Exercise Hemodynamics and Risk Assessment in Asymptomatic Aortic Stenosis

Robert O. Bonow, MD

More than half a century ago, in the American Journal of Cardiology, Dr Paul Wood aptly described aortic stenosis (AS) as “a simple mechanical fault which, if severe enough, imposes a heavy burden on the left ventricle and sooner or later overcomes it.” Our subsequent understanding of the pathophysiology of AS, using more sophisticated tools than those at Dr Wood’s disposal, has confirmed his concept. Severe chronic pressure overload and outflow obstruction beget left ventricular (LV) hypertrophy and its attendant myocardial fibrosis and impaired coronary vasodilator reserve, leading to LV systolic and diastolic dysfunction, and progressing ultimately to the anticipated symptoms of dyspnea, angina, and presyncope or syncope, which are harbingers of death within a few years. Once symptoms develop, the treatment strategy is clear, because aortic valve replacement (AVR) improves symptoms, improves LV function, and improves survival. The indications for AVR in asymptomatic patients, however, remain less clear and the subject of ongoing debate. Although the current evidence-based guidelines recommend a watchful waiting approach for most patients, with no class I indications for surgery in asymptomatic patients with normal LV systolic function, numerous studies have shown that patients with severe AS have a high likelihood of developing symptoms within 3 to 5 years and some series have reported that asymptomatic patients with severe AS are also at risk of death when managed without surgery. Because the operative risk of AVR is low in experienced centers, there is intense interest in identifying the subsets of asymptomatic patients that have the highest likelihood of dying or developing symptoms over the short term and that might benefit from early, preemptive AVR rather than a watchful waiting approach.

Determination which patients with AS are truly asymptomatic is not an exact science. Patients often have difficulty describing their exercise limitations and may appear to be asymptomatic because they have downgraded their activities to limit dyspnea. In addition, interpreting mild exertional dyspnea as a cardiac symptom is complex in the many patients who are elderly, deconditioned, or overweight. Exercise testing has been proposed as a means of identifying higher risk patients by unmasking symptoms or abnormal blood pressure responses. Several studies have shown that patients who develop symptoms or fail to increase blood pressure with exercise testing have a high likelihood of developing symptoms within a few years and requiring AVR. However, in such studies a posttest referral bias may occur, with the possibility that the stress test results themselves might bias physicians to intervene earlier in those with abnormal tests, thereby inflating the predictive value of exercise test responses. In addition, sooner or later all patients (and normal individuals) develop limiting symptoms with exercise testing, and deconditioned or frail patients are likely to have low exercise capacity. Determining a cardiac versus noncardiac symptom response can be highly subjective.

Against this backdrop, noninvasive assessment of exercise hemodynamics with Doppler echocardiography emerges as an attractive alternative to exercise testing without imaging, with the potential to provide much more objective insights into exercise physiology than symptoms and blood pressure measurements alone, that can add to the echocardiographic assessment at rest of severity of AS and its impact on LV function. Previous work has shown that the change in aortic valve gradient with exercise may be useful in stratifying risk in patients with asymptomatic AS, with 2 studies reporting that increases in the mean gradient of 18 mm Hg to 20 mm Hg or more during exercise identify patients likely to develop symptoms or die during mean follow-up periods of 15 to 19 months. The exercise-induced increase in mean valve gradient yielded independent prognostic information that was additive to resting valve gradients and exercise capacity. As in most studies of exercise testing in asymptomatic patients with AS, the patient samples were small and the composite end point was driven by patients developing symptoms with only a few deaths (and many of the deaths were preceded by symptoms).

In this issue of Circulation, Lancellotti et al confirm their previous observations linking increases in aortic valve gradient with exercise to outcomes in patients with severe, asymptomatic AS, and extend their work with novel data addressing the relationship between exercise-induced pulmonary hypertension and outcomes. The data relating pulmonary artery pressure with exercise and subsequent death, heart failure, and AVR have important implications for future patient management.

Several features of the study of Lancellotti et al are noteworthy. All patients studied had severe AS with valve area indexes <0.6 cm²/m², preserved LV systolic function, and normal exercise tests, thus excluding those with diminished exercise capacity (<75 W), failure to increase blood...
pressure at least 20 mm Hg, or development of \( \geq 2 \)-mm ST-segment depression. Although few patients had pulmonary hypertension at rest, which is a known high-risk finding,\(^{20,21}\) over half of patients in their series (55\%) developed pulmonary hypertension with exercise, defined as a systolic pulmonary artery pressure \( > 60 \) mm Hg (as estimated from the tricuspid valve regurgitant jet). Exercise-induced pulmonary hypertension was related to the severity of AS, as determined by the peak and mean valve gradient at rest and also during exercise. Exercise pulmonary hypertension was also associated with greater increases during exercise in LV volume, LV stiffness (estimated from the \( e' \) wave velocity), and left atrial volume. Thus, these data suggest that increases in pulmonary artery pressure with exercise unmask patients with severe AS in whom the relationship between LV hypertrophy and left atrial compliance is compensated at rest, but marginally so, such that an increase in outflow gradient during tachycardia and augmented stroke volume is tolerated poorly, triggering LV dilatation and increased LV filling pressures, leading to sudden increases in left atrial and pulmonary pressures. This concept that such patients are on the cusp of clinical deterioration is supported by the significant association between exercise-induced pulmonary hypertension and subsequent cardiac events during the mean follow-up period of 19 months. Patients with pulmonary hypertension during exercise had roughly twice the event rate as those without pulmonary hypertension (67\% versus 36\%), and all 7 deaths occurred in patients with pulmonary hypertension with exercise. Peak aortic ejection velocity at rest was the strongest hemodynamic determinant of the combined end point of death and symptomatic deterioration, but exercise pulmonary hypertension was an independent determinant in a multivariate model, thus adding incremental prognostic information to the resting and exercise aortic valve gradient.

One would anticipate that patients with exercise-induced pulmonary hypertension might have more severe or earlier symptoms with exercise, reduced exercise capacity, or higher exercise heart rates, but, interestingly, there was no difference in these exercise variables between those with and those without exercise pulmonary hypertension. Exercise capacity and other measures of exercise performance were also not associated with outcome. Although this may be related, in part, to the exclusion of patients who developed symptoms at low workloads, the data do demonstrate the unique value of intracardiac hemodynamic measurements in those with more normal exercise capacity.

There are several issues regarding these data that may limit their general applicability. The investigators studied patients using a semisupine bicycle exercise protocol, with Doppler measurement of hemodynamics during the peak of exercise,\(^{19}\) in keeping with the previous studies of exercise hemodynamics in patients with asymptomatic AS.\(^{17,18}\) Thus, these data cannot be extrapolated readily to results that might be obtained in the many laboratories in which stress echocardiography is performed using upright treadmill exercise with imaging performed during the immediate postexercise phase, when hemodynamics may be changing dramatically and unpredictably. Obtaining the noninvasive hemodynamic measurements during peak exercise is challenging technically, and even in the hands of these experienced investigators, exercise data could not be obtained in 35 of 140 patients (25\%). In addition, pulmonary artery pressure with exercise was estimated with the assumption that right atrial pressure was constant between rest and exercise, which may not be the case in patients with AS, especially in those with dramatic increases in pulmonary artery pressure with exercise. Last, it is also uncertain whether these unique measures of pulmonary artery pressure with exercise, which provide important physiological insights but are difficult to obtain, will provide better prognostication than other emerging determinants of risk, such as serum biomarkers (most notably brain natriuretic peptide\(^{22}\)) and measures of interstitial myocardial fibrosis by cardiac magnetic resonance imaging.\(^{23,24}\)

Although the exercise hemodynamics provided important prognostic information in this study, with a 2-fold increase in cardiac events in those with versus those without exercise pulmonary hypertension, it is noteworthy that the overall event rate was quite high, with 53\% of patients dying or developing symptoms during a mean follow-up period of only 1.5 years, even after the exclusion of the highest-risk patients. One might question, with this high event rate, whether it would be reasonable to recommend early operation for all patients with such severe AS as determined with resting echocardiography,\(^{2,4}\) considering age and comorbidities, and whether the added cost and complexity of stress echocardiography or other markers of risk will yield improved clinical outcomes. The field of valvular heart disease has been held back compared with other areas of cardiovascular medicine because of the lack of definitive prospective clinical trials. A clinical trial to determine whether AVR or conservative management is the most appropriate strategy for patients with severe asymptomatic AS, and to determine the most effective method of risk stratification, is needed to guide the future management of this very prevalent disease.

**Disclosures**

None.

**References**

7. Otto CM, Burwash IG, Legget ME, Munt BI, Fujioka M, Healy NL, Kraft CD, Miyake-Hull CY, Schwaegler RG. Prospective study of asymptomatic...
atic valvular aortic stenosis: clinical, echocardiographic, and exercise predictors of outcome. 


_Circulation_. 2010;121:151–156.


_Heart_. 2001;86:381–386.


_Eur Heart J_. 2010;31:1390–1397.


**Key Words:** Editorials ■ aortic stenosis ■ echocardiography ■ exercise physiology ■ exercise testing ■ pulmonary hypertension
Exercise Hemodynamics and Risk Assessment in Asymptomatic Aortic Stenosis

Robert O. Bonow

Circulation. 2012;126:803-805; originally published online July 25, 2012; doi: 10.1161/CIRCULATIONAHA.112.130591

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2012 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/126/7/803

An erratum has been published regarding this article. Please see the attached page for:
/content/126/13/e215.full.pdf

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/
In the article by Bonow et al, “Exercise Hemodynamics and Risk Assessment in Asymptomatic Aortic Stenosis,” which was published in the August 14, 2012 issue of the journal (Circulation. 2012;126:803–805), a few errors occurred.

The quote given in the first sentence was incorrectly attributed to Circulation. It was a quote from the American Journal of Cardiology. The first sentence of the editorial should have read: More than half a century ago, in the American Journal of Cardiology, Dr Paul Wood aptly described aortic stenosis (AS) as “a simple mechanical fault which, if severe enough, imposes a heavy burden on the left ventricle and sooner or later overcomes it.”

In addition, the journal name in reference 1 was also incorrect. Reference 1 should read:


On page 804, an error occurred in the first full sentence. The corrected sentence should read as follows, with a greater than symbol before 60 mm Hg: “Although few patients had pulmonary hypertension at rest, which is a known high-risk finding, over half of patients in their series (55%) developed pulmonary hypertension with exercise, defined as a systolic pulmonary artery pressure >60 mm Hg (as estimated from the tricuspid valve regurgitant jet).”

The error has been corrected in the current online version of the article. The authors regret the error.