Left Ventricular Hypertrophy: Relationship of Anatomic, Echocardiographic and Electrocardiographic Findings

NATHANIEL REICHEK, M.D., AND RICHARD B. DEVEREUX, M.D.

SUMMARY Anatomic, echocardiographic and ECG findings of left ventricular hypertrophy (LVH) were compared in 34 subjects. Echocardiographic LV mass correlated well with postmortem LV weight ($r = 0.96$) and accurately diagnosed LVH (sensitivity 93%, specificity 95%). In contrast, Romhilt-Estes (RE) point score and Sokolow-Lyon (SL) voltage criteria for ECG LVH were insensitive (50% and 21%, respectively) but specific (both 95%). RE correlated weakly with LV weight ($r = 0.64$), but SL did not. Echocardiographic LV mass was then compared with RE and SL in an unselected clinical series of 100 subjects, in 28 subjects with severe aortic stenosis (AS) and in 14 with severe aortic regurgitation (AR). Results in the clinical series were comparable to those in the necropsy series. In the AS and AR groups, with a high prevalence of LVH, the low sensitivity of RE point score and SL criteria led to poor overall results. Analysis of individual ECG variables showed that most voltage information is contained in leads aV$_1$ and V$_r$. Correction of voltage for distance from the left ventricle did not substantially improve results. Individual nonvoltage criteria were each nearly as sensitive as RE point score. We could not devise new ECG criteria that improved diagnostic results. We conclude that the ECG is specific but insensitive in recognition of LVH. Moreover, when true LVH prevalence is less than 10%, more false-positive than true-positive diagnoses will be obtained. M-mode echocardiographic LV mass is superior to ECG criteria for clinical diagnosis of LVH.

RECOGNITION of left ventricular hypertrophy (LVH) is essential in assessment of the cardiac patient. Methods of diagnosis include physical examination, electrocardiography and chest roentgenography, but all have limitations. Biplane left ventriculography provides quantitative assessment of LV muscle mass, but complexity, cost and risk limit its use. M-mode echocardiography reveals septal and posterior wall thickness and a left ventricular minor diameter. Good correlations between M-mode echocardiographic and angiographic LV mass have been reported. We have described a modification of the "cube-function" method, which permits prediction of postmortem weight with an accuracy comparable to that of biplane angiography. This method has research value, but its clinical impact is uncertain. Therefore, we examined the relationships of anatomic, echocardiographic and ECG indexes of LVH and their clinical implications.

Methods

Study Populations

Four populations were examined. In group 1 (34 subjects), echocardiograms and ECGs obtained shortly before death were compared with postmortem anatomic LV weight. Group 2 was an unselected clinical series of 100 consecutive subjects in whom echocardiograms and ECGs were obtained. Both groups were similar in age, sex distribution and diagnosis (table 1). Subjects with genetic asymmetric septal hypertrophy, known prior myocardial infarction or left bundle branch block were excluded from the clinical series because these disorders impair ECG recognition of LVH. However, most subjects with coronary disease in the necropsy series had pathologically demonstrated areas of infarction and one had left bundle branch block. Group 3 consisted of 28 consecutive subjects with significant aortic stenosis (AS), defined as a peak systolic aortic valve gradient of 50 mm Hg or more or an aortic valve area index of 0.5 cm$^2$ or less. Group 4 consisted of 14 consecutive subjects with severe aortic regurgitation (AR), defined as 3-4+ angiographic regurgitation.

Electrocardiography

Standard 12-lead ECGs obtained within 2 weeks of echocardiography were interpreted blindly by both investigators. No differences in interpretation were encountered. ECG variables recorded included R-wave voltage in leads I, II, III, aV$_R$, aV$_L$ and V$_3$ to V$_6$; S-wave voltage in V$_1$ to V$_3$; QRS frontal plane axis and duration, intrinsiocid deflection; left atrial abnormality; STT pattern of "strain"; Sokolow-Lyon voltage criteria (SL, S-wave voltage in V$_1$ plus R wave in lead V$_3$ or V$_6$ $\geq 35$ mm); and Romhilt-Estes (RE) point score for LVH. RE point scores were corrected for digitals administration.

Echocardiography

M-mode LV echocardiograms were recorded with a Smith Kline 20A echograph, a Honeywell 1856
TABLE 1. *Population of Groups 1 and 2 (n = 134)*

<table>
<thead>
<tr>
<th>Ages 17–84 years; 40% male</th>
<th>34% normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25% valvular heart disease</td>
</tr>
<tr>
<td></td>
<td>22% hypertensive heart disease</td>
</tr>
<tr>
<td></td>
<td>8% coronary disease</td>
</tr>
<tr>
<td></td>
<td>7% congestive cardiomyopathy</td>
</tr>
<tr>
<td></td>
<td>4% miscellaneous</td>
</tr>
</tbody>
</table>

recorder and a 2.25-MHz transducer at a paper speed of 50 mm/sec. Long and transverse sweeps of the left ventricle were recorded whenever possible. Echocardiograms were blindly interpreted by one investigator and cross-read by the second. The few minor differences of interpretation were resolved by discussion. LV echograms were measured at or just below the tips of the mitral leaflets in areas of the recording that showed the largest left ventricular internal dimension (LVID). End-diastolic LVID, posterior wall thickness (PWT) and interventricular septal thickness (ST) were identified by hand using the “Penn measurement convention” (fig. 1), taking the peak of the R wave as end-diastole. Conventional measurements were also made for comparison. Recordings were calibrated, measured and computations made on a Hewlett-Packard programmable calculator and digitizer. Echocardiographic LV mass (echo LVM) was determined with a regression-corrected “cube formula” \( \text{echo LVM} = 1.04 \left( \text{LVID} + \text{PWT} + \text{ST} \right) - 14 \) g using mean data from four cardiac cycles per recording.

LV Weight

In the necropsy series (group 1), LV weight was determined by the chamber dissection method of Bove et al., including the interventricular septum in LV weight. Formalin-fixed hearts had 3% subtracted from measured LV weight.

Definition of LVH

No available definition of LVH is entirely satisfactory, as autopsy and angiographic data suffer from distortions due to population selection. Bove et al. proposed 200 g as the upper limit of normal LV weight. However, the largest normal left ventricle in this study weighed 215 g, so we defined LVH as LV weight more than 215 g, which exceeds the largest reported normal value in six earlier studies.

Statistical Methods

Sensitivity, specificity and accuracy were defined as follows:

\[
\text{Sensitivity (\%)} = \frac{\text{true positives correctly diagnosed}}{\text{total true positives}} \times 100.
\]

\[
\text{Specificity (\%)} = \frac{\text{true negatives correctly diagnosed}}{\text{total true negatives}} \times 100.
\]

\[
\text{Accuracy (\%)} = \frac{\text{positives + negatives correctly diagnosed}}{\text{total tested}} \times 100.
\]

Comparisons of quantitative variables were performed using standard least-squares linear regression analysis.

Results

Pathologic and Echocardiographic Findings in the Necropsy Series

LV weight exceeded 215 g in 14 of 34 subjects (41%) (table 2, fig. 2). Echo LV mass correctly categorized 13 of 14 subjects with LVH and 19 of 20 normal subjects (sensitivity 93%, specificity 95%, accuracy 94%). Two misdiagnoses were in error by 4 g and 14 g, respectively. Echo LV mass and anatomic LV weight correlated extremely well, as previously reported \( (r = 0.96) \), even when myocardial infarction or LV dilation was present. Because of the excellent quantitative and qualitative accuracy of echo LV mass in
the necropsy series, it was used as a reference standard for ECG in groups 2–4 (table 2).

Sokolow-Lyon Voltage Criteria for LVH

In the necropsy series, SL voltage criteria correlated poorly with LV weight (fig. 3, \( r = 0.30 \), \( P = \text{NS} \)). Correct SL diagnoses of LVH were made in only three of 14 subjects with LVH (table 3). There was also one false-positive diagnosis among 20 normal subjects (sensitivity 21%, specificity 95%, accuracy 65%).

In the clinical series (group 2), echo LV mass showed true LVH in 30 of 100 subjects, and SL voltage criteria performed slightly better (sensitivity 53% [16 of 30], specificity 86% [60 of 70], accuracy 76%).

In AS (group 3), SL criteria correctly diagnosed nine of 21 subjects with LVH and six of seven normal subjects (sensitivity 43%, specificity 86%) (fig. 4); these results were similar to those in group 2, but because of the high prevalence of LVH, accuracy was only 54%.

In AR (group 4), nine of 13 subjects with LVH were correctly identified, but the one true negative was falsely positive (sensitivity 69%, accuracy 64%) (fig. 4).

In group 2, the correlation of SL voltage and echo

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**TABLE 2. Left Ventricular Mass in Groups 1-4**

<table>
<thead>
<tr>
<th>Group</th>
<th>Type</th>
<th>n</th>
<th>Range of LV mass (g)</th>
<th>% LVH</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Necropsy</td>
<td>34</td>
<td>105-505</td>
<td>41%</td>
<td>Anatomic</td>
</tr>
<tr>
<td>2</td>
<td>Clinical series</td>
<td>100</td>
<td>50-602</td>
<td>30%</td>
<td>Echo</td>
</tr>
<tr>
<td>3</td>
<td>Aortic stenosis</td>
<td>28</td>
<td>88-567</td>
<td>75%</td>
<td>Echo</td>
</tr>
<tr>
<td>4</td>
<td>Aortic regurgitation</td>
<td>14</td>
<td>175-725</td>
<td>93%</td>
<td>Echo</td>
</tr>
</tbody>
</table>

Abbreviations: LV = left ventricular; LVH = left ventricular hypertrophy.

---

**FIGURE 2.** Regression-corrected echocardiographic left ventricular mass (LVM) correlated well with anatomic LV weight in group 1 (necropsy series). Qualitatively, diagnoses of left ventricular hypertrophy and normality by echocardiography are highly accurate. Two hearts were misclassified, but the error was less than 15 g in each instance.

**FIGURE 3.** Sokolow-Lyon (SL) voltage criteria (left ventricular hypertrophy, \( \geq 35 \text{ mm} \)) correlated poorly with anatomic left ventricular (LV) weight in group 1. Qualitative diagnosis of left ventricular hypertrophy was insensitive but specific, and overall accuracy was poor.
LV mass was weak but statistically significant ($r = 0.45$, $p < 0.01$). In contrast, in the AS and AR groups, which had a high prevalence of true LVH, there was no correlation with LV mass (fig. 4).

Romhilt-Estes Point Score Criteria for LVH

In the necropsy series, the RE point score showed a weak but significant correlation with LV weight ($r = 0.66$), with a wide scatter (fig. 5). RE point score correctly identified 19 of 20 true normal subjects (95% specificity), but only seven of 14 true LVH subjects were correctly diagnosed (sensitivity 50%). Overall accuracy was 74%. Comparison with echo LV mass in the clinical series (group 2) showed a sensitivity of 50% (15 of 30), specificity of 97% (68 of 70) and accuracy of 83% (table 4, fig. 6).

In AS, the RE point score correctly diagnosed only six of 21 true positives (sensitivity 29%) and three of seven true negatives were falsely diagnosed as positive (specificity 57%) (table 4, fig. 7). Overall accuracy was only 32%. In AR, sensitivity increased to 69% (nine of 13) but the one true negative was misclassified, so overall accuracy was 65%.

The unselected clinical series showed a correlation between echo LV mass and RE point score similar to that with anatomic LV weight in group 1 ($r = 0.64$, fig. 6). A significant correlation was also found in AR (fig. 7). In AS however, no correlation was observed.

Relationship of ECG Voltage to LV Mass

To clarify the role of ECG voltage in recognition of LVH, we examined qualitative and quantitative aspects of voltage–LV mass relationships in group 2. Selected results are shown in tables 5 and 6. Other potential voltage criteria examined gave less satisfactory results.

Relationship of Nonvoltage Criteria to LV Mass

To clarify the role of nonvoltage criteria in ECG LVH, we examined the qualitative and quantitative accuracy of individual criteria. These results are shown in tables 7 and 8.

**TABLE 3. Sokolow-Lyon Voltage Criteria for Left Ventricular Hypertrophy**

<table>
<thead>
<tr>
<th>Group</th>
<th>Type</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Necropsy</td>
<td>21% (21/14)</td>
<td>95% (57/60)</td>
<td>67% (22/34)</td>
</tr>
<tr>
<td>2</td>
<td>Clinical</td>
<td>53% (48/90)</td>
<td>86% (60/70)</td>
<td>76% (76/100)</td>
</tr>
<tr>
<td>3</td>
<td>Aortic stenosis</td>
<td>43% (8/21)</td>
<td>86% (6/7)</td>
<td>54% (15/28)</td>
</tr>
<tr>
<td>4</td>
<td>Aortic regurgitation</td>
<td>89% (3/28)</td>
<td>0 (0/1)</td>
<td>64% (9/14)</td>
</tr>
</tbody>
</table>

**FIGURE 4.** (left) Sokolow-Lyon (SL) voltage criteria compared with echocardiographic left ventricular (LV) mass in group 3 subjects with aortic stenosis (AS). Quantitative correlation was not significant. Sensitivity of SL diagnosis of left ventricular hypertrophy was low, but specificity was relatively high, as in groups 1 and 2. (right) SL voltage criteria compared with echocardiographic LV mass in group 4 subjects with aortic regurgitation (AR). Sensitivity was moderately high, as was overall accuracy, but no significant quantitative relationship was shown.
Effect of Other Variables on ECG Accuracy

The relationship between voltage criteria and echo LV mass was similar in men and women. Pericardial effusions, which were generally small, in 25 of 100 subjects in group 2 did not influence ECG sensitivity. It has been suggested that ECG voltage may correlate more closely with LV wall thickness than with LV mass, but in group 2, voltage correlated more closely with LV mass than with either conventional or Penn measurement of posterior wall or septal thickness. For example, for S-wave voltage in lead V1, \( r = 0.35 \) vs standard posterior wall thickness but \( 0.60 \) vs LV mass.

Discussion

Our necropsy data confirm that the RE point score is specific but insensitive. In contrast, necropsy data on SL voltage do not support the widespread impression that SL is more sensitive but less specific than RE. Rather, SL was less sensitive than RE, with comparable specificity. Prior quantitative data with necropsy correlation are not available for either RE or SL criteria. This study indicates that neither set of criteria correlates closely with LV weight.

The excellent sensitivity, specificity and accuracy obtained using echocardiographic criteria for LVH, and the excellent quantitative correlation between LV weight and echo LV mass, clearly show that this method is highly reliable and is far better than existing ECG methods in a population with a wide range of LV size and morphology, and lacking only subjects with genetic asymmetric septal hypertrophy, LV aneurysm or massive myocardial infarction. Nixon et al. have also confirmed the reliability of the method angiographically.

![Figure 5](https://example.com/fig5.png)

**Figure 5.** Romhilt-Estes (RE) point score (left ventricular hypertrophy, \( \geq 5 \) points) compared with anatomic left ventricular (LV) weight in group 1 (necropsy series). A weak but significant qualitative correlation was observed. Qualitatively, recognition of anatomic left ventricular hypertrophy was insensitive but quite specific.

![Figure 6](https://example.com/fig6.png)

**Figure 6.** Romhilt-Estes (RE) point score compared with echocardiographic left ventricular (LV) mass in group 2 (clinical series). Low sensitivity, high specificity and weak but significant quantitative correlation are evident. These results are similar to those in group 1 using anatomic LV weight rather than echocardiographic LV mass.
Hypertrophy
triclar
t voltage
SL
T
sBLI.
aVL
R
voltage
RE
Sokolow-Lyon
Sv1/(distance to mid-LV) vs LVM
0.71*
*S p < 0.01.
Abbreviation: LVM = left ventricular mass.

Figure 7. (left) Romhilt-Estes (RE) point score compared with echocardiographic left ventricular (LV) mass in group 3 subjects with aortic stenosis (AS). No significant quantitative relationship was present. Qualitative sensitivity of diagnosis of left ventricular hypertrophy was low and specificity was poor. (right) RE point score vs echocardiographic mass in group 4 subjects with aortic regurgitation (AR). A good quantitative relationship was present, but sensitivity was low and overall accuracy poor.

Table 4. Romhilt-Estes Point Score for Left Ventricular Hypertrophy

<table>
<thead>
<tr>
<th>Group</th>
<th>Type</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Necropsy</td>
<td>50% (7/14)</td>
<td>95% (19/20)</td>
<td>74% (26/34)</td>
</tr>
<tr>
<td>2</td>
<td>Clinical</td>
<td>50% (15/30)</td>
<td>97% (68/70)</td>
<td>83% (83/100)</td>
</tr>
<tr>
<td>3</td>
<td>Aortic stenosis</td>
<td>29% (6/21)</td>
<td>57% (4/7)</td>
<td>32% (9/28)</td>
</tr>
<tr>
<td>4</td>
<td>Aortic regurgitation</td>
<td>69% (9/13)</td>
<td>0 (0/1)</td>
<td>64% (9/14)</td>
</tr>
</tbody>
</table>

Table 5. Electrocardiographic Voltage Criteria for Left Ventricular Hypertrophy (Group 2)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE voltage</td>
<td>20% (6/30)</td>
<td>93% (65/70)</td>
<td>71%</td>
</tr>
<tr>
<td>SL voltage</td>
<td>53% (16/30)</td>
<td>86% (60/70)</td>
<td>76%</td>
</tr>
<tr>
<td>R aVL ≥ 11 mm</td>
<td>47% (14/30)</td>
<td>99% (69/70)</td>
<td>83%</td>
</tr>
</tbody>
</table>

Abbreviations: RE = Romhilt-Estes; SL = Sokolow-Lyon.

Table 6. Quantitative Relationship of Electrocardiographic Voltage to Left Ventricular Mass (Group 2)

<table>
<thead>
<tr>
<th></th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 vs LVM</td>
<td>0.60*</td>
</tr>
<tr>
<td>R aVL vs LVM</td>
<td>0.63*</td>
</tr>
<tr>
<td>Sokolow-Lyon voltage vs LVM</td>
<td>0.45*</td>
</tr>
<tr>
<td>Rv1 vs LVM</td>
<td>0.11</td>
</tr>
<tr>
<td>Rv6 vs LVM</td>
<td>0.18</td>
</tr>
<tr>
<td>S1/(distance to mid-LV) vs LVM</td>
<td>0.71*</td>
</tr>
</tbody>
</table>

Table 7. Accuracy of Nonvoltage Criteria for Left Ventricular Hypertrophy (Group 2)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Strain&quot;</td>
<td>30% (15/30)</td>
<td>93% (65/70)</td>
<td>80%</td>
</tr>
<tr>
<td>Left atrial abnormality</td>
<td>47% (14/30)</td>
<td>91% (64/70)</td>
<td>78%</td>
</tr>
<tr>
<td>QRS &gt; 90 msec</td>
<td>57% (17/30)</td>
<td>94% (66/70)</td>
<td>83%</td>
</tr>
<tr>
<td>Left axis (≥ -30)</td>
<td>33% (10/30)</td>
<td>97% (68/70)</td>
<td>78%</td>
</tr>
<tr>
<td>Intrinsicsoid ≥ 50 msec</td>
<td>30% (9/30)</td>
<td>100% (70/70)</td>
<td>79%</td>
</tr>
</tbody>
</table>

Table 8. Quantitative Relationship of Nonvoltage Criteria to Left Ventricular Mass

<table>
<thead>
<tr>
<th></th>
<th>r*</th>
</tr>
</thead>
<tbody>
<tr>
<td>QRS duration</td>
<td>0.51</td>
</tr>
<tr>
<td>Ventricular activation time</td>
<td>0.49</td>
</tr>
<tr>
<td>QRS axis</td>
<td>-0.56</td>
</tr>
<tr>
<td>Point Score</td>
<td>0.64</td>
</tr>
</tbody>
</table>

*All p < 0.01.
In contrast, early attempts to estimate LV wall thickness and mass by cross-sectional echocardiography in man have been disappointing, despite excellent results in animal models.16 Our initial in vitro data suggest that quantitative cross-sectional echocardiography may ultimately provide more accurate results than M-mode.27

The differing populations we studied permit assessment of the limitations of RE and SL criteria in a variety of settings. In a clinical population with moderate LVH prevalence (e.g., group 2), the principal problem was false negatives, but the accuracy of both methods was above 75%. In contrast, in populations with a high prevalence of LVH (e.g., groups 3 and 4), the high false-negative rate renders both sets of ECG criteria essentially worthless. The poor quantitative results obtained in AS and AR with SL and in AS with RE suggest that ECG LVH is not likely to have inherent prognostic value in these settings. The relatively good quantitative results obtained with RE criteria in AR are noteworthy, and may explain the apparent prognostic value of RE point score in this setting.18 Our data also predict that when LVH prevalence is below 10%, both RE and SL criteria will identify more false positives than true positives. Thus, it may be unwise to use ECG LVH for screening or epidemiologic purposes.

Analysis of the relationship of voltage criteria to LV weight and echo LV mass yielded several surprises. R waves in V5 and V6 leads contain little useful information about LVH. Instead, most voltage information is found in leads aVL and V1. We evaluated several new voltage formulas for LVH, but none was superior to the RE point score. Correction of voltage for the effect of distance attenuation19 failed to enhance results appreciably. This may be due to a decrease in ratio of voltage to LV mass with progressive LV dilatation.20

Nonvoltage markers of LVH gave diagnostic accuracy comparable to RE point score or SL voltage in group 2, including STT strain, left atrial abnormality, QRS prolongation, left-axis deviation and intrinsoid delay. Thus, the clinician, in the absence of other known causes, could take any one of these criteria as a sign of LVH.

Our findings clarify and extend several recent reports with respect to echocardiographic and ECG recognition of LVH,21-25 using larger numbers of patients, a variety of study populations, and an absolute anatomic reference standard. The poor relative sensitivity of ECG criteria and the limited correlation between SL voltage and LV mass are confirmed.5, 21-25 We have also shown that the RE point score does not consistently improve ECG results, and that a simple M-mode echocardiographic method substantially improved the clinical recognition of LVH in all populations studied. We conclude that available ECG criteria for LVH are of limited value. When accurate noninvasive recognition of LVH is required, M-mode echocardiographic determination of LV mass is the method of choice.

Acknowledgment

We are indebted to Janice Green and Patricia Klunder for invaluable assistance in completing these studies; to the Pathology Department, Hospital of the University of Pennsylvania for cooperation; to Patricia Klunder for preparation of this manuscript; and to Dr. John A. Kastor for encouragement, support and thoughtful review of the manuscript.

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Quantitation of Human Left Ventricular Mass and Volume by Two-dimensional Echocardiography: 
In Vitro Anatomic Validation

JOSEPH W. HELAK, M.D., AND NATHANIEL REICHEK, M.D.

SUMMARY The reliability of two-dimensional echocardiographic (2-DE) quantitation of left ventricular (LV) section area, volume and myocardial mass was assessed in vitro in 13 postmortem human hearts (LV weight 115–454 g). The pathologic diagnoses included: two normal, five coronary artery disease with infarction and/or aneurysm, three valvular heart disease, two cardiomyopathy and one left ventricular hypertrophy. Hearts were divided into six to 24 short-axis slices (n = 123), imaged in a tank filled with mineral oil and the images planimetered. Calibrated photographs and actual LV weight served as reference standards. Estimates of section LV cavity volume and myocardial volume were derived by multiplying the appropriate area by section thickness. Section LV mass was obtained by multiplying the myocardial volume by myocardial density. Total LV cavity volume and myocardial mass were derived using Simpson’s rule and a short axis area-apical length method. In absolute terms, 2-DE underestimated LV cavity area but accurately estimated LV myocardial area. Excellent correlations were obtained between 2-DE and photographic standards for section cavity area (r = 0.95) and volume (r = 0.90). Simpson’s rule (r = 0.97) and area-length (r = 0.82, r = 0.90, excluding one heart with a bizarrely shaped LV cavity secondary to extensive mural thrombus) estimates of total LV cavity volume also correlated well with reference standards. Similarly, section LV myocardial area correlated well with photographic myocardial area (r = 0.89) and 2-DE and photographic estimates of section LV mass correlated well with actual LV weight (r = 0.92 and 0.96). Consequently, total LV mass obtained with Simpson’s rule or the area-length method was highly reliable (r = 0.93 and 0.92, respectively). We conclude that 2-DE can provide reliable estimates of LV volume and mass using the short-axis Simpson’s rule or area-length methods and appropriate regression corrections. The area-length method is simple enough to permit clinical application.

TWO-DIMENSIONAL ECHOCARDIOGRAPHY (2-DE) is a potentially valuable noninvasive tool for the quantitative assessment of left ventricular (LV) volume and myocardial mass in man. Validation studies of 2-DE in several laboratories have demonstrated the accuracy of in vitro canine LV volume and mass in symmetric and asymmetric ventricles.1–3 LV volume determination in a beating dog heart preparation,4, 5 in vivo canine LV volume and mass,6–10 and in vitro human LV cast volume.11 Moderately good correlation of human in vivo 2-DE LV volume and ejection fraction with angiographic and/or radionuclide methods has also been reported.8, 12–18 However, 2-DE assessments of LV volume and mass have not been validated directly with quantitative anatomy in man. The present study was designed to test the accuracy of 2-DE imaging of individual cardiac sections and of derived estimates of total LV volume and mass in the postmortem human heart.

Methods

Specimen Collection

Thirteen postmortem human hearts, 300–1100 g, with a wide range of pathologic diagnoses (table 1) were obtained from the necropsy service. Nine were...
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N Reichek and R B Devereux

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