Editorial Comment

Emerging Importance of the Right Ventricle*

MARTIN E. GOLDMAN, MD, FACC

New York, New York

Recently, investigators have appreciated the importance of right ventricular dysfunction in many disease states including coronary artery disease (1–3), mitral stenosis and regurgitation (4,5), tricuspid regurgitation (6), pulmonary hypertension (7), congenital heart disease (8) and pericardial effusion and tamponade (9). Noninvasive techniques, specifically nuclear gated blood pool and first-pass scanning and two-dimensional and Doppler echocardiography, have shed new light on the once forgotten right ventricle. However, routine functional analysis of the right ventricle is complex because of its pyramidal shape and structural influences and interactions: the pericardium, the left ventricle and importantly its shared wall, the interventricular septum.

Normal and abnormal septal motion. The interventricular septum is a contracting membrane between two blood-filled chambers (the right and left ventricles). The observed echocardiographic motion of the septum is dependent on several factors, namely, spatial mobility of the entire heart, intrinsic septal contraction (thickening) and relative pressure gradient between the two ventricles. Normally, in the two-dimensional diastolic short-axis view, the left ventricle is circular in shape with the interventricular septum hammocking into the crescent-shaped right ventricle. During systole, as the heart contracts, the round left ventricular shape is maintained, the left and right ventricular free walls thicken symmetrically and the septum moves posteriorly relative to the anterior chest wall as it contracts.

Two-dimensional echocardiography has elucidated the ambiguous M-mode term "paradoxical septal motion," which is due to diverse mechanisms and seen in a variety of conditions such as conduction abnormalities (10), myocardial infarction (11), pericardial effusion (9) and right ventricular volume overload (12) as well as postoperatively (13). For instance, after pericardiotomy, there is exaggerated anterior motion of the entire heart, and the ventricular septum moves anteriorly toward the chest wall transducer; thus, it will appear to move "pardoxically" despite normal contraction. This is to be differentiated from "paradoxical" motion, which is actually dyskinesia related to septal infarction, in which the septum fails to thicken and is passively thrust anteriorly by reflected intracavitary pressure waves generated by hypercontractile, normal, residual ventricular segments.

Ordinarily, isolated septal contraction would result in thickening without displacement, or a straight flat shape. Therefore, normal or abnormal septal curvature is frequently a result of relative ventricular volume and pressure gradients. In right ventricular volume overload states such as tricuspid regurgitation, the right ventricular diastolic volume exceeds that of the left and, therefore, the septum is flat or hammocks into the left ventricle and is concave in relation to the right ventricle (14–16). During isovolumetric contraction in early systole, left ventricular pressure exceeds that of the right, and the septum bulges into the right ventricle (concave to the left ventricle). However, the rapid shift of the septum from diastolic posterior hammocking into the left ventricle to systolic anterior bulging into the right ventricle is perceived as "paradoxical" or, preferably, "abnormal" septal motion. In contrast, right ventricular pressure overload states, such as pulmonary hypertension, are differentiated by an elevated right to left ventricular pressure gradient that remains abnormal in both diastole and systole (17). Hence, during systole, the septum remains flat or hammocked into the left ventricle and concave to the right ventricle.

The eccentricity index. The study by Ryan et al. (18) in this issue of the Journal attempts to quantify the distortion of the left ventricle due to the abnormal motion of the interventricular septum in right ventricular pressure or volume overload states by an "eccentricity index," defined as the ratio of two short-axis diameters: one that bisects and is perpendicular to the interventricular septum (D_1), and a second (D_2) that is perpendicular to D_1 and parallel to the septum. In a normal spherical ventricle the eccentricity index approximates one. The concept of applying this index to left ventricular geometry is not new. In 1973, Vokonas et al. (19) advocated it for evaluating ventricular dimensions in mitral regurgitation by angiographic techniques. They noted that the normal elliptical left ventricle evolved into a more globular shape with increasing mitral regurgitation. In 1980, Schreiber et al. (20) developed an eccentricity index from the two-dimensional short-axis echogram to assess ventricular geometry in atrial septal defect. They found an abnormally elevated index (the greater the value, the greater the degree of deformity) due to the flattening of the interventricular septum secondary to volume overload, which partially normalized after repair of the atrial septal defect.

*Editorials published in *Journal of the American College of Cardiology* reflect the views of the authors and do not necessarily represent the views of JACC or the American College of Cardiology.

From the Division of Cardiology, Department of Medicine, Mount Sinai Medical Center, New York, New York.

Address for reprints: Martin E. Goldman, MD, Division of Cardiology, Mount Sinai Medical Center, 1 Gustave Levy Place, New York, New York 10029.

0735-1097/85/$3.30

In the present study, Ryan et al. (18) applied the same eccentricity index to differentiate right ventricular volume from pressure overload states. Patients in the two groups have similar left ventricular shapes and indexes during diastole, but the volume overload group has a normal systolic shape while the pressure overload group has continued distortion during systole and an elevated eccentricity index. The method of measuring the eccentricity index can be done manually without computer assistance and appears to effectively separate the two groups. For practical purposes, the eccentricity index can be estimated on-line merely by observing the left ventricular systolic shape. The volume overload group consisted primarily of patients with atrial septal defect and not tricuspid regurgitation, which was intentionally excluded because of difficulties in its quantification. Whether this index applies to tricuspid regurgitation remains to be proven. Of greater importance is the lack of correlation of the eccentricity index with systolic pulmonary pressure in either the volume or pressure overload group. Therefore, inferences regarding pulmonary pressure cannot be made based on the eccentricity index beyond the arbitrary division of a systolic pulmonary pressure of greater or less than 45 mm Hg made by the authors to separate the right ventricular pressure from the volume overload group. This limitation is related to the septum, whose motion is mediated by the right to left ventricular volume and pressure gradient. The authors may have found a closer correlation of the eccentricity index to the ratio of ventricular pressures than to actual systolic pulmonary pressure.

Pulmonary artery pressure and right ventricular function. Because of their anatomic relation, right ventricular function is exquisitely sensitive to alterations in pulmonary artery pressure. Recently, noninvasive techniques have been used to assess the pulmonary circulation. Radionuclide right ventricular ejection fraction correlates well with mean pulmonary artery pressure (6,21). In patients with atrial septal defect, Shimada et al. (12) showed a good correlation between four types of interventricular septal configuration and right ventricular systolic pressure as well as the ratio of left to right ventricular pressure. These findings have not been confirmed in other right ventricular volume or pressure overload states. The M-mode pulmonary valve echogram combined with systolic time intervals correlated well with pulmonary pressure in a study by Leier et al. (22). Recent Doppler ultrasound studies accurately measuring pulmonary pressure have been very encouraging. Kitabatake et al. (23) reported a close correlation between the ratio of right ventricular Doppler acceleration time divided by the right ventricular ejection time and mean pulmonary artery pressure. Specifically, in patients with tricuspid regurgitation, right ventricular systolic pressure can be obtained with Doppler ultrasound by adding the transtricuspid valve gradient to the mean jugular venous pressure (24).

Successful efforts have been directed to understanding the function and interactions of the right ventricle in health and disease. Additionally, a new focus has developed for noninvasive cardiology: direct and indirect measurements of pulmonary pressures for both diagnostic and therapeutic purposes. The eccentricity index, as proposed by Ryan et al., may be applied on-line to effectively and simply estimate right ventricular pressure and indirectly estimate systolic pulmonary pressure.

I thank Valentin Fuster, MD for his assistance in preparation of this manuscript.

References

1. Johnson LL, McCarthy DM, Sciacca RR, Cannon PJ. Right ventricular ejection fraction during exercise in patients with coronary artery disease. Circulation 1979;60:1284–91.
2. Slutsky R, Hooper W, Gerber K, et al. Assessment of right ventricular function at rest and during exercise in patients with coronary heart disease: a new approach using equilibrium radionuclide angiography (abstr). Am J Cardiol 1980;45:69.
3. Maddahi J, Berman DS, Matsuoka DT, Wasman AD, Forrester JS, Swan HJC. Right ventricular ejection fraction during exercise in normal subject and in coronary artery disease patients: assessment by multiple-gated equilibrium scintigraphy. Circulation 1980;62:133–9.
4. Iskandrian AS, Hakki AH, Ren J, et al. Correlation among right ventricular preload, afterload and ejection fraction in mitral valve disease: radionuclide, echocardiographic and hemodynamic evaluation. J Am Coll Cardiol 1984;3:1403–11.
5. Berger HJ, Matthay R. Radionuclide right ventricular ejection fraction: applications in valvular heart disease. Chest 1981;79:497–8.
6. Grose R, Strain J, Yipintosoi T. Right ventricular function in valvular heart disease: relation to pulmonary pressure. J Am Coll Cardiol 1983;2:225–33.
7. Furey III SA, Zieske HA, Levy MN. The essential function of the right ventricle. Am Heart J 1984;107:404–10.
8. Liberthson RR, Boucher CA, Strauss HW, Dinsmore RE, McKusick KA, Pohost GM. Right ventricular function in adult atrial septal defect: preoperative and postoperative assessment and clinical implications. Am J Cardiol 1981;47:56–60.
9. Armstrong WF, Schilt BF, Helper DJ, Dillon JC, Feigenbaum H. Diastolic collapse of the right ventricle with cardiac tamponade: an echocardiographic study. Circulation 1973;65:1491–6.
10. McDonald IG. Echocardiographic demonstration of an abnormal motion of the interventricular septum in left bundle branch block. Circulation 1973;48:272–7.
11. Mikell FL, Asinger RW, Hodges M. Functional consequences of interventricular septal involvement in right ventricular infarction: echocardiographic, clinical and hemodynamic observations. Am Heart J 1983;105:393–401.
12. Shimada R, Takeshita A, Nakamura M. Noninvasive assessment of right ventricular systolic pressure in atrial septal defect: analysis of the end-systolic configuration of the ventricular septum by two-dimensional echocardiography. Am J Cardiol 1984;53:1117–23.
13. Kerber RE, Lichfield R. Postoperative abnormalities of interventricular septal motion: two-dimensional and M-mode correlations. Am Heart J 1982;104:263–8.
14. Kingma I, Tyberg JV, Smith ER. Effects of diastolic transseptal pressure gradient on ventricular septal position and motion. Circulation 1983;68:1304–14.
15. Tanaka H, Tei C, Nakao S, et al. Diastolic bulging of the interventricular septum toward the left ventricle. Circulation 1980;62:558–63.

16. Pearlman AS, Clark CE, Henry WL, Morganroth J, Itscoitz SB, Epstein SE. Determinants of ventricular septal motion: influence of relative right and left ventricular size. Circulation 1976;54:83–91.

17. King ME, Braun H, Goldblatt A, Liberthson R, Weyman A. Interventricular septal configuration as a predictor of right ventricular systolic hypertension in children: a cross-sectional echocardiographic study. Circulation 1983;68:68–75.

18. Ryan T, Petrovic O, Dillon JC, Feigenbaum H, Conley MJ, Armstrong WF. An echocardiographic index for separation of right ventricular volume and pressure overload. J Am Coll Cardiol 1985;5:918–24.

19. Vokonas PS, Gorlin R, Cohn PF, Herman MV, Sonnenblick EH. Dynamic geometry of the left ventricle in mitral regurgitation. Circulation 1973;48:786–96.

20. Schreiber TL, Feigenbaum H, Weyman AE. Effect of atrial septal defect on left ventricular geometry and degree of mitral valve prolapse. Circulation 1980;61:888–96.

21. Korr KS, Gandsman J, Winkler J, Shulman RS, Bough EW. Hemodynamic correlates of right ventricular ejection fraction measured with gated radionuclide angiography. Am J Cardiol 1982;49:71–7.

22. Leier CV, Sahar D, Hermiller JB, Magorien RD, Unverferth DV. Combined systolic time intervals and M-mode echocardiography in the evaluation of central hemodynamics in primary pulmonary hypertension. Respiration 1984;45:422–9.

23. Kitabatake A, Inoue M, Asao M, et al. Noninvasive evaluation of pulmonary hypertension by a pulsed Doppler technique. Circulation 1983;68:302–9.

24. Yock PG, Popp RL. Noninvasive estimation of right ventricular systolic pressure by Doppler ultrasound in patients with tricuspid regurgitation. Circulation 1984;70:657–62.