A Novel Method for Cine-CMR Automated Assessment of Left Ventricular Diastolic Dysfunction

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INTRODUCTION: Accurate assessment of left ventricular (LV) diastolic function is important for diagnosis and treatment of patients with congestive heart failure [1]. LV volumetric filling curves have been used to assess diastolic dysfunction [2, 3], but this has been impractical with CMR due to the laborious task of manually segmenting multiple phases across multiple short axis slices. We present a novel automated approach based upon the LV-METRIC segmentation algorithm [4] that assesses diastolic function from SSFP cine-CMR by generating ventricular filling profiles.

ALGORITHM/PROCESSING: LV-METRIC [4] was used for measuring LV volume across all cardiac phases. A seed point for the first cine SSFP image is set manually on the LV cavity, and the following automation is applied: 1) LV region grows iteratively with successively lower thresholds until breaching myocardium and effusion. 2) Myocardial breaching point allows determination of myocardial signal intensity (SI) for precise LV-myocardial border detection. 3) Seed points for adjacent/successive cine SSFP images are estimated by looking for a point close to the current segmentation's center-of-mass with similar SI to blood. This automation is stopped when all images in a matrix are segmented (**Figure 1**).

Diastolic function parameters are calculated with an automated processing tool (MATLAB) that transforms volumetric data into a volume-filling curve reflecting volume (y axis) versus time (x axis) (**Fig 2A**). Diastolic filling rate profiles (**2B**) were generated by taking the 3-point derivative of the volume-filling curve.

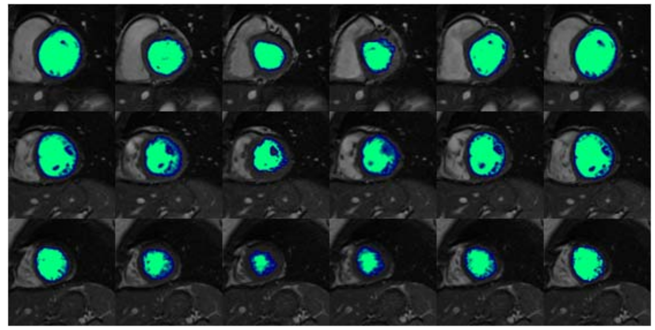

Figure 1 A representative matrix of cine-SSFP image elements segmented by LV-METRIC algorithm for full-volume assessment. Y axis represents slice position. X axis represents time along cardiac cycle.

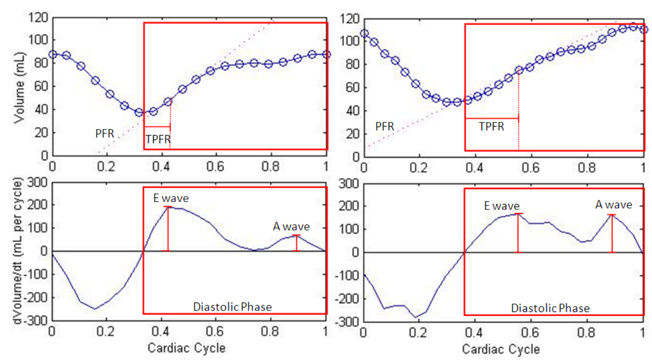

Figure 2A (Top) LV volume-filling curve of a normal (left) and abnormal (right) cases. **2B (Bottom)** Diastolic filling rate profiles of t representative normal (L) and abnormal (R) cases.

METHODS: Patients with normal systolic function (n=47) by cine CMR (EF>55%) were imaged at 1.5T (GE, Signa HDx 14.0) using short axis SSFP (6mm slice thickness, 20-28 phases) with expiratory breath holds. Four CMR diastolic parameters were evaluated: *Peak Flow Rate* [PFR] - calculated as maximal flow (Δvolume/Δtime), *Time to Peak Flow Rate* [TPFR] - calculated as time interval between end-systole and peak flow. *Diastolic Volume Half-Time* [DVHT] - calculated as normalized time fraction at which 50% diastolic volume recovery occurs, *Early (E) to late (A) diastolic profile* [E/A ratio] - calculated as ratio of E to A wave magnitude (diastolic rate profile). In order to compare CMR diastolic parameters to an established clinical standard, transthoracic echocardiography (echo) was performed for dedicated assessment of diastolic function within 60 days of CMR (mean interval = 12.6±15.6 days). Patients were categorized as having diastolic dysfunction by echo if demonstrated by both mitral inflow and tissue Doppler indices.

RESULTS: 47 patients were studied; 24 had normal diastolic function and 23 had abnormal diastolic function by echo. LV-METRIC rapidly generated volumetric data in all patients (mean time 66±36 sec, 199±41 images). There were no differences in systolic or volumetric indices between groups. In patients with diastolic dysfunction, there was decreased peak filling rate (PFR normalized to RR interval), increased time to peak filling rate (TPFR), increased diastolic volume half time (DVHT), and decreased E/A ratio indicating delayed ventricular filling (**Table 1**). DVHT, as measured by CMR, correlated with deceleration time by echo (r = 0.39, p = 0.01).

CONCLUSIONS: Automated segmentation by LV-METRIC assesses diastolic function on routine cine SSFP CMR. Our proposed diastolic filling parameters agree with echo findings, are rapidly extracted from short axis images requiring no additional imaging. Automated assessment of ventricular filling profiles holds the potential to improve diagnostic classifications and tailor clinical therapies for patients with diastolic dysfunction.

	Overall (n = 47)	**Normal (n = 24)**	**Abnormal (n = 23)**	**P**
Diastolic Parameters				
E/A Ratio	2.67 ± 2.28	3.92 ± 2.19	1.43 ± 1.84	**<0.001**
PFR (cc/sec)	278.5 ± 102.1	303.9 ± 95.6	252.0 ± 103.9	0.08
NPFR* (cc/sec/RR duration)	249.1 ± 100.4	290.4 ± 106.8	206.0 ± 73.2	**< 0.01**
TPFR (msec)	140.2 ± 87.1	106.5 ± 35.1	173.8 ± 109.1	**< 0.05**
NTPFR* (msec/RR duration)	0.2 ± 0.1	0.1±0.04	0.2 ± 0.2	**< 0.01**
DVHT	0.66 ± 0.15	0.63 ± 0.08	0.74 ± 0.09	**< 0.0001**
Systolic Parameters				
Ejection Fraction	65.1 ± 13.8	66.2 ± 6.3	68.8 ± 8.5	0.2
End Diastolic Volume	130.5 ± 46.1	138.0 ± 41.9	129.0 ± 47.5	0.5
End Systolic Volume	43.3 ± 19.5	46.7 ± 17.0	41.8 ± 22.3	0.4

Table 1: Statistical results from 47 patients, for which normal and abnormal diastolic functions were categorized based on echocardiography. * Heart rate normalized.

References: [1] Persson et al. J Am Coll Cardiol 2007; 49:687-94. [2] Magorien et al. Circulation 1983; 67:844-53. [3] Villari et al. J Nucl Med 1991; 32:1849-53. [4] Codella et al. Radiology 2008; 248:1004-13.