JACC: CARDIOVASCULAR IMAGING
VOL. 5, NO. 1, 2012
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ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC.
DOI:10.1016/j.jcmg.2011.07.010

Simultaneous Right and Left Heart Real-Time, Free-Breathing CMR Flow Quantification Identifies Constrictive Physiology

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OBJECTIVES The purpose of this study was to evaluate the ability of a novel cardiac magnetic resonance (CMR) real-time phase contrast (RT-PC) flow measurement technique to reveal the discordant respirophasic changes in mitral and tricuspid valve in flow indicative of the abnormal hemodynamics seen in constrictive pericarditis (CP).

BACKGROUND Definitive diagnosis of CP requires identification of constrictive hemodynamics with or without pericardial thickening. CMR to date has primarily provided morphological assessment of the pericardium.

METHODS Sixteen patients (age 57 ± 13 years) undergoing CMR to assess known or suspected CP and 10 controls underwent RT-PC that acquired simultaneous mitral valve and tricuspid valve inflow velocities over 10 s of unrestricted breathing. The diagnosis of CP was confirmed via clinical history, diagnostic imaging, cardiac catheterization, intraoperative findings, and histopathology.

RESULTS Ten patients had CP, all with increased pericardial thickness (6.2 ± 1.0 mm). RT-PC imaging demonstrated discordant respirophasic changes in atrioventricular valve inflow velocities in all CP patients, with mean ± SD mitral valve and tricuspid valve inflow velocity variation of 46 ± 20% and 60 ± 15%, respectively, compared with 16 ± 8% and 24 ± 11% in patients without CP ($p < 0.004$ vs. patients with CP for both) and 17 ± 5% and 31 ± 13% in controls ($p < 0.001$ vs. patients with CP for both). There was no difference in atrioventricular valve inflow velocity variation between patients without CP compared with controls ($p > 0.3$ for both). Respiratory variation exceeding 25% across the mitral valve yielded a sensitivity of 100%, a specificity of 100%, and an area under the receiver-operating characteristic curve of 1.0 to detect CP physiology. Using a cutoff of 45%, variation of transtricuspid valve velocity had a sensitivity of 90%, a specificity of 88%, and an area under the receiver-operating characteristic curve of 0.98.

CONCLUSIONS Accentuated and discordant respirophasic changes in mitral valve and tricuspid valve inflow velocities characteristic of CP can be identified noninvasively with RT-PC CMR. When incorporated into existing CMR protocols for imaging pericardial morphology, RT-PC CMR provides important hemodynamic evidence with which to make a definite diagnosis of CP. (J Am Coll Cardiol Img 2012;5:15–24) © 2012 by the American College of Cardiology Foundation

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Manuscript received May 10, 2011; revised manuscript received July 7, 2011, accepted July 13, 2011.

Constrictive pericarditis (CP), an important cause of heart failure, requires accurate diagnosis due to the potentially curative effect of directed treatment that is distinct from usual heart failure therapies (1). Despite the availability of noninvasive modalities commonly used for clinical evaluation such as transthoracic echocardiography, computed tomography (CT), and cardiac magnetic resonance (CMR), the diagnosis of CP remains challenging (2–4). Although CMR can visualize the entire pericardium without limitation imposed by body habitus or previous surgical procedures, approximately 20% of patients with CP do not have pericardial thickening, and a thickened pericardium itself is not necessarily diagnostic of CP (5–7). To make the diagnosis, it is essential to demonstrate the characteristic hemodynamic changes caused by constricted filling of the right and left ventricles. Cine imaging may show an early diastolic septal bounce and respirophasic septal shift (8–11), or one may infer the presence of increased right-sided pressures by identifying inferior vena cava (IVC) plethora; however, these secondary findings are not diagnostic of CP.

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ABBREVIATIONS AND ACRONYMS

CMR = cardiac magnetic resonance
CP = constrictive pericarditis
CT = computed tomography
IVC = inferior vena cava
MV = mitral valve
ROI = region of interest
RT-PC = real-time phase contrast
TTE = transthoracic echocardiography
TV = tricuspid valve

Historically, Doppler echocardiography has been pivotal in the noninvasive diagnosis of CP due to its ability to demonstrate dissociation between intracardiac and intrathoracic pressures and ventricular interdependence via respiratory variations in transvalvular inflow velocities (12–14). With this approach, one serially examines mitral valve (MV) and tricuspid valve (TV) inflow variation over respiratory cycles. Magnetic resonance–based real-time phase contrast (RT-PC) imaging is capable of measuring velocities with improved temporal resolution without the need for breath holding (15). The aims of this study were: 1) to evaluate the accuracy of RT-PC as part of a comprehensive CMR-based evaluation of CP; and 2) to compare RT-PC flow measurements among patients with CP, patients without CP, and healthy controls.

METHODS

Patients. Consecutive patients (November 2009 to November 2010) with known or suspected CP referred for CMR were prospectively screened for participation in an institutional review board–approved human subjects protocol. Ten healthy controls (reference group) were recruited from advertisements for an ongoing, institutional review board–approved CMR technique development protocol. Exclusion criteria consisted of the presence of mechanical valves, valvular heart disease that was more than moderate in severity, history of right ventricular infarction, restrictive cardiomyopathy, significant pulmonary disease, or atrial fibrillation at the time of CMR examination. The reference standards for diagnosis of CP included: 1) standard noninvasive imaging such as transthoracic echocardiography (TTE) and cardiac CT and CMR findings of respirophasic septal shift, diastolic septal bounce, IVC plethora (>2.5 cm), and pericardial thickness >4 mm; 2) invasive hemodynamic evidence from cardiac catheterization; and/or 3) intraoperative and histopathology findings consistent with CP in the context of a consistent clinical history (2,3,5–7,14,16). The catheterization criteria included left ventricular end-diastolic pressure/right ventricular end-diastolic pressure ≤5 mm Hg, pulmonary arterial systolic pressure <55 mm Hg, right ventricular end-diastolic pressure/right ventricular systolic pressure >1/3, inspiratory decrease in right atrial pressure <5 mm Hg, inspiratory decrease in pulmonary capillary wedge pressure/left ventricular end-diastolic pressure difference of >5 mm Hg, and systolic area index >1.1 (7).

The diagnosis of CP was adjudicated by 2 observers blinded to CMR RT-PC imaging. All patients must have had a clinical history in which CP was in the differential diagnosis. Then if cardiac catheterization was available and the findings were consistent with CP, the diagnosis was made. The diagnosis was further confirmed on intraoperative and histopathologic findings (if available). If cardiac catheterization was not available or the findings were equivocal, physiological and morphological changes with echocardiography, CMR, and/or CT were used for the diagnosis. For exclusion of CP, hemodynamic changes must have been absent on cardiac catheterization and/or echocardiography.

CMR methods. All CMR studies were performed on a 1.5-T scanner (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany) with a maximum gradient amplitude of 45 mT/m, slew rate of 200 mT/m/ms, and 12-channel phased-array coil. In addition to RT-PC imaging, a complete CMR protocol for CP evaluation included: 1) coronal, axial, and transverse stacks of dark blood half-Fourier single-shot turbo spin echo images;

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