Abstract

Background: The 6-min walking test (6MWT) is a simple test, which does not require expensive equipment or advanced training. It has been used in heart failure patients to assess exercise tolerance, the effects of therapy and prognosis. Accordingly, post-surgical cardiac rehabilitation may be a potential field of application of this test. Materials and method: One thousand three hundred seventy patients (70% males, mean age 64 ± 10 years), consecutively admitted for intensive cardiac rehabilitation, underwent 6MWT within 15 days after different types of cardiac surgery (67% coronary artery bypass graft (CABG), 25% valve replacement, 4% both, 4% other). The 6MWT was repeated in a subgroup of 348 patients after 15/6-3 days of an in-hospital cardiac rehabilitation programme. Results: 6MWT (expressed as absolute value in metres and as a percentage of the predicted value) was well tolerated in all patients. The mean distance walked in 1370 patients was 304 ± 89 m (corresponding to 58 ± 15% of the predicted value). Distances walked were significantly shorter in older patients than younger (p < 0.05) and in women compared to men (251 ± 78 m, 53 ± 15%, vs 328 ± 34 m, 60 ± 14%, p < 0.001). Furthermore, the absolute distance walked in 6 min was significantly shorter in diabetics compared to non-diabetics (283 ± 85 m vs 302 ± 87 m, p = 0.001) and in no CABG compared to CABG patients (285 ± 91 m vs 303 ± 84 m, p < 0.001); no relation was found between distance walked and left ventricular ejection fraction (p = 0.5). Gender, age, comorbidities and type of surgery were independently associated with 6MWT in the multivariate model. In the subgroup of patients repeating the 6MWT after the rehabilitation programme, the distance walked significantly increased (from 281 ± 90 m, 51 ± 76%, to 411 ± 107 m, 77 ± 81%, p < 0.001). The extent of improvement observed was similar according to sex, age, presence/absence of diabetes and type of surgery. Conclusions: Our data suggest that 6MWT is feasible and well tolerated in adult and older patients shortly after uncomplicated cardiac surgery and provides reference values for distance walked after cardiac surgery in this population.

Keywords: 6-min Walking test; Cardiac rehabilitation; Cardiac surgery; Functional capacity
able to perform a standard 6MWT, whereas 878 patients (35%) were excluded from testing because of cardiovascular contraindications (e.g., uncontrolled systemic hypertension or angina, life threatening arrhythmias, NYHA class IV heart failure), musculoskeletal problems that limited walking, or because they refused to participate in the study; 1370 patients (84% of the sample) performed the 6MWT within 15 days (9 ± 2 days) after cardiac surgery (67% coronary artery bypass graft (CABG), 25% valve replacement, 4% both, 4% other) and 252 patients (16% of the sample) performed the 6MWT shortly after an uncomplicated acute myocardial infarction. Starting from July 2004, the 6MWT was systematically repeated at the end of an in-hospital cardiac rehabilitation programme; accordingly, distance walked was obtained in a subgroup of 348 post-cardiac surgery patients (21%) before and after a training programme of average duration of 15 ± 3 days. The rehabilitation programme included exercise training, using the treadmill and/or the exercise bicycle, and aerobic exercise such as a combination of rowing, walking, jogging, stair climbing and step aerobics. The intensity of the training programme was established according to the clinical condition and the results of a symptom-limited exercise test performed at the time of hospital admission. Exercise training was conducted twice a day and was supervised by members of the cardiac rehabilitation staff. Each exercise session lasted up to 60 min (as tolerated) and included at least 5 min each for warm-up and cool-down exercises. Participants in the study had complete data on age, sex, comorbid conditions, such as diabetes mellitus (defined as fasting glucose level > 126 mg/dl or hypoglycaemic drugs) and renal failure (defined as serum creatinine value > 1.5 mg/dl). Left ventricular ejection fraction (LVEF) was measured by transthoracic echocardiography performed on admission to the rehabilitation unit. Participants were considered as having depressed or preserved LVEF according to the presence of values of LVEF below or above 50%, respectively. Complete information was also available on atherosclerotic risk factors such as hypertension (defined as systemic arterial pressure more than 140/90 mmHg on several occasions or use of anti-hypertensive therapy), hypercholesterolemia (defined as serum total cholesterol levels more than 200 mg/dl or use of lipid-lowering drugs), history of smoking and family history of coronary artery disease. Additional information was collected regarding the type of surgery (CABG or no CABG, defined as valve replacement or other) and time between the index event and the admission to the rehabilitation unit.

2.2. 6-min Walking test (6MWT)

The patients were instructed to walk as far as possible along a 40-m straight, flat hospital corridor in 6 min [16]. The test was symptom-limited, so patients who became symptomatic (e.g., angina, severe dyspnoea, dizziness and musculoskeletal pain) were told to stop walking and restart when possible. Encouragement was not given. The total distance walked was measured to the nearest metre and recorded. Before the test, the patient’s resting heart rate and blood pressure were monitored in sitting position. Immediately after completion of the 6MWT, a cardiac rehabilitation staff nurse measured peak exercise data, including heart rate, blood pressure, rating of perceived exertion and total distance walked. Other measured parameters included the number of rest periods, duration of rest periods, and symptoms such as angina and/or severe dyspnoea. These measures were obtained primarily for patient monitoring and safety purposes and were not formally collected or analysed.

The results of the 6MWT are given as absolute value in metres and as a percentage of the predicted value, taking into account anthropometric variables (age, sex, weight and height) according to the reference equation proposed by Enright and Scherril in healthy subjects [11]. The effects of the cardiac rehabilitation programme were evaluated as a percentage of increase in the distance walked between the two tests. The institutional ethical committee approved the study and a written informed consent was obtained from all participants.

3. Statistical analysis

Mean and standard deviations for all continuous variables were calculated. Comparison of data of those patients who completed both initial and follow-up exercise test was performed using the paired and unpaired t-test. The non-normally distributed data were analysed using the Mann–Whitney and the Wilcoxon tests. The association between demographic and clinical variables and 6MWT performance were assessed by Pearson coefficient of correlation when the variables were continuous. Variables found to be significant at univariate analysis were further analysed by a multivariate linear regression model in order to identify a set of variables independently associated with 6MWT performance. The 6-min walking performance on admission after cardiac surgery was classified as poor or preserved performance if the walked distance was within or above the lower quartile, respectively. A two-tailed p value ≤ 0.05 was considered statistically significant. All analyses were performed using the SAS statistical package (SAS Institute Inc., Cary, North Carolina).

4. Results

Demographic and clinical characteristics of the whole study population are presented in Table 1. As expected, most patients were male and over 65 years of age, more than a 20% had comorbidities such as diabetes or renal dysfunction, or both, and approximately 1/5 had LVEF < 50%. The women were slightly older than the men (66 ± 11 years vs 63 ± 10 years, p < 0.001). The 6MWT was performed by the fourth day after hospital admission in all patients and within 15 days after cardiac surgery or acute myocardial infarction (9 ± 2 days). The subgroup of post-cardiac surgery patients (n = 348) who repeated the test at the beginning and the end of the in-hospital cardiac rehabilitation programme was similar to the study population considered as a whole (n = 1622) (Table 1).

5. 6MWT performance

The test was well tolerated by all patients and no cardiopulmonary complications were reported. At baseline,
the mean walking distance was 304 ± 89 m, corresponding to 58 ± 15% of the predicted values, calculated according to the regression equation obtained in healthy subjects [11]. The distance walked was significantly shorter after cardiac surgery than after acute myocardial infarction (299 ± 87 m, 57 ± 15% predicted, vs 330 ± 98 m, 63 ± 15% predicted, respectively, p < 0.001).

In the subsequent analysis post-myocardial infarction patients were excluded and all reported results concerned only patients following cardiac surgery.

Fig. 1 shows the percentage distribution of 1370 patients according to the distance walked after cardiac surgery, before the rehabilitation programme; about 1/5 of these patients showed a relevant reduction of exercise tolerance, as indicated by a distance walked <200 m. The absolute value of distance walked was inversely related to age (r = −0.36, p < 0.001) and was significantly greater in men than in women (p < 0.001) in all age groups (Table 2). Furthermore, the absolute distance walked in 6 min was lower in patients with diabetes and valve surgery, and not different between patients with preserved (≥50%) or depressed (<50%) LVEF (Table 3). At multivariate analysis, the 6MWT was positively associated with gender (p < 0.001) and type of surgery (p = 0.004), and negatively associated with age (p < 0.0001) and diabetes mellitus (p = 0.0014) (Table 4). No significant relation was found between distance walked and LVEF, even among the 84 patients with severe reduction of LV systolic function (LVEF < 35%).

In the subgroup of 348 patients who repeated the 6MWT after the rehabilitation programme, the distance walked increased significantly from 281 ± 90 m (55 ± 16%) to 411 ± 107 m (81 ± 20%) (p < 0.001). The extent of improvement observed was similar according to sex, age > or <70 years, presence/absence of diabetes, type of surgery and left ventricular ejection fraction (Table 5). After training, the patients showed an increase in 6MWT distance and percentage of predicted value in men and women divided according to age.
relative improvement in exercise tolerance for each age and/or gender subgroup was greater in older women (≥75 years) than in younger men (<65 years): +33% versus +24%, respectively (p = 0.01). Furthermore, most patients (300/348, 85%) showed >10% increase in distance walked between the two tests; according to previous studies, this increase should be considered a true improvement in functional capacity as a consequence of therapeutic intervention and not inter-test variability [12]. Patients not showing >10% increase in distance walked at the final test had a better exercise tolerance at baseline (64% vs 54% of predicted value) and fewer comorbidities. A different approach was also used classifying patients as having poor or preserved 6MWT performance if the walked distance on admission was, respectively, within or above the lower quartile of percentage of predicted value (predicted cut-off 45%). Patients with low initial functional capacity (<45% walking distance predicted) demonstrated a greater improvement in functional capacity after training compared with patients with preserved performance (+31% vs +25%, p < 0.001).

6. Discussion

This study was performed in a large group of patients after uncomplicated cardiac surgery and admitted to a single-centre rehabilitation programme. The results indicate that the functional capacity, as expressed by distance walked during the 6MWT, is significantly reduced shortly after cardiac surgery and quickly improves after physical training. The improvement is observed independently of age, sex, comorbid conditions and baseline functional capacity.

The 6MWT is a more 'natural' form of exercise test compared to the bicycle or treadmill exercise and may better reflect daily activity. The advantages of the 6MWT over other stress tests are its simplicity, safety and low cost. It is usually well accepted by patients, easily administered and with an acceptable reproducibility. Obviously, when the 6MWT is used as a measure of exercise capacity in patients with chronic disease, it should be performed in a strictly standardised manner [13], so as to provide useful information on the patient’s physical status. Previous trials have shown that the results of the 6MWT were concordant with changes in symptoms, suggesting that it may be used as supportive evidence for clinical evaluation [14–21]. Our study confirmed the feasibility and the safety of the 6MWT shortly after cardiac surgery. It was an observational study, conducted in a single cardiac rehabilitation centre, thus reducing the variability of the test performance observed in multimember studies. The results of the 6MWT were given both as an absolute value in metres and as a percentage of the predicted value, according to the reference equation published previously [13]. It should be noted that expressing the distance walked in these two different ways (absolute value and percentage of predicted value) might have clinical relevance. The same absolute distance walked, 250 m for example, may indicate a lower limit of normal functional capacity in an 80-year-old man and a severe reduction in effort tolerance in a 45-year-old man. Instead, the percentage of predicted value, taking into account anthropometric variables such as sex, age, weight and height, allows physicians to express the extent of functional limitation of an individual subject compared to the healthy population with similar demographic characteristics. On the other hand, the result expressed as an absolute value can be useful in the single patient when evaluating the effects of therapeutic intervention. Our data confirm previous studies that the distance walked in the 6MWT is lower in women and

<table>
<thead>
<tr>
<th>Subjects (N = 348)</th>
<th>Initial distance walked</th>
<th>Final distance walked</th>
<th>%Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m)</td>
<td>%Predicted</td>
<td>(m)</td>
</tr>
<tr>
<td>Men (n = 248)</td>
<td>300 ± 86</td>
<td>52 ± 90</td>
<td>429 ± 104</td>
</tr>
<tr>
<td>Women (n = 100)</td>
<td>235 ± 82</td>
<td>50 ± 15</td>
<td>366 ± 103</td>
</tr>
<tr>
<td>Age &lt;70 years (n = 212)</td>
<td>304 ± 88</td>
<td>55 ± 16</td>
<td>444 ± 102</td>
</tr>
<tr>
<td>Age ≥70 years (n = 136)</td>
<td>246 ± 81</td>
<td>45 ± 12</td>
<td>359 ± 94</td>
</tr>
<tr>
<td>No diabetes (n = 274)</td>
<td>288 ± 87</td>
<td>52 ± 85</td>
<td>416 ± 104</td>
</tr>
<tr>
<td>Diabetes (n = 74)</td>
<td>258 ± 97</td>
<td>51 ± 17</td>
<td>394 ± 119</td>
</tr>
<tr>
<td>EF &lt; 50% (n = 50)</td>
<td>282 ± 63</td>
<td>59 ± 16</td>
<td>407 ± 53</td>
</tr>
<tr>
<td>EF ≥ 50% (n = 298)</td>
<td>218 ± 106</td>
<td>56 ± 21</td>
<td>411 ± 17</td>
</tr>
<tr>
<td>No CABG (n = 133)</td>
<td>283 ± 96</td>
<td>52 ± 16</td>
<td>420 ± 117</td>
</tr>
<tr>
<td>CABG (n = 215)</td>
<td>281 ± 87</td>
<td>51 ± 29</td>
<td>407 ± 103</td>
</tr>
</tbody>
</table>
in elderly patients [22]. Furthermore, we observed that the 6MWT was significantly shorter after cardiac surgery than after myocardial infarction. We hypothesised that several factors, including prolonged bed rest, pain and respiratory limitation following sternotomy may have contributed to this difference. Moreover, in our study the distance walked in 6 min was also significantly related, besides gender and age, to the presence of at least one comorbidity (diabetes), and to the type of surgery (higher in coronary artery than in valve and other surgery). To the best of our knowledge, there are no published reports on the effects of in-patient cardiac rehabilitation after surgery for ‘CABG’ and ‘no CABG’ groups using the 6MWT. According to previous data, we considered >10% increase in distance walked between the initial and final test to indicate a true improvement in functional capacity as a consequence of therapeutic intervention [18]. Most patients (85%) significantly improved in terms of exercise tolerance after 2 weeks of in-hospital rehabilitation programme. It should be noted that patients not showing >10% increase in distance walked at the final test had a better exercise tolerance at baseline (64% vs 54% of predicted value) and fewer comorbidities. We hypothesised that this less compromised group may have required less intensive physical training and hence obtained less satisfactory results. Furthermore, patients with low functional capacity at baseline, expressed as a percentage of the predicted value of distance walked in the lower quartile (<45% predicted), showed the largest increase in the final test (performed at the end of the rehabilitation programme). Although the exercise capacity achieved in this group was still lower than in patients with preserved baseline exercise performance, the results emphasise the need for an intensive physical programme, even — perhaps specifically — in the more compromised patients.

7. Study limitations

There are some major limitations of this study. First, we did not compare the results of the 6MWT with a reference test, such as maximal exercise test with oxygen uptake assessment; nor did we consider the effects of medical therapy on distance walked at hospital discharge. However, the exercise tolerance obtained at the end of an in-hospital rehabilitation programme of short duration (2—3 weeks), as in our study, should not have been influenced by medical therapy optimisation. Second, no conclusion regarding the difference between the myocardial infarction group and the surgery group could be drawn because of the small size of the former group; this was not, in fact, a primary aim of our study. Third, physiological variables measured at peak exercise of 6MWT and symptoms or number of exercise interruptions were collected but not formally analysed since these measures were obtained primarily for patient monitoring and safety purposes. Finally, each patient underwent the 6MWT once only, before and after cardiac rehabilitation. The effect of familiarisation with the 6MWT is well known [23]; Guyatt and others [3,24,25] found a learning effect to be evident over the first three 6MWT sessions, suggesting that a minimum of 2—3 walks should be performed initially to establish a baseline. Time and staff limitations induced us to test all patients once only, therefore we cannot rule out that the improvement in 6MWT distance observed after cardiac rehabilitation programme may, at least partly, depend on the learning effect.

Other mechanisms potentially involved in the improvement of distance walked observed at the end of rehabilitation programme include several factors, such as the correction of anaemia, the reduction of chest pain and of respiratory limitation usually appearing early after surgery. The appropriate treatment of these problems is a relevant component of an in-hospital rehabilitation programme, independent from the physical training component. The knowledge of their contribution is important in evaluating the final results of the rehabilitation and in attributing the proper role to physical activity in post-cardiac surgery patients. Of interest, in a different clinical setting, that of moderate to severe heart failure, only 3 weeks of moderate intensity physical training have been able to determine a relevant (approximately 40%) increase of distance walked, in absence of other therapeutic interventions [26].

8. Conclusion

The 6MWT is feasible and well tolerated in adult and older patients shortly after uncomplicated cardiac surgery. Exercise training after cardiac surgery yielded significant improvements in exercise tolerance also in subjects older than 75 years of age and those with an initial poor performance, regardless of the type of cardiac surgery or comorbidity. Finally, this study provides useful reference values for distance walked after cardiac surgery obtained from a large group of subjects referred to a single-centre rehabilitation programme. The knowledge of reference values may be used in the clinical assessment of patients early after cardiac surgery and for a proper definition of rehabilitation programme.

Acknowledgement

We thank Professor John G Cleland, from the University of Hull, Castle Hill Hospital, Kingston-upon-Hull, UK, for the critical review of the manuscript and helpful comments.

References


