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Echocardiographic assessment of the right ventricle and associated hemodynamics

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Abstract Echocardiographic imaging of the right ventricle has inherent challenges stemming from the chamber's complex shape. More focus has been placed on right ventricular function recently because it is an independent prognostic indicator of morbidity and mortality in heart failure and pulmonary hypertension. Echocardiography is a widely available, inexpensive, and well-validated tool that allows for comprehensive evaluation of the right ventricle's size and function. With improvements in ultrasound techniques and methods, there are many qualitative and quantitative indices that, when used in conjunction with noninvasive pulmonary hemodynamics, provide important diagnostic and prognostic information to the clinician. As echocardiographic modalities – particularly three-dimensional imaging – improve, enhanced assessment of the right ventricle will lead to a better understanding of the pathophysiology of right heart failure and enhanced ability to follow responses to therapy. (Prog Cardiovasc Dis 2012;55:144-160)

Keywords: Echocardiography; Right ventricle; Heart failure; Pulmonary hypertension

Right ventricular (RV) function is an important predictor of morbidity and mortality in patients with heart failure and pulmonary hypertension.[1-7] With thin and compliant walls accustomed to the low pressures and resistance of the pulmonary vasculature, the RV first increases in size and hypertrophies to overcome elevated pulmonary vascular resistance (PVR). Patients with longstanding pulmonary vascular disease or secondary pulmonary hypertension initially develop RV hypertrophy with normalization of RV volume, but this is eventually followed by progressive dilatation and deterioration of systolic and diastolic function.[1,6,8,9] Historically, prognostic assessment for heart failure has focused on the left ventricle (LV), consistent with this chamber serving most commonly as the primary locus of disease. Unlike the RV, the left ventricle (LV) has a relatively predictable shape and is easy to image. Numerous studies have led to established normal values for LV dimension, volumes, mass and function,[10] and such parameters have been documented to be strong predictors of morbidity and mortality in a variety of clinical settings.[11-16] More recently, investigators have focused research on RV size and function. RV dysfunction has been shown to be a major predictor of outcome following myocardial infarction, as well as a key prognostic indicator in patients with chronic heart failure.[17-19] Importantly, these prognostic features of RV dysfunction have been documented to be independent of LV parameters.[20,21] Owing to the RV's strong association with clinical outcomes, accurate assessment of RV size and function is an essential component to comprehensive evaluation of the patient with heart failure and/or pulmonary vascular disease.

Echocardiographic evaluation of the RV is challenging because of its complex shape, comprising the smooth muscular inflow, the trabecular apex and the outflow region. As a result, unlike the LV, geometric models for volumetric and functional quantification have been a

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Abbreviations and Acronyms

2D = two dimensional

3D = three dimensional

ASD = atrial septal defect

ASE = American Society of Echocardiography

IVC = inferior vena cava

FAC = fractional area change

LV = left ventricle or left ventricular

LVOT = left ventricular outflow tract

MPI = myocardial performance index

MRI = magnetic resonance imaging

PASP = pulmonary artery systolic pressure

PVR = pulmonary vascular resistance

Qp/Qs = pulmonary/systolic flow ratio

RA = right atrium

RV = right ventricular or right ventricle

RVOT = right ventricular outflow tract

RVSP = right ventricular systolic pressure

TAPSE = tricuspid annular plane systolic excursion

TEE = transesophageal echocardiography

VSD = ventricular septal defect

VTI = velocity time integral

challenge.[22] In addition, ultrasound waves do not penetrate the RV's retrosternal position well. Despite these limitations, echocardiography remains the mainstay in RV evaluation, as it is noninvasive, portable, inexpensive, and widely available. As therapeutic interventions continue to expand for heart failure and pulmonary hypertension, echocardiography serves as an important tool for screening patients at risk and tracking response to treatment.

Echocardiographic approach

A systematic approach to the echocardiographic assessment of the right ventricle, a crescent-shaped structure that wraps around the LV, is essential. Because of its complex shape, the RV is not completely visualized in any single two-dimensional (2D) echocardiographic view. Therefore, all available acoustic windows and views should be utilized to provide complementary information and permit complete assessment of the different RV segments. The American Society of Echocardiography (ASE) recommends standard acoustic windows, as well as RV-focused views, in the apical 4-chamber, 5-chamber and coronary-sinus views to better visualize the RV anterior, lateral, and inferior walls.[22] Multiple views should also be used for Doppler measurements to allow for optimal alignment of flow with the ultrasound beam.

It must be emphasized that because the most common cause of RV dysfunction is left ventricular dysfunction, standard echocardiographic assessment of left-sided structure and function is an indispensable component of the evaluation of the RV in the patient with suspected pulmonary vascular disease. Such assessment is beyond the purview of this manuscript; the reader is referred to relevant professional guidelines[10,23,24] for detailed recommendations in this regard.

Size and morphology of the right heart

Right atrium

The RA serves three main functions in RV filling: a reservoir for systemic venous return when the tricuspid valve is closed, a passive conduit in early diastole, and an active conduit during atrial contraction in late diastole. Quantitative assessments of RA size are performed from the apical 4-chamber view. RA measurements are obtained at the end of ventricular systole, when chamber size is maximal. Standard measurements include RA area, which is estimated by planimetry, and RA long-axis and minor-axis linear dimensions.[25] The RA long-axis distance is measured from the center of the tricuspid annulus to the center of the superior RA wall, while the mid-RA minor distance is measured from the mid level of the RA free wall

Table 1
Reference limits recommended by the American Society of Echocardiography for measures of right heart size and function.[22]

Measure		Abnormal
Chamber dimensions		
RV basal diameter		>4.2 cm
RV mid-cavity diameter		>3.5 cm
RV longitudinal diameter		>8.6 cm
RV end-diastolic area		>25 cm^2
RV end-systolic area		>14 cm^2
RV end-diastolic volume index		>80 mL/m^2
RV end-systolic volume index		>46 mL/m^2
3D RV end-diastolic volume index		>89 mL/m^2
3D RV end-systolic volume index		>45 mL/m^2
RV subcostal wall thickness		>0.5 cm
RA major dimension		>5.2 cm
RA minor dimension		>4.4 cm
RA end-systolic area		>18 cm^2
Systolic function		
TAPSE		<1.6 cm
Pulsed Doppler peak velocity at the annulus		<10 cm/s
Pulsed Doppler MPI	–	>0.40
Tissue Doppler MPI	–	>0.55
Fractional area change		<35 %
Diastolic function		
E/A ratio	–	<0.8 or >2.1
E′		<8 cm/s
E/E′ ratio	–	>6
E′/A′	–	>1.9
Deceleration time		<120 ms
Isovolumic relaxation time		>73 ms

E = Peak velocity of the early passive filling wave by transmitral Doppler.
A = Peak velocity of the atrial filling wave by transmitral Doppler.
E′ = Peak velocity of the tricuspid annulus in early diastole by pulsed tissue Doppler.
A′ = Peak velocity of the tricuspid annulus in late diastole by pulsed tissue Doppler.