Function of Left Ventricle and Extent of Coronary Arterial Lesions: Failure of Correlation in Cineangiographic Studies*

Herman L. Falsetti, M.D.; Anthony R. Geraci, M.D.; Ivan L. Bunnell, M.D.; David G. Greene, M.D., F.C.C.P.; and Colin Grant, M.B.

In patients with technically adequate selective coronary arteriograms and left ventriculograms, a scoring system was used to grade the severity of coronary obstruction from 0 (no disease) to 15 (total obstruction of all three major coronary arteries). The median score in 75 consecutive cases was 10. Three hemodynamic measurements were examined in these patients; left ventricular end-diastolic pressure (EDP), end-diastolic volume (EDV) and residual fraction. Left ventricular volume estimates were derived from one-plane cineangiograms in the right anterior oblique view. These hemodynamic parameters (EDP, EDV and residual fraction) did not correlate significantly with the severity of coronary disease. However, in eight patients who had clinical evidence of congestive failure, all had abnormal values of EDP, EDV, and residual fraction. These same measurements were also abnormal in three patients without clinical evidence of failure; a fourth patient had an increase in residual fraction without other abnormality; this group of four patients have myocardial impairment without the congestive failure syndrome. All 12 patients with an increased residual fraction had akinesis or dyskinesis of the ventricular wall. As expected, EDV correlated well with residual fraction \((r = 0.72)\) and worse with EDP \((r = 0.44)\).

In the past, measurements of heart rate, rate of pressure rise, cardiac output, and left ventricular end-diastolic pressure have been used to assess myocardial contractility. These parameters have not satisfactorily separated patients with decreased left ventricular contractile state and several investigators\(^1-3\) have searched for new methods to quantitate myocardial contractility in patients with coronary disease. The purpose of this report is to correlate the severity of coronary artery disease with end-diastolic pressure, left ventricular volumes and residual fractions in 75 patients with angiographically proved coronary artery disease.

**METHODS**

Seventy-five patients with angiographically demonstrated coronary artery disease, 56 men and 19 women, age 31 to 63, form the basis of this study. The 75 consecutive cases were selected solely on the basis of coronary arteriograms and left ventricular volumes of technically satisfactory quality. Cardiac catheterization and angiography were carried out under mild sedation (sodium pentobarbital, meperidine and promethazine hydrochloride) and local anesthesia with patients in the fasting state. Left ventricular volumes were measured from cineangiograms in the right anterior oblique projection made at 60 frames per record using a Picker 9-inch intensifier as 25 to 40 ml of 78 percent meglumine diatrizoate (Renografin) were injected into the left ventricle from a catheter passed retrograde across the aortic valve. Left ventricular volumes were determined by the one plane cineangiographic method.\(^4\) In this method \(L\), the long axis, and \(M\), the short axis at right angles to the midpoint of \(L\), are both measured directly in the right anterior oblique projection. The assumption is made that the short axis that is not visible and perpendicular to both \(L\) and \(M\) is equal \(\pi\). Magnification and distortion of each axis are corrected by \(f\). The formula for volume \(V\) is then:

\[
V' = KL^2M^2, \quad \text{where } K = \frac{\pi}{6f^3}
\]

Previous studies\(^5,6\) have demonstrated that angiographic volumes calculated from an ellipsoid of revolution exceed known volumes of the left ventricular chamber determined at postmortem. We have previously published data\(^4\) demonstrating the linear relationship between postmortem volume estimates.
from one-plane cineangiogram and known volumes of barium sulfate paste. Statistical analysis of these data reveals a regression equation:

\[ V = 0.848 V' - 10.24 \text{ ml} \]  

(2)

where \( V \) is the known volume and \( V' \) is angiographic volume (Fig 1). The correlation coefficient \( (r) \) is 0.976 and the standard error of the estimate \( (S) \) is 15.7 ml. These numbers are identical to that determined in animals\(^7\) and similar to that reported by Sandler and Dodge\(^6\) when single plane A-P 30 x 30 cm film is used to determine volume or

\[ V = 0.883 (V') - 6.6 \text{ ml} r = 0.99 \]  

(3)

A recent study by Kasser and Kennedy\(^8\) has compared left ventricular volume obtained by one-plane cineangiography and biplane angiograms. They noted a high correlation \((0.988)\) between the two methods. Their regression equation for one-plane cine is:

\[ V = (0.787)V' + 7.8 \text{ ml} \]  

(4)

This equation gives results that are only slightly different from those presented in this paper. The Kasser-Kennedy equation will give slightly larger end-systolic volumes and slightly smaller end-diastolic volumes than ours. These small differences may reflect measurement technique (planimetered area and length versus a simple width and length measurement).

End-diastolic volume was taken as the average of the largest measured volumes on three successive cardiac cycles. End-systolic volume was the average of three smallest measured volumes. Patients with atrial fibrillation and/or multiple premature beats during angiograms were excluded from the study.

Left ventricular pressure was obtained by means of a well-flushed No. 7 or No. 8 side hole catheter, 100 cm in length, directly connected to a Statham P 23 Db transducer. All pressures were referred to a zero level 10 cm above the table top. Selective coronary arteriography was performed by ei-

<table>
<thead>
<tr>
<th>Patient Group</th>
<th>Residual Fraction (&gt;0.50)</th>
<th>End-diastolic Volume (&gt;175 ml)</th>
<th>End-diastolic Pressure (&gt;12 mm Hg)</th>
<th>Akinesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical evidence of CHF (8)</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8*</td>
</tr>
<tr>
<td>Elevated RF but no evidence of CHF (4)</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4**</td>
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<tr>
<td>Normal RF and no evidence of CHF (63)</td>
<td>0</td>
<td>5</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>Total (75)</td>
<td>12</td>
<td>16</td>
<td>46</td>
<td>16</td>
</tr>
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*Includes one patient with mitral regurgitation.
**One patient with dyskinesis.
ther the technique of Sones or Judkins. No vasoactive drugs were given prior to the coronary arteriograms. Each of the three main coronary vessels (right, left circumflex and left anterior descending) were graded by arteriogram on a system from one to five: (1) 0 percent to 30 percent narrowing of lumen, (2) 30 percent to 50 percent, (3) 50 percent to 75 percent, (4) 75 percent to 90 percent and (5) completely occluded. Thus, scores of 1 (0 percent to 30 percent occlusion of one coronary artery) to 15 (complete occlusions of all 3 major vessels) were theoretically possible.

RESULTS

Correlation of Hemodynamic Measurements with Clinical Evidence of Congestive Heart Failure (CHF)

Eight patients (Table 1) had clinical evidence of congestive heart failure (enlarged heart, gallop rhythm, rales and dyspnea on exertion). These patients did not necessarily have extensive three vessel disease. In fact, the majority (five of eight) had severe disease (grade 4 or 5 occlusion) of the left descending and minimal disease of the other vessels. All eight had an elevated end-diastolic pressure (EDP) and volume (EDV) as well as abnormally high residual fraction (RF). The residual fraction (end-systolic volume divided by end-diastolic volume) is considered abnormal if greater than 50 percent of blood is left in the ventricle at end-systole. In four other patients (without evidence of CHF) residual fraction was abnormal and in three of these EDP and EDV were elevated; the fourth patient had a normal EDP and EDV.

In 46 patients EDP was elevated (eight with CHF and 38 without evidence of CHF). It should be noted that left ventricular end-diastolic pressure was measured before selective coronary arteriography in 25 patients and after in 50 patients. In these 50 patients the pressure was always measured before the left ventriculogram and at least five minutes after the last selective coronary arteriogram since it has been demonstrated that ventriculography may increase EDP.

Left ventricular end-diastolic pressure was measured before and after selective coronary arteriograms in ten patients and showed no significant change. Left ventricular end-diastolic volume was elevated (greater than 175 ml) in 16 patients. Eight of

Table 2—Distribution of Hemodynamic Abnormalities before and after Selective Coronary Arteriography.

<table>
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<tr>
<th>Patient Group</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Before coronary arteriography (25)</td>
<td>6</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>After coronary arteriography (50)</td>
<td>6</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td>Total (75)</td>
<td>12</td>
<td>16</td>
<td>46</td>
</tr>
</tbody>
</table>

![Figure 2. Severity of coronary artery obstruction versus left ventricular end-diastolic pressure. The severity of coronary artery disease is coded from 1 to 15 by selective coronary arteriogram (see text for details).](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21516/ on 06/26/2017)
these patients had evidence of CHF. The other eight had an elevated EDP and three of this group had an elevated residual fraction. All eight patients with congestive failure had akinesis and one patient had mitral regurgitation in addition. There were eight other patients with evidence of disordered wall motion, including one patient with dyskinesis.

**Figure 3.** Severity of coronary artery obstruction versus left ventricular end-diastolic volume.

**Figure 4.** Severity of coronary artery obstruction versus residual fraction.

**Relationship between the Severity of Coronary Artery Disease to Left Ventricular End-diastolic Pressure, Left Ventricular End-diastolic Volume, and Residual Fraction**

Figure 2 illustrates the relationship between the severity of coronary artery obstruction (on a scale...
from 1 to 15) versus the left ventricular end-diastolic pressure (EDP). The open circles refer to the 63 patients with a normal residual fraction\textsuperscript{16} (end-systolic volume divided by end-diastolic volume less than 0.50). The closed triangles refer to 12 patients with an abnormally high residual fraction.
Figure 7. Residual fraction versus end-diastolic volume.

Relationship of Left Ventricular End-diastolic Pressure to End-diastolic Volume and Residual Fraction

Figure 5 illustrates the relationship between EDP and EDV in all 75 patients. Once again there appears to be no direct relationship as illustrated by the correlation coefficient.

Figure 6 is a plot of EDP versus residual fraction for all 75 patients. There is no relationship as noted by the correlation coefficient.

Relationship between Residual Fraction and Left Ventricular End-diastolic Volume

Figure 7 is a plot of residual fraction versus end-diastolic volume. In this plot there appears to be a direct relationship as indicated by the regression equation $y=(.0019) x + .054$ with a correlation coefficient of 0.718. This correlation is somewhat predictable, although there are disease states (volume overload of the left ventricle) where this is not true.

As previously stated (see Methods) the regression equation used in this paper gives slightly smaller end-systolic volumes than those reported by other investigators. This gives small residual fractions in patients with small left ventricles and probably accounts for the unusually large number of patients with low residual fractions and low end-diastolic volumes seen in Figure 7.

Effect of Selective Coronary Arteriography

Data from the 75 patients were initially analyzed in three ways: Group 1, patients with left ventricular end-diastolic pressure and left ventriculograms before coronary arteriography (25 patients); Group 2, patients with EDP and left ventriculogram after selective coronary arteriography (50 patients) and Group 3, all 75 patients. Table 2 illustrates the distribution of abnormalities for all three patient groups. Regression equations and correlation coefficients for all the data presented in Figures 2 to 7 were obtained for all three patient groups. Statistical analysis shows that there is no significant difference in the patient groups; thus, we believe it
is valid to present data from the whole group of 75 patients as representative of the pressure-volume relationship in coronary artery disease.

**Discussion**

Left ventricular enlargement in coronary artery disease has been the subject of many clinical and pathologic studies. There are inherent difficulties in clinical studies which utilize chest x-rays and physical examination for indications of cardiac size. Similarly, it is very difficult to measure left ventricular volume at postmortem examination. Hemodynamic studies combined with angiography have the advantage of measuring left ventricular size, pressure and function in the living patient.

The present study is an attempt to grade the severity of coronary artery disease and to correlate with the grading three well known hemodynamic parameters (end-diastolic pressure, end-diastolic volume, and residual fraction). One might postulate, a priori, that severe generalized arterial disease would lead to severe impairment of the heart as a pump. We found that there is no direct correlation between the severity of disease and these hemodynamic parameters. Indeed, there were several patients with severe coronary artery narrowing who had normal cardiac function. This confirms a recent study showing lack of correlation between number of coronary arteries involved and left ventricular end-diastolic pressure or cardiac index. The reasons for this lack of correlation are not clear and are open to speculation. The most obvious explanations are (1) the relationship of left ventricular function to patients with coronary artery disease is dependent on many factors such as adequacy of cardiac metabolism, collateral circulation, the functional importance of particular areas of muscle, and perhaps the effect of prior exercise, (2) the grading system and/or selective coronary arteriograms are not adequate to assess the complete severity of coronary artery disease and (3) the hemodynamic parameters used in this study were not sufficiently sensitive to detect subtle changes and other parameters such as velocity of contractile element would be a better discriminator.

Previous studies have demonstrated that there are large patient differences in the end-diastolic pressure-volume relationship. For example, patients with aortic stenosis may have elevated end-diastolic pressure and normal or small end-diastolic volume. The patients in this study also exhibited wide differences in the end-diastolic pressure-volume relationship (Fig 5) as evidenced by the low correlation coefficient (0.44). There also appears to be a spectrum of hemodynamic abnormalities in coronary artery disease; ranging from patients with elevated end-diastolic pressure and no clinical manifestations to patients with elevated end-diastolic pressure and volume either with or without clinical CHF to finally those patients with increased residual fractions (with or without clinical CHF). It is striking to note that all of the patients with an elevated residual fraction in this study had either akinesis or dyskinesis.

The reason for enlarged end-diastolic volume and abnormally high residual fraction in some patients is not clear. Gorlin and colleagues have noted motion disturbances (akineti or dyskinetic left ventricular aneurysm) in 24 percent of patients undergoing coronary arteriography. This would suggest that scarring of the left ventricular wall plays an important role in decreasing left ventricular function. In another group of patients studied by Rackley and co-workers for chronic congestive failure and/or angina pectoris there was a high incidence of mitral regurgitation associated with an enlarged left ventricle and no mention is made of akinesis or dyskinesis. In this paper we have noted a high incidence of ventricular wall motion disturbances in patients with coronary artery disease (Table 1). During the same period of time several other patients were referred because of congestive heart failure associated with akinesis and/or mitral regurgitation secondary to coronary artery disease. These patients did not have coronary arteriograms and are not included in this study but form another report. Each of the above studies would suggest that an enlarged left ventricle in coronary artery disease is most often associated with disordered wall motion and/or mitral regurgitation.

**References**

Health Hazards of Modern Agricultural Proficiency

The following is quoted from the WHO Chronicle 13:19, 1959: "It is a tragic irony that in many parts of the world the vast irrigation schemes constructed with the aim of improving the standard of living have had the effect of undermining the health of the areas they serve. The network of canals designed to carry water to arid territories have proved ideally suited for carrying bilharziasis to the inhabitants". Thus in some areas the prevalence of bilharziasis has increased over tenfold. In 1968 it was estimated that schistosomiasis affects 200 million people throughout the world. In addition to Africa, Japan, the Philippines, Brazil, Venezuela, some of the Middle East countries and some of the Caribbean Islands are gravely involved. Relative to the life history of schistosomes of man, the mature eggs are discharged with feces or urine, hatch and release larvae. The latter penetrates into the intermediary snail host and become sporocytes which produce daughter sporocytes. These are transformed into a second type of larvae which enter the human body through unbroken skin while these persons are wading in infected water. The parasites reach their respective site of habitat through the blood stream. Then they mature and mate. In the latter process the male partially enfolds the female into its deep ventral body groove throughout the long period of copulation and egg laying. Acute manifestations of the disease may last for three to ten weeks. Pulmonary involvement appears in two forms. 1. Bronchitis or bronchospasm simulating bronchial asthma, bronchiecstasy, pneumonitis, necrotizing focal pneumonia or fibrosis. The ova cause bilharzial tubercles which are seen as milliary nodules in chest x-ray films. 2. Necrotizing arteriolitis, endarteritis obliterans; in severe cases there is thickening of the walls of branches of the pulmonary artery. Consequent hypertrophy, dilatation and failure of the right ventricle are likely to follow. In some regions schistosomiasis is the most common cause of Ayerza's syndrome. In the chronic stage of the disease, one may note anorexia, malaise, hemoptysis, hematemesis, dyspnea on exertion, cirrhosis of the liver, splenomegaly, portal and pulmonary hypertension. Myocardial involvement may appear as foreign body type of inflammatory reaction, proliferation of connective tissue or localized calcification. The global menace of schistosomiasis ranks in importance next to tuberculosis and malaria. It is gratifying to record that developments in science are making significant strides against this scourge and justify an optimistic outlook in this regard. Successful approach to the conquest of schistosomiasis is based on threefold means. 1. Direct attack on the intermediate host: A. by chemicals put into irrigation canals (dinitro-cyclohexylphenol against S. japonicum; sodium pentachlorophenate against S. monasori and S. haematobium). B. by drainage of snail habitats and clearance of useless vegetation. C. by using electric current which immobilizes molusks at the negative electrode. 2. Specific drug therapy. 3. Education of all concerned as to avoidance of exposure.

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