Impact of Left Ventricular Trabeculations and Papillary Muscles on Mass, Geometry, and Association With Incident Adverse Cardiovascular Events

The Framingham Heart Study

Increased left ventricular mass (LVM) predicts cardiovascular disease (CVD) morbidity and mortality. Most prior studies considered only compacted left ventricular mass (CLVM); here we sought to determine whether addition of trabecular and papillary-muscle (TPM) mass to CLVM augments prediction of incident adverse CVD events over CLVM alone.

A subset of the Framingham Offspring cohort (N = 1,424, 65 ± 9 years of age, 45.5% men) without clinical CVD underwent cardiac magnetic resonance during the 2002 to 2006 period using an electrocardiogram-gated, balanced steady-state free precession sequence (repetition time = 3.2 ms, echo time = 1.6 ms, 60° flip angle) at 1.5-T. Images were acquired in the LV short-axis orientation (slice thickness = 10 mm, no gap). Epicardial and compacted endocardial borders were segmented for CLVM; TPM mass was quantified using a previously reported semiautomatic fuzzy-thresholding algorithm (1). We defined "total LVM" as TLVM = CLVM + TPM mass. Both CLVM and TLVM were indexed (i) to body surface area. Reproducibility of LVM measures was high, with both intraobserver and interobserver intraclass correlation coefficients = 0.99 (1). Clinical covariates (height, weight, blood pressure, fasting total and high-density lipoprotein cholesterol, status of smoking, diabetes, hypertension) were obtained at the 7th Offspring exam (1998 to 2001). The study was approved by the Boston University Medical Center and the Beth Israel Deaconess Medical Center Institutional Review Boards.

We compared the predictive value of CLVMi and TLVMi for CVD events (composite of CVD death, myocardial infarction, coronary insufficiency, ischemic stroke, first heart failure admission) in Cox proportional hazards models, adjusted for Framingham risk factors, using Harrell C-statistic. We also assessed 2 measures of concentricity: total mass-volume ratio treated TPM as additional myocardium, whereas compacted mass-volume ratio treated TPM as part of blood pool. Finally, TPM as a percentage of TLVM was denoted TPM%mass. LV parameters among the Offspring cohort experiencing and not experiencing an adverse event were compared using age- and-sex-adjusted analysis of covariance.

Over a median 8.4-year follow-up, there were 75 incident CVD events (31 myocardial infarctions, 20 first heart failure admissions, 18 ischemic strokes, 2 coronary insufficiencies, 4 CVD deaths). In Framingham risk factors-adjusted Cox models, CLVMi (hazard ratio [HR]: 1.43 per SD; 95% confidence interval [CI]: 1.13 to 1.82), and TLVMi (HR: 1.41 per SD; 95% CI: 1.11 to 1.80) were similarly predictive; Harrell C = 0.757 for CLVMi (95% CI: 0.697 to 0.816) and C = 0.753 for TLVMi (95% CI: 0.694 to 0.813). Neither measure of concentricity was a significant predictor of adverse events in this study sample. Participants experiencing an adverse event had greater CLVMi, TLVMi, and compacted mass-volume ratio than event-free participants did (**Table 1**). Total mass-volume ratio did not differ, whereas TPM%mass was lower among participants experiencing an event.

Alternate methods for quantifying trabecular burden, such as ratio of compacted to noncompacted wall thicknesses (2) or areas (3), or fractal analyses (4), have been reported but were not used in the present study. However, our results are broadly concordant with Zemrak et al. (2) who, using imaging endpoints, found no relationship between

TABLE 1 LV Parameters by Sex and CVD-Event Status

	Men		Women		p Value*, +Event vs. No-Event
	No Event (n = 603)	Incident (+)Event (n = 45)	No Event (n = 746)	Incident (+)Event (n = 30)	
CLVMi, g/m^2	62.0 ± 10.4	65.5 ± 13.9	48.2 ± 7.6	52.0 ± 9.7	0.0008
TLVMi, g/m^2	78.6 ± 12.1	81.5 ± 15.4	62.6 ± 8.9	66.3 ± 11.6	0.011
CMVR, g/ml	0.89 ± 0.17	0.94 ± 0.19	0.80 ± 0.13	0.84 ± 0.16	0.02
TMVR, g/ml	1.46 ± 0.27	1.49 ± 0.26	1.35 ± 0.23	1.36 ± 0.23	0.43
TPM%mass, %	27.3 ± 7.3	25.2 ± 7.0	30.4 ± 6.7	28.0 ± 6.1	0.008

*The p values are sex-pooled.

CLVMi = compacted left ventricular mass index; CMVR = compacted mass-volume ratio; CVD = cardiovascular disease; LV = left ventricular; TLVMi = total left ventricular mass index; TMVR = total mass-volume ratio; TPM%mass = trabecular and papillary-muscle as a percentage of total left ventricular mass.

burden of trabeculated myocardium and adverse alterations in LV volumes or ejection fraction over 9.5-year follow-up in the MESA (Multi-Ethnic Study of Atherosclerosis) population.

There is extensive literature showing that greater CLVMi is associated with excess CVD morbidity and mortality, but to our knowledge this is the first report to directly compare TLVMi with CLVMi in a free-living population. We found no predictive difference between CLVMi and TLVMi, but this may be due to the relative paucity (5.3%) of events despite 8.4-year follow-up. Our study population was white and middle-aged or older; these results may not generalize to other age or ethnic groups: for example, MESA found greater trabecular thicknesses among blacks and Chinese than among whites (5).

In a community-dwelling cohort initially free of clinical CVD, both CLVMi and TLVMi were predictors of incident adverse CVD events over standard Framingham risk factors, but there was no additional predictive value with use of TLVMi in this cohort.

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