Imaging for the Assessment of Heart Failure in Congenital Heart Disease

Ventricular Function and Beyond

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KEYWORDS

• Heart defect • Congenital • Echocardiography • Cardiac magnetic resonance • Heart failure • Clinical assessment

KEY POINTS

- Assessment of heart failure often relies on accurate cardiac imaging.
- Current noninvasive imaging modalities include many nongeometric methods for ventricular function that are ideally suited for the unique challenges of congenital heart disease.
- Research is still needed to aid in understanding how imaging parameters may guide management.

INTRODUCTION

Heart failure (HF) is a clinical syndrome with multiple causes. Patients with adult congenital heart disease (ACHD) typically have more than 1 substrate for developing HF, including prolonged cyanosis, myocardial damage related to multiple surgical and interventional procedures, chronic pressure/volume loading related to residual lesions, intrinsic myocardial disease, and HF secondary to arrhythmia. Clinical HF assessment is generally based on symptoms (exertional dyspnea, orthopnea, paroxysmal nocturnal dyspnea), physical findings related fluid retention (distended neck veins, edema, ascites), and insufficient cardiac output (reduced peripheral perfusion with colder extremities, orthostasis, circulatory shock). While not universal in patients with HF and a structurally normal heart, these findings tend to be even more unreliable among adults with congenital heart disease (CHD). Use of additional more objective measures of HF such as biomarkers, measured exercise capacity, and ventricular performance is particularly helpful for this patient population. This article focuses on the use of echocardiography, cardiac magnetic resonance imaging (CMR), and cardiac computed tomography (CT) techniques, and their use in the management of ACHD patients with HF. These imaging modalities are increasingly being used to replace cardiac catheterization, which still is the gold standard for measuring ventricular pressures, cardiac output, and vascular resistance. Each modality offers unique information and has specific limitations; given the heterogeneity of CHD vulnerable to HF, all have a role and are considered here (Table 1). Despite an expanding array of imaging options, a major challenge in HF management is to integrate the findings with other clinical data to

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Table 1
Strengths and limitations of imaging modalities

Imaging Modality	Factors Influencing Choice of Modality	Strengths	Limitations
Echocardiography	Imaging capabilities	Ventricular volumes/mass/global function (2D and 3D) Diastolic function Regional ventricular function and myocardial contractility (TDI, strain, myocardial performance index) Valvular regurgitation severity and mechanism	Volumetric methods assume uniform ventricular geometry often not present in ACHD patients Variable reproducibility Underestimation of ventricular volumes by 3D echo Limited extracardiac evaluation Retrosternal position of right ventricle may limit echocardiographic evaluation
	Technical considerations	Safe Portable Inexpensive	Poor acoustic windows Beam alignment (TDI)
CMR	Imaging capabilities	Ventricular volumes/mass/global function Dedicated software for right ventricular functional assessment Flow measurements (valvular regurgitation) Ventricular mechanics Myocardial fibrosis and scar Extracardiac evaluation	Susceptibility metal artifact/field distortion (coils and stents) Contraindicated in patients with pacemakers/defibrillators and those with severe renal dysfunction Inferior to CT for coronary imaging
	Technical considerations	No ionizing radiation Enables longitudinal review without cumulative radiation exposure	Limited availability and/or expertise Long imaging times Long breath holds Claustrophobia Expense
CT	Imaging capabilities	Ventricular volumes/mass/global function (2D and 3D) Vascular abnormalities including coronary artery disease, collaterals, and AV malformations Hybrid CT/PET for localization of regional myocardial ischemia Extracardiac evaluation	Overestimation of ventricular volumes No flow measurements
	Technical considerations	Short imaging times High resolution Higher reproducibility vs MR and echo	Ionizing radiation (7–12 mSv) Less suitable for longitudinal review owing to radiation exposure and cancer risk Iodinated contrast (nephrotoxicity, anaphylaxis) Tachycardia and arrhythmias reduce image quality Expense

Abbreviations: 2D, 2-dimensional; 3D, 3-dimensional; ACHD, adult congenital heart disease; AV, atrioventricular; CMR, cardiac magnetic resonance imaging; CT, computed tomography; MR, magnetic resonance; PET, positron emission tomography; TDI, tissue Doppler imaging.