WHEN TO RECOMMEND aortic valve replacement for mildly symptomatic or asymptomatic patients with moderate-to-severe aortic regurgitation is a difficult clinical problem. Severe chronic aortic regurgitation is associated with a generally favorable prognosis. \(^1\)\(^-\)\(^2\) Approximately 75\% of the patients are alive 5 years and 50\% 10 years after the diagnosis. \(^2\) However, when symptoms develop, the patient’s condition often deteriorates rapidly. Without surgery, the patient usually dies within 5 years after the onset of angina and 2 years after developing heart failure. \(^5\)\(^-\)\(^4\) Accordingly, most cardiologists recommend surgery for symptomatic patients with clinical, hemodynamic and angiographic evidence of moderate-to-severe aortic regurgitation. After successful surgery, left ventricular (LV) end-diastolic volume and mass decrease significantly. \(^5\)\(^-\)\(^7\) In patients with impaired preoperative LV performance, the risk of early and late postoperative morbidity and mortality usually increases and the effects of successful aortic valve replacement on LV performance are highly variable. Many patients show little or no improvement of a depressed preoperative LV ejection fraction. \(^6\)\(^-\)\(^8\)\(^-\)\(^9\) (Rahimtoola SH: personal communication).

Often, patients with severe aortic regurgitation (LV dilatation and hypertrophy and large regurgitant fraction) develop impaired LV performance before the onset of symptoms caused by heart failure or myocardial ischemia. Optimally, aortic valve replacement should be performed before LV dysfunction develops. However, it is difficult to advise aortic valve replacement, which has potential complications including a small but definite risk of perioperative mortality, in patients with no symptoms.

Aortic root and LV cineangiography have been the “gold standards” for defining the severity of aortic regurgitation and its effects on LV performance. In patients with severe chronic aortic regurgitation and initially normal ventricular performance, serial LV angiograms are impractical. Therefore, several noninvasive techniques have been used recently in such patients for the serial evaluation of LV size and performance to define the optimal time for surgery. However, few quantitative data have indicated what measurements portend a poor long-term prognosis in patients with chronic aortic regurgitation who undergo aortic valve replacement.

In this issue of *Circulation*, Henry and associates report the results of serial M-mode echocardiographic studies in 50 consecutive symptomatic patients who underwent aortic valve replacement for isolated, moderate-to-severe aortic regurgitation. \(^10\)\(^-\)\(^11\) In these studies, several echocardiographic indices were predictive of late death due to congestive heart failure in symptomatic patients who underwent otherwise successful aortic valve replacement. Specifically, a preoperative LV end-systolic dimension (ESD) of > 55 mm and percent fractional dimension shortening (%ΔD) < 25\% indicated an increased incidence of perioperative morbidity and late postoperative congestive heart failure and death compared with patients with similar symptoms but less depressed LV systolic function. A combination of the two findings (ESD > 55 mm and %ΔD < 25\%) was the most powerful predictor; 11 of 13 patients (85\%) with these findings either died (nine patients) or had evidence of severe congestive heart failure postoperatively. Five of the nine deaths occurred in the immediate postoperative period. This high perioperative mortality risk may not be applicable to patients currently undergoing aortic valve replacement, owing to newer operative techniques for preserving myocardial function.

The data of Henry and associates are consistent with the LV cineangiographic studies by Borow and co-workers, \(^8\) who found that the immediate and long-term results of aortic valve replacement were poor in the patients in whom the LV end-systolic volume index was markedly elevated (> 90 ml/m\(^2\)). In the latter study the preoperative LV ejection fraction was less predictive value. In contrast, Clark and associates reported no perioperative mortality in 17 patients with symptomatic aortic regurgitation and impaired LV performance. \(^8\) Also, they found no difference in late mortality in patients with a preoperative cineangiographic end-systolic volume of > 110 ml/m\(^2\) compared with those who had a smaller end-systolic volume. However, the 5-year survival in patients with an ejection fraction of < 45\% was 33 ± 19\%, compared with 94 ± 6\% (p < 0.001) in those with an ejection fraction > 45\%. However, not all patients with preoperative impairment of LV performance do poorly after aortic valve replacement; late postoperative LV systolic function improves in as many as 50\% of the patients. \(^8\)\(^-\)\(^9\)

Henry and co-workers also reported serial M-mode echocardiographic data in 37 initially asymptomatic patients with aortic regurgitation, 14 of whom subsequently developed symptoms and were recommended for operation. \(^11\) In this study, the LV ESD and %ΔD tended to identify patients likely to develop symptoms.

---

From the Department of Medicine, Division of Cardiology, University of Texas Health Science Center, San Antonio, Texas.

Address for correspondence: Robert A. O’Rourke, M.D., Division of Cardiology, University of Texas Health Science Center, 7703 Floyd Curl Drive, San Antonio, Texas 78284.

*Circulation* 61, No. 3, 1980.
of congestive heart failure or myocardial ischemia. The average values for the two measurements differed in patients who subsequently underwent surgery compared with those who remained asymptomatic; however, there was considerable patient overlap. LV ESD was more useful than \( \%\Delta D \) in indicating which patients were likely to become operative candidates. Four of five patients (80%) with an ESD > 55 mm developed symptoms and came to operation during a mean follow-up of 39 months. In contrast, only four (20%) of the 20 patients with initial ESD < 50 mm developed symptoms and underwent aortic valve replacement. None of these 20 patients died during follow-up. Six of 12 patients with an initial ESD of 50–54 mm underwent surgery during a mean follow-up period of 22 months. Four of these patients developed symptoms without an ESD > 55 mm; in the other two the ESD was > 55 mm when symptoms appeared. Henry and associates now recommend aortic valve replacement in asymptomatic patients with an ESD of > 55 mm and follow patients with a smaller ESD serially by echocardiography, the frequency of this noninvasive study depending on the initial LV size.

These two studies by Henry and associates provide interesting information concerning a common clinical problem. However, a note of caution is necessary for cardiologists planning to use these results to decide the time for aortic valve replacement in their own patients with moderate-to-severe aortic regurgitation. First, M-mode echocardiography is an excellent technique for defining LV minor-axis dimensions and percent shortening. This technique generally correlates well with biplane cineangiography for measuring LV dimensions and ejection phase indices in patients with normal-size left ventricles or mild-to-moderate LV dilatation.\(^{12-14}\) However, in patients with marked LV volume overload, as occurs with severe aortic regurgitation, there is marked dilatation of the ventricle, and M-mode echocardiography tends to underestimate end-diastolic and end-systolic dimensions and overestimate ejection phase indices.\(^{15,16}\) In patients with a large left ventricle, changes in the patient's position and alterations in transducer angulation may cause errors in measurements of LV dimensions of as much as 20%.\(^{17}\) (Shah PM: personal communication). Therefore, M-mode echocardiography often inaccurately estimates LV performance in patients with severe aortic regurgitation, even in the absence of coincident ischemic heart disease and segmental wall motion abnormalities.

Second, as discussed by Henry and co-workers, echocardiographic assessment of global LV systolic function after operation is subject to considerable error because of abnormal septal motion, which occurs in approximately 90% of patients after aortic valve replacement.\(^{18}\) Measurements of LV ESD and \( \%\Delta D \) are highly inaccurate in this situation and should not be used to assess total LV performance.\(^{19}\) Therefore, the serial postoperative echocardiographic data included in their two studies may not adequately reflect changes in LV systolic function. Since no angiographic data are given before and after surgery, we do not know whether or not some of the patients with impaired preoperative LV performance improved after aortic valve replacement.

Finally, measurements of LV end-diastolic and end-systolic dimensions and \( \%\Delta D \) are only as good as the echocardiograms from which they are measured. Unless high-quality LV echocardiograms are obtained, they should not be used to assess LV dimensions or function in any patients, including those with chronic aortic regurgitation.

The M-mode echocardiographic serial studies reported by Henry and associates in patients with moderate-to-severe aortic regurgitation are of some interest to the clinical cardiologist. Their observations in symptomatic patients who undergo aortic valve replacement further support early operation in patients with symptoms of congestive heart failure or myocardial ischemia caused by chronic aortic regurgitation. This study, like others, indicates that symptomatic patients with markedly depressed LV systolic function before aortic valve replacement have a higher incidence of congestive heart failure and death in the late postoperative period.

Their echocardiographic data in initially asymptomatic patients who underwent serial studies are also noteworthy but less conclusive. Validation of these results in a large number of patients is necessary before other physicians can recommend aortic valve replacement for all asymptomatic patients with chronic aortic regurgitation and an LV ESD > 55 mm. Only five patients had ESD > 55 mm at the initiation of serial follow-up. Four of these patients were recommended for aortic valve replacement on the basis of congestive heart failure symptoms. Whether a similar percentage of a larger number of asymptomatic patients with aortic regurgitation and ESD > 55 mm would develop symptoms during a similar period of follow-up remains to be proved. We do not know whether such asymptomatic patients will have a poor short- or long-term prognosis after valve replacement compared with patients who have smaller ESDs.

In the future, other noninvasive techniques may be useful for defining patients with asymptomatic chronic aortic regurgitation who are candidates for early aortic valve replacement. Recent data indicate that most symptomatic patients with severe aortic regurgitation have a subnormal increment or reduction in LV ejection fraction during exercise as measured by radionuclide angiography.\(^{20}\) Whether or not the ability to identify LV dysfunction during exercise should influence the decision of when to operate in asymptomatic patients with severe aortic regurgitation is unknown. Additional radionuclide techniques recently have been introduced for the noninvasive quantitation of the aortic regurgitant fraction and may be useful for the serial assessment of such patients.\(^{21,22}\)

Available data indicate that patients with moderate-to-severe aortic regurgitation resulting in symptoms of congestive heart failure or ischemia should undergo aortic valve replacement. If occlusive coronary artery
disease is present, particularly in patients with symp-
toms of myocardial ischemia, coronary artery bypass
grafting is indicated at the same operation. In sym-
tomatic patients, both short- and long-term prognosis
appears better when LV performance is normal or
only mildly impaired, but operation is feasible in
patients with severely impaired LV function because
some improvement in LV performance can be ex-
pected in as many as 50% of the patients.

There are increasing data to support early operation
in asymptomatic patients with severe aortic regurgita-
tion and LV dysfunction in order to optimize surgical
results. The echocardiographic studies of Henry and
associates, despite the limitations of M-mode echocar-
diography, support these data. Aortic valve replace-
ment seems reasonable in hospitals with < 5%
perioperative mortality for asymptomatic patients
with severe aortic regurgitation and impaired LV per-
formance as quantitated by LV cineangiography (both
dehased LV ejection fraction and increased end-
systolic volume). However, each asymptomatic
patient with severe aortic regurgitation must be
assessed individually and there is no precise quan-
titative formula for making an unequivocal decision
on who should undergo aortic valve replacement.
Certainly, an LV ESD > 55 mm by M-mode echocar-
diography is not a proven criteria by which to make
such decisions in asymptomatic patients.

References
1. Spagnuolo M, Kloth H, Taranta A, Doyle E, Pasternack B:
Natural history of rheumatic aortic regurgitation. Criteria
predictive of death, congestive heart failure and angina in young
patients. Circulation 44: 368, 1971
2. Heggin R, Scheu H, Rothlin M: Aortic insufficiency. Circula-
tion 37 (suppl V): V-77, 1968
3. Degeorges M, Delazt JF: Elements de pronostic de l'in-
suffisance aortique isolée recueillis chez 206 malades ages du
moins de 50 ans. Sem Hop Paris 42: 1171, 1966
4. Scholmerich P: Biographische aspekte der entzündlichen
klappeninsuffizienz Pathogenase-Verlauf-Prognose. Verh
Deutsch Ges Kreislauforsch 31: 165, 1965
5. Kennedy JW, Doses J, Stewart DK: Left ventricular function
before and following aortic valve replacement. Circulation 56:
944, 1977
6. Pantely G, Morton M, Rahimtoo SH: Effects of successful,
uncomplicated valve replacement on ventricular hypertrophy,
volume and performance in aortic stenosis and in aortic in-
7. Gaasch WH, Andrias CW, Levine HJ: Chronic aortic
regurgitation: the effect of aortic valve replacement on left ven-
8. Borow K, Green LH, Mann T, Sloss LH, Collins JJ Jr, Cohn L,
Grossman W: End-systolic volume as a predictor of
postoperative left ventricular function in volume overload from
9. Clark DG, McAnulty JH, Rahimtoo SH: Results of valve
replacement in aortic incompetence with left ventricular
10. Henry WL, Bonow RO, Borer JS, Ware JH, Kent KM,
Redwood DR, McIntosh CL, Morrow AG, Epstein SE: Observa-
tions on the optimum time for operative intervention for aor-
tic regurgitation. I. Evaluation of the results of aortic valve
on the optimum time for operative intervention for aortic
regurgitation. II. Serial echocardiographic evaluation of
asymptomatic patients. Circulation 61: 484, 1980
12. Pombo JF, Troy BL, Russell RO Jr: Left ventricular volumes
and ejection fraction by echocardiography. Circulation 43: 480,
1971
13. Cooper RH, O'Rourke RA, Karliner JS, Peterson KL,
Leopold GR: Comparison of ultrasound and cineangiographic
measurements of the mean rate of circumferential fiber shorten-
assessment of left ventricular function with special reference
to normalized velocities. Circulation 50: 42, 1974
15. Johnson AD, Alpert JS, Francis GS, Vieweg, WVR, Ockene I,
Hagan AD: Assessment of left ventricular function in severe
16. Bhati DR, Isabel-Jones JF, Villoria GI, Nakazawa M, Yabek
SM, Richard MA, Jarmakani JM: Accuracy of echocar-
diography in assessing left ventricular dimensions and volume.
Circulation 57: 699, 1978
17. Linhart JW, Mintz GS, Segal BL, Kawai N, Kotler MN: Left
ventricular volume measurement by echocardiography: fact or
fiction? Am J Cardiol 36: 114, 1975
18. Burggraf GW, Craig E: Echocardiographic studies of left ven-
tricular wall motion and dimensions after valvular heart sur-
gery. Am J Cardiol 35: 473, 1975
19. Righetti A, Crawford MH, O'Rourke RA, Schelbert H, Daily
PO, Ross J Jr: Interventricular septal motion and left ven-
tricular function after coronary bypass surgery. Evaluation with
echocardiography and radionuclide angiography. Am J Cardiol
39: 372, 1977
20. Borner JS, Bacharach SL, Green MV, Kent KM, Henry WL,
Rosing DR, Seides SF, Johnston GS, Epstein SE: Exercise-
induced left ventricular dysfunction in asymptomatic and symp-
tomatic patients with aortic regurgitation: assessment by
21. Rigo P, Alderson PO, Robertson RM, Becker LC, Wagner
HN: Measurement of aortic and mitral regurgitation by gated
22. Sorensen SG, Groves BM, O'Rourke RA, Chaudhuri T:
Noninvasive quantitation of valvular regurgitation by gated
23. Richardson JV, Kouchookus NT, Wright JO, Karp RB:
Combined aortic valve replacement and myocardial revas-
Timing of valve replacement in patients with chronic aortic regurgitation.
R A O’Rourke and M H Crawford

Circulation. 1980;61:493-495
doi: 10.1161/01.CIR.61.3.493
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1980 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/61/3/493.citation

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/