
Right ventricular dysfunction in advanced heart failure

Stefano Ghio, Luigi Tavazzi

Department of Cardiology, IRCCS Policlinico San Matteo, Pavia, Italy

Key words:
Heart failure;
Right ventricle.

For many years cardiologists were not interested in studying right ventricular function and the role of the right ventricle in heart failure and in other disease states has therefore been largely underestimated. More recently a consensus has grown on the critical role of right ventricular function in patients with advanced congestive heart failure. The estimation of right ventricular function is nowadays warranted in the standard evaluation of patients with heart failure either due to ischemic heart disease or to primary dilated cardiomyopathy, since it is helpful in the clinical assessment and in the prognostic stratification of such patients. Most information may be obtained non-invasively using sound but simple and reproducible echocardiographic indicators of right ventricular function.

(Ital Heart J 2005; 6 (10): 852-855)

© 2005 CEPI Srl

Address:

Dr. Stefano Ghio

Dipartimento
di Cardiologia
IRCCS Policlinico
San Matteo
Piazzale Golgi, 2
27100 Pavia
E-mail:
s.ghio@smatteo.pv.it

For many years cardiologists were not much interested in studying right ventricular function and the role of the right ventricle in heart failure and in other disease states has therefore been largely underestimated.

In recent years, there has been a growing consensus among cardiologists on the critical role of right ventricular function in patients with advanced congestive heart failure. A more widespread use of a simplified echocardiographic approach to the evaluation of the right ventricle has greatly contributed to the higher awareness of the importance of this chamber. In fact, although echocardiography does not allow calculation of right ventricular volumes and ejection fraction, it is now accepted that clinically useful indicators of right ventricular function can be obtained by M-mode and two-dimensional echocardiography^{1,2} (Figs. 1 and 2).

Over the last 5 years we have therefore been able to reach a better understanding of why right ventricular dysfunction occurs in patients with advanced heart failure and what is its clinical and prognostic significance in such patients.

Why does right ventricular dysfunction occur in advanced heart failure patients?

Due to its peculiar anatomic characteristics, it is easier for the right ventricle to tolerate volume overload than pressure

overload; as a matter of fact, an inverse relation between pulmonary artery pressure and right ventricular ejection fraction has uniformly been shown in previous studies³⁻⁶. However, in patients with advanced heart failure right ventricular dysfunction not only may be a consequence of pulmonary hypertension but it may be related either to primary myocardial disease or to ischemia/infarction^{7,8}. A small case-controlled study (10 patients with ischemic heart disease and 10 patients with idiopathic dilated cardiomyopathy) suggested that, for similar levels of left ventricular dysfunction, right ventricular systolic function is more altered in idiopathic dilated cardiomyopathy⁹. The issue of the coupling between pulmonary artery pressure and right ventricular ejection fraction has also been addressed in a study enrolling 379 patients with advanced heart failure due to either dilated cardiomyopathy or ischemic heart disease¹⁰. The study confirmed, as expected, the inverse relationship between right ventricular ejection fraction measured with rapid response thermodilution and pulmonary artery pressure but it also showed that the slope of this relationship does not differ according to the etiology of heart failure. From a clinical point of view this observation is not irrelevant since a previous hypothesis was that the knowledge of right ventricular function could be helpful to identify the etiology of disease in patients with heart failure¹¹. In addition, the inverse re-

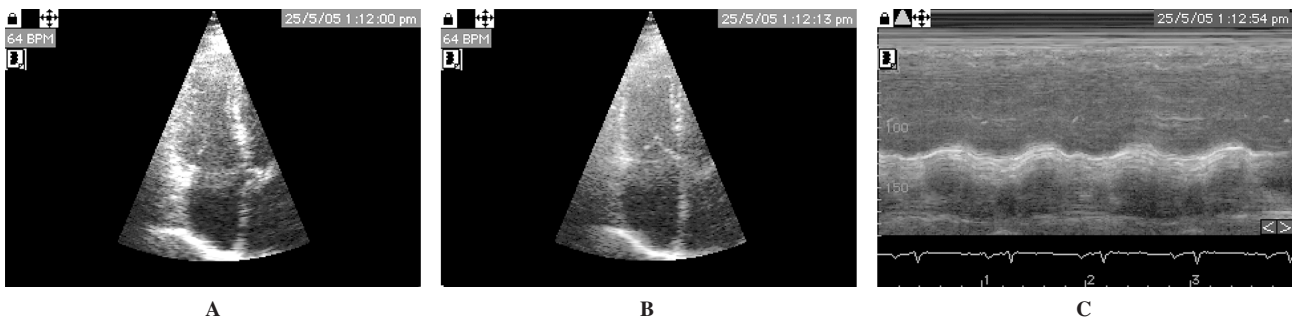


Figure 1. Echocardiographic images obtained in a patient with primary dilated cardiomyopathy and reduced right ventricular function (confirmed by a reduced right ventricular ejection fraction at rapid response thermodilution). Right ventricular end-diastolic (A) and end-systolic (B) areas: the calculated area shrinkage is around 20%. The tricuspid annular plane systolic excursion (C) is 9 mm.

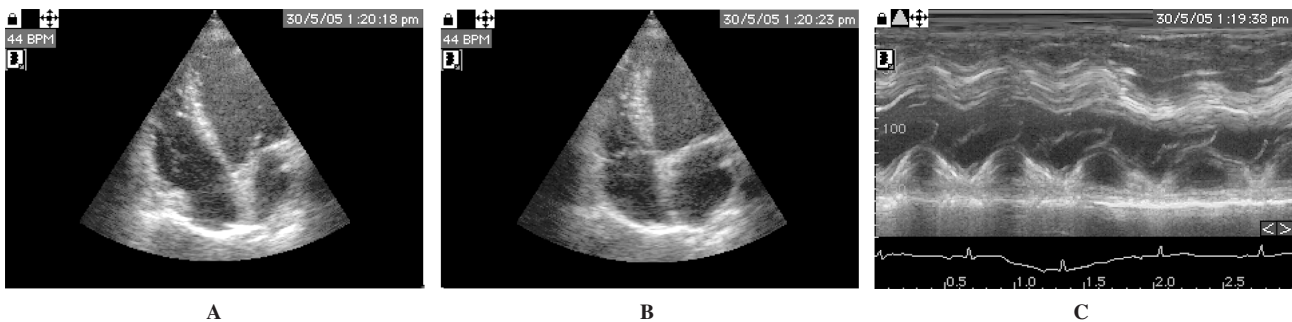


Figure 2. Echocardiographic images obtained in a patient with primary dilated cardiomyopathy and normal right ventricular function (confirmed by a normal right ventricular ejection fraction at rapid response thermodilution). Right ventricular end-diastolic (A) and end-systolic (B) areas: the calculated area shrinkage is around 40%; the right ventricular free wall nearly approaches the interventricular septum. The tricuspid annular plane systolic excursion (C) is 23 mm.

relationship between afterload and function is not a mathematical rule and exceptions are not infrequent in clinical practice¹⁰. First, right ventricular ejection fraction can be preserved in a substantial number of patients despite the presence of pulmonary hypertension; the reason for this is not clear, but it is tempting to hypothesize a more recent onset of pulmonary hypertension in such patients. Second, right ventricular dysfunction may be observed in patients with normal pulmonary artery pressure; possible explanations are a primary reduction in right ventricular contractility or excessive reduction in right ventricular preload due to overtreatment with diuretic drugs or atrial fibrillation. Importantly, these observations may be relevant from a prognostic point of view.

Molecular biology strongly supports the hypothesis that pulmonary hypertension is the primary cause for myocardial contractile failure of the right ventricle: a recent study demonstrated that the integrity of the amino (N)-terminus of dystrophin (a protein which plays a key role in the transduction of physical forces in the striated muscle) is disrupted both in the left and in the right ventricle of end-stage heart failure patients and that unloading the left ventricle via a left ventricular assist device ameliorates cardiac structure not only in the left but in the right ventricle as well¹².

What is the clinical and prognostic significance of right ventricular dysfunction in advanced heart failure patients?

Right ventricular dysfunction and reduced exercise tolerance. It is well known that the symptoms of chronic heart failure are poorly related to the degree of left ventricular dysfunction and much more dependent on the alterations of skeletal muscle characteristics¹³. However, the pulmonary circulation and right ventricular function are important determinants of exercise performance in heart failure patients. Although an inverse relationship has been demonstrated between peak oxygen consumption and resting pulmonary artery pressure and vascular resistance, as a matter of fact, the impact of pulmonary hypertension on the cardiac output response to exercise seems to be modulated by right ventricular function: a substantial proportion of pulmonary hypertension patients showed a decrease in capillary wedge pressure and an increase in right atrial pressure during exercise, a hemodynamic profile indicating right ventricular failure^{14,15}. In fact, peak oxygen consumption correlated significantly with resting or peak exercise right ventricular ejection fraction^{16,17}.

Right ventricular dysfunction and prognosis. Right ventricular function estimated at echocardiography or

at radionuclide ventriculography is an important prognostic indicator in patients with heart failure due to ischemic heart disease or primary dilated cardiomyopathy¹⁸⁻²¹. Interestingly, the systolic excursion of the tricuspid annular plane turned out to be a significant and independent predictor of mortality after having included in the multivariate model the NYHA class and the well consolidated echocardiographic predictors such as left ventricular ejection fraction and the deceleration time of the E wave²¹. The finding that right ventricular dysfunction correlates significantly with other prognostic indicators in heart failure, such as heart rate variability or plasma brain natriuretic levels, further reinforces the relevance of the right ventricle as determinant of prognosis in such patients^{22,23}. Two studies emphasized the importance of combining information on right heart hemodynamics with a functional evaluation of the right ventricle when trying to define the risk of patients with advanced heart failure. The first one demonstrated that right ventricular ejection fraction (obtained using rapid-response thermodilution) and mean pulmonary artery pressure have independent and additive prognostic value: the association of pulmonary hypertension with right ventricular dysfunction yielded a very poor prognosis whereas in the presence of pulmonary hypertension and normal right ventricular ejection fraction the prognosis was similar to that of the patients with normal pulmonary pressure¹⁰. The second study, performed in the subgroup of patients who underwent a test of reversibility of pulmonary hypertension, showed that, although the acute reduction in pulmonary vascular resistance did not predict the outcome, a better prognosis was observed in those patients in whom the afterload reduction elicited a substantial improvement in right ventricular ejection fraction, indicating the presence of right ventricular functional reserve²⁴. The concept that right ventricular contractile reserve can be of help to stratify the prognosis was previously suggested in a small population of NYHA class IV patients: a 100% increase in right ventricular end-systolic elastance predicted a better short-term outcome²⁵. Unlike the calculation of load-independent contractility indices, the evaluation of changes in right ventricular ejection fraction after an acute afterload reduction is a simpler method to disclose the presence of a functional reserve of the right ventricle.

Conclusions

The estimation of right ventricular function is warranted in the standard evaluation of patients with heart failure due to ischemic heart disease or primary dilated cardiomyopathy. It is helpful for clinical assessment and for prognostic stratification of such patients, and it is therefore an important tool to plan the follow-up. To this aim, the possibility of using sound but simple and

reproducible echocardiographic indicators of right ventricular function allows to obtain the feasibility which is necessary in serial clinical testing.

References

1. Forni G, Pozzoli M, Cannizzaro G, et al. Assessment of right ventricular function in patients with congestive heart failure by echocardiographic automated boundary detection. *Am J Cardiol* 1996; 78: 1317-21.
2. Kaul S, Tei C, Hopkins JM, Shah PM. Assessment of right ventricular function using two-dimensional echocardiography. *Am Heart J* 1984; 107: 526-31.
3. Brent BM, Berger HJ, Matthay RA, Mahler D, Pytlik L, Zaret BL. Physiologic correlates of right ventricular ejection fraction in chronic obstructive pulmonary disease: a combined radionuclide and hemodynamic study. *Am J Cardiol* 1982; 50: 255-62.
4. Sibbald WJ, Driedger AA, Myers ML, Short AI, Wells GA. Biventricular function in the adult respiratory distress syndrome. *Chest* 1983; 84: 126-34.
5. Morrison D, Goldman S, Wright AL, et al. The effect of pulmonary hypertension on systolic function of the right ventricle. *Chest* 1983; 84: 250-7.
6. Konstam MA, Salem DN, Isner JM, et al. Vasodilator effect on right ventricular function in congestive heart failure and pulmonary hypertension: end-systolic pressure-volume relaxation. *Am J Cardiol* 1984; 54: 132-6.
7. Pinamonti B, Pagnan L, Bussani R, Ricci C, Silvestri F, Camerini F. Right ventricular dysplasia with biventricular involvement. *Circulation* 1998; 98: 1943-5.
8. Hirose K, Shu NH, Reed JE, et al. Right ventricular dilatation and remodeling the first year after an initial transmural wall left ventricular myocardial infarction. *Am J Cardiol* 1993; 72: 1126-30.
9. Juillière Y, Buffet P, Marie PY, Berder V, Danchin N, Chierier F. Comparison of right ventricular systolic function in idiopathic dilated cardiomyopathy and healed anterior wall myocardial infarction associated with atherosclerotic coronary artery disease. *Am J Cardiol* 1994; 73: 588-90.
10. Ghio S, Gavazzi A, Campana C, et al. Independent and additive prognostic value of right ventricular systolic function and pulmonary artery pressure in patients with chronic heart failure. *J Am Coll Cardiol* 2001; 37: 183-8.
11. Iskandrian AS, Helfeld H, Lemlek J, Lee J, Iskandrian B, Heo J. Differentiation between primary dilated cardiomyopathy and ischemic cardiomyopathy based on right ventricular performance. *Am Heart J* 1992; 123: 768-73.
12. Vatta M, Stetson SJ, Jimenez S, et al. Molecular normalization of dystrophin in the failing left and right ventricle of patients treated with either pulsatile or continuous flow-type ventricular assist devices. *J Am Coll Cardiol* 2004; 43: 811-7.
13. Clark AL, Poole-Wilson PA, Coats AJ. Exercise limitation in chronic heart failure: central role of the periphery. *J Am Coll Cardiol* 1996; 28: 1092-102.
14. Franciosa JA, Baker BJ, Seth L. Pulmonary versus systemic hemodynamics in determining exercise capacity of patients with chronic left ventricular failure. *Am Heart J* 1985; 110: 807-13.
15. Butler J, Chomsky DB, Wilson JR. Pulmonary hypertension and exercise intolerance in patients with heart failure. *J Am Coll Cardiol* 1999; 34: 1802-6.
16. Baker BJ, Wilen MM, Boyd CM, Dinh H, Franciosa JA. Relation of right ventricular ejection fraction to exercise capacity in chronic left ventricular failure. *Am J Cardiol* 1984; 54: 596-9.

17. Di Salvo TG, Mathier M, Semigran MJ, Dec GW. Preserved right ventricular ejection fraction predicts exercise capacity and survival in advanced heart failure. *J Am Coll Cardiol* 1995; 25: 1143-53.
18. de Groote P, Millaire A, Foucher-Hossein C, et al. Right ventricular ejection fraction is an independent predictor of survival in patients with moderate heart failure. *J Am Coll Cardiol* 1998; 32: 948-54.
19. Zornoff LAM, Skali H, Pfeffer MA, et al, for the SAVE Investigators. Right ventricular dysfunction and risk of heart failure and mortality after myocardial infarction. *J Am Coll Cardiol* 2002; 39: 1450-5.
20. Karatasakis GT, Karagounis LA, Kalyvas PA, et al. Prognostic significance of echocardiographically estimated right ventricular shortening in advanced heart failure. *Am J Cardiol* 1998; 82: 329-34.
21. Ghio S, Recusani F, Klersy C, et al. Prognostic usefulness of the tricuspid annular plane systolic excursion in patients with congestive heart failure secondary to idiopathic or ischemic dilated cardiomyopathy. *Am J Cardiol* 2000; 85: 837-42.
22. Lucreziotti S, Gavazzi A, Scelsi L, et al. Five-minute recording of heart rate variability in severe chronic heart failure: correlates with right ventricular function and prognostic implications. *Am Heart J* 2000; 139: 1088-95.
23. Mariano-Goulart D, Eberlé MC, Boudousq V, et al. Major increase in brain natriuretic peptide indicates right ventricular systolic dysfunction in patients with heart failure. *Eur J Heart Fail* 2003; 5: 481-8.
24. Gavazzi A, Ghio S, Scelsi L, et al. Response of the right ventricle to acute pulmonary vasodilation predicts the outcome in patients with advanced heart failure and pulmonary hypertension. *Am Heart J* 2003; 145: 310-6.
25. Gorcsan J 3rd, Murali S, Counihan PJ, Mandarino WA, Kormos RL. Right ventricular performance and contractile reserve in patients with severe heart failure. Assessment by pressure-area relations and association with outcome. *Circulation* 1996; 94: 3190-7.