: Dates are presented as mean ± SD. Chi square test and Student's t-test were used to compare the data. SPSS 23.0 software (IBM, NY, USA) was used to process the data and GraphPad Prism 6.02 (GraphPad Software, CA, USA) was used to draw the graphs. $P < 0.05$ was considered statistically significant.

RESULTS

Table 2 shows the clinical characteristics of patients. (Table 2) Eighty percent of patients were male. The average age was 61.94, NYHA classification was 2.28, BMI was 25.17, and number of bypass grafts was 2.99. Forty-nine percent of patients were suffering from diabetes, while 79% suffered from hypertension. Patients who underwent off-pump CABG accounted for 90%. Forty-one percent of patients were smokers.

As shown in Table 3, there's no significant difference between IRG and BRG in patient clinical characteristics ($P > 0.05$). (Table 3)

Cardiac function: The 6MWD, LVEF, BNP, and LVEDD of IRG was similar with BRG in pre-op ($P > 0.05$) (Figures 2A-2D). (Figure 2) Comparing with BRG, the 6MWD on post-op day 10 was significantly higher in IRG and remaining higher on post-op day 60, while the BNP was significantly lower in IRG (all $P < 0.05$) (Figures 2A and 2C). Comparing with pre-op, the 6WMD was significantly higher in IRG on post-op day 10 and 60, while in BRG only on post-op day 60 (all $P < 0.05$) (Figure 2A).

The LVEF of IRG was significantly higher than BRG in post-op, while the LVEDD of IRG was significantly lower ($P < 0.05$) (Figures 2B and 2D). Similarly, comparing with pre-op, LVEF of IRG in post-op was significantly improved ($P < 0.05$), while BRG was not ($P > 0.05$) (Figure 2B).

Time consumption: The time to first out-of-bed activity of IRG in post-op was significantly shorter than BRG ($P < 0.05$) (Figure 3A). (Figure 3) Besides, the ICU stay time and post-op HS time of IRG also were significantly shorter than BRG ($P < 0.05$) (Figures 3B and 3C).

QoL of patients: Mean scores on the SF-36 subscales are presented in Table 4. (Table 4) In pre-op, the IRG and BRG patients scored similar scores on the SF-36 PF ($P = 0.446$), RP ($P = 0.582$), BP ($P = 0.577$), GH ($P = 0.863$), VT ($P = 0.615$), SF ($P = 0.398$), RE ($P = 0.698$), and MH ($P = 0.870$). While in post-op, the IRG patients scored significantly higher on the SF-36 PF, RP, BP, GH, VT, SF, RE, and MH (all $P < 0.05$).

Table 4: The SF-36 scores of the patients in IRG and BRG.

Clinical characteristics	IRG	BRG	*P*-value
PF			
Pre-op	40.50±9.79	38.88±9.16	0.446
Post-op	67.63±7.51	44.00±9.75	0.000*
RP			
Pre-op	5.63±10.57	4.38±9.62	0.582
Post-op	17.50±18.08	6.25±10.96	0.001*
BP			
Pre-op	26.68±9.18	25.55±8.77	0.577
Post-op	74.23±10.21	45.08±9.31	0.000*
GH			
Pre-op	42.13±7.01	41.83±8.43	0.863
Post-op	70.18±6.88	53.78±7.40	0.000*
VT			
Pre-op	40.38±9.09	41.38±8.62	0.615
Post-op	71.38±6.60	50.63±8.41	0.000*
SF			
Pre-op	44.03±11.11	42.13±8.76	0.398
Post-op	69.25±8.29	50.63±8.34	0.000*
RE			
Pre-op	19.15±21.18	17.48±16.84	0.698
Post-op	56.62±24.11	22.48±19.06	0.000*
MH			
Pre-op	42.45±8.18	42.75±8.20	0.870
Post-op	73.20±8.21	50.90±8.74	0.000*

* Significant correlation.

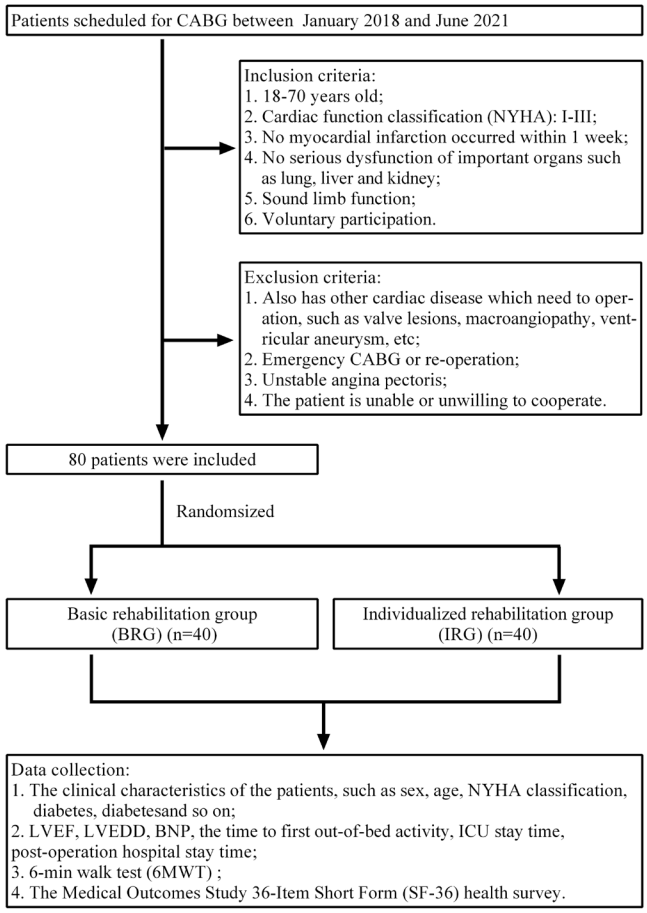

Figure 1. The study flow

DISCUSSION

The morbidity of CHD is rising and seriously endangers human health. For many CHD patients, CABG is the only treatment option. There are almost 40000 CABG operations in China every year [Circulation 2021; Improvement 2021]. Systematic evaluated CR is safe and helpful for patients undergoing CABG [Dibben 2021]. To our knowledge, it has not been widely accepted and applied in our country. So, an individualized CR strategy that contains detailed evaluation and exercise rules was formulated to provide safe and effective CR for patients undergoing CABG. No cardiovascular adverse events occurred in the study.

It is reported that respiratory exercises can improve patients' cardiac function, which is measured by 6MWD at discharge but not at 30d post-discharge [Hirschhorn 2008]. Meanwhile, Zanini et al. reported that the 6WMD was significantly higher in groups that included exercise training on post-op day 6 and at 30 d post-discharge [Zanini 2019]. The different results may be related to the different CR strategy. In our study, we obtained similar results with Zanini et al., the 6WMD of IRG is significantly higher than BRG both on post-op day 10 and 60. So there is reason to believe that individualized CR could improve cardiac function in patients undergoing CABG. This conclusion is further verified by comparing the BNP of the two groups. The BNP of IRG is significantly lower than BRG both on post-op day 10 and 60. Besides, the better LVEF and LVEDD verified the conclusion again. This conclusion is similar with Lv; he reported that exercise rehabilitation can improve cardiac function indexes, such as LVEF, BNP, and left ventricular end-diastolic volume in patients with chronic heart failure [Lv 2022].

The consumption of hospital stay time also is our focus. One study conducted by Herdy et al. demonstrated that CR could reduce the length of hospital stay after surgery [Herdy 2008]. On this basis, we did further research, and we found that individualized CR cannot only reduce post-op HS time, but also significantly reduce the time to first out-of-bed activity and ICU stay time. This may be because the patients' cardiac function was improved by individualized CR, so they can do out-of-bed activity earlier and recover faster.

Various questionnaires can be used to evaluate the QoL of patients. But it is reported that the SF-36 questionnaire

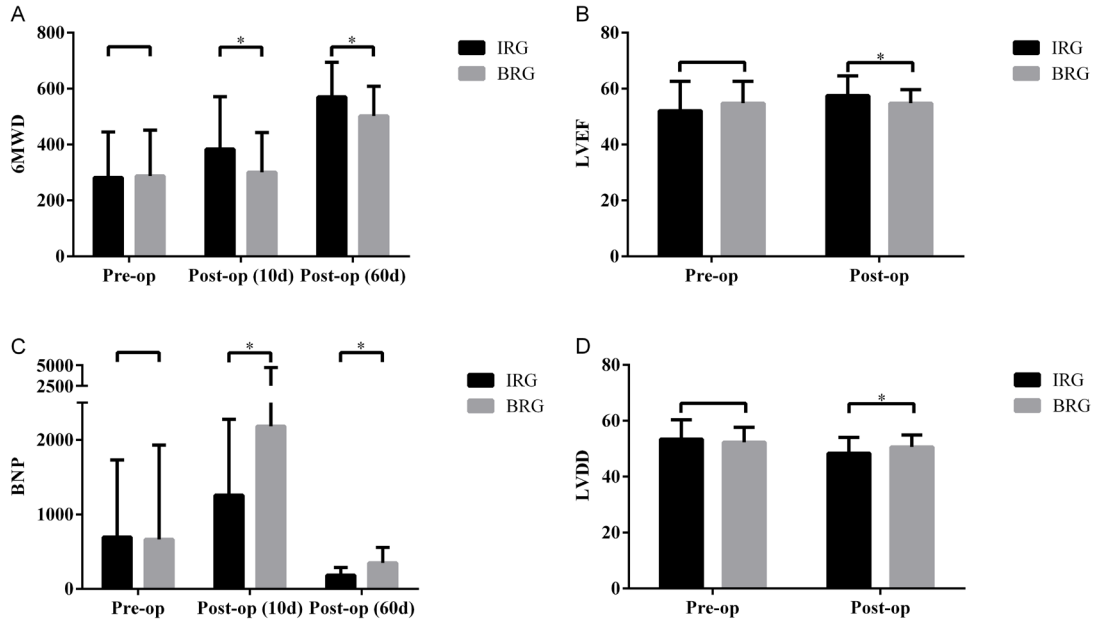

Figure 2. The patients' cardiac function was improved by individualized CR. A) The 6MWD on post-op day 10 was significantly higher in IRG, remaining higher on post-op day 60. B) The LVEF of IRG was significantly higher than BRG in post-op. C) The BNP of IRG was significantly lower than BRG in post-op day 10 and 60. D) The LVDD was significantly lower in IRG than in BRG.

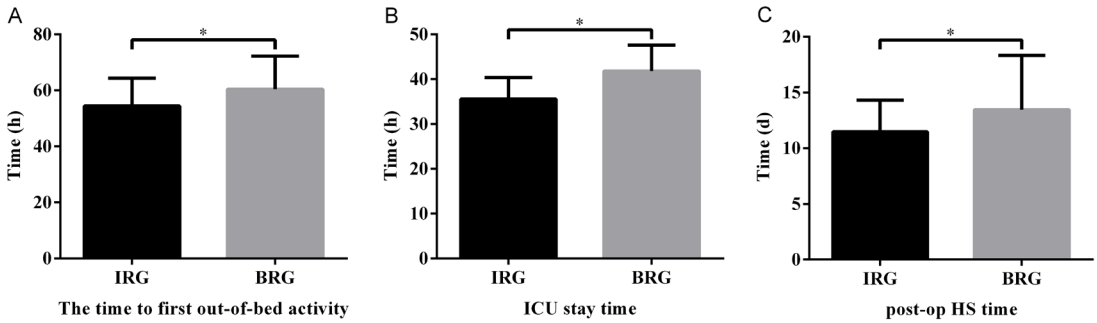

Figure 3. Individualized CR can reduce the time consumption of patients undergoing CABG. A) The time to first out-of-bed activity of IRG was significantly shorter than BRG. B) The ICU stay time was of IRG was significantly shorter than BRG. C) The post-op HS time was significantly shorter than BRG.

is the most appropriate instrument to examine the QoL of cardiac patients, when compared with other generic questionnaires [Dempster 2000]. Thus, in the present study, the SF-36 questionnaire was chosen and a significant improvement in all domains of QoL, especially BP, was observed in IRG. This showed that individualized CR was safe and can improve the QoL of patients undergoing CABG.

CONCLUSION

Individualized CR is safe and can reduce the time consumption and improve the cardiac function and QoL of patients undergoing CABG. We hope that this study can provide some references for the formulation of individualized CR strategy and promote the wide application of CR.

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