

## Editorial

# Exercise testing to guide surgery in aortic stenosis

Exercise testing has a long but largely forgotten pedigree in the assessment of patients with aortic stenosis. Before the development of echocardiography, a blunted rise in systolic blood pressure and the development of ST segment depression on an ECG during exercise were used to differentiate severe from more mild stenosis in children.<sup>1</sup> In adults, ST segment depression is not sufficiently well correlated with coronary disease to be clinically useful.<sup>2,3</sup> However the symptomatic and blood pressure responses to exercise may aid the timing of surgery in patients with equivocal or no symptoms.

### Why is an objective assessment of symptoms necessary?

The prognosis in asymptomatic severe stenosis is widely regarded as too good to justify prophylactic surgery. However, as soon as symptoms develop, survival falls sharply and 10% of patients die within the first few months.<sup>4,5</sup> This figure is far higher than the surgical risk of isolated aortic valve replacement which, even in unselected patients of all ages, was 4.4% in the UK during 1995-96 (Society of Cardiothoracic Surgeons, UK Cardiac Surgical Register). In a study advocating a conservative approach<sup>4</sup> three of 113 apparently asymptomatic patients died within three months of developing symptoms before these were brought to the attention of their physician. Furthermore Lund *et al* reported that seven of 99 symptomatic patients died on a six month waiting list.<sup>5</sup> It is possible that an earlier warning of the development of symptoms using treadmill exercise testing might have saved some of these patients. Otto *et al* found that three of 104 apparently asymptomatic patients with all grades of aortic stenosis developed chest pain on exercise,<sup>3</sup> but the number with severe aortic stenosis was not given. We found that four of 13 apparently asymptomatic patients with severe aortic stenosis and four of 19 with moderate stenosis but none of 22 with mild or no stenosis developed chest pain or dizziness on exercise.<sup>6</sup> These patients were either sedentary or poor witnesses and there seems no reason to manage them any differently from those with spontaneously volunteered symptoms.

It is also possible, but not proved, that some patients should be offered prophylactic surgery to preserve left ventricular function. While left ventricular hypertrophy is initially an adaptation to normalise wall stress in pressure overload, it leads ultimately to irreversible myocardial fibrosis. As a result, recovery of left ventricular systolic function is incomplete after aortic valve replacement in 24% to 66% of patients with low preoperative ejection fractions.<sup>7,8</sup> Even in patients with apparently normal systolic function, exercise capacity may be substantially reduced late after aortic valve replacement<sup>9,10</sup> probably partly as a result of persisting diastolic dysfunction. These observations suggest that we may be operating too late on some patients with severe aortic stenosis. A recent British Cardiac Society document<sup>11</sup> suggested that prophylactic surgery should be considered for asymptomatic severe aortic stenosis "if the gradient is > 100 mm Hg or the patient is particularly active". However, we should not remain imprinted exclusively on the gradient itself. More important are the effects of that gradient on left ventricular and peripheral circulatory function. These may vary, and a

patient with moderate aortic stenosis may be more limited than one with severe stenosis based purely on consideration of the gradient.<sup>3,6</sup> It is an unproved possibility that early evidence of systolic dysfunction based on indexed systolic volumes<sup>7</sup> or long axis function<sup>12</sup> may guide prophylactic surgery. However, exercise testing is a more readily performed investigation representing a combined biological end point encompassing left ventricular systolic and diastolic function, coronary flow, and the systemic vascular response to aortic stenosis.

In the study by Otto *et al*,<sup>3</sup> the rise in systolic blood pressure on the baseline exercise test was smaller in those who died or required aortic valve surgery (15 mm Hg) than in those who remained asymptomatic (29 mm Hg;  $p < 0.001$ ). Although this effect was no longer independently significant in the multivariate analysis, only baseline exercise data were considered despite a follow up period of 2.5 (1.4) years. Decreased exercise tolerance, heart failure, or angina were noted in 76% of those having surgery, suggesting that serial studies of blood pressure response on exercise might have been revealing. This study did not address the question of recovery of left ventricular function or of exercise ability after surgery.

It is possible that a severe reduction of exercise duration might be a reasonable guide for prophylactic surgery,<sup>13</sup> but we lack adequate thresholds and to date there are no predictive data available.

### How safe is exercise testing in aortic stenosis?

Symptomatic severe stenosis is traditionally regarded as an absolute contraindication to exercise testing, and moderate stenosis without symptoms as a relative contraindication.<sup>14</sup> A survey of 50 000 exercise studies at 12 centres in Sweden,<sup>15</sup> mostly using bicycle exercise, suggested a higher than average proportion of complications in aortic stenosis, but unfortunately relative incidence was not given nor was it clear how many patients had symptoms. Overall the morbidity rate including patients with valve and coronary disease was only 0.0005% and the mortality was 0.00004%. Exercise testing should be avoided in patients with unequivocal heart failure, chest tightness, or exertional presyncope or syncope. In those with non-specific breathlessness or no symptoms, it should be symptom limited and should be stopped if the systolic blood pressure falls by more than 10 mm Hg. ST segment depression of up to 5 mm can be ignored in the absence of symptoms, arrhythmia or relative hypotension. Using these criteria, exercise testing appears safe.<sup>2,3</sup> We must not forget that patients exercise to some degree in the outside world and it is usually better to have a complication under observation during a treadmill test than walking up a hill in the country.

### Which patients should be considered for exercise testing?

Patients with unequivocal symptoms on exertion usually require invasive investigation with a view to surgery. Exercise testing can be used in patients who have moderate or severe aortic stenosis on echocardiography who claim to be asymptomatic and who are not excluded from surgery by other factors such as concomitant disease. What we mean

by moderate and severe needs discussion. A peak instantaneous velocity of 3.0 m/s has been suggested as a threshold,<sup>3</sup> but peak velocity may not be a good way of summarising a waveform that lasts throughout systole and is highly flow dependent. Patients with a peak instantaneous velocity > 4.0 m/s will almost always have at least moderate stenosis. However, because of the square relation between pressure and velocity, the range in peak velocity between 3.0 and 4.0 m/s is approximately equivalent to a peak instantaneous pressure difference of between 35 and 65 mm Hg, potentially encompassing patients with everything from mild to severe stenosis. Effective area using the continuity equation has methodological limitations but also compensates for flow and—when correctly applied—uses the waveform over the whole of systole. An effective area < 1.0 cm<sup>2</sup> is an almost universally used threshold for moderate and severe stenosis.

### Conclusions

Exercise testing is widely accepted in assessing coronary disease, another condition in which symptoms may be unreliable. The conservative management of patients with asymptomatic severe aortic stenosis is acknowledged to require extreme vigilance<sup>16</sup> particularly when a surgical waiting list may be months rather than weeks in length. The difference in prognosis between asymptomatic and symptomatic aortic stenosis is extreme and should not be left to subjective history taking alone. Exercise testing can be used in asymptomatic patients who have moderate or severe aortic stenosis on echocardiography defined by a peak instantaneous velocity > 4.0 m/s or effective orifice area by the continuity equation < 1.0 cm<sup>2</sup>. The predictive value of a blunted systolic blood pressure response or a progressive reduction in exercise duration require further investigation before being used to recommend prophylactic surgery either to prevent sudden death or to preserve left ventricular function. However, if chest tightness develops, it is reasonable to prepare for aortic valve replacement.

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- 1 James FW, Schwartz DC, Kaplan S, *et al.* Exercise electrocardiogram, blood pressure, and working capacity in young patients with valvular or discrete subvalvular aortic stenosis. *Am J Cardiol* 1982;**50**:769–75.
- 2 Clyne CA, Arrighi JA, Maron BJ, *et al.* Systemic and left ventricular responses to exercise stress in asymptomatic patients with valvular aortic stenosis. *Am J Cardiol* 1991;**68**:1469–76.
- 3 Otto CM, Burwash IG, Legget ME, *et al.* Prospective study of asymptomatic valvular aortic stenosis—clinical, echocardiographic, and exercise predictors of outcome. *Circulation* 1997;**95**:2262–70.
- 4 Pellikka PA, Nishimura RA, Bailey KR, *et al.* The natural history of adults with asymptomatic, hemodynamically significant aortic stenosis. *J Am Coll Cardiol* 1990;**15**:1012–17.
- 5 Lund O, Nielsen TT, Emmertsen K, *et al.* Mortality and worsening of prognostic profile during waiting time for valve replacement in aortic stenosis. *Thoracic Cardiovasc Surg* 1996;**44**:289–95.
- 6 Takeda S, Rimington H, Cook B, *et al.* Exercise time correlates with long-axis dysfunction in apparently asymptomatic patients with aortic stenosis [abstract]. *Heart* 1998;**80**(suppl 1):S31.
- 7 Hwang MH, Hammermeister KE, Oprian C, *et al.* Preoperative identification of patients likely to have left ventricular dysfunction after aortic valve replacement. Participants in the Veterans Administration cooperative study on valvular heart disease. *Circulation* 1989;**80**:165–76.
- 8 Connolly HM, Oh JK, Orszulak TA, *et al.* Aortic valve replacement for aortic stenosis with severe left ventricular dysfunction. Prognostic indicators. *Circulation* 1997;**95**:2395–400.
- 9 Munt BI, Legget ME, Healy NL, *et al.* Effects of aortic valve replacement on exercise duration and functional status in adults with valvular aortic stenosis. *Can J Cardiol* 1997;**13**:346–50.
- 10 Monrad ES, Hess OM, Murakami T, *et al.* Abnormal exercise haemodynamics in patients with normal systolic function late after aortic valve replacement. *Circulation* 1988;**77**:613–24.
- 11 Prendergast BD, Banning AP, Hall RJC. Valvular heart disease. Investigation and management. Recommendations of a working group of the British Cardiac Society and the Research Unit of the Royal College of Physicians. London: Royal College of Physicians 1996.
- 12 Takeda S, Rimington H, Hayes A, *et al.* Long axis function is impaired in patients with aortic stenosis and apparently normal systolic function [abstract]. *Circulation* 1997;**96**:I-540.
- 13 Areskog N-H. Exercise testing in the evaluation of patients with valvular aortic stenosis. *Clin Physiol* 1984;**4**:201–8.
- 14 Gibbons RJ, Balady GJ, Beasley JW, *et al.* ACC/AHA guidelines for exercise testing. A report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee on exercise testing). *J Am Coll Cardiol* 1997;**30**:260–315.
- 15 Atterhog J-H, Johnsson B, Samuelsson R. Exercise testing: a prospective study of complication rates. *Am Heart J* 1979;**98**:572–9.
- 16 Vaile JC, Griffith MJ. Management of asymptomatic aortic stenosis: masterly inactivity but cat-like observation. *Heart* 1997;**78**:215–17.