

# Exercise Training for Patients After Coronary Artery Bypass Grafting Surgery

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## 1. Introduction

Patients with coronary artery disease (CAD) who suffer persistent symptoms and reduced quality of life while receiving medical therapy are considered for revascularization.<sup>1</sup> Coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) are the most common methods of revascularization for symptomatic CAD. These two interventions can reduce ischemic symptoms such as angina or dyspnea,<sup>2</sup> thus improving the ability to undertake physical training. Shorter length of hospitalization,<sup>3</sup> earlier return to work,<sup>4</sup> and better life adaptation<sup>5</sup> were reported in patients undergoing PCI. However, the incidence rate of restenosis following PCI is higher than CABG,<sup>6</sup> and PCI patients who required further interventions outnumbered the patients who underwent CABG.<sup>7-8</sup> A recent meta-analysis study found that the mortality rate and the rate of revascularization were significantly lower in the CABG group than the PCI group (9.9% vs 24.5%).<sup>9</sup> In a subgroup analysis, the 5-year mortality rate of DM patients was also lower in the CABG group.

In the era of drug-eluting stent (DES), the Synergy between PCI with Taxus and Cardiac Surgery (SYNTAX) trial<sup>10</sup> found that major adverse cardiovascular events rates at 12 months were significantly higher in the PCI group (17.8% vs 12.4%), and the rate of revascularization was lower in the CABG group (5.9% vs 13.5%), but stroke was significantly higher in the CABG group (2.2% vs 0.6%). However, the application of new surgical technique, such as off-pump CABG (OPCAB) may reduce the rate of stroke after surgery. In general, CABG remains the method of choice in patients with left main disease, multivessel disease, especially in diabetic patients, or patients with left ventricular dysfunction, in the event of failure of PCI, and in-stent restenosis.<sup>11</sup> Although the procedure risk is higher for patients receiving CABG, the extent of revascularization is more complete,<sup>12</sup> and hence the potential of training is higher than patients with PCI. The objective of this study is to review the effect of exercise training program in patients with CABG.

## 2. Principle of exercise training

Exercise is a major component for patients with CAD. Cardiac rehabilitation (CR) usually beginning during hospitalization (phase I, inpatient), followed by a supervised outpatient program lasting 3-6 months (phase II), and continuing in a lifetime

maintenance stage in minimally supervised or unsupervised setting (phase III). According to the recommendations of American College of Sports Medicine,<sup>13</sup> patients with CABG should perform aerobic exercise 3-5 times per week and 20-60 minutes for each session, at the intensity of 40-80% of  $\dot{v}O_{2peak}$ . Strength training is suggested to perform 2-3 times per week at the intensity of 40-50 % of maximal voluntary contraction with 10-15 repetitions.

For the coronary patients, exercises with moderate intensity have been shown to improve functional capacity, and it may provide greater safety during unsupervised training. Lower intensity exercise training also increases the acceptance of exercise program, particularly unfit and elderly patients. Therefore, some oriental conditioning exercises deserve more attention because they are less intense, easily accessible, low cost and therefore suitable for implementation in the community.

### 3. Benefits of exercise training

#### 3.1 Cardiorespiratory fitness

Cardiac rehabilitation exercise training improves exercise capacity, without significant complications or other adverse effects. Peak oxygen uptake is the best indicator for cardiorespiratory fitness, and attaining a high  $\dot{v}O_{2peak}$  requires integration of high levels of pulmonary, cardiovascular and neuromuscular function. In patient with CAD, the level of  $\dot{v}O_{2peak}$  is also a good predictor for mortality rate. Kavanagh et al.<sup>14</sup> reported exercise test data for 12,169 male rehabilitation candidates, and found the most powerful predictor of cardiac and all-cause mortality was  $\dot{v}O_{2peak}$ . Values of <15, 15 to 22, and >22 mL·kg<sup>-1</sup>·min<sup>-1</sup> yielded respective hazard ratios of 1.00, 0.62, and 0.39 for cardiac deaths and 1.00, 0.66, and 0.45 for all-cause deaths. Additionally, the mortality rate might decrease 9% for each 1 mL·kg<sup>-1</sup>·min<sup>-1</sup> increase of  $\dot{v}O_{2peak}$ .<sup>14</sup> For patients with CABG, previous studies reported 10.5%-48.2% increase of  $\dot{v}O_{2peak}$  in outpatient CR, and the increase of absolute value was 1.9-6.6 mL·kg<sup>-1</sup>·min<sup>-1</sup> (Table 1),<sup>15-32</sup> depended on different exercise protocol and the initial level of fitness.

Study	Patients	Intervention	Outcomes
Haennel et al <sup>15</sup> (1991)	24 men 9-10 wk after CABG	Cycle training (n=8): cycling 24 min, 3 times/wk for 8 wk Hydraulic circuit training (HCT, n=8): 24 min circuit training 3 times/wk for 8 wk Control (n=8)	$\dot{v}O_{2peak}$ between baseline and 8 wk: Cycling: 21.4 vs 25.7 mL·kg <sup>-1</sup> ·min <sup>-1</sup> (20.1%) HCT: 21.2 vs 23.6 mL·kg <sup>-1</sup> ·min <sup>-1</sup> (11.3%) Cardiac output between baseline and 8 wk: Cycling: 14.3 vs 16.8 L·min <sup>-1</sup> (17.5%) HCT: 13.1 vs 15.1 L·min <sup>-1</sup> (15.3%)
Engblom et al <sup>16</sup> (1992)	171 men 2 mon after CABG	Rehabilitation group (n=93) 3- wk exercise followed by 2-day refresher for 8 m Reference group (n=78)	Maximal work load increased in both groups, but the increase is greater in rehabilitation group than in reference group 12 months post-operatively.

Study	Patients	Intervention	Outcomes
Dubach et al <sup>17</sup> (1995)	42 men 1 mon after CABG	Exercise group (n=22): walking 1 h twice daily for 1 m, followed by 1 m of usual care Control group (n=20): usual care for 1 m, followed by walking 1 h twice daily for 1 m	$\dot{V} O_{2peak}$ between baseline and 1 mon: Ex: 22.6 vs 24.5 mL · kg <sup>-1</sup> · min <sup>-1</sup> (8.4%) Control: 21.0 vs 23.7 mL · kg <sup>-1</sup> · min <sup>-1</sup> (12.9%) $\dot{V} O_{2peak}$ between 1 mon and 2 mon: Ex: 24.5 vs 26.4 mL · kg <sup>-1</sup> · min <sup>-1</sup> (7.8%) Control: 23.7 vs 25.0 mL · kg <sup>-1</sup> · min <sup>-1</sup> (5.5%)
Daida et al <sup>18</sup> (1996)	15 M, 2 F 53±3 y/o, 3 m after CABG	6-8 wk aerobic training, 3 times/wk, 40 min each time, at RPE 12-13	$\dot{V} O_{2peak}$ between baseline and 9 mon: 21.9 vs 27.4 mL · kg <sup>-1</sup> · min <sup>-1</sup> (25.1%) ↑Exercise time, O <sub>2</sub> pulse, peak HR
Mariorana et al <sup>19</sup> (1997)	26 Men 60±8.5 y/o, 18 mon after CABG	Circuit weight training group, (CWT, n=12):10 wks CWT at 40-60% max. contraction Control group (n=14)	Strength increased by 18% in five out of seven exercise in the CWT group, but unchanged in the control group $\dot{V} O_{2peak}$ : no increase in both groups
Lan et al <sup>20</sup> (1999)	20 men 56.5±7.4 y/o 5 mon after CABG	Tai Chi group (n=9): 1-yr TC training, 3.8 times/wk, 1 h each time, at 48-57% of HR reserve Control group (n=11)	$\dot{V} O_{2peak}$ between baseline and 1 yr: TC : 26.2 vs 28.9 mL · kg <sup>-1</sup> · min <sup>-1</sup> (10.3%) Control: 26.0 vs 25.6 mL · kg <sup>-1</sup> · min <sup>-1</sup> (-1.5%)
Goodman et al <sup>21</sup> (1999)	31 subjects 53±1 y/o 8-10 wk after CABG	12-wk of walking program Initial intensity at 50-60% of $\dot{V} O_{2peak}$ , then increase to 75-80% of $\dot{V} O_{2peak}$ , 5 times/wk, 45-60 min each session for 3 m	$\dot{V} O_{2peak}$ between baseline and 3 mon: CABG: 19.0 vs 21.0 mL · kg <sup>-1</sup> · min <sup>-1</sup> (10.5%) Ejection Fraction (EF): At 40% of $\dot{V} O_{2peak}$ : 60 vs 63% At 70% of $\dot{V} O_{2peak}$ : 61 vs 64% ↑18% ischemic exercise calf blood flow
Takeyama <sup>22</sup> (2000)	28 patients (26M/2F) 1 wk after CABG	Exercise group (n=13): 30 min bicycle exercise, twice daily for 2 wk, intensity at ventilatory threshold (VeT) Control group (n=15): walking 200-500 meters for 2 wk	$\dot{V} O_{2peak}$ between 1 wk and 3 wk: Ex: 13.1 vs 16.1 mL · kg <sup>-1</sup> · min <sup>-1</sup> (22.9%) Control:13.7 vs 14.8 mL · kg <sup>-1</sup> · min <sup>-1</sup> (8.0%) Peak CO between 1wk and 3 wk: Ex: 10.6 vs 13.4 L/min (26.4%) Control:11.9 vs 12.0 L/min (0.1%)

Study	Patients	Intervention	Outcomes
Adachi et al <sup>23</sup> (2001)	57 patients (46 M/ 11F) 1 wk after CABG	Exercise group (n=34): 30 min exercise, twice daily for 2 wk, intensity at VeT Control group (n=23)	$\dot{V} O_{2peak}$ between 1 wk and 3 wk: Ex: 13.7 vs 20.3 mL · kg <sup>-1</sup> · min <sup>-1</sup> (48.2%) Control: 13.7 vs 14.3 mL · kg <sup>-1</sup> · min <sup>-1</sup> (4.4%) ↑ Ventilatory efficiency and cardiac output in exercise group
Kodis et al <sup>24</sup> (2001)	1,042 patients 6-8 wk after CABG	Supervised Ex (n=713): 2 times per wk, at 40-70% of functional capacity for 6 m Home Ex (n=329)	Supervised Ex group: ↑23.7% in $\dot{V} O_{2peak}$ , ↑HDL-C, ↓LDL-C Home Ex group: ↑17.2% in $\dot{V} O_{2peak}$ , ↑HDL-C
Lan et al <sup>25</sup> (2002)	20 men 56.5±7.4 y/o 2 mon after CABG	Aerobic exercise for 3 m, 3 time/ wk, 30 min each session, at 51-59 % of functional capacity	$\dot{V} O_{2peak}$ between baseline and 3 m: Ex: 19.8 vs 26.3 mL · kg <sup>-1</sup> · min <sup>-1</sup> (32.8%) $\dot{V} O_2$ at VeT between baseline and 3 m: Ex: 11.9 vs 14.7 mL · kg <sup>-1</sup> · min <sup>-1</sup> (23.5%)
Chuang et al <sup>26</sup> (2005)	32 patients 2-3 mon after CABG	Virtual reality (VR, n=17) group: simulated exercise 2 times per wk, 30 min for 3 m Non-VR (n=15) group: exercise without simulation	$\dot{V} O_{2peak}$ between baseline and 3 m: VR: 17.7 vs 22.5 mL · kg <sup>-1</sup> · min <sup>-1</sup> (27.1%) Non-VR: 15.1 vs 16.8 mL · kg <sup>-1</sup> · min <sup>-1</sup> (11.3%) ↑ $\dot{V} O_2$ at VeT in both groups
Sumide et al <sup>27</sup> (2009)	42 patients (40 M/ 2F) 61±8 y/o	Aerobic and resistance exercise for 6 m, 1-2 time/wk, 60 min each session	$\dot{V} O_{2peak}$ between baseline and 6 m: Ex: 15.1 vs 21.7 mL · kg <sup>-1</sup> · min <sup>-1</sup> (43.7%) ↑ Peak torque in knee extensor/ flexor, and calf circumference
Moholdt <sup>28</sup> (2009)	59 patients AIT: 24M/ 4F MCT: 24M/ 7F	Aerobic interval training (AIT) Moderate continuous training (MCT) 4 wk in rehab center, then 6- m home-based exercise	$\dot{V} O_{2peak}$ between baseline and 4 wk: AIT: 27.1 vs 30.4 mL · kg <sup>-1</sup> · min <sup>-1</sup> (12.2%) MCT: 26.2 vs 28.5 mL · kg <sup>-1</sup> · min <sup>-1</sup> (8.8%) $\dot{V} O_{2peak}$ between 4wk and 6 m: AIT: 30.4 vs 32.2 mL · kg <sup>-1</sup> · min <sup>-1</sup> (5.9%) MCT: 28.5 vs 29.5 mL · kg <sup>-1</sup> · min <sup>-1</sup> (3.5%)
Onishi et al <sup>29</sup> (2009)	32 patients with metabolic syndrome 5-14 days after CABG	Supervised CR program for 6 months, including aerobic exercise (60 min) and resistance training, at VeT	$\dot{V} O_{2peak}$ between baseline and 6 m: Ex: 14.2 vs 19.2 mL · kg <sup>-1</sup> · min <sup>-1</sup> (35.2%) ↑ peak torques of knee extensor (13.4%) and knee flexors (15.3%) ↓ Triglyceride, LDL-C and CRP

Study	Patients	Intervention	Outcomes
Bilinska et al <sup>30</sup> (2010)	120 Men 55±6 y/o 3 mon after CABG	Ex group (n= 60), 6 wk aerobic training, 3 times/wk, at 70-80% HRmax Control group (n=60)	Handgrip-induced increases in HR, BP, and TPR were lower, whereas SV and CO were higher (by 13% and 15%, respectively) in Ex group. A higher increase in NO level and a lower increase in noradrenaline in Ex group.
Shabani et al <sup>31</sup> (2010)	60 women	Ex group (n=30): 12 wk aerobic exercise Control group (n=30): usual care	Estimated exercise capacity and 6 min walking test increased in Ex group Exercise duration time↑49.2% and rate pressure product↑10.3% in Ex group
Smith et al <sup>32</sup> (2011)	196 patients	Hospital Ex group: aerobic Ex 30-50 min per session, 3 times/wk, at 60-80% HR reserve for 6 m Home Ex group: walking in home 5 times per wk	MET between baseline and 6 m: Hospital Ex: 4.5 vs 6.2 MET (37.8%) Home Ex: 5.1 vs 6.4 MET (25.5%) Home-based exercise maintained higher physical capacity during 6 yrs follow up than hospital-based exercise

Table 1. Effect of Exercise Training to Functional Capacity in Patients with CABG

### 3.2 Muscular strength

Traditionally, CR program involving aerobic exercise training such as walking and cycling is emphasized. However, muscular strength is important in vocational activities and activities of daily living. Previous studies showed that moderate intensity resistance exercise might significantly increase muscular strength for cardiac patients.<sup>33-34</sup> It is recommended that cardiac patient should start a low weight and perform one set of 10-15 repetitions using 8-10 different exercises. Some studies reported that resistance training might increase aerobic power,<sup>15,33-34</sup> but other study found that resistance training can only improve muscular strength.<sup>19</sup> Therefore, resistance training should be integrated into an aerobic exercise program. Sumide et al<sup>27</sup> reported a 6-month aerobic exercise and resistance training program was beneficial to patients with CABG. After training, the  $\dot{V}O_{2peak}$  and peak lower limb torques significantly increased, and the circumferences of thigh and calf were also increased. In a recent study, Onishi et al.<sup>29</sup> reported a 6-month aerobic and resistance training program also improved  $\dot{V}O_{2peak}$  and isokinetic peak torques of knee extensor and flexor in patients after CABG. It appears that a combined aerobic and resistance training program significantly increased exercise tolerance and lower limb muscle strength.

### 3.3 Cardiac function

Exercise training in healthy individuals may enhance physical capacity by both an increase in cardiac output, a central mechanism, and a widening of the arteriovenous oxygen difference, a peripheral mechanism. In patients with heart disease, previous studies suggested the enhancement of  $\dot{V}O_{2peak}$  only relied on peripheral adaptations,<sup>35-37</sup> however, recent studies found the increase of  $\dot{V}O_{2peak}$  might be partially attributed to an elevation in cardiac output.

Nakai et al.<sup>38</sup> reported the effects of exercise training on recovery of cardiac function in 115 patients after CABG. After training, stroke index increased significantly in the exercise group, but not in the usual care group. Takeyama et al.<sup>22</sup> applied a 2-week bicycle program to 13 patients with CABG, and they exercised 30-minute twice daily. The peak cardiac output increased 22.9% from 10.6 L/min to 13.4 L/min, while the control group showed no significant improvement. Adachi et al.<sup>23</sup> assigned 34 patients with CABG to a 2-week exercise program, and cardiac output during exercise at 20 watt and at peak exercise significantly increased in the exercise group. In a recent study, Bilinska et al.<sup>30</sup> reported that after 6 weeks of aerobic training at 70–80% of  $HR_{peak}$ , the stroke volume and cardiac output were higher (by 13% and 15%, respectively) in trained patients compared with controls. Goodman et al.<sup>21</sup> has explored central and peripheral adaptations after exercise training in 31 patients with CABG. Patients underwent 12 weeks of exercise training consisting of walking and jogging, at 75% to 80%  $\dot{V}O_{2peak}$ . The results showed a significant improvement in  $\dot{V}O_{2peak}$  and an increase of the ejection fraction during submaximal exercise ( $60 \pm 3\%$  vs  $63 \pm 2\%$  at 40%  $\dot{V}O_{2peak}$ ;  $61 \pm 3\%$  vs  $64 \pm 3\%$  at 70%  $\dot{V}O_{2peak}$ ). Peak ischemic exercise calf blood flow and vascular conductance were also increased. The result indicated that exercise training in patients after CABG can elicit significant improvements in functional capacity that, for the most part, are secondary to peripheral adaptations, with lesser contribution of central adaptation.

### 3.4 Ventilatory efficiency

Shortness of breath is a major complaint when ventilation is accelerated during exercise. Although exercise training may attenuate exertional dyspnea during exercise, whether exercise training improves ventilatory efficiency in patients after CABG was not clear. Adachi et al.<sup>23</sup> reported the effects of exercise training on ventilatory response and cardiac output during exercise in patients following CABG. The minute ventilation–carbon dioxide output ( $\dot{V}E$ – $\dot{V}CO_2$ ) slope decreased from  $38.9 \pm 8.1$  to  $35.1 \pm 6.7$  in the exercise group, and there was a correlation between improvement of the  $\dot{V}E$ – $\dot{V}CO_2$  slope and peak cardiac output in the exercise group. The results showed that short-term physical training after CABG might improve ventilatory efficiency to exercise.

### 3.5 Lipid profile

Exercise training is not recommended as a sole intervention for lipid modification because the inconsistent effect on lipid and lipoprotein levels. Optimal lipid management requires dietary and pharmacologic management, in addition to CR exercise training. Wosornu et al.<sup>39</sup> compared the effects of 6-month aerobic or strength exercise training after CABG. Both groups showed a significant increase in physical capacity, but there were no changes in lipoprotein levels. Brügemann et al.<sup>40</sup> randomized 137 men who underwent an coronary procedure (111 received CABG) to two types of CR, and blood lipid profile was unaffected by exercise training. However, Kodis et al.<sup>24</sup> conducted a retrospective review of 1,042 patients with CABG and found that exercise might induce beneficial changes to lipid profile. Following 6 months of exercise training, the supervised exercise group had significant lower cholesterol and LDL-cholesterol than the home-based group. Patients in the supervised exercise group had significant improvements in triglyceride, LDL-cholesterol and HDL-cholesterol, whereas the home-based group showed improvement in HDL-cholesterol only. In a recent study, Onishi et al.<sup>29</sup> also reported CR exercise training might

improve LDL-cholesterol and total cholesterol in CABG patients with metabolic syndrome. Additionally, metabolic scoring defined by the number of the modified Adult Treatment Panel criteria of the US National Cholesterol Education Program was significantly improved.

### 3.6 Hemodynamic and neurohormonal response

In order to measure hemodynamic and neurohormonal response to static exercise, Bilinska et al.<sup>30</sup> randomized 120 male patients to either 6 weeks of aerobic training at a 70–80% of the  $HR_{peak}$  or to a control group. After 3 months of training, handgrip-induced increases in HR, BP, and total peripheral resistance were lower, whereas stroke volume and cardiac output were higher (by 13% and 15%, respectively) in trained patients compared with controls. Moreover, a higher increase in nitric oxide level (46% vs 14%) and a lower increase in noradrenaline (11% vs 20%) were observed in trained patients compared with controls. The result showed that short-term dynamic training caused significant improvement of hemodynamic and neurohormonal responses to static exercise.

### 3.7 Quality of life

Heather et al.<sup>40</sup> recruited 249 patients on a waiting list for elective CABG and randomized them into an intervention group and a control group. During the waiting period, the training group exercised twice per week, with education and reinforcement. After surgery, both groups participated in a CR program. Quality of life was measured by short-form 36 (SF-36) questionnaire during the waiting period, and patients in the intervention group showed a significant increase in the scores of physical role, physical functioning, bodily pain and composite physical summary score. The intervention group displayed better quality of life than the control group, but mainly in physical component, and the improvement continued up to 6 months after surgery.

In a recent study, Brügemann et al.<sup>41</sup> randomized 137 men to one of two types of CR: physical training plus information ('Fit' program) during 6 weeks or comprehensive CR which, on top of the Fit-program, included weekly psycho-education sessions and relaxation therapy ('Fit-Plus' program) for 8 weeks. The results showed that quality of life improved in both treatment groups in the course of time up to 9 months after training, and there was no difference between the two types of CR.

### 3.8 Graft patency, cardiac events and readmission

Nakai et al.<sup>38</sup> reported the effects of exercise training on recovery of cardiac function and graft patency in 115 patients after CABG. The patients were divided into Group I (n = 60) with and Group II (n = 55) without a CR program. The rate of graft patency was 98% in Group I and 80% in Group II. After training, the exercise stroke index increased significantly in Group I, but not in Group II. The result suggested that physical exercise training should be started as early as possible after CABG to improve graft patency and recovery of cardiac function.

Perk J et al.<sup>42</sup> reported in a study including 49 CABG patients participating in a comprehensive CR program and 98 matched patients receiving standard care. During the first year after CABG, fewer study group patients were readmitted to hospital (14% vs 32%) and on fewer occasions (1.1 vs 2.9). There were no differences in the rates of returning to work (59% vs 64%). In a long-term follow-up, the study group patients rated their physical

work capacity higher, and more patients had continued with regular physical training (66% vs 46%). Hedbäck et al.<sup>43</sup> reported in a study included 49 patients who underwent CABG and were offered a CR program consisting of education in risk-factor control and a physical training program. After 10 years of follow up, the study group had lower cardiac events than in the control group (18.4% versus 34.7%). The number of readmissions to hospital (2.1 versus 3.5 per patient) and length of admissions (11 versus 26 days per patient) were significantly lower in the study group. The result proved that a comprehensive CR program after CABG will improve long-term prognosis and reduce the need for hospital care. In a recent study, Plüss et al.<sup>44</sup> randomized 224 patients with acute myocardial infarction or undergoing CABG to expanded CR (a one-year stress management program, increased physical training, staying at a 'patient hotel' for five days after the event, and cooking sessions), or to standard CR. The number of cardiovascular events was reduced in the expanded CR group compared with the standard CR (47.7% versus 60.2%). This was mainly because of a reduction of myocardial infarctions in the expanded CR group. Days at hospital for cardiovascular reasons were significantly reduced in patients who received expanded CR (median 6 days) compared with standard CR (median 10 days). The result showed that expanded CR reduces cardiovascular morbidity and days at hospital.

#### **4. Tai Chi Chuan training**

Tai Chi Chuan (TCC) is a popular Chinese conditioning exercise. The exercise intensity of TCC was low to moderate, depends on its training style, posture and duration. Participants can choose to perform a complete set of TC or selected movements according to their needs. Previous research substantiates that TC enhances aerobic capacity, muscular strength, endothelial function and psychological well-being. In addition, TC benefits to some cardiovascular risk factors, such as hypertension and dyslipidemia. Recent studies also prove that TC is safe and effective for patients with myocardial infarction, bypass surgery and heart failure. Channer et al.<sup>45</sup> reported that the application of TCC for patients with acute myocardial infarction was safe and showed benefits to blood pressure. There are several reasons to recommend TCC as an exercise program for patients with CABG. First, TCC did not need special facility or expensive equipment. Second, TCC is effective for enhancing health fitness and improving cardiovascular risk factors. Third, TCC is low cost and low technology, and can be easily implemented in the community. We have applied a 12-month TCC program to patients with CABG as a phase III cardiac rehabilitation program.<sup>25</sup> After training, the TCC group showed an increase of 10.3% in  $\dot{V}O_{2peak}$  and 11.9% in peak work rate. Therefore, TC may be prescribed as an alternative exercise program for selected patients with CABG.

#### **5. Off-pump and minimally invasive CABG**

Off-pump coronary artery bypass grafting (OPCAB) uses fewer resources than conventional CABG with cardiopulmonary bypass (CABG-CPB). It was estimated that 20% of CABG operations using OPCAB in western countries, but over 60% of isolated CABG have been performed in Japan using the OPCAB technique. OPCAB grafting reduces the risk of postoperative morbidity, length of hospital stay than conventional surgery with cardiopulmonary bypass.

In a recent study, Angelini et al.<sup>46</sup> reported the graft patency 6-8 years after CABG was similar between OPCAB and CABG-CPB, and the major adverse cardiovascular events or death showed no difference between the two groups. The health-related quality of life was similar between the OPCAB and CABG-CPB groups. In addition, with increasing expertise and technology, minimally invasive and robotic techniques have been developed to enhance post-operative recovery and patient satisfaction.<sup>47</sup> However, there is no study compare the effect of exercise training on conventional CABG and those new techniques, further study is needed to evaluate the difference between conventional and new surgical techniques to the outcomes in patients with CABG.

## 6. Conclusion

Short-term exercise training for patients with CABG showed benefits to cardiorespiratory function, muscular strength, metabolic profile, cardiac function, ventilatory efficiency, hemodynamic function and quality of life. Additionally, exercise training may improve graft patency, reduce cardiac events and readmission rate. Thus, CR exercise training is an important intervention and should be recommended to most of the patients after CABG.

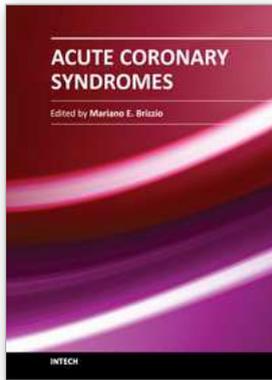
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## **Acute Coronary Syndromes**

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This book has been written with the intention of providing an up-to-the minute review of acute coronary syndromes. Atherosclerotic coronary disease is still a leading cause of death within developed countries and not surprisingly, is significantly rising in others. Over the past decade the treatment of these syndromes has changed dramatically. The introduction of novel therapies has impacted the outcomes and surviving rates in such a way that the medical community need to be up to date almost on a "daily bases". It is hoped that this book will provide a timely update on acute coronary syndromes and prove to be an invaluable resource for practitioners seeking new and innovative ways to deliver the best possible care to their patients.

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