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Cardiopulmonary Exercise Testing in the Pre-Operative Assessment of Patients for Repair of Abdominal Aortic Aneurysm

A. M. Nugent, M. Riley, J. Megarry, M. J. G. O'Reilly*, J. MacMahon, R. Lowry

Department of Respiratory Medicine, Belfast City Hospital, Lisburn Road, Belfast BT9 7AB, Northern Ireland.
**Department of Vascular Surgery, Belfast City Hospital, Belfast BT9 7AB, Northern Ireland.*

Abstract

We have investigated the value of cardiopulmonary exercise testing in the pre-operative assessment of patients for abdominal aortic aneurysm repair. Thirty-six patients were entered into the study. All had a pre-operative clinical assessment and investigations including chest radiograph, electrocardiograph, spirometry and echocardiogram with measurement of left ventricular ejection fraction. Each patient performed a symptom limited treadmill exercise test using a STEEP protocol with on-line measurement of respiratory gas exchange. Patients were followed up for 12 months post-operatively by review of casenotes.

Thirty out of 36 patients had surgical repair of abdominal aortic aneurysm. There was 1 death in the perioperative period and 2 deaths in the following 12 months. Seven other patients suffered post-operative complications. There were no significant differences in left ventricular ejection fraction, spirometry and peak achieved oxygen consumption (PVO_2) between those patients who died or who had post-operative complications and those who had not. However, PVO_2 < 20ml/min/kg was found in 70 per cent of patients who had complications compared with 50 per cent of those who had not. Also 4 patients considered medically unfit for surgery all had PVO_2 <20ml/min/kg. Cardiopulmonary exercise testing with measurement of PVO_2 may be helpful in identifying patients more at risk of post-operative complications but should not be used in isolation without thorough clinical assessment.

Introduction

The repair of an abdominal aortic aneurysm constitutes major surgery. Careful selection of patients is of great importance to avoid operating on patients who are at high risk of developing complications. Many patients with an abdominal aortic aneurysm have coexistent cardiac disease[1]. Aortic surgery places an extra burden on the diseased heart as it necessitates clamping off the aorta for a variable period of time with a consequent increase in the afterload presented to the left ventricle. This can result in acute myocardial ischaemia with acute left ventricular dilatation and raised pulmonary wedge pressures. Removal of the clamp causes an abrupt reduction in vascular resistance with a sudden return of acidic blood to the heart which can cause cardiac depression. There is a reduced circulating volume because vasodilation has developed in the lower limbs which can be helped by adequate volume loading before gradual removal of the cross-clamp. Because of the acute haemodynamic changes associated with aortic cross-clamping and releasing, post-operative complications such as pulmonary oedema and myocardial infarction may occur. There is also a risk of major pulmonary complications following abdominal surgery[2]. There is currently wide variation in pre-operative assessment of patients undergoing elective repair of abdominal aortic aneurysm and there is a need for a sensitive pre-operative test which can predict those patients most at risk of complications[3]. Resting non-invasive tests of cardiac function including electrocardiograph and measurement of left ventricular ejection fraction by echocardiography or radionuclide methods may lack sensitivity and specificity[4]. More dynamic tests such as dobutamine stress echocardiography have been better predictors of post-operative cardiac morbidity and mortality[5]. Pulmonary function tests including spirometry are not reliable predictors of post-operative pulmonary complications[6]. Cardiopulmonary exercise testing is a good way of assessing both cardiac and pulmonary reserve[7] and may be a better predictor of outcome than static tests of cardiac and pulmonary function. The aim of this study was to investigate the value of cardiopulmonary exercise testing in the pre-operative assessment of patients for repair of abdominal aortic aneurysm.

Subjects and Methods

Patients awaiting elective repair of an abdominal aortic aneurysm were considered for entry into the study. Patients with musculoskeletal disease or intermittent claudication leading to premature cessation of exercise were excluded. All subjects gave written informed consent and the study was approved by the Ethics Committee of the Queen's University of Belfast. Thirty-six patients were recruited (27 male; mean age 72.2 yr, range 57-85 yr; mean height 1.67 metres, range 1.45-1.89 metres; mean weight 69.1 kg, range 45-98 kg). All had pre-operative assessment

Address for Correspondence:
Dr. A. M. Nugent,
Department of Respiratory Medicine,
Belfast City Hospital, Lisburn Road,
Belfast BT9 7AB, Northern Ireland.

which comprised clinical history and examination, chest radiograph, resting 12-lead electrocardiograph, spirometry and echocardiogram with measurement of left ventricular ejection fraction. These results were available to the surgical team. Fourteen patients were smokers and 15 were ex-smokers. A history of hypertension was found in 8 patients. Ten patients had a history of previous myocardial infarction, 4 patients had a history of angina and 1 had a history of left ventricular failure. One patient had known peripheral vascular disease and 1 patient had a previous stroke. One patient had a pacemaker in situ and 3 patients had atrial fibrillation / flutter. Two patients had non-insulin dependent diabetes mellitus and 1 patient had known hypercholesterolaemia. Six patients had a history of chronic chest disease. Medication included beta blockers (3 patients), angiotensin converting enzyme inhibitors (5 patients), other vasodilators (8 patients), diuretics (8 patients), digoxin (3 patients) and aspirin (6 patients).

Each patient attended for a cardiopulmonary exercise test and underwent an initial familiarisation test. A symptom limited treadmill exercise test was then carried out using a STEEP protocol[8] which is based on exponential increases in workload with on-line measurement of respiratory gas exchange ie. minute ventilation, oxygen consumption and carbon dioxide production. Ventilation was measured using a vane turbine and measurement of fractional concentrations of expired oxygen and carbon dioxide levels was by paramagnetic and infrared analysis respectively. Calibrating of the turbine and gas analysers was performed prior to each test. There was continuous monitoring of heart rate by ECG (CM5 lead) and oxygen saturation by pulse oximetry. Blood pressure was recorded at 3 min intervals throughout the test and at peak exercise using mercury syphgmomanometry. After completion of the test, patients were asked to rate their perceived exertion on a scale of up to 10 points (Borg score)[9]. The results of the exercise test were not made available to the surgical team so as to avoid selection bias. The patients were followed up for 12 months after their operation by review of the casenotes. Information obtained included details of surgery, post-operative course, length of hospital stay and subsequent morbidity or mortality.

Analysis of exercise tests: Peak VO_2 was defined as the highest VO_2 recorded during the final 30 seconds of exercise. Anaerobic threshold was determined by plots of VCO_2 against VO_2[10]. Peak oxygen pulse, an indication of exercise stroke volume, was calculated as the quotient of PVO_2 and heart rate. ST segment depression of >0.1mV was considered positive for myocardial ischaemia. For the purposes of calculating an exercise score, an abnormal PVO_2 was defined as <83 per cent of the age, gender and size predicted value[11], and an abnormal anaerobic threshold or oxygen pulse as any value below the lower 95 per cent confidence limits for normality[12]. Abnormalities of PVO_2, anaerobic threshold, oxygen pulse or ischaemic ST depression each scored 1 point. An exercise score of 2 or more points was considered impaired exercise performance.

Statistical analysis

Inter-group comparisons were made using the Mann Whitney U test and a level of $p<0.05$ was regarded as significant. Chi-square analysis was used as a measure of association between 2 categorical variables.

Results

All patients completed the treadmill exercise test uneventfully. Of the 36 patients studied, 6 were excluded from analysis: 4 patients were considered medically unfit for surgery, 1 patient refused the operation and 1 patient was felt to have too small an aneurysm to justify surgery.

The remaining 30 patients (24 male; mean age 71.3 yr, range 57-85 yr) were followed up. All patients had abdominal aortic aneurysms with mean maximum diameter 6.3cm, range 3.8-8.7cm. In 4 cases the renal vessels were involved, while in the remaining patients the aneurysm was below the renal arteries. Surgery was performed by a consultant vascular surgeon and assisted by at least 1 surgical registrar. All patients had a standard midline abdominal incision to approach the aneurysm except in 3 cases where there was a transverse incision with retroperitoneal approach. Seven patients had bifurcated grafts inserted and the remainder had straight aortic grafts inserted. The average intra-operative blood loss was 1900 mls (range 410-7575 mls). Intra-operative blood transfusion varied from 0-12 units of packed cells with a mean of 2 units per patient. All patients received a standard anaesthetic regime. General anaesthesia was induced with thiopentone, analgesia was provided with fentanyl, muscle relaxation with atracurium and anaesthesia maintained with isoflurane in nitrous oxide and oxygen. Dopamine infusion was given to maintain urinary output. Following surgery patients were generally extubated and transferred overnight to the intensive care unit before returning to the surgical ward. Post-operative

TABLE I
Demographic details, peak VO_2 and LVEF for patients who suffered post-operative complications, including the type of complication.

Patient	Age (years)	Sex	Peak VO_2 (ml/min/kg)	LVEF (%)	Complication
1	72	M	14.6	55	Died day 2 post-op: circulatory failure.
2	79	F	16.17	57.5	Died 5 months post-op: sudden death.
3	67	F	12.7	25	Died 10 months post-op: intractable cardiac failure.
4	57	M	25.92	62.5	Pneumonia: day 7
5	76	F	22.39	57.5	Pneumonia. CCF: day 6
6	70	M	15.97	65	Haemorrhage: day 1
7	85	F	17.74	40	Pulmonary oedema: day 10
8	66	M	23.42	55	Arrhythmia: day 2 Above knee amputation: day 7
9	60	M	18.52	65	Pneumonia: day 5
10	80	M	18.43	25	Haemorrhage: day 1

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TABLE II
Results of LVEF, spirometry, exercise test and length of hospital stay for patients with complications (Group 1) and those with no complications (Group 2), shown as mean (SEM)

	Group 1 n=10	Group 2 n=20	p
Age (years)	71.2 (2.8)	70.8 (1.5)	NS
LVEF (%)	50.8 (4.9)	53.5 (2.2)	NS
FEV_1 (l/min)	2.11 (0.22)	2.31 (0.20)	NS
FEV_1 (%)	75.9 (5.7)	75.8 (6.1)	NS
peak VO_2 (ml/min/kg)	18.6 (1.3)	21.8 (1.4)	NS
peak VO_2 (%)	85.7 (6.6)	107.7 (6.9)	NS
Exercise score	0.40 (0.22)	0.57 (0.19)	NS
Length of post-op stay (days)	17.7 (4.0)	10.3 (0.4)	<0.001

analgesia consisted of a thoracic epidural infusion of fentanyl and bupivicaine. Two patients required post-operative ventilation: 1 patient had alot of bleeding at the time of surgery and ventilation was continued post-operatively but he died 2 days later from circulatory failure; another patient was ventilated overnight following surgery when a femoral embolectomy was also carried out. Two patients died in the follow-up period - one at 5 months post-surgery was a sudden death, presumably cardiac in origin, and another died 10 months post-surgery from intractable congestive cardiac failure. Seven other patients suffered post-operative complications and full details are shown in Table I. The results were analysed by dividing the patients into 2 groups, those who had perioperative complications or died within the first yr (Group 1) and those who did not (Group 2). Perioperative complications were identified as significant cardiopulmonary or surgical complications occurring within 30 days of surgery. All those patients listed in Table I were included within Group 1. Parameters compared between the 2 groups included age, left ventricular ejection fraction, forced expiratory volume in 1 second, peak achieved oxygen consumption, exercise score and length of post-operative hospital stay (Table II). The only significant difference was in length of post-operative hospital stay which was longer in the complication group as would be expected. Results were also looked at after excluding the two patients who developed post-operative haemorrhage from the

TABLE III
Complication rate for patients with PVO_2 above and below 20ml/min/kg, and exercise score above and below 2 compared with patients with no complications.

	Complications n=10	No complications n=20	p
PVO_2 <20ml/min/kg	7	10	NS
PVO_2 > 20ml/min/kg	3	10	
Exercise score <2	9	17	NS
Exercise score >2	1	3	

TABLE IV
Details of patients considered medically unfit for surgery.

Patient	Age (years)	Sex	Peak VO_2 (ml/min/kg)	Reason for no surgery
1	83	F	16.73	Cholangiocarcinoma
2	82	F	11.48	Valvular heart disease with pulmonary hypertension; Pancytopenia
3	73	M	16.26	Ischaemic heart disease
4	76	M	18.56	Left ventricular failure and atrial fibrillation

complication group, as cardiopulmonary exercise testing should not be expected to predict this complication; again there were no other significant differences. A peak achieved oxygen consumption of <20ml/min/kg was found in 7/10 patients (70 per cent) in the complication group and in 10/20 patients (50 per cent) in the no complication group, which did not reach statistical significance (Table III). Exercise score >2 was not found more frequently in the complication group (Table III). Of the 4 patients who were considered medically unfit for surgery, all had a peak VO_2 of <20ml/min/kg. Full details are shown in Table IV.

Discussion

Cardiopulmonary exercise testing has been shown to be of value in predicting post-operative outcome in patients undergoing lung resection[13,14]. The measurement of maximal oxygen uptake reflects the integrated response of all the systems involved in exercise including pulmonary ventilation and gas exchange and cardiac output. Reductions in maximal oxygen uptake parallel reductions in functional capacities of each system fairly closely and also correlate well with symptomatic limitations[7]. Patients with a maximal oxygen uptake of >20 ml/min/kg have been shown to be less likely to have post-operative complications[13]. A similar trend was seen in our study. Although there was no significant difference in peak VO_2 between the group with complications and those with no complications, there was a trend towards a higher complication rate in those patients with a peak VO_2 <20 ml/min/kg. Of note, the patients considered medically unfit for surgery all had a peak VO_2 <20 ml/min/kg. This is suggestive of a clinical bias towards selecting the fittest patients for surgery. Patients with an abdominal aortic aneurysm do not have a malignant tumour, unlike patients for lung resection, many of whom have a lung neoplasm. Despite the risk of aneurysm rupture, there may be less tendency to operate on clinically 'borderline' patients with abdominal aortic aneurysm compared with lung cancer patients. It may then be more difficult to identify a sensitive and specific predictor of post-operative outcome. The further analysis of each exercise test to calculate an exercise score on the basis of abnormalities in peak VO_2, anaerobic threshold, oxygen pulse and ST depression on ECG monitoring failed to predict post-operative outcome. A major limitation of this study is the relatively small

number of patients in each group for analysis leading to a high probability of a type 2 error. The perioperative mortality rate was 1/30 (3.3 per cent) and the complication rate was 8/30 (26.7 per cent), although this is similar to that reported in previous studies[1,2]. Measurement of left ventricular ejection fraction at rest and spirometry (forced expiratory volume in 1 second and forced vital capacity) were similar in the group with complications compared with the group with no complications. The length of post-operative hospital stay was significantly longer in the group with complications. The additional financial consequences of this also needs to be considered.

In conclusion, cardiopulmonary exercise testing with measurement of peak VO_2 may be helpful in identifying patients more at risk of post operative complications. However, it should not be used in isolation and cannot replace thorough clinical assessment.

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