Comparison of Left Ventricular and Pulmonary Arterial Injection Sites in Determination of Cardiac Output by Indicator Dilution Technique*


Cardiac outputs calculated from left ventricular indicator dilution curves were compared to outputs calculated from pulmonary arterial curves in 58 patients with a variety of cardiac abnormalities. Cardiac outputs calculated from left ventricular and pulmonary arterial curves differed by only 0.037 ± 0.052 L/min. Individual measurements of cardiac output using left ventricular curves had an estimated standard error of 0.41 L/min (9.0 percent of output); individual measurements using pulmonary arterial curves had an estimated standard error of 0.35 L/min (7.7 percent of output). Thus, the two methods gave nearly identical values for cardiac output and were equally reproducible. A significant association (P = 0.02) was found between mitral regurgitation and dissimilar values for cardiac output determined by the two methods. It is concluded that the site of injection of the indicator does not appreciably influence calculation of cardiac output except in the presence of severe mitral regurgitation.

The validity of the indicator dilution technique for measuring cardiac output has been established by comparing the values obtained with those determined simultaneously by the Fick method.1-3 In those studies the indicator was injected in the right side of the heart and was sampled in a systemic artery. Since right heart catheterization is not performed routinely in patients undergoing coronary arteriography, injecting indicator in the left ventricle and sampling it in a systemic artery would be a convenient method of obtaining cardiac output in such patients. There have been few studies which have validated this method by comparing it, in a large number of patients, with either the Fick method or with indicator dilution curves utilizing right heart injections.4,5 The present study was undertaken to assess the accuracy and reproducibility of cardiac output determinations from left ventricular indicator dilution curves by comparing them with outputs obtained when indicator is injected into the pulmonary artery.

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Methods

Table 1—Hemodynamic Abnormalities.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral stenosis</td>
<td>6</td>
</tr>
<tr>
<td>Mixed mitral regurgitation and stenosis</td>
<td>8</td>
</tr>
<tr>
<td>Mitral regurgitation (4 severe, 1 mild)</td>
<td>5</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>7</td>
</tr>
<tr>
<td>Mixed aortic regurgitation and stenosis</td>
<td>3</td>
</tr>
<tr>
<td>Severe aortic regurgitation</td>
<td>5</td>
</tr>
<tr>
<td>Idiopathic hypertrophic subaortic stenosis</td>
<td>6</td>
</tr>
<tr>
<td>Multiple valve disease</td>
<td>9</td>
</tr>
<tr>
<td>Postoperative</td>
<td>7</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>58</strong></td>
</tr>
</tbody>
</table>
In each patient four indicator dilution curves were obtained in rapid succession. In any patient, the arterial sampling site remained constant, and dye was alternately injected in the left ventricle and pulmonary artery. Two or 3 ml of indocyanine green (1.25 mg/ml) were injected in less than one second and the catheter flushed rapidly with normal saline. Arterial blood was sampled with a constant withdrawal-infusion pump through a Colson densitometer. To avoid a change in blood volume a sterile cuvette was employed, and the sampled blood was reinfused after the inscription of each curve. The sensitivity setting on the densitometer was the same for all four curves. The curves were calibrated using a concentration of 5 mg of indocyanine green per liter of the patient’s blood; the patient’s blood without dye served as a blank. Curves were replotted on semilog paper, and the terminal portion of the descending limb of the primary curve was extrapolated. Cardiac output was calculated according to the Hamilton formula.1 The results were assessed statistically by an analysis of variance in which only within-patient differences were used for estimating standard errors.

RESULTS

Cardiac output calculated from the left ventricular curves (mean = 4.56 L/min; range = 1.58-7.91) exceeded that calculated from the pulmonary arterial curves (mean = 4.53 L/min; range = 1.64-9.25) by 0.037 ± 0.052 L/min (mean algebraic difference ± standard error of the mean difference). Thus, there was no significant difference between cardiac output measured from left ventricular curves and that measured from pulmonary arterial curves.

In individual patients the absolute numerical difference (without regard to sign) between the mean output of the two left ventricular curves and the mean output of the two pulmonary artery curves (Fig 1) ranged from 0 to 1.51 L/min and averaged 0.287 L/min (6 percent of output). The ratio of average cardiac output calculated from the two left ventricular curves to average output from the two pulmonary arterial curves differed from unity by less than 10 percent in 46 patients and by 10 percent or more in 12 patients. Mitral regurgitation was present in only 11 of the 46 patients (24 percent) whose cardiac outputs obtained from pulmonary arterial and left ventricular curves differed by less than 10 percent, whereas mitral regurgitation was found in eight of 12 patients (67 percent) whose output determinations differed by more than 10 percent. Thus, a significant (P = .02) association was found between mitral regurgitation and a large difference between output determinations by the two methods. No such association was found with any other hemodynamic abnormality. In seven of the eight patients with mitral regurgitation and dissimilar outputs, cardiac output measured from the left ventricular curve exceeded that measured from the pulmonary arterial curve, and in some of them the differences were large (range 11 percent to 38 percent, mean 22 percent).

In individual patients cardiac output determined from the first left ventricular curve did not differ significantly from that determined from the second left ventricular curve (Fig 2), nor did the outputs measured from the two pulmonary arterial curves differ from one another (Fig 3). The estimated standard error of an individual measurement of

![Figure 1](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21543/ on 06/25/2017)

**Figure 1.** The average cardiac output from the two pulmonary arterial curves in each patient (vertical axis) is plotted against the average cardiac output from the two left ventricular curves in the same patient (horizontal axis). The diagonal line in this figure and in Figures 2 and 3 is the line of identity.

![Figure 2](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21543/ on 06/25/2017)

**Figure 2.** The cardiac output obtained from the first left ventricular curve in each patient (vertical axis) is plotted against the output from the second left ventricular curve in the same patient (horizontal axis).
Cardiac output was 0.41 L/min (9.0 percent of output) using a left ventricular curve and 0.35 L/min (7.7 percent of output) using a pulmonary arterial curve. The difference in the estimated standard errors for left ventricular and pulmonary arterial curves was not significant. Therefore, one method was essentially as reproducible as the other in measuring cardiac output.

**Discussion**

The results of this study indicate that injection of indicator into the left ventricle with sampling from a systemic artery is a generally reliable method for determining cardiac output. Outputs calculated from these curves do not differ from outputs calculated from pulmonary arterial curves. Furthermore, output determinations from left ventricular curves are as reproducible as those from pulmonary arterial curves. Thus, although several investigators have determined that indicator injected in the left ventricle incompletely mixes with blood while in that chamber (a serious problem in the measurement of ventricular volume by the indicator dilution technique),7,8 by the time indicator and blood reach the aorta's first large branch, the innominate artery, mixing is sufficient for the determination of cardiac output.

Outputs calculated from left ventricular and pulmonary arterial curves differed by more than 10 percent in only 4 of 39 patients without mitral regurgitation, but in 8 of 19 patients with mitral regurgitation. In addition, we have studied an occasional patient with severe mitral regurgitation whose left ventricular curves had breaks on the downslopes similar to those seen in patients with left-to-right shunts (Fig 4). Because the descending limbs of such curves do not give straight lines when replotted on semilog paper, such patients were not included in this study. These data suggest that in the presence of severe mitral regurgitation, neither left ventricular nor pulmonary arterial curves give a reliable measure of cardiac output. However, in patients without hemodynamically significant mitral regurgitation, cardiac output can be determined reliably from either a left ventricular or a pulmonary arterial curve provided a straight line can be obtained when the descending limb of the curve is replotted on semilog paper.9 In these patients a right heart catheterization which is otherwise unnecessary need not be performed solely for the purpose of measuring cardiac output.
ACKNOWLEDGMENTS: We wish to thank Mr. Morton Raff and Miss Joan Gurian, Biometrics Research Branch, National Heart and Lung Institute, for statistical analysis of the data.

REFERENCES
4 Rahimtoola SH, Swan HJC: Calculation of cardiac output from indicator-dilution curves in the presence of mitral regurgitation. Circulation 31:711, 1965
5 Flamm MD, Cohn KE, Hancock EW: Measurement of systemic cardiac output at rest and exercise in patients with atrial septal defect. Amer J Cardiol 23:258, 1969

Editorial Expression
The indicator dilution technique is the most frequently used method for determining cardiac output and has withstood the test of time. The injected indicator must mix completely and recirculated particles have to be excluded from the calculation. This study of Shepherd et al emphasizes the feasibility of determining flow when only the left side of the heart is catheterized and should encourage measurement of cardiac output in such patients. Use of heat as an indicator will become increasingly more common in clinical practice because of the advantages of the thermo-dilution technique. The arterial system is not entered, blood is not withdrawn, recirculation of indicator does not occur, calibration is easy and accurate, and dye curves can be performed frequently.

An exciting new development in this field is roentgen videodensitometry which offers great promise. A small amount of contrast medium is injected and x-ray absorption is measured. This technique allows for measurement of cardiac output, valvular regurgitation, regional blood flow, blood flow in vessels and in aorta-coronary bypass grafts.

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