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Correlation of Trabeculae and Papillary Muscles With Clinical and Cardiac Characteristics and Impact on CMR Measures of LV Anatomy and Function

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OBJECTIVES The goal of this study was to assess the relationship of left ventricular (LV) trabeculae and papillary muscles (TPM) with clinical characteristics in a community-based, free-living adult cohort and to determine the effect of TPM on quantitative measures of LV volume, mass, and ejection fraction (EF).

BACKGROUND Hypertrabeculation has been associated with adverse cardiovascular events, but the distribution and clinical correlates of the volume and mass of the TPM in a normal left ventricle have not been well characterized.

METHODS Short-axis cine cardiac magnetic resonance images, obtained using a steady-state free precession sequence from 1,494 members of the Framingham Heart Study Offspring cohort, were analyzed with software that automatically segments TPM. Absolute TPM volume, TPM as a fraction of end-diastolic volume (EDV) (TPM/EDV), and TPM mass as a fraction of LV mass were determined in all offspring and in a referent group of offspring free of clinical cardiovascular disease and hypertension.

RESULTS In the referent group (mean age 61 ± 9 years; 262 men and 423 women), mean TPM was 23 ± 3% of LV EDV in both sexes ($p = 0.9$). TPM/EDV decreased with age ($p < 0.02$) but was not associated with body mass index. TPM mass as a fraction of LV mass was inversely correlated with age ($p < 0.0001$), body mass index ($p < 0.018$), and systolic blood pressure ($p < 0.0001$). Among all 1,494 participants (699 men), LV volumes decreased 23%, LV mass increased 28%, and EF increased by 7.5 EF units ($p < 0.0001$) when TPM were considered myocardial mass rather than part of the LV blood pool.

CONCLUSIONS Global cardiac magnetic resonance LV parameters were significantly affected by whether TPM was considered as part of the LV blood pool or as part of LV mass. Our cross-sectional data from a healthy referent group of adults free of clinical cardiovascular disease demonstrated that TPM/EDV decreases with increasing age in both sexes but is not related to hypertension or obesity. (J Am Coll Cardiol Img 2012;5:1115–23) © 2012 by the American College of Cardiology Foundation

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Left ventricular (LV) "hypertrabeculation" has been associated with adverse cardiovascular outcomes (1–3) and with extracardiac disease, including neuromuscular disorders (4), but the normal range of trabeculation and papillary muscle mass on cardiac magnetic resonance (CMR) imaging has not been fully characterized. In addition, the effect of the trabeculae and papillary muscles (TPM) on determination of LV volume, mass, and ejection fraction (EF) has not been assessed in a large, community-dwelling population. Cine steady-state free precession (SSFP) CMR provides high-resolution imaging of the left ventricle, with excellent visual contrast between myocardium and LV blood pool (5,6). These desirable attributes emphasize the papillary muscles and the trabeculae carnae, which were less well-visualized with other CMR sequences. There is variability in the treatment of TPM with respect to quantification of LV mass (LVM) and EF, important indexes with diagnostic and prognostic value. The TPM are often considered part of the LV cavity volume (i.e., blood pool) because this simplifies analysis and has been shown to improve observer reproducibility, particularly with manual tracing of endocardial contours (7). Although this is a reasonable approach for many patients, the proportional impact of TPM may be greater in select patient groups, such as those with hypertrophic cardiomyopathy (8) or markedly impaired LV EF (9).

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ABBREVIATIONS AND ACRONYMS

BMI = body mass index

CMR = cardiac magnetic resonance

EDV = end-diastolic volume

EF = ejection fraction

ESV = end-systolic volume

+HTN = participants with history of hypertension

ICC = intraclass correlation coefficient

LV = left ventricular

LVM = left ventricular mass

SBP = systolic blood pressure

SSFP = steady-state free precession

TPM = trabeculae and papillary muscles

TPMm = calculated mass of trabeculae and papillary muscles

+WMA = participants with wall motion abnormalities

The goal of this study was to determine the relation of TPM to global LV cavity size, mass, and global systolic function metrics in a cohort of free-living adults and to assess the effect of treating TPM as LV blood pool, versus as myocardial mass, on those LV metrics. We also sought to determine whether TPM varies with sex, age, body mass index (BMI), and history of hypertension or previous adverse cardiovascular events.

METHODS

Study population. The Framingham Heart Study Offspring cohort was initiated in 1971 and comprises 5,124 participants who are the children of the original cohort or the spouses of those children (10). Offspring cohort members were eligible for participation in the CMR substudy if they attended the seventh offspring cycle examination (1998 to 1999, N = 3,799), were in sinus rhythm, and had no contraindications to CMR. A total of 1,794 offspring underwent CMR from 2002 to 2006. All participants provided written informed consent, and the study was approved by the institutional review boards of the Beth Israel Deaconess Medical Center and the Boston University Medical Center.

Clinical covariates and medication information (blood pressure, height, weight, BMI, and antihypertensive drug treatment) were collected in a structured examination by a physician during the seventh cycle examination. Hypertension was defined as a systolic blood pressure (SBP) ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg on the mean of 2 measurements by a physician or use of antihypertensive medication. Data regarding cardiovascular disease events, such as myocardial infarction and heart failure, were collected and reviewed. All cardiovascular disease events were adjudicated by a panel of 3 physicians who were blinded to participant CMR data and who used standardized criteria (11).

CMR imaging. Participants underwent supine CMR scanning using a 1.5-T system with a 5-element cardiac array coil for radiofrequency signal reception (Gyroscan NT, Philips Healthcare, Best, the Netherlands). After scout imaging to determine the orientation of the heart within the thorax, a contiguous stack of short-axis two-dimensional SSFP cine images, encompassing the left ventricle from apex to base, was obtained. Imaging parameters included: TR = 3.2 ms, TE = 1.6 ms, and flip angle = 60°. Slice thickness was 10 mm (no interslice gap) with 1.9- × 1.6-mm^2 in-plane spatial resolution.

Image analysis. Images were transferred to a dedicated workstation (Extended MR Workspace 2009, Philips Healthcare) for analysis. Epicardial and endocardial LV contours were delineated across the cardiac cycle using an automated contour detection algorithm followed by manual correction as needed. The automated contour detection method was applied to the LV short-axis images only and has been previously described (12). Briefly, it models the short-axis myocardium as a ribbon of variable width, with the inner (endocardial) and outer (epicardial) contours described by interpolation of a minimal number of splines for each. An energy-