

## Chapter

### Current Approach to Heart Failure

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# Right Heart Failure

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## Abstract

Right heart failure is a complex clinical syndrome, which includes structure and/or function alterations of the right heart circulatory system leading to suboptimal delivery of blood flow to the pulmonary circulation and/or elevated venous pressures at rest and/or with exercise. Variety of underlying conditions may contribute to the development of right heart failure with the left ventricular pathology and pulmonary hypertension remaining the primary reasons. Recent recognition of the right ventricular (RV) dysfunction as an important predictor of cardiovascular morbidity and mortality in various conditions highlighted a need in a more comprehensive understanding of RV anatomy, physiology, pathophysiology and development of management strategies. These include early diagnosis of RV dysfunction, judicious fluid management, decrease of afterload, improvement of myocardial contractility, as well as identification and treatment of the underlying cause of right heart failure. Development of RV-specific diagnostic and treatment methodologies should be considered one of the primary aims of future research.

## Keywords

Right heart failure Right ventricular dysfunction Right ventricular volume Volume overload Pressure overload Pulmonary hypertension Echocardiographic assessment

## References

1. Mehra MR, Park MH, Landzberg MJ, Lala A, Waxman AB. Right heart failure: toward a common language. *Pulm Circ United States*. 2013;3(4):963–7.  
*CrossRef* (<http://dx.doi.org/10.1086/674750>)
2. Galie N, Humbert M, Vachiery J-L, Gibbs S, Lang I, Torbicki A, et al. 2015 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension: the Joint Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS): Endor. *Eur Heart J England*. 2016;37(1):67–119.  
*CrossRef* (<http://dx.doi.org/10.1093/eurheartj/ehv317>)

3. McMurray JV, Adamopoulos S, Anker SD, Auricchio A, Bohm M, Dickstein K, et al. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart. Eur Heart J England. 2012;33(14):1787–847.

CrossRef (<http://dx.doi.org/10.1093/eurheartj/ehs104>)

4. Harjola V-P, Mebazaa A, Celutkiene J, Bettex D, Bueno H, Chioncel O, et al. Contemporary management of acute right ventricular failure: a statement from the Heart Failure Association and the Working Group on Pulmonary Circulation and Right Ventricular Function of the European Society of Cardiology. Eur J Heart Fail England. 2016;18(3):226–41.

CrossRef (<http://dx.doi.org/10.1002/ejhf.478>)

5. Sheehan F, Redington A. The right ventricle: anatomy, physiology and clinical imaging. Heart England. 2008;94(11):1510–5.

CrossRef (<http://dx.doi.org/10.1136/hrt.2007.132779>)

6. Vitarelli A, Terzano C. Do we have two hearts? New insights in right ventricular function supported by myocardial imaging echocardiography. Heart Fail Rev United States. 2010;15(1):39–61.

CrossRef (<http://dx.doi.org/10.1007/s10741-009-9154-x>)

7. Pettersen E, Helle-Valle T, Edvardsen T, Lindberg H, Smith H-J, Smevik B, et al. Contraction pattern of the systemic right ventricle shift from longitudinal to circumferential shortening and absent global ventricular torsion. J Am Coll Cardiol United States. 2007;49(25):2450–6.

CrossRef (<http://dx.doi.org/10.1016/j.jacc.2007.02.062>)

8. Haddad F, Hunt SA, Rosenthal DN, Murphy DJ. Right ventricular function in cardiovascular disease, part I: anatomy, physiology, aging, and functional assessment of the right ventricle. Circulation United States. 2008;117(11):1436–48.

CrossRef (<http://dx.doi.org/10.1161/CIRCULATIONAHA.107.653576>)

9. Berlin DA, Bakker J. Understanding venous return. Intensive Care Med United States. 2014;40(10):1564–6.

CrossRef (<http://dx.doi.org/10.1007/s00134-014-3379-4>)

10. Naeije R, Brimioule S, Dewachter L. Biomechanics of the right ventricle in health and disease (2013 Grover Conference series). Pulm Circ United States. 2014;4(3):395–406.

CrossRef (<http://dx.doi.org/10.1086/677354>)

11. Aguero J, Ishikawa K, Hadri L, Santos-Gallego C, Fish K, Hammoudi N, et al. Characterization of right ventricular remodeling and failure in a chronic pulmonary hypertension model. Am J Physiol Heart Circ Physiol. United States; 2014;307(8):H1204–15.

12. Naeije R. Assessment of right ventricular function in pulmonary hypertension. Curr Hypertens Rep United States. 2015;17(5):35.

CrossRef (<http://dx.doi.org/10.1007/s11906-015-0546-0>)

13. Tedford RJ, Hassoun PM, Mathai SC, Girgis RE, Russell SD, Thiemann DR, et al. Pulmonary capillary wedge pressure augments right ventricular pulsatile loading. Circulation United States. 2012;125(2):289–97.

CrossRef (<http://dx.doi.org/10.1161/CIRCULATIONAHA.111.051540>)

14. Ryan JJ, Tedford RJ. Diagnosing and treating the failing right heart. Curr Opin Cardiol United States. 2015;30(3):292–300.

CrossRef (<http://dx.doi.org/10.1097/HCO.0000000000000164>)

15. Haddad F, Doyle R, Murphy DJ, Hunt SA. Right ventricular function in cardiovascular disease, part II: pathophysiology, clinical importance, and management of right ventricular failure. Circulation United States. 2008;117(13):1717–31.

CrossRef (<http://dx.doi.org/10.1161/CIRCULATIONAHA.107.653584>)

16. Voelkel NF, Gomez-Arroyo J, Abbate A, Bogaard HJ. Mechanisms of right heart failure-A work in progress and a plea for failure prevention. Pulm Circ India. 2013;3(1):137–43.

CrossRef (<http://dx.doi.org/10.4103/2045-8932.109957>)

17. Hayek S, Sims DB, Markham DW, Butler J, Kalogeropoulos AP. Assessment of right ventricular function in left ventricular assist device candidates. Circ Cardiovasc Imaging United States. 2014;7(2):379–89.

CrossRef (<http://dx.doi.org/10.1161/CIRCIMAGING.113.001127>)

18. Argiriou M, Kolokotron S-M, Sakellaridis T, Argiriou O, Charitos C, Zarogoulidis P, et al. Right heart failure post left ventricular assist device implantation. J Thorac Dis China. 2014;6 Suppl 1:S52–9.

19. Stoica SC, Satchithananda DK, White PA, Sharples L, Parameshwar J, Redington AN, et al. Brain death leads to abnormal contractile properties of the human donor right ventricle. J Thorac Cardiovasc Surg [Internet] 2006;132(1):116–23. Available from: <http://www.sciencedirect.com/science/article/pii/S0022522306002091> (<http://www.sciencedirect.com/science/article/pii/S0022522306002091>) .

20. Badano LP, Miglioranza MH, Edvardsen T, Colafranceschi AS, Muraru D, Bacal F, et al. European Association of Cardiovascular Imaging/Cardiovascular Imaging Department of the Brazilian Society of Cardiology recommendations for the use of cardiac imaging to assess and follow patients after heart transplantation. Eur Heart J Cardiovasc Imag England. 2015;16(9):919–48.

21. Guglin M, Verma S. Right side of heart failure. Heart Fail Rev United States. 2012;17(3):511–27.

CrossRef (<http://dx.doi.org/10.1007/s10741-011-9272-0>)

22. Oikawa M, Kagaya Y, Otani H, Sakuma M, Demachi J, Suzuki J, et al. Increased [18F]fluorodeoxyglucose accumulation in right ventricular free wall in patients with pulmonary hypertension and the effect of epoprostenol. *J Am Coll Cardiol United States*. 2005;45(11):1849–55.  
*CrossRef* (<http://dx.doi.org/10.1016/j.jacc.2005.02.065>)
23. Archer SL, Fang Y-H, Ryan JJ, Piao L. Metabolism and bioenergetics in the right ventricle and pulmonary vasculature in pulmonary hypertension. *Pulm Circ India*. 2013;3(1):144–52.  
*CrossRef* (<http://dx.doi.org/10.4103/2045-8932.109960>)
24. Bogaard HJ, Natarajan R, Henderson SC, Long CS, Kraskauskas D, Smithson L, et al. Chronic pulmonary artery pressure elevation is insufficient to explain right heart failure. *Circulation United States*. 2009;120(20):1951–60.  
*CrossRef* (<http://dx.doi.org/10.1161/CIRCULATIONAHA.109.883843>)
25. Sutendra G, Dromparis P, Paulin R, Zervopoulos S, Haromy A, Nagendran J, et al. A metabolic remodeling in right ventricular hypertrophy is associated with decreased angiogenesis and a transition from a compensated to a decompensated state in pulmonary hypertension. *J Mol Med (Berl) Germany*. 2013;91(11):1315–27.  
*CrossRef* (<http://dx.doi.org/10.1007/s00109-013-1059-4>)
26. Hancock EW, Deal BJ, Mirvis DM, Okin P, Kligfield P, Gettes LS, et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part V: electrocardiogram changes associated with cardiac chamber hypertrophy: a scientific statement from the American Heart Association Electrocardiography. *J Am Coll Cardiol United States*. 2009;53(11):992–1002.  
*CrossRef* (<http://dx.doi.org/10.1016/j.jacc.2008.12.015>)
27. Surawicz B, Childers R, Deal BJ, Gettes LS, Bailey JJ, Gorgels A, et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part III: intraventricular conduction disturbances: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee. *J Am Coll Cardiol United States*. 2009;53(11):976–81.  
*CrossRef* (<http://dx.doi.org/10.1016/j.jacc.2008.12.013>)
28. Wagner GS, Macfarlane P, Wellens H, Josephson M, Gorgels A, Mirvis DM, et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part VI: acute ischemia/infarction: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clin. *J Am Coll Cardiol United States*. 2009;53(11):1003–11.  
*CrossRef* (<http://dx.doi.org/10.1016/j.jacc.2008.12.016>)
29. Marcus FI, McKenna WJ, Sherrill D, Basso C, Bauce B, Bluemke DA, et al. Diagnosis of arrhythmogenic right ventricular cardiomyopathy/dysplasia: proposed modification of the Task Force Criteria. *Eur Heart J England*. 2010;31(7):806–14.  
*CrossRef* (<http://dx.doi.org/10.1093/eurheartj/ehq025>)
30. Reesink HJ, Tulevski II, Marcus JT, Boomsma F, Kloek JJ, Vonk Noordegraaf A, et al. Brain natriuretic peptide as noninvasive marker of the severity of right ventricular dysfunction in chronic thromboembolic pulmonary hypertension. *Ann Thorac Surg Netherlands*. 2007;84(2):537–43.  
*CrossRef* (<http://dx.doi.org/10.1016/j.athoracsur.2007.04.006>)
31. Mariano-Goulart D, Eberle M-C, Boudousq V, Hejazi-Moughari A, Piot C, de Kerleau C C, et al. Major increase in brain natriuretic peptide indicates right ventricular systolic dysfunction in patients with heart failure. *Eur J Heart Fail Netherlands*. 2003;5(4):481–8.  
*CrossRef* ([http://dx.doi.org/10.1016/S1388-9842\(03\)00041-2](http://dx.doi.org/10.1016/S1388-9842(03)00041-2))
32. Nagaya N, Nishikimi T, Uematsu M, Satoh T, Kyotani S, Sakamaki F, et al. Plasma brain natriuretic peptide as a prognostic indicator in patients with primary pulmonary hypertension. *Circulation United States*. 2000;102(8):865–70.  
*CrossRef* (<http://dx.doi.org/10.1161/01.CIR.102.8.865>)
33. Naito A, Tanabe N, Jujo T, Shigeta A, Sugiura T, Sakao S, et al. Pentraxin3 in chronic thromboembolic pulmonary hypertension: a new biomarker for screening from remitted pulmonary thromboembolism. *PLoS One United States*. 2014;9(11):e113086.  
*CrossRef* (<http://dx.doi.org/10.1371/journal.pone.0113086>)
34. Breidthardt T, Vanpoucke G, Potocki M, Mosimann T, Ziller R, Thomas G, et al. The novel marker LTBP2 predicts all-cause and pulmonary death in patients with acute dyspnoea. *Clin Sci (Lond) England*. 2012;123(9):557–66.  
*CrossRef* (<http://dx.doi.org/10.1042/CS20120058>)
35. Jurcut R, Giusca S, La Gerche A, Vasile S, Ginghina C, Voigt JU. The echocardiographic assessment of the right ventricle: what to do in 2010? *Eur J Echocardiogr*. 2010;11(2):81–96.  
*PubMed* ([http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list\\_uids=20124362](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=20124362)) *CrossRef* (<http://dx.doi.org/10.1093/ejehocard/jep234>)
36. Voelkel NF, Quaife RA, Leinwand LA, Barst RJ, McGoon MD, Meldrum DR, et al. Right ventricular function and failure: report of a National Heart, Lung, and Blood Institute Working Group on Cellular and Molecular Mechanisms of Right Heart Failure. *Circulation [Internet]* 2006;114 (17):1883–91. Available from: <http://circ.ahajournals.org/content/114/17/1883.short> (<http://circ.ahajournals.org/content/114/17/1883.short>) .
37. Addetia K, Maffessanti F, Yamat M, Weinert L, Narang A, Freed BH, et al. Three-dimensional echocardiography-based analysis of right

ventricular shape in pulmonary arterial hypertension. Eur Heart J Cardiovasc Imag England. 2016;17(5):564–75.

CrossRef (<http://dx.doi.org/10.1093/ehjci/jev171>)

38. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* [Internet] Elsevier Inc; 2015;28(1):1–39.e14. Available from: <http://dx.doi.org/10.1016/j.echo.2014.10.003> (<http://dx.doi.org/10.1016/j.echo.2014.10.003>).
39. Rudski LG, Lai WW, Afilalo J, Hua L, Handschumacher MD, Chandrasekaran K, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the American Society of Echocardiography. *J Am Soc Echocardiogr* [Internet]. Elsevier Inc. 2010;23(7):685–713 quiz 786–8. Available from: <http://dx.doi.org/10.1016/j.echo.2010.05.010> (<http://dx.doi.org/10.1016/j.echo.2010.05.010>).
- CrossRef (<http://dx.doi.org/10.1016/j.echo.2010.05.010>)
40. Portnoy SG, Rudski LG. Echocardiographic evaluation of the right ventricle: a 2014 perspective. *Curr Cardiol Rep United States*. 2015;17(4):21.
- CrossRef (<http://dx.doi.org/10.1007/s11886-015-0578-8>)
41. Lai WW, Gauvreau K, Rivera ES, Saleeb S, Powell AJ, Geva T. Accuracy of guideline recommendations for two-dimensional quantification of the right ventricle by echocardiography. *Int J Cardiovasc Imaging United States*. 2008;24(7):691–8.
- CrossRef (<http://dx.doi.org/10.1007/s10554-008-9314-4>)
42. Leibundgut G, Rohner A, Grize L, Bernheim A, Kessel-Schaefer A, Bremerich J, et al. Dynamic assessment of right ventricular volumes and function by real-time three-dimensional echocardiography: a comparison study with magnetic resonance imaging in 100 adult patients. *J Am Soc Echocardiogr United States*. 2010;23(2):116–26.
- CrossRef (<http://dx.doi.org/10.1016/j.echo.2009.11.016>)
43. Gopal AS, Chukwu EO, Iwuchukwu CJ, Katz AS, Toole RS, Schapiro W, et al. Normal values of right ventricular size and function by real-time 3-dimensional echocardiography: comparison with cardiac magnetic resonance imaging. *J Am Soc Echocardiogr United States*. 2007;20(5):445–55.
- CrossRef (<http://dx.doi.org/10.1016/j.echo.2006.10.027>)
44. Lu X, Nadvoretskiy V, Bu L, Stolpen A, Ayres N, Pignatelli RH, et al. Accuracy and reproducibility of real-time three-dimensional echocardiography for assessment of right ventricular volumes and ejection fraction in children. *J Am Soc Echocardiogr United States*. 2008;21(1):84–9.
- CrossRef (<http://dx.doi.org/10.1016/j.echo.2007.05.009>)
45. Zhang QB, Sun JP, Gao RF, Lee AP-W, Feng YL, Liu XR, et al. Feasibility of single-beat full-volume capture real-time three-dimensional echocardiography for quantification of right ventricular volume: validation by cardiac magnetic resonance imaging. *Int J Cardiol Netherlands*. 2013;168(4):3991–5.
46. De Simone R, Wolf I, Mottl-Link S, Bottiger BW, Rauch H, Meinzer H-P, et al. Intraoperative assessment of right ventricular volume and function. *Eur J Cardiothorac Surg England*. 2005;27(6):988–93.
- CrossRef (<http://dx.doi.org/10.1016/j.ejcts.2005.01.022>)
47. Tamborini G, Marsan NA, Gripari P, Maffessanti F, Brusoni D, Muratori M, et al. Reference values for right ventricular volumes and ejection fraction with real-time three-dimensional echocardiography: evaluation in a large series of normal subjects. *J Am Soc Echocardiogr United States*. 2010;23(2):109–15.
- CrossRef (<http://dx.doi.org/10.1016/j.echo.2009.11.026>)
48. Maffessanti F, Muraru D, Esposito R, Gripari P, Ermacora D, Santoro C, et al. Age-, body size-, and sex-specific reference values for right ventricular volumes and ejection fraction by three-dimensional echocardiography: a multicenter echocardiographic study in 507 healthy volunteers. *Circ Cardiovasc Imag United States*. 2013;6(5):700–10.
- CrossRef (<http://dx.doi.org/10.1161/CIRCIMAGING.113.000706>)
49. Damy T, Goode KM, Kallvikbacka-Bennett A, Lewinter C, Hobkirk J, Nikitin NP, et al. Determinants and prognostic value of pulmonary arterial pressure in patients with chronic heart failure. *Eur Heart J England*. 2010;31(18):2280–90.
- CrossRef (<http://dx.doi.org/10.1093/eurheartj/ehq245>)
50. Melenovsky V, Hwang S-J, Lin G, Redfield MM, Borlaug BA. Right heart dysfunction in heart failure with preserved ejection fraction. *Eur Heart J England*. 2014;35(48):3452–62.
- CrossRef (<http://dx.doi.org/10.1093/eurheartj/ehu193>)
51. Pleister A, Kahwash R, Haas G, Ghio S, Cittadini A, Baliga RR. Echocardiography and heart failure: a glimpse of the right heart. *Echocardiography United States*; 2015;32 Suppl 1:S95–107.
52. D'Alto M, Romeo E, Argiento P, Di Salvo G, Badagliacca R, Cirillo AP, et al. Pulmonary arterial hypertension: the key role of echocardiography. *Echocardiography United States*. 2015;32 Suppl 1:S23–37.

53. Buechel ERV, Mertens LL. Imaging the right heart: the use of integrated multimodality imaging. *Eur Heart J.* 2012;33(8):949–60.  
[CrossRef](http://dx.doi.org/10.1093/eurheartj/ehr490) (<http://dx.doi.org/10.1093/eurheartj/ehr490>)
54. Altmayer SPL, Teeuwen LA, Gorman RC, Han Y. RV mass measurement at end-systole: improved accuracy, reproducibility, and reduced segmentation time. *J Magn Reson Imag United States.* 2015;42(5):1291–6.  
[CrossRef](http://dx.doi.org/10.1002/jmri.24899) (<http://dx.doi.org/10.1002/jmri.24899>)
55. Swift AJ, Rajaram S, Campbell MJ, Hurdman J, Thomas S, Capener D, et al. Prognostic value of cardiovascular magnetic resonance imaging measurements corrected for age and sex in idiopathic pulmonary arterial hypertension. *Circ Cardiovasc Imag United States.* 2014;7(1):100–6.  
[CrossRef](http://dx.doi.org/10.1161/CIRCIMAGING.113.000338) (<http://dx.doi.org/10.1161/CIRCIMAGING.113.000338>)
56. Peacock AJ, Crawley S, McLure L, Blyth K, Vizza CD, Poscia R, et al. Changes in right ventricular function measured by cardiac magnetic resonance imaging in patients receiving pulmonary arterial hypertension-targeted therapy: the EURO-MR study. *Circ Cardiovasc Imag United States.* 2014;7(1):107–14.  
[CrossRef](http://dx.doi.org/10.1161/CIRCIMAGING.113.000629) (<http://dx.doi.org/10.1161/CIRCIMAGING.113.000629>)
57. van de Veerdonk MC, Kind T, Marcus JT, Mauritz G-J, Heymans MW, Bogaard H-J, et al. Progressive right ventricular dysfunction in patients with pulmonary arterial hypertension responding to therapy. *J Am Coll Cardiol United States.* 2011;58(24):2511–9.  
[CrossRef](http://dx.doi.org/10.1016/j.jacc.2011.06.068) (<http://dx.doi.org/10.1016/j.jacc.2011.06.068>)
58. Babu-Narayan SV, Goktekin O, Moon JC, Broberg CS, Pantely GA, Pennell DJ, et al. Late gadolinium enhancement cardiovascular magnetic resonance of the systemic right ventricle in adults with previous atrial redirection surgery for transposition of the great arteries. *Circulation United States.* 2005;111(16):2091–8.  
[CrossRef](http://dx.doi.org/10.1161/01.CIR.0000162463.61626.3B) (<http://dx.doi.org/10.1161/01.CIR.0000162463.61626.3B>)
59. Mertens LL, Friedberg MK. Imaging the right ventricle – current state of the art. *Nat Rev Cardiol England.* 2010;7(10):551–63.  
[CrossRef](http://dx.doi.org/10.1038/nrcardio.2010.118) (<http://dx.doi.org/10.1038/nrcardio.2010.118>)
60. Dupont MVM, Dragean CA, Coche EE. Right ventricle function assessment by MDCT. *AJR Am J Roentgenol United States.* 2011;196(1):77–86.  
[CrossRef](http://dx.doi.org/10.2214/AJR.09.3801) (<http://dx.doi.org/10.2214/AJR.09.3801>)
61. Ghaye B, Ghysen A, Bruyere P-J, D’Orio V, Dondelinger RF. Can CT pulmonary angiography allow assessment of severity and prognosis in patients presenting with pulmonary embolism? What the radiologist needs to know. *Radiographics United States.* 2006;26(1):23–40.  
[CrossRef](http://dx.doi.org/10.1148/rg.261055062) (<http://dx.doi.org/10.1148/rg.261055062>)
62. Tedford RJ, Mudd JO, Girgis RE, Mathai SC, Zaiman AL, Houston-Harris T, et al. Right ventricular dysfunction in systemic sclerosis-associated pulmonary arterial hypertension. *Circ Heart Fail United States.* 2013;6(5):953–63.  
[CrossRef](http://dx.doi.org/10.1161/CIRCHEARTFAILURE.112.000008) (<http://dx.doi.org/10.1161/CIRCHEARTFAILURE.112.000008>)
63. Hoeper MM, Lee SH, Voswinckel R, Palazzini M, Jais X, Marinelli A, et al. Complications of right heart catheterization procedures in patients with pulmonary hypertension in experienced centers. *J Am Coll Cardiol United States.* 2006;48(12):2546–52.  
[CrossRef](http://dx.doi.org/10.1016/j.jacc.2006.07.061) (<http://dx.doi.org/10.1016/j.jacc.2006.07.061>)
64. Diller G-P, Dimopoulos K, Okonko D, Li W, Babu-Narayan SV, Broberg CS, et al. Exercise intolerance in adult congenital heart disease: comparative severity, correlates, and prognostic implication. *Circulation United States.* 2005;112(6):828–35.  
[CrossRef](http://dx.doi.org/10.1161/CIRCULATIONAHA.104.529800) (<http://dx.doi.org/10.1161/CIRCULATIONAHA.104.529800>)
65. Wensel R, Opitz CF, Anker SD, Winkler J, Hoffken G, Kleber FX, et al. Assessment of survival in patients with primary pulmonary hypertension: importance of cardiopulmonary exercise testing. *Circulation United States.* 2002;106(3):319–24.  
[CrossRef](http://dx.doi.org/10.1161/01.CIR.0000022687.18568.2A) (<http://dx.doi.org/10.1161/01.CIR.0000022687.18568.2A>)
66. Weinstein AA, Chin LMK, Keyser RE, Kennedy M, Nathan SD, Woolstenhulme JG, et al. Effect of aerobic exercise training on fatigue and physical activity in patients with pulmonary arterial hypertension. *Respir Med England.* 2013;107(5):778–84.  
[CrossRef](http://dx.doi.org/10.1016/j.rmed.2013.02.006) (<http://dx.doi.org/10.1016/j.rmed.2013.02.006>)
67. Chan L, Chin LMK, Kennedy M, Woolstenhulme JG, Nathan SD, Weinstein AA, et al. Benefits of intensive treadmill exercise training on cardiorespiratory function and quality of life in patients with pulmonary hypertension. *Chest United States.* 2013;143(2):333–43.  
[CrossRef](http://dx.doi.org/10.1378/chest.12-0993) (<http://dx.doi.org/10.1378/chest.12-0993>)
68. Griffith KE, Jenkins E, Stulak J, Paugh T, Pagani FD. Long-term use of the CentriMag(R) Ventricular Assist System as a right ventricular assist device: a case report. *Perfusion England.* 2012;27(1):65–70.  
[CrossRef](http://dx.doi.org/10.1177/026765911424634) (<http://dx.doi.org/10.1177/026765911424634>)

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