International Journal of Cardiology 214 (2016) 54–69

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

The use of multimodality cardiovascular imaging to assess right ventricular size and function

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ARTICLE INFO

Article history:
Received 27 November 2015
Received in revised form 7 March 2016
Accepted 19 March 2016
Available online 25 March 2016

Keywords:
Right ventricle
Two-dimensional echocardiography
Three-dimensional echocardiography
Cardiac magnetic resonance
Computed tomography
Reference values

ABSTRACT

Right ventricular (RV) size and function have been found to be important predictors of cardiovascular morbidity and mortality in patients with various conditions. However, non-invasive assessment of the RV is a challenging task due to its complex anatomy and location in the chest. Although cardiac magnetic resonance (CMR) is considered a "gold standard" for RV assessment, the development of novel echocardiographic techniques, including three-dimensional (3DE) and two-dimensional speckle-tracking echocardiography (2DSTE) opened new exciting opportunities in RV imaging. 3DE has proven accurate in measuring RV volumes and ejection fraction when compared with CMR while 2DSTE plays a critical role in measuring RV myocardial deformation, which is a powerful predictor of patients' functional capacity and survival. Cardiac computed tomography provides an accurate and reproducible assessment of the RV volumes and can be considered a reliable alternative for patients who are not suitable for either echocardiography or CMR.

The purpose of this review is to summarize currently available data on the role of the different noninvasive cardiac imaging modalities in assessment of RV size, function and mechanics, with an emphasis on the benefits of novel imaging techniques and on how the latter can be applied in the various clinical settings.

1. Introduction

The right ventricle (RV) has long been considered as a dispensable cardiac chamber, which does not contribute significantly to overall cardiac function. The introduction of the Fontan procedure, excluding the RV from the circulation in patients with congenital heart diseases, had further contributed to this misconception [1].

RV regained attention only in the last two decades when the clinical and prognostic importance of RV geometry and function has been recognized, also stimulating the development of new applications of imaging techniques capable of a comprehensive assessment of the RV [2–6]. Due to RV complex anatomy and mechanics, the evaluation of its size and function is challenging. The ideal imaging technique should be capable of comprehensive, accurate and reproducible assessment of the RV morphology, contraction mechanics and hemodynamic performance, effectively coping with its three-dimensional (3D) geometry, unique myocardial fiber architecture, unfavorable location within the chest, limited number of well-defined anatomical landmarks, and complex mechanism of contraction. In addition, this imaging technique should be widely available, safe and cheap, allowing the assessment of the RV in a timely manner and in different clinical settings, including acute conditions, intra- and perioperative care.

Currently, there is no single imaging modality, which satisfies all the requirements outlined above. Accordingly, the use of multimodality

Abbreviations: 2DE, two-dimensional echocardiography; 2DSTE, two-dimensional speckle-tracking echocardiography; 3DE, three-dimensional echocardiography; a, anterior leaflet of tricuspid valve; ARVC, arrhythmogenic right ventricular cardiomyopathy; CMR, cardiac magnetic resonance; CT, computed tomography; EF, ejection fraction; EDA, end-diastolic area; EDV, end-diastolic volume; EDVi, index of end-diastolic volume; ESA, end-systolic area; ESV, end-systolic volume; ESVi, index of end-systolic volume; FAC, fractional area change; GFR, glomerular filtration rate; GS, global strain; IVC, inferior vena cava; IVS, interventricular septum; LA, left atrium; LV, left ventricle; MV, mitral valve; p, posterior leaflet of tricuspid valve; PA, pulmonary artery; PISA, proximal isovelocity area; PV, pulmonary valve; RA, right atrium; RIMP, right ventricular myocardial performance index; RV, right ventricle; RVD1, right ventricular basal diameter; RVD2, right ventricular mid cavity diameter; RVIT, right ventricular inflow tract; RVOT, right ventricular outflow tract; RVOT Dist, distal diameter of the right ventricular outflow tract; RVOT Prox, proximal diameter of the right ventricular outflow tract; s, septal leaflet of tricuspid valve; S, systolic velocity across lateral segment of tricuspid annulus by tissue Doppler imaging; SD, standard deviation; SPECT, single photon emission computed tomography; SSFP, steady-state free precession sequence; SV, stroke volume; TAPSE, tricuspid annular plane systolic excursion; TDI, tissue Doppler imaging; TEE, transesophageal echocardiography; TR, tricuspid regurgitation; TTE, transthoracic echocardiography; TV, tricuspid valve; WMA, wall motion abnormalities.

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http://dx.doi.org/10.1016/j.ijcard.2016.03.074
0167-5273/

Table 1
Strengths and limitations of the various imaging modalities in assessing the right ventricle.

	2DE	3DE	CMR	CT
Technical aspects				
Availability	++++	+++	++	++
Cost	+	++	++++	+++
Typical scan duration (min)	25–30	30–35	40–60	10–15
Safety	++++	++++	++/+++ contraindicated in patients with metallic implants; claustrophobia; contrast potentially associated with nephrogenic systemic fibrosis in patients with gfr < 30 ml/min; allergic reaction to contrast; restricted only to hemodinamically stable patients	+ ionizing radiations; potentially nephrotoxic contrast; allergic reaction to contrast
Imaging window dependence	Present	Present	Absent	Absent
Temporal resolution	+++	++	++	+
Spatial resolution	+++	++	+++	++++
3D acquisition	Absent	Present	Only in selected sequences	Present
Real-time 3D imaging	Absent	Present	Present, but with limitations	Absent
Assessment of RV geometry, size and function				
Evaluation of RV wall thickness	Present	Present	Present	Present
Determination of RV diameters	++	+++	++++	++++
Accuracy of RV volume	−	+++	++++	++++
Accuracy of RV EF	−	+++	++++	++++
Parameters of RV systolic function	FAC, TAPSE, TDI S	EF	EF	EF
Estimation of RV diastolic function	Only used in clinical practice	−	−	−
Evaluation of RV mechanics	+++	+	++++	+++
Major limitations	• Inability to acquire the whole RV in one view • Geometric assumptions • Poor visualization of RV endocardial border • Lack of spatial orientation	• Need of stable cardiac rhythm and cooperative patients • Visualization of RV endocardial border • No data about RV mass	• Costs • Low availability • Challenging identification of the RVOT boundaries	• Ionizing radiation • Potentially nephrotoxic contrast • Stable cardiac rhythm with a low heart rate for image acquisition

+ — low, ++ — moderate, +++ — high, ++++ — very high, − — major limitation of the modality, 3D — three-dimensional, EF — ejection fraction, FAC — fractional area change, GFR — glomerular filtration rate, RV — right ventricle, S — systolic velocity across lateral segment of tricuspid annulus, TAPSE — tricuspid annular plane systolic excursion.