CARDIOVASCULAR MEDICINE

Ventilatory variables are strong prognostic markers in elderly patients with heart failure

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Objective: To evaluate the safety and prognostic capacity of cardiopulmonary exercise testing in patients ≥ 60 years old who are hospitalised with heart failure caused by left ventricular dysfunction.

Design: Prospective study.

Setting: University hospital.

Patients: Study participants were 67 patients (66% men) with clinical heart failure stabilised on medical treatment. The study is a part of a nursing intervention study. Mean (SD) age was 74 (6) years, New York Heart Association functional class II–III, and ejection fraction 0.36 (0.11).

Interventions: Cardiopulmonary exercise testing and echocardiography.

Main outcome measures: Peak oxygen consumption ($\dot{V}O_2$), peak ventilatory equivalents for carbon dioxide ($\dot{V}E/\dot{V}CO_2$) and oxygen ($\dot{V}E/\dot{V}O_2$), left ventricular volumes, and mortality.

Results: Mean (SD) peak $\dot{V}O_2$ was 11.7 (3.7) ml/kg/min, peak $\dot{V}E/\dot{V}CO_2$ 43 (9), and peak $\dot{V}E/\dot{V}O_2$ 46 (11). During 12–59 months of follow up, 14 patients died. In univariate analyses peak $\dot{V}O_2$, $\dot{V}E/\dot{V}O_2$, and $\dot{V}E/\dot{V}CO_2$ were all strongly related ($p < 0.01$) to mortality. In a multivariate Cox regression analysis, peak $\dot{V}E/\dot{V}CO_2$ was the strongest predictor of mortality ($p < 0.001$), followed by left ventricular end systolic volume ($p < 0.001$). A cut off of peak $\dot{V}E/\dot{V}CO_2$ at ≥ 45 gave a univariate hazard ratio of 6.7 for death during follow up. No adverse events occurred during the exercise test.

Conclusion: These findings extend results found in selected middle aged patients to elderly patients with heart failure and show that ventilatory parameters from a cardiopulmonary exercise test, such as peak $\dot{V}O_2$, $\dot{V}E/\dot{V}O_2$, and $\dot{V}E/\dot{V}CO_2$ are powerful predictors of mortality.

The prevalence of heart failure is increasing throughout the western world because the population is aging and management of patients suffering from acute coronary syndromes and their late complications is improving.^{1–3} Heart failure is associated with a high mortality rate, in particular in New York Heart Association (NYHA) functional classes III–IV. Indeed, one year after hospital discharge for treatment of heart failure, approximately 30% of the patients have died.^{4,5} Improvement in diagnostic procedures and the development of new drugs make it possible to tailor the treatment of heart failure in the individual patient. To do this and to monitor prognosis, functional assessment of patients with heart failure is of great importance. The classification of heart failure according to NYHA functional class provides a rough estimate of the physical status of the patient in activities of daily life and has been shown to be a useful predictor of mortality.⁶ The NYHA classification does not, however, provide objective measurement of physical capacity. The six minute walk test does not relate to cardiac function and relates only moderately to exercise capacity.⁷ In contrast, the cardiopulmonary exercise test gives important additional information by providing ventilatory parameters, such as oxygen uptake ($\dot{V}O_2$) and the ventilatory equivalents for oxygen ($\dot{V}E/\dot{V}O_2$) and carbon dioxide ($\dot{V}E/\dot{V}CO_2$), at submaximal and at peak exercise. Previous studies have shown that patients with heart failure reach their anaerobic threshold at an earlier stage than healthy controls and that their peak $\dot{V}O_2$ is lower.^{8,9} However, the use of a cardiopulmonary exercise test has been restricted mainly to the prognostic evaluation of middle aged patients, often on the waiting list for a heart transplant.¹⁰

We hypothesised that the cardiopulmonary exercise test can provide useful prognostic information to a broader population of patients with heart failure. Thus, this study aimed at evaluating whether the test can be carried out safely and give infor-

mation on the prognosis in a population representative of hospitalised patients with heart failure.

METHODS

Study design

The OPTIMAL (optimising congestive heart failure outpatient clinic project) is a prospective study in 208 patients hospitalised with heart failure between January 1996 and December 1999 in our institution. Participants were > 60 years old with heart failure (NYHA class II–IV) and left ventricular systolic dysfunction by echocardiography, defined as ejection fraction (EF) < 0.45 or atrioventricular plane displacement (AVPD) < 10 mm. Exclusion criteria were valve stenosis, an acute myocardial infarction or unstable angina pectoris within the previous three months, dementia, severe chronic lung disease, or other severe concomitant disease. In all, 285 patients were screened for participation in the study. Of those, 77 patients were not included in the study as they did not wish to participate ($n = 32$), did not have systolic dysfunction at screening echocardiography ($n = 23$), had valve stenosis ($n = 5$) or a recent ischaemic event ($n = 4$), or suffered from dementia ($n = 4$) or from other severe concomitant disease ($n = 9$).

The patients were randomly assigned to follow up in a nurse based outpatient clinic at the hospital or to conventional follow up and treatment, usually in primary care. The primary end point of the study is to assess whether a nurse based outpatient clinic leads to improvement of quality of life.

Abbreviations: AVPD, atrioventricular plane displacement; EF, ejection fraction; NYHA, New York Heart Association; OPTIMAL, optimising congestive heart failure outpatient clinical project; $\dot{V}CO_2$, carbon dioxide production; $\dot{V}E$, ventilatory equivalent; $\dot{V}O_2$, oxygen consumption

Evaluation of cardiac function, morbidity, and mortality are secondary end points.

After stabilisation of their heart failure, all patients were asked to perform a cardiopulmonary exercise test with metabolic monitoring before discharge. We here report on the 67 subjects in this elderly population who underwent the test. The main reasons not to perform the exercise test ($n = 141$) were unwillingness to participate in the test ($n = 46$), other conditions such as asthma, blindness, and temporary confusion ($n = 42$), other diseases of the cardiovascular system such as arrhythmias, angina, and stroke ($n = 21$), non-availability of exercise equipment ($n = 21$), and joint diseases ($n = 11$).

Outcome on all cause mortality was determined from death certificates when all patients had a follow up of at least one year. Each patient gave informed consent to participate in the study, which was approved by the local ethics committee and conforms to the principles outlined in the Declaration of Helsinki.

Exercise test and protocol

The exercise test was performed on an electrically braked bicycle. The equipment used was a cardiopulmonary exercise system (Medical Graphics, St Paul, Minnesota, USA) for breath by breath measurements of $\dot{V}E$, $\dot{V}O_2$, and $\dot{V}CO_2$. Derived entities such as $\dot{V}E$ for O_2 and CO_2 ($\dot{V}E/\dot{V}O_2$, $\dot{V}E/\dot{V}CO_2$), the respiratory quotient $\dot{V}CO_2/\dot{V}O_2$, and respiratory rate per minute were presented on line. The equipment was calibrated before every test. A 12 lead ECG was monitored for possible arrhythmia and ST segment changes. The test began with two minutes of sampling at rest and was followed by two minutes of freewheeling exercise. A ramp test with a continuous increase of workload by 10 W/min was chosen. The exercise test was symptom limited, using a Borg scale from 0 to 10 for dyspnoea, fatigue, and chest pain.¹¹ The patients were encouraged to exercise until they were exhausted. The physician interfered according to standard criteria. Blood pressure and heart rate were measured every other minute. All respiratory parameters were measured from plots over time, giving moving average values. Peak $\dot{V}O_2$, $\dot{V}E/\dot{V}O_2$, and $\dot{V}E/\dot{V}CO_2$ were calculated as the last value of three during the last 30 seconds of exercise. If this last value was not the highest, the mean of the last three values was calculated. Slopes of $\dot{V}E/\dot{V}O_2$ and $\dot{V}E/\dot{V}CO_2$ were calculated by linear regression analysis. The anaerobic threshold was calculated by the V slope method.¹²

Echocardiography

All examinations were performed with an Acuson 128 XP/10 (Mountain View, California, USA) with a 2.5–4.0 MHz (V4c) probe and the patient in the left semilateral position. Recordings were stored on videotape and analysed at the end of the study. Left ventricular dimensions in diastole and systole were measured by M mode technique. The EF was calculated according to the recommendations of the American Society of Echocardiography.¹³ Biplane volumes were calculated from area tracings using the disc summation method (modified Simpson's rule). Left ventricular systolic function was also evaluated with the AVPD method.¹⁴ The displacement was measured by M mode from an apical window. Mean values from four sites and three beats or more were used and the overall mean was calculated. Patients were enrolled into the study if a screening echocardiographic examination after medical stabilisation showed systolic dysfunction, defined as EF < 0.45 or AVPD < 10 mm. These measurements were not used further in the study. All echocardiographic findings presented in this paper are from an extensive baseline investigation, sometimes performed a few days after screening.

Statistical procedures

Data are presented as frequencies, median or mean (SD), as appropriate. The χ^2 test was used for comparison of

Table 1 Demographic data at baseline ($n=67$)

Mean (range) age (years)	74 (60–86)
Male sex	44 (66%)
Ejection fraction	0.36 (0.11)
NYHA class	II–IV
Heart rate (beats/min)	86 (21)
Systolic blood pressure (mm Hg)	134 (28)
Diastolic blood pressure (mm Hg)	81 (14)
Ischaemic heart disease	44 (67%)
Atrial fibrillation	32 (48%)
Hypertension	19 (30%)
Diabetes mellitus	10 (15%)
Cardiomyopathy	9 (14%)
Valve disease	5 (8%)
Furosemide	63 (94%)
ACE inhibitors	55 (82%)
β Blockers	40 (60%)
Digitalis	34 (51%)

Values are mean (SD) unless otherwise indicated. ACE, angiotensin converting enzyme; NYHA, New York Heart Association functional class. There were 49 patients in NYHA II, 17 in NYHA III, and 1 in NYHA IV

proportions. For correlations, Pearson's product-moment method was used. Survival curves were generated by the Kaplan-Meier method and the log rank test was used to assess differences in outcome between groups. The prognostic power of the variables for mortality was evaluated by Cox proportional hazard survival analysis, performed with Statistica 5.5 software (StatSoft, Tulsa, Oklahoma, USA) by a stepwise procedure. Hazard ratios and 95% confidence intervals were calculated, when appropriate. The final model was adjusted for age, sex, and NYHA functional class. A probability value of $p < 0.05$ was considered significant.

RESULTS

Table 1 gives demographic characteristics and medication of the patients who underwent exercise testing. The mean daily doses at baseline of angiotensin converting enzyme inhibitors were 55 mg of captopril, 4 mg of ramipril, and 14 mg of enalapril. The mean daily furosemide dose was 128 mg. When the study group was compared with the remaining patients in the entire OPTIMAL study who did not perform a cardiopulmonary exercise test, the latter group were somewhat older but the groups were otherwise comparable.

Cardiopulmonary exercise test

Table 2 and fig 1 show the results of the exercise test of 67 patients. No adverse events occurred during the tests. The anaerobic threshold was not always reached or possible to detect but was determined in 49 patients (73%). The peak respiratory quotient was > 1 in 53 patients (79%). While $\dot{V}E/\dot{V}O_2$ increased between the anaerobic threshold and the maximal effort, the corresponding $\dot{V}E/\dot{V}CO_2$ was relatively unchanged throughout the test. Table 2 shows that the anaerobic threshold was reached at approximately 30% of peak work rate. The threshold probably is low because some patients ($n = 13$) reached the anaerobic threshold very early, during the two minutes of rest on the bicycle or the following two minutes working without load. All of these 13 patients continued to exercise, though, reaching a mean peak work load of 51 W. Forty eight patients chose to stop the test because of exhaustion ($n = 21$), dyspnoea ($n = 14$), or both in combination ($n = 13$). The physician discontinued the test because of a fall in blood pressure ($n = 12$), angina pectoris or arrhythmia in one patient each, and pronounced ST segment depression in the remaining five subjects. The physician did not stop any test because of conductance disorders or depressed heart rate responses.

Table 2 Results from the cardiopulmonary exercise test

	Rest		Anaerobic threshold		Peak exercise	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Heart rate (beats/min)	78 (16)	38–117			118 (27)	69–195
SBP (mm Hg)	126 (24)	85–220			150 (29)	95–240
Work load (W)			21 (20)	0–63	72 (29)	0–129
$\dot{V}O_2$ (ml/kg/min)			7.7 (2.6)	2.4–12.7	11.7 (3.6)	3.1–18.0
$\dot{V}E/\dot{V}O_2$			38 (9)	22–60	46 (11)	26–73
$\dot{V}E/\dot{V}CO_2$			43 (9)	28–68	43 (9)	27–64
$\dot{V}E$ (l/min)					39 (14)	11–67
Respiratory quotient					1.1 (0.1)	0.86–1.31

Data from 67 patients. SBP, systolic blood pressure; $\dot{V}CO_2$, carbon dioxide production; $\dot{V}E$, ventilatory equivalent; $\dot{V}O_2$, oxygen uptake. Slope $\dot{V}E/\dot{V}O_2 = 41$ (8); slope $\dot{V}E/\dot{V}CO_2 = 45$ (8).

Figure 1 Relations between mortality and peak oxygen uptake (peak $\dot{V}O_2$), peak work load, and the quotients of ventilation to oxygen uptake ($\dot{V}E/\dot{V}O_2$) and ventilation to carbon dioxide production (peak $\dot{V}E/\dot{V}CO_2$). Mean values for 67 patients.

Echocardiography

The baseline ejection fraction was 0.36 (0.11) and atrioventricular plane displacement 6.9 (2.0) mm. The baseline left ventricular end systolic diameter was 47 (13) mm, left ventricular end diastolic diameter 57 (10) mm, end systolic volume 89 (51) ml, and end diastolic volume 132 (61) ml. Table 3 shows echocardiographic characteristics in relation to mortality. Table 4 shows the correlations between ventilatory and echocardiographic data. The strongest correlation was between peak $\dot{V}O_2$ and atrioventricular plane displacement.

Predictors of survival

Table 3, fig 1, and fig 2 show patient characteristics, and exercise and echocardiographic results in relation to mortality in December 2000, when all patients had been followed up for at least one year. During follow up 14 patients died (median sur-

Table 3 Characteristics of surviving and non-surviving patients at follow up

	Non-survivors (n=14)	Survivors (n=53)	p Value
Age (years)	74 (7)	73 (6)	NS
Male sex	11 (79%)	33 (62%)	NS
SBP (mm Hg)	121 (22)	138 (28)	<0.05
DBP (mm Hg)	75 (9)	82 (15)	NS
Ejection fraction	0.30 (0.11)	0.37 (0.10)	<0.05
LVSD (mm)	54 (15)	45 (12)	<0.05
LVDD (mm)	64 (13)	55 (9)	<0.05
ESV (ml)	129 (60)	78 (43)	<0.001
EDV (ml)	176 (68)	119 (52)	<0.01

Values are mean (SD) unless otherwise indicated. DBP, diastolic blood pressure; ESV, end systolic volume; EDV, end diastolic volume; LVDD, left ventricular end diastolic diameter; LVSD, left ventricular end systolic diameter.

Table 4 Correlations between ventilatory and echocardiographic variables

	EF	AVPD	ESV	EDV
Peak $\dot{V}O_2$	0.35*	0.39*	-0.36*	-0.33*
Peak $\dot{V}E/\dot{V}O_2$	-0.26*	-0.53*	0.26*	0.24
Peak $\dot{V}E/\dot{V}CO_2$	-0.34*	-0.64*	0.25	0.19

Data from 61 subjects. * $p < 0.05$. AVPD, atrioventricular plane displacement, EF, ejection fraction.

vival 11.8 months). Median follow up time for the survivors was 30.8 months. In univariate analyses, mortality was positively related, in declining order of significance, to peak $\dot{V}E/\dot{V}CO_2$ (50.8 v 40.9, $p < 0.001$), peak $\dot{V}E/\dot{V}O_2$ (54.9 v 43.3, $p < 0.001$), slope $\dot{V}E/\dot{V}O_2$ (46.8 v 39.7, $p = 0.006$), and slope $\dot{V}E/\dot{V}CO_2$ (49.7 v 43.8, $p = 0.02$), and inversely related to peak $\dot{V}O_2$ (9.3 v 12.4 ml/kg/min, $p = 0.004$). As expected, peak and slope $\dot{V}E/\dot{V}O_2$ ($r = 0.8$) and $\dot{V}E/\dot{V}CO_2$ ($r = 0.9$) were highly correlated. Thus, in univariate analysis, peak $\dot{V}E/\dot{V}CO_2$ and $\dot{V}E/\dot{V}O_2$ were stronger prognostic predictors than slope. Furthermore, a low ejection fraction ($p < 0.05$) and large left end systolic ($p < 0.001$) and end diastolic ($p < 0.05$) ventricular volumes predicted mortality. The strongest univariate predictor of mortality in Cox regression analysis was peak $\dot{V}E/\dot{V}CO_2$ (Wald $\chi^2 = 15.3$, $p < 0.001$), followed by peak $\dot{V}E/\dot{V}O_2$ (Wald $\chi^2 = 11.7$, $p < 0.001$) and left ventricular end systolic volume (Wald $\chi^2 = 11.0$, $p < 0.001$). In the final multivariate model, peak $\dot{V}E/\dot{V}CO_2$ was the strongest independent prognostic predictor (Wald $\chi^2 = 11.3$, $p < 0.001$), followed by left ventricular end systolic volume (Wald $\chi^2 = 10.6$, $p = 0.001$) when adjusted for age, sex, and NYHA class (global $\chi^2 = 30.3$, $p < 0.001$). Peak $\dot{V}O_2$ had no independent prognostic value in addition to either peak $\dot{V}E/\dot{V}CO_2$ or left ventricular end systolic volume.

Figure 2 Kaplan-Meier survival curve with a $\dot{V}E/\dot{V}CO_2$ cut off of ≥ 45 . Odds ratio 6.7 (95% confidence interval 1.9 to 24.2).

With a cut off for peak $\dot{V}E/\dot{V}CO_2$ of ≥ 45 , the univariate hazard ratio of survival was 6.7 (95% confidence interval 1.9 to 24.2, log rank $p < 0.001$) (fig 2). Adjusted for age, sex, left ventricular end systolic volume, and NYHA class, the hazard ratio of survival was 4.3 ($p < 0.05$). Sensitivity was 79% for mortality, specificity was 70%, the positive predictive value was 44%, the negative predictive value was 92%, and the positive likelihood ratio was 2.6. We did not find age, sex, aetiology of heart failure, presence of atrial fibrillation, or medication to have an impact on mortality.

DISCUSSION

The present prospective study is the first to assess the usefulness of a cardiopulmonary exercise test in elderly patients hospitalised with heart failure. We found peak $\dot{V}O_2$ to be severely impaired among these patients, reaching only 62% of the predicted value. The peak $\dot{V}E/\dot{V}CO_2$ reached high values and was the strongest predictor of mortality in univariate and in multivariate analyses. Our finding support and extend recent observations by Davies *et al* from exercise testing in ambulatory elderly patients with heart failure.¹⁵ They included patients with a mean age of 75.9 years and found a mean peak $\dot{V}O_2$ of 15.2 ml/kg/min, a mean slope $\dot{V}E/\dot{V}CO_2$ of 38.7, and both to predict the prognosis. The slightly better performance in their patients probably is a result of the difference between ambulatory and hospitalised patients with heart failure. Indeed, peak $\dot{V}O_2$ ¹⁰ and other measurements, particularly $\dot{V}E/\dot{V}CO_2$, have been shown to predict mortality in patients with heart failure.^{16–18} In a study of 60 male patients with heart failure in NYHA class II and III, Bol *et al* found that the slope of $\dot{V}E/\dot{V}O_2$ was the strongest prognostic predictor of all cause mortality.¹⁹ Both peak and slope $\dot{V}E/\dot{V}O_2$ and $\dot{V}E/\dot{V}CO_2$ have been used. It may be argued that slope is less effort dependent, as the peak depends on the level of exercise. In our study, however, the predictive power of the peak value was stronger.

Mancini *et al* divided middle aged patients with heart failure into four classes according to the cardiopulmonary exercise test results of peak $\dot{V}O_2$.¹⁰ Not always compatible with the NYHA classes, this classification has been shown to be useful as a prognostic tool for patients on the waiting list for a heart transplant. Thus, a patient with peak $\dot{V}O_2 > 14$ ml/kg/min has a good prognosis and can often be deferred from the transplant waiting list. Interestingly, when we applied this cut off to our subjects representing a different group of patients with heart failure, we found 95% survival in subjects with peak $\dot{V}O_2 > 14$ ml/kg/min. However, our results show that peak $\dot{V}E/\dot{V}CO_2$ provides the strongest predictive information. Thus, in a multivariate analysis also including left ventricular end systolic volume, we show $\dot{V}E/\dot{V}CO_2$ to be superior. A cut off for $\dot{V}E/\dot{V}CO_2$ of ≥ 45 may be most useful in assessing mortality risk in clinical practice.

The prognostic value of echocardiography in elderly patients with heart failure is unclear. Taffet *et al* showed that in male patients with heart failure who were 75 years or older,

the ejection fraction was not related to one year survival.²⁰ However, many elderly patients may have heart failure caused by diastolic dysfunction and systolic function is often preserved.²¹ In the present study, confined to patients with systolic left ventricular dysfunction, left ventricular end systolic volume was an independent strong prognostic indicator. Furthermore, there was a correlation between ventilatory variables and echocardiographic findings, in particular systolic left ventricular function. Few studies have investigated relations between $\dot{V}O_2$ and echocardiographic findings. In the study of Bol *et al*¹⁹ the combination of a high $\dot{V}E/\dot{V}O_2$ slope and a relatively high left ventricular ejection fraction was particularly unfavourable for prognosis. Florea *et al* described changes in peak $\dot{V}O_2$ but not ejection fraction over time to predict outcome.²² In another study in middle aged patients with dilated cardiomyopathy, peak $\dot{V}O_2$ correlated with left ventricular dimensions, filling patterns, and ejection fraction.²³ Thus, left ventricular size and in particular end systolic volume provide independent prognostic information in elderly patients with heart failure, whereas ejection fraction fails to do so in this context. However, peak $\dot{V}E/\dot{V}CO_2$ provides stronger prognostic information.

There are potential limitations to this study. Firstly, only one in three of these elderly hospitalised patients with heart failure eventually performed the cardiopulmonary exercise test. Cardiac patients unable to perform a provocation test probably have a worse prognosis.²⁴ This would decrease the predictive value of the provocation test in the current study. In our study, the patients who underwent the cardiopulmonary exercise test had a prognosis similar to those of the other patients in OPTIMAL. Secondly, this study included only patients with systolic left ventricular dysfunction. The prognostic information of the cardiopulmonary exercise test in patients with diastolic dysfunction remains to be studied.

The cardiopulmonary exercise test has been used for several years in middle aged patients, often on the transplant waiting list. We show that it can be used safely in elderly hospitalised patients with heart failure and can provide strong and independent prognostic information.

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REFERENCES

- 1 Ho KK, Pinsky JL, Kannel WB, *et al*. The epidemiology of heart failure: the Framingham study. *J Am Coll Cardiol* 1993;**22**(suppl):6A–13A.
- 2 Bonneux L, Barendregt JJ, Meeter K, *et al*. Estimation of clinical morbidity due to ischemic heart disease and congestive heart failure: the future rise of heart failure. *Am J Public Health* 1994;**84**:20–8.
- 3 Mejthert M, Edner M, Persson H, *et al*. Epidemiology of heart failure in Sweden: a national survey. *Eur J Heart Fail* 2001;**1**:97–103.
- 4 Cline C, Broms K, Willenheimer RB, *et al*. Hospitalization and health care costs due to congestive heart failure in the elderly. *Am J Geriatr Cardiol* 1996;**5**:10–4.
- 5 Mejthert M, Holmgren J, Wändell P, *et al*. Diagnostic tests, treatment and follow-up in heart failure patients: is there a gender bias in the coherence to guidelines? *Eur J Heart Fail* 1998;**1**:407–10.
- 6 Parameshwar J, Keegan J, Sparrow J, *et al*. Predictors of prognosis in severe chronic heart failure. *Am Heart J* 1992;**123**:421–6.
- 7 Opasich C, Pinna GD, Mazza A, *et al*. Six-minute walking performance in patients with moderate to severe heart failure: is it a useful indicator in clinical practice? *Eur Heart J* 2001;**22**:488–96.
- 8 Weber KT, Kinazewitz GT, Jannicki JS, *et al*. Oxygen utilization and ventilation during exercise in patients with chronic cardiac failure. *Circulation* 1982;**6**:1213–23.

- 9 **Opasich C**, Pinna GD, Bobbio M, *et al*. Peak exercise oxygen consumption in chronic heart failure: toward efficient use in the individual patient. *J Am Coll Cardiol* 1998;**31**:766–75.
- 10 **Mancini DM**, Eisen H, Kussmaul W, *et al*. Value of peak exercise oxygen consumption for optimal timing of cardiac transplantation in ambulatory patients with heart failure. *Circulation* 1991;**83**:778–86.
- 11 **Borg G**. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med* 1970;**2**:92–8.
- 12 **Wasserman K**, Beaver WL, Whipp BJ. Gas exchange theory and the lactic acidosis (anaerobic) threshold. *Circulation* 1990;**81**(suppl II):II14–30.
- 13 **American Society of Echocardiography Committee on standards**. Recommendations for quantification of the left ventricle by two-dimensional echocardiography. *J Am Soc Echocardiogr* 1989;**2**:358–67.
- 14 **Höglund C**, Alam M, Thorstrand C. Atrioventricular valve plane displacement in healthy persons: an echocardiographic study. *Acta Med Scand* 1988;**224**:557–62.
- 15 **Davies LS**, Francis DP, Piepoli M, *et al*. Chronic heart failure in the elderly: value of cardiopulmonary exercise testing in risk stratification. *Heart* 2000;**83**:147–51.
- 16 **Francis DP**, Shamim W, Davies LC, *et al*. Cardiopulmonary exercise testing for prognosis in chronic heart failure: continuous and independent prognostic value from VE/VCO₂ slope and peak VO₂. *Eur Heart J* 2000;**21**:154–61.
- 17 **Kleber FX**, Vietzke G, Wernecke KD, *et al*. Impairment of ventilator efficiency in heart failure, prognostic impact. *Circulation* 2000;**101**:2803–9.
- 18 **Metra M**, Faggiano P, D'Alòia A, *et al*. Use of cardiopulmonary exercise testing with hemodynamic monitoring in the prognostic assessment of ambulatory patients with chronic heart failure. *J Am Coll Cardiol* 1999;**33**:943–50.
- 19 **Bol E**, De Vries WR, Mosterd WL, *et al*. Cardiopulmonary exercise parameters in relation to all-cause mortality in patients with chronic heart failure. *Int J Cardiol* 2000;**72**:255–63.
- 20 **Taffet GE**, Teasdale TA, Bleyer AJ, *et al*. Survival of elderly men with congestive heart failure. *Age Ageing* 1992;**21**:49–55.
- 21 **Pernenkil R**, Vinson JM, Atul SS, *et al*. Course and prognosis in patients >70 years of age with congestive heart failure and normal versus abnormal left ventricular ejection fraction. *Am J Cardiol* 1997;**79**:216–9.
- 22 **Florea VG**, Heinem MY, Anker SD, *et al*. Prognostic value of changes over time in exercise capacity and echocardiographic measurements in patients with chronic heart failure. *Eur Heart J* 2000;**21**:146–53.
- 23 **Pepi M**, Agostoni P, Marenzi G, *et al*. The influence of diastolic and systolic function on exercise performance in heart failure due to dilated cardiomyopathy or ischemic heart disease. *Eur J Heart Fail* 1999;**1**:161–7.
- 24 **Lundin P**, Eriksson SV, Strandberg LE, *et al*. Prognostic information from on-line vectorcardiography in acute myocardial infarction. *Am J Cardiol* 1994;**74**:1103–8.

IMAGES IN CARDIOLOGY

Giant congenital aneurysm of the non-coronary sinus of Valsalva

A 57 year old woman underwent echocardiography following deep vein thrombosis of the left lower limb with consecutive pulmonary embolism. The exam incidentally revealed a giant congenital aneurysm of the non-coronary sinus of Valsalva with protrusion towards both atrial cavities, but without signs of rupture or penetration. There was low perfusion of the aneurysmal sack confined to diastole as its orifice was small and additionally covered by the non-coronary cusp during systole; no thrombus material could be detected inside the aneurysm. Mild aortic regurgitation resulted from

slight detachment of the non-coronary commissure. Preoperative cardiac catheterisation confirmed the huge balloon-like aneurysm of the non-coronary sinus of Valsalva. The aneurysm ruptured while the patient was on the waiting list for elective operation and an emergency ligation had to be performed a few weeks after initial diagnosis. The postoperative course was uneventful and the patient is doing well.

Left and centre panels below show right anterior oblique-like transoesophageal echocardiographic view with the giant aneurysm of the non-coronary sinus of Valsalva

arising posteriorly to the aortic root. Pronounced protrusion of the aneurysm towards the left atrium is visualised in this 101° echocardiographic plane. The right panel shows right anterior oblique angiographic projection of the left ventricle, the aortic root and the ascending aorta with the balloon-like aneurysm of the non-coronary sinus of Valsalva extending posteriorly and also to the right of the non-coronary sinus. Note the relatively faint filling of the aneurysmal sack with contrast dye as compared to the left ventricle and the aorta.

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