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Comparison of m-mode echocardiographic left ventricular mass measured using digital and strip chart readings: The Atherosclerosis Risk in Communities (ARIC) study

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Abstract

Background: Epidemiological and clinical studies frequently use echocardiography to measure LV wall thicknesses and chamber dimension for estimating quantitative measures of LV mass. While echocardiographic M-mode LV images have traditionally been measured using hand-held calipers and strip-chart paper tracings, digitized M-mode LV image measurements made directly on the computer screen using electronic calipers have become standard practice. We sought to determine if systematic differences in LV mass occur between the two methods by comparing LV mass measured from simultaneous M-mode strip chart recordings and digitized recordings.

Methods: The Atherosclerosis Risk in Communities study applied the latter method. To determine if systematic differences in LV mass occur between the two methods, LV mass was measured from simultaneous M-mode strip chart recordings and digitized recordings.

Results: We found no difference in LV mass ($p > .25$) and a strong correlation in LV mass between the two methods ($r = 0.97$). Neither age, sex, nor hypertension status affected the correlation of LV mass between the two methods.

Conclusions: We conclude that digital estimates of LV mass provide unbiased estimates comparable to the strip-chart method.

Background

Echocardiography is an established method of evaluating left ventricular (LV) mass and hypertrophy. M-mode echocardiography is widely used in epidemiologic studies to measure LV wall thicknesses and chamber dimension for estimating quantitative measures of LV mass. M-mode determined LV mass is highly accurate [1,2] and reproducible. [3–8] M-mode LV images have traditionally been measured using hand-held calipers and strip-chart paper tracings. More recently, digitized M-mode LV image measurements have been made directly on the computer screen using electronic calipers. We sought to determine if systematic differences in LV mass occur between the two methods by comparing LV mass measured from simultaneous M-mode strip chart recordings and digitized recordings.

Methods

Study Design and Population

Data were collected from the Jackson cohort of the Atherosclerosis Risk in Communities (ARIC) study, [9] a prospective investigation of the etiology, clinical sequelae, and natural history of atherosclerosis in four US communities (Forsyth County, North Carolina, Jackson, Mississippi, the northwestern suburbs of Minneapolis, Minnesota, and Washington County, Maryland). The Jackson cohort was selected from those African-Americans ages 45–64 years residing within the city limits of Jackson during 1986–1989. An echocardiogram was added to the second follow-up visit of the cohort, conducted between 1993 and 1995. The sample for this report was derived from 100 consecutive echocardiograms collected in the Jackson participants. Eighteen subjects were excluded from the analysis because of missing strip chart data (n = 11), missing computer screen data (n = 4), or missing medical or demographic data (n = 3). The final sample included 82 men and women.

Echocardiography

Two-dimensionally guided M-mode and Doppler echocardiographic examinations were performed with the Acuson 128XP/10c, equipped with 2.5 Mhz, 3.5 Mhz, and 5.0 Mhz transducers. Imaging was performed with the highest frequency transducer that provided satisfactory penetration. All scans were performed with the head of the table inclined at an angle of 15 degrees and the participant rotated 30–45 degrees in the left lateral decubitus position at end-expiration. The parasternal acoustic window was used to record LV internal diameter and wall thicknesses at or just below the tips of the leaflets of the mitral valve in both short and long axis views. Images were digitized on the Freeland Cineview System, an Intel computer system that received video input from the Acuson cardiac ultrasound system and digitized the image for recording, transport, analyses, and storage onto an optical disc. Images were also recorded on super VHS tape and by a strip chart recorder.

The American Society of Echocardiography (ASE) recommendations for measuring LV wall thickness were employed for making all M-mode echocardiographic measurements, with end diastole identified at the beginning of the QRS complex of the simultaneous recorded ECG. Measurements were taken using the leading edge to the leading edge at the onset of the QRS wave.[10] Computer screen readings were performed using the Analyzed Freeland Prism 5000 by one cardiologist. Five separate measurements were recorded and averaged. Similarly, 5 separate beats were measured and averaged for the strip chart recordings. LV mass was calculated by the corrected ASE simplified cubed equation, LVM (grams) = $0.8 [1.05 [(LVID + IVST + PWT)^3 - (LVID)^3]]$ where LVID = left ventricular internal dimension, IVST = intraventricular septum thickness, and PWT = posterior wall thickness. Body surface area (BSA) was calculated by the formula, BSA = $(0.0001) \times (71.84) \times (weight)^{0.425} \times (height)^{0.725}$ where weight was measured in kilograms and height was measured in centimeters. LV mass was divided by BSA to calculate the LV mass index (LVMI). The cutoff points for LV hypertrophy using the LVM/BSA ratio were 150 g/m^2 for males and 120 g/m^2 for females. The ratio of LV mass to height (LVM/hgt) was calculated by dividing LVM by height (g/m): the cutoffs for LVH using the LVM/hgt criterion was 163 g/m for males and 121 g/m for females.[11] The adjusted BSA formulae has been used in numerous epidemiological studies based on Caucasians, but there has been no large study investigating the cutoff criteria in African Americans.

Other measurements

Blood pressure was measured three times by trained and certified technicians using a random-zero sphygmomanometer. The average of the last 2 measurements was used in analyses. Participants brought all medications taken in the prior two weeks and these were transcribed by the interviewer. Antihypertensive medication use was coded as positive if blood pressure lowering medications were identified in the medication transcription. Hypertension was defined as systolic blood pressure greater than 140 mm Hg or diastolic blood pressure greater than 90 mm Hg or taking antihypertensive drugs. Weight was collected in fasting participants using a standardized protocol. Participants wore scrub suits and emptied their bladders prior to anthropomorphic measurements.

Statistical Analysis

The range, mean, median, and variance of LV mass measurements were determined. Paired T-tests were calculated to determine if statistically significant differences in mean LV mass measures were present between the two methods. A scatter plot contrasting measures from each method was graphed and the Pearson correlation was calculated. Data were subsequently stratified according to gender, hypertension, and age $\geq$ 60 years. For each stratification variable, correlation coefficients between the two methods within each stratum were calculated. Kappa coefficients were calculated for LV hypertrophy using the strip chart measurements as the standard.

Results

The study sample consisted of 47 women and 35 men. Hypertension was present in 55% of women and 52% of men, who were between 51 years and 70 years. The mean age was 58 years, and did not differ by gender. Using the

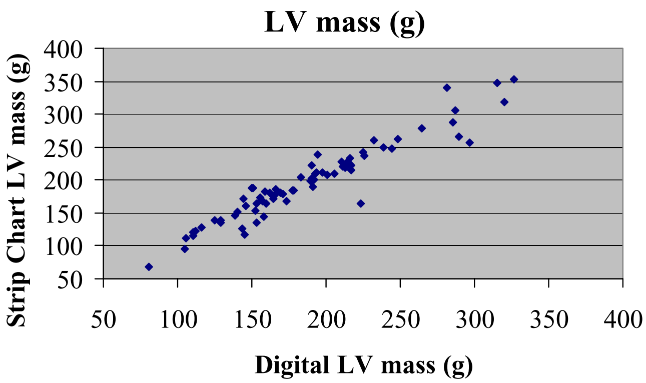

Figure 1
Scatterplot of estimated LV mass (g), measured with digital and strip chart methods.

classical cutpoints for BMI (<18.5 underweight, 18.5–24.9 normal, 25–29.9 overweight, and over 30 obese) the sample was on average overweight. Women had a BMI range of 20.32 kg/m^2 to 49.44 kg/m^2 with a mean of 30.92 kg/m^2 and men with a BMI range of 18.09 kg/m^2_to 38.05 kg/m^2 and a mean BMI of 27.69 kg/m^2.

The means, mean differences, and standard deviation of the means and differences between the digital and strip chart LV mass measurements are presented in Table 1. The difference between the two methods was small (10.8 gms, 8.6 g/m^2, or 9.9 g/m), which reflects about a 5% difference in LV mass between the two methods ($p = 0.36$, $p = 0.37$, $p = 0.36$). Scatterplots (Figure 1) indicate a strong concordance in LV mass between the two methods, and the Pearson correlation was excellent before and after indexing for BSA and height ($p < .001$). The sample was stratified by gender, hypertension, and age (>60, ≤ 60 years). We found the correlation of LV mass determined by the two methods to be similar in men and women: hypertensives and normotensives, and older (≤60 years) and younger (< 60 years) participants (Table 2).

LV hypertrophy prevalence was slightly lower, but not statistically different, for the strip chart reading compared to the computer screen reading (LVMI: 53 versus 60%, LVM/hgt, 53 versus 56%, respectively). Kappa coefficients were calculated in men and women separately using the strip chart LV hypertrophy as the reference standard. The Kappa coefficient for LVH defined by the sex-specific LVMI criterion was 0.93.

Discussion

The emergence of digitized M-mode echocardiography imaging and computerized reading methods has led to the adoption of digital reading protocols for making quantitative estimates of LV mass and hypertrophy in many epidemiologic studies. The advantages of using digitized echocardiographic data include the ability to store large volumes of data in less space, to retrieve data quickly, and to compare studies side by side when making longitudinal estimates of changes in LV structure. Digitized data also provide better resolution (0.5 mm) than strip chart recordings (1.0 mm), which may result in better accuracy for digitized data. However, a comparison with LV mass estimated from digitized versus strip chart reading methods is not, to the best of our knowledge, available in the literature.

Since the digitized technology was adopted by the Jackson Center of the ARIC Study, we considered it important to assess whether data derived from the digitized technology was comparable to data derived from the strip chart method. Specifically, our goal was to determine whether our estimates of LV mass estimated with digital technology were unbiased relative to strip chart readings to assure comparability between our study and other epidemiologic studies that employed the strip chart method. Our data indicate that estimates of LV mass and LV hypertrophy derived using M-mode digitized images read directly from the computer screen with electronic calipers are equivalent to estimates made using M-mode strip chart recordings and hand-held calipers. Moreover, the accuracy of the LV mass measures in not altered by demographic or clinical conditions associated with poor data acquisition or LV hypertrophy, including older age, male sex, and hypertension. [12,13]

One limitation of our study is the lack of a gold standard to clarify which measurement technique is more accurate for estimation of LV mass. In our study, the correlation between the strip chart and the digitized readings of LV mass was close to 1.0, and the absolute difference between the two measures was less than 5% of the mean level of LV mass. Since the original validation of the LV mass calculation by Devereux and Reicheck[1] using strip chart recordings found excellent accuracy for M-mode measures of LV mass relative to post-mortem measures as a gold standard, it is likely that the accuracy of the two methods is similar.

In summary, the majority of the literature on prevalence, determinants, and outcomes of echocardiographic LV hypertrophy is based on M-mode strip chart measurements. Nonetheless, the echocardiography field is moving toward digital M-mode acquisition and analysis. It is important to understand whether the newer technology produces measurements comparable to the older methodology so that we can extrapolate the prior literature to current measurements. Our data suggest that clinicians and researchers can reasonably conclude that digital estimates

Table 1: Comparison of mean values, (standard deviations), and range for LV mass (g), LV mass index (g/m²), and LV mass/height (g/m) for digital and strip chart readings, and the mean differences between the two methods.

Mean Values	Digital	Strip Chart	Mean Difference	P value
LV Mass (g)				
Mean (SD)	197.8 (57.8)	186.9 (54.4)	-9.1 (10.8)	0.36
Range	69.0–352.0	80.4–326.7	-58.3–40.6	
LV Mass (g/m^2)				
Mean (SD)	101.6 (21.0)	96.9 (20.1)	-4.6 (8.6)	0.37
Range	35.0–162.1	40.8–160.1	-32.4–25.2	
LV Mass (g/m)				
Mean (SD)	116.7 (26.8)	111.4 (31.8)	-5.2 (9.9)	0.36
Range	40.4–204.1	47.0–185.6	-34.7–25.2	

Table 2: Correlation coefficients between computer screen and strip chart measurements by strata of gender, hypertension, and age.

Variable	LV Mass (g)	LV Mass/m^2	LV Mass/m
Male (n = 35)	0.97	0.97	0.97
Female (n = 47)	0.98	0.97	0.98
Normotensive (n = 41)	0.98	0.98	0.97
Hypertensive (n = 41)	0.98	0.98	0.97
Age ≤ 60 (n = 57)	0.98	0.97	0.98
Age > 60 (n = 25)	0.97	0.96	0.96

of LV mass provide unbiased estimates of LV mass measured using the strip chart recordings.

There are no competing interests. All authors have contributed to the editing of this manuscript.

Authors' contributions

Donna K. Arnett, Lead author

Thomas N. Skelton, Read echocardiograms

Philip R. Liebson, Performed quality control

Emelia Benjamin, Performed quality control

Richard G. Hutchinson, Recruited participants

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