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Journal Title: Clinical Cardiology
Volume: Volume 31, Number 7
Publisher: Wiley Open Access: Various Creative Commons Licenses | 2008-07-01, Pages 323-327
Type of Work: Article | Final Publisher PDF
Publisher DOI: 10.1002/clc.20223
Permanent URL: https://pid.emory.edu/ark:/25593/v10s3

Final published version: http://dx.doi.org/10.1002/clc.20223

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ABSTRACT

Background: Elevated left ventricular mass (LVM) has been shown to be an important predictor of adverse cardiac events. Calculation of LVM using contrast ventriculography, as described by Rackley, involves measuring left ventricular wall thickness in a single plane, with assumptions made about ventricular geometry.

Hypothesis: We hypothesized that a modification of the Rackley method, involving multiple measurements of left ventricular (LV) wall thickness in 2 orthogonal planes, may add value in the determination of LVM in patients with LV remodeling and dysfunction.

Methods: The LVM was determined in 24 patients with LV dysfunction who had undergone both cardiac magnetic resonance imaging (CMRI) and contrast left ventriculography. Right anterior oblique (RAO) and left anterior oblique (LAO) still frames in diastole were used to measure LV length, chamber area, and wall thickness. From these variables, LV volume, myocardial volume, and LVM were calculated. The LVM calculations using an average wall thickness from the LAO and RAO projections were compared with LVM measured by CMRI.

Results: Eighty eight percent of patients had hypertension, 100% had coronary artery disease, and mean left ventricular ejection fraction by contrast left ventriculography was $41\pm14\%$. Averaging left ventricular wall thickness from RAO and LAO projections using biplane ventriculography for LVM calculation yielded a strong correlation ($r = 0.77$, $p<0.01$) with LVM calculated from CMR.

Conclusions: In patients with left ventricular dysfunction, biplane left ventricular wall thickness measurements for contrast ventriculography LVM calculations render a strong correlation with LVM calculated by CMRI.

Key words: hypertrophy, cardiac catheterization, diagnostic intervention, heart failure, cardiac transplantation, cardiomyopathy, myocarditis

Introduction

Elevated left ventricular mass (LVM) is an important predictor of adverse cardiac events in patients with normal ventricular function, as well as for those with myocardial infarction,[1,2] even after adjustment for other known cardiac risk factors such as hypertension, tobacco use, diabetes, and elevated serum cholesterol.[3] Therefore, a simple tool for measurement of LVM in patients undergoing cardiac catheterization may add important prognostic data to that derived from left ventriculography and coronary angiography. In this era of cost containment in healthcare, this information could limit the need for added tests, such as echocardiography or cardiac magnetic resonance imaging (CMRI).

The LVM was first determined in humans by Rackley in 1964, using contrast left ventriculography and was validated against autopsy data.[4,5] More recent methods of LVM determination, such as echocardiography and CMRI, have been validated against contrast left ventriculography, and have now become standard means for making such calculations.[6,7]

The Rackley method for determination of LVM by contrast ventriculography has been criticized for making measurements of left ventricular (LV) wall thickness in a single plane. This may be especially limiting in patients with dysfunctional and remodeled ventricles, in whom the assumptions regarding ventricular geometry may lead to inaccuracies. We hypothesized that a modified version of the Rackley method, involving multiple measurements of the LV wall thickness in 2 orthogonal planes, may add value in the determination of LVM in patients with LV remodeling and dysfunction. Accordingly, we compared measurement of LVM by biplane ventriculography with LVM measurement by CMRI in patients with normal and depressed LV function. Cardiac magnetic resonance imaging was used as the gold standard, as it has been extensively validated against autopsy in the 3-Dimensional (3-D) measurement of LVM.[8,9]

Received: June 12, 2007
Accepted with revision: June 16, 2007

Published online in Wiley InterScience. (www.interscience.wiley.com)
DOI:10.1002/clc.20223

Methods

Patient Population

The patient population consisted of 24 patients who had undergone biplane contrast left ventriculography and CMRI between February 2000 and July 2001 at the University of Virginia in Charlottesville, Virginia, USA. Informed, written consent was obtained from all subjects.

Ventriculography

Biplane left ventriculography was performed in all patients by using power injection, and LVM was calculated from contrast left ventriculography using a biplane modification of the Rackley method.[4] In diastole, 30° right anterior oblique (RAO) and 30° left anterior oblique (LAO) still frames were used to measure LV length and chamber area, from which the transverse diameter of the ellipse approximating the LV chamber was calculated. Planimetry measurements were made using DICOMview software (Agfa Healthcare, Ridgefield Park, NJ, USA) and calibrated to the known diameter of the catheter tip used for administration of contrast into the left ventricle. The LV wall thickness was measured approximately two-thirds of the distance from the aortic root to the apex in the RAO projection, and at the mid-portion of the posterior wall in the LAO projection. Four measurements were made in each projection and were averaged to calculate a mean LV wall thickness. The LVM was calculated using the equation described by Rackley[4] and is outlined in Figure 1. The LVM was calculated using the average LV wall thickness from the LAO and RAO projections. The use of calibration software precluded the need for further correction of these measurements to account for differences in the acquisition of images (i.e., in the distance between the chest wall and the camera during ventriculography).

Magnetic Resonance Imaging

Breath-hold, short-axis gradient echo, and cinema (cine) MRI was performed on a Siemens Vision 1.5T scanner (Siemens, Deerfield Park, Ill., USA). Imaging parameters included repetition time (100 msec with view sharing and 50 msec temporal resolution), echo time (4.8 msec), flip angle (20°), slice thickness (7 mm), field of view (FOV) (30 cm), matrix (126×256, 15 heartbeats), and was performed in short-axis slices from apex to base.

The LVM was calculated by planimetry of epicardial and endocardial areas from stacked end-diastolic, short-axis, breath-hold, cine MRI slices from apex to base using Argus software (Siemens Medical Solutions, Princeton, NJ, USA) and a modified Simpson's rule using a factor of 1.05 to account for density of the myocardium.

Statistical Analysis

Comparisons between the LVM calculations made by left ventriculography and CMRI were made using Pearson's r for continuous correlations. Agreement between the 2 methods was further tested using a Bland-Altman analysis. A p-value of <0.05 was considered to be significant.

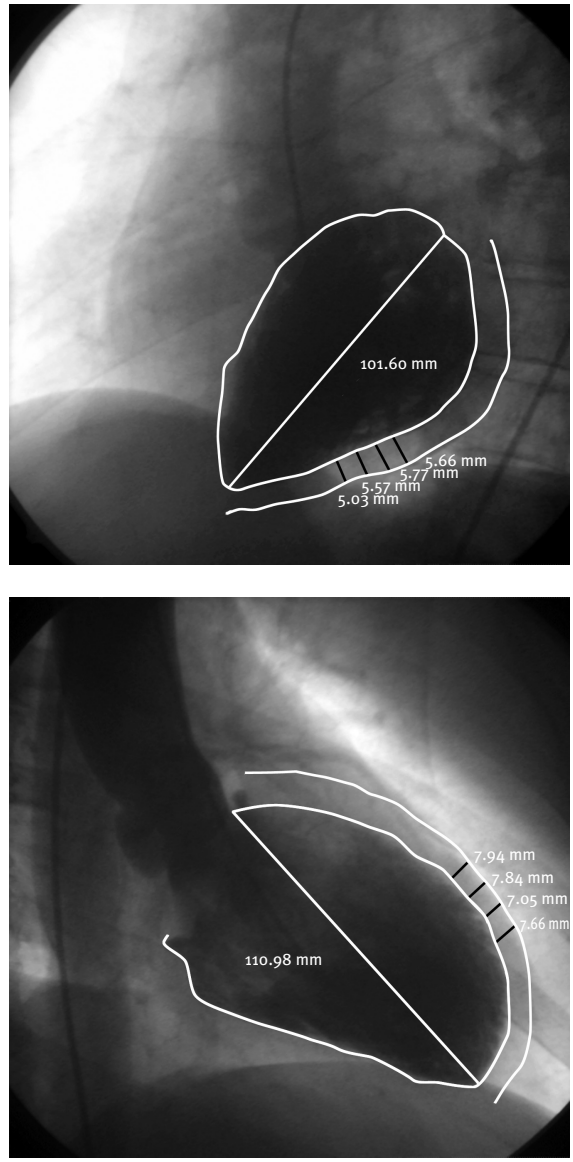

Figure 1: The Rackley equation for determination of LVM and representative still frames from contrast left ventriculography. LVM = left ventricular mass; d_{LAO} = transverse diameter of ellipse approximating the LV in the LAO view; d_{RAO} = transverse diameter of ellipse approximating the LV in the RAO view; h = LV wall thickness; A = chamber area; ℓ = maximum chamber length: $LVM = 1.050(4/3\pi\,[d_{RAO}/2 + h]\,[d_{RAO}/2 + h]\,[1/2 + h] - 0.928\pi[1/6]\,[d_{LAO}]\,[d_{RAO}] + 3.8)$ where $d_{LAO} = 4A/\pi\ell$; $d_{RAO} = 4A/\pi\ell$.

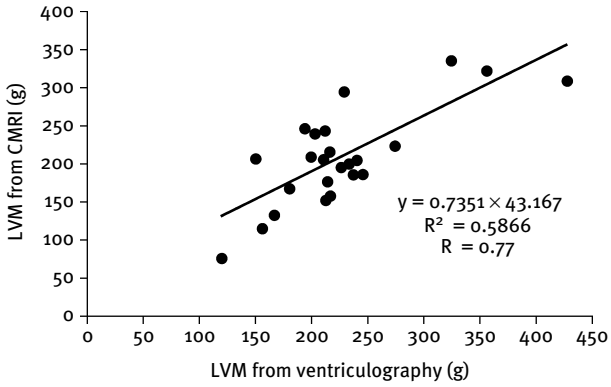

Figure 2: Comparison of LVM calculated from biplane ventriculography and CMRI.

Results

Clinical Data

The study group consisted of 24 patients (18 men and 6 women, mean age was 59±11 y), and clinical data was available for all 24 patients. Hypertension and diabetes were present in 21/24 patients (88%) and 12/24 (50%) patients, respectively (Table 1). Coronary angiography coronary artery disease (>50% stenosis in at least one epicardial vessel) was present in all 24 patients (100%), and contrast left ventriculography revealed a mean LV ejection fraction of 41±14%.

The mean baseline LV end-diastolic volume measured by CMRI was 124±56 mL, and the mean end-systolic volume was 72±52 mL. The mean stroke volume was 53±20 mL, corresponding to a mean LV ejection fraction of 45±16%, similar to that determined by contrast left ventriculography.

LVM Data

The LVM calculations for each patient are displayed in Table 2. Mean LVM was not significantly different between the 2 different techniques: 226±66 grams by contrast left ventriculography, and 209±63 grams by CMRI (p = NS). A significant correlation was observed between LVM calculated by CMRI and LVM measured by biplane left ventriculography (r = 0.77, p<0.01) (Figure 2). The results of a Bland-Altman analysis are shown in Figure 3. Left ventriculography slightly overestimated LVM, with a bias of

TABLE 1: Clinical and angiographic characteristics in relation to LVEF and CAD

Mean (y)	59±11
LVEF (%)	41±14
Any angiographic CAD (%)	100
Multivessel CAD (%)	71
Hypertension (%)	88
Hyperlipidemia (%)	83
Diabetes mellitus (%)	50

Abbreviations: CAD = coronary artery disease; LVEF = left ventricular ejection fraction.

TABLE 2: The LVM determined by ventriculography, using LV wall thickness averaged from the LAO and RAO views, and correlation with CMRI

Patient #	Ventriculography	CMRI
1	237.40	205.20
2	166.50	134.00
3	243.50	187.10
4	232.90	201.10
5	213.10	179.40
6	211.40	152.60
7	215.50	156.40
8	179.90	168.60
9	119.30	75.60
10	155.90	116.50
11	209.80	207.80
12	236.00	188.00
13	228.30	295.80
14	210.80	245.90
15	427.10	309.60
16	324.00	336.50
17	274.20	225.40
18	193.60	246.30
19	355.20	324.20
20	228.60	195.60
21	202.60	240.70
22	199.30	209.90
23	150.20	208.50
24	214.40	216.70
Correlation with CMRI	000.77	N/A

Abbreviations: CMRI = cardiac magnetic resonance imaging; LAO = left anterior oblique; LV = left ventricular; LVM = left ventricular mass; RAO = right anterior oblique.

Published online in Wiley InterScience. (www.interscience.wiley.com)
DOI:10.1002/clc.20223

16.8 g; however, this bias was not significant (95% confidence interval −2.0 to 35.5).

Discussion

This study demonstrates that LVM determined using biplane contrast left ventriculography correlates well with that calculated by CMRI in patients with LV dysfunction.

Importance of LVM as a Prognostic Tool

The prevalence of elevated LVM has been documented in the Framingham Study (16% in men and 19% in women).[10] A 4-y follow-up analysis showed that patients with elevated LVM had higher all-cause mortality, and a higher risk of death from cardiovascular disease. This relation persisted even after adjustment for traditional cardiac risk factors, including hypertension, tobacco use, diabetes, and elevated serum cholesterol.[3] Further work has shown that elevated LVM is an independent variable predicting adverse cardiac events following uncomplicated myocardial infarction.[2] Therefore, a clinically applicable tool for measurement of LVM in patients undergoing cardiac catheterization may add prognostic value to the existing data derived from angiography and ventriculography. In many patients, other tests are ordered with the primary goal of evaluating LV morphology and function. It is reasonable to apply contrast ventriculography to assess LVM in patients undergoing cardiac catheterization; thus, obviating the need for other costly procedures.

Biplane Versus Single Plane Measurement of LVM by Contrast Ventriculography

As first discussed by Rackley, et al.,[4] the calculation of LVM from contrast left ventriculography involves the determination of the ellipsoids approximating both the entire left ventricle and the LV chamber. The difference in volume between these ellipsoids estimates the volume of myocardium comprising the left ventricle. Because the specific gravity of myocardium is a known value, the

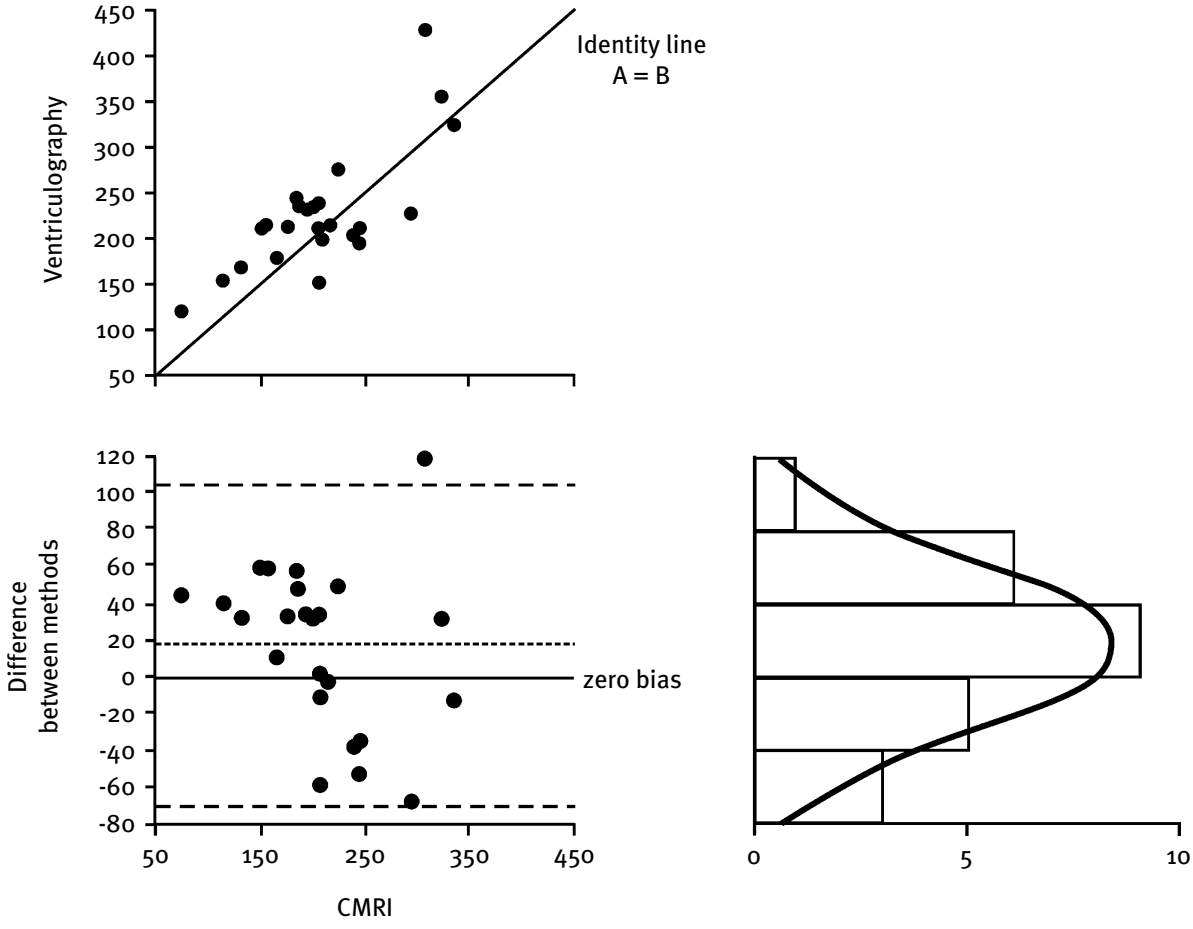

Figure 3: Bland-Altman analysis comparing LV mass calculated using biplane ventriculography with CMRI.

calculation of myocardial mass from myocardial volume is easily performed. The original calculations performed by Rackley were validated against LVM data from autopsied hearts,[5] and was an important contribution. However, myocardial volume determinations were based on an average LV wall thickness measured two-thirds of the distance from the aortic root to the apex in the LAO projection, which does not account for regional variance in the LV wall thickness, particularly in eccentric ventricular hypertrophy or remodeling. In addition, as the ventricular free wall may be less easily seen in ventriculography than in other imaging modalities, the paucity of measurements performed in a single plane may magnify errors in the measurement of ventricular thickness and chamber area. We found a strong correlation between LVM determined by contrast left ventriculography and that calculated by CMRI by using biplane techniques to measure LV wall thickness in 2 planes. We believe that the 4 measurements performed in 2 planes mitigate some of the inherent limitations of single plane contrast ventriculography. This may be especially important in the growing number of patients with LV dysfunction, where assumptions of ventricular geometry are even less precise. The acquisition of LVM data in patients undergoing left heart catheterization may provide important prognostic information without subjecting patients to additional testing, and thereby, minimizing healthcare costs. Furthermore, the addition of LVM data to large catheterization databases may be of substantial benefit in promoting prognostic research studies.

Limitations

Measurement of LVM by contrast ventriculography can be undertaken when the procedure is performed using a power injector in catheterization laboratories equipped with biplane facilities. It is unlikely that LVM can be accurately measured when the left ventricle is suboptimally opacified.

Conclusion

In patients with normal or depressed LV function, contrast ventriculography LVM calculations render a strong correlation with LVM calculated by CMRI. These data suggest that LVM can be accurately measured in patients undergoing left heart catheterization, thus providing additional prognostic information without subjecting patients to additional testing.

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DOI:10.1002/clc.20223