A New Two-dimensional Echocardiographic Technique for Evaluating Right Ventricular Size and Performance in Patients with Obstructive Lung Disease

MARK R. STARLING, M.D., MICHAEL H. CRAWFORD, M.D., SHERMAN G. SORENSEN, M.D., AND ROBERT A. O’ROURKE, M.D.

SUMMARY To compare two-dimensional (2-D) echocardiographic estimates of right ventricular size and performance to similar determinations from equilibrium radionuclide angiography (RNA) before and after isosorbide dinitrate, we evaluated 19 patients with severe chronic obstructive pulmonary disease. The end-diastolic and end-systolic volumes estimated from subcostal 2-D echocardiographic views of the right ventricle correlated with the RNA end-diastolic and end-systolic counts ($r = 0.76$ and $0.82$, respectively). The 2-D echocardiographic and RNA right ventricular ejection fraction (EF) estimates also correlated ($r = 0.80$), and the average right ventricular EF measures of $42 \pm 11\%$ and $40 \pm 12\%$, respectively, did not differ significantly. Nitrate administration produced a significant increase in heart rate ($99 \pm 11$ to $108 \pm 14$ beats/min, $p < 0.001$) and a decrease in systolic arterial pressure ($139 \pm 23$ to $120 \pm 22$ mm Hg, $p < 0.001$). Nitrates also significantly decreased the average 2-D echocardiographic end-diastolic and end-systolic volumes ($22 \pm 16\%$ and $18 \pm 12\%$, $p < 0.001$), as well as RNA end-diastolic and end-systolic counts ($33 \pm 17\%$ and $32 \pm 22\%$, $p < 0.001$), but did not significantly decrease the average right ventricular EF values ($4 \pm 12\%$ and $4 \pm 24\%$, respectively). Nevertheless, after isosorbide dinitrate, the 2-D echocardiographic right ventricular end-diastolic and end-systolic volume estimates continued to correlate with the corresponding RNA count measures ($r = 0.76$ and $0.79$, respectively), as did the 2-D echocardiographic and RNA right ventricular EF values ($r = 0.75$). We conclude that 2-D echocardiographic evaluation of right ventricular size and performance is feasible in selected patients with chronic obstructive pulmonary disease, and that 2-D echocardiographic measures of right ventricular size and performance compare favorably with similar determinations by RNA at rest and after nitrate administration.

RIGHT VENTRICULAR volumes and performance are difficult to measure accurately in man because of the unusual shape of the right ventricle. Previous studies using contrast biplane cineangiography and various geometric formulas to calculate right ventricular volumes have correlated well with actual volume measurements obtained by water displacement from right ventricular casts. Moreover, contrast cineangiographic measures of right ventricular volumes and performance in patients have been validated by comparing cineangiographic right ventricular stroke volume estimates with other determinations of stroke volume. However, this method is not widely applicable in patients under different physiologic conditions, where repeat measurements are desirable. Radionuclide techniques are suited ideally for evaluating right ventricular size and performance because they are relatively independent of geometry and can be repeated easily. Equilibrium radionuclide (RNA) background-corrected count data can provide accurate estimates of cineangiographic left ventricular volumes. Also, changes in RNA counts (stroke counts) have provided accurate estimates of stroke volume, as compared with aortic electromagnetic flow probe measurements, and accurate quantitation of Fick cardiac output changes during exercise in normal patients. Moreover, since the ratio of RNA right to left ventricular stroke counts accurately estimates contrast cineangiographic regurgitant fraction in patients with mitral or aortic regurgitation, it is reasonable to assume that RNA count data can provide estimates of right ventricular size. Furthermore, RNA right and left ventricular ejection fraction (EF) measures have correlated closely with those obtained from other noninvasive and invasive techniques.

Recently, Bonner and co-investigators reported that two-dimensional (2-D) echocardiographic cross-sectional area measurements of right ventricular cast preparations correlated highly with actual cast volume measurements determined by water displacement. However, 2-D echocardiography has not been used to estimate right ventricular volumes and performance in patients or to compare these results with those obtained by a technique that is independent of geometry. Therefore, we evaluated selected patients with chronic obstructive pulmonary disease to obtain a range of right ventricular size and performance measures to compare resting 2-D echocardiographic estimates of right ventricular size and performance with similar RNA determinations and to compare right ventricular size and performance measures by these noninvasive techniques at different right ventricular volumes in the same patients after nitrate administration.

Methods

Patients

Forty-two patients with stable chronic obstructive...
pulmonary disease were evaluated with 2-D echocardiography from the subcostal transducer position. Twenty-seven of the 42 patients (64%) had high-quality 2-D echocardiographic views of the right ventricle in two mutually perpendicular planes. Nineteen of these 27 patients consented to further investigation. All 19 patients in this investigation were men, ages 35–69 years (mean 60 years). All 19 patients had resting arterial hypoxemia with arterial oxygen tensions of 47–76 mm Hg and were considered to have severe chronic obstructive pulmonary disease by pulmonary function testing (table 1). During this investigation, all 19 patients were being treated with aminophylline. Finally, patients who had a history of or an ECG consistent with prior myocardial infarction, evidence of tricuspid regurgitation on physical examination, or atrial tachydysrhythmias were excluded.

Protocol
All patients gave written, informed consent for participation in this investigation on a form approved by our Institutional Review Board. The patients were placed in the recumbent position with their heads elevated to approximately 30°. Electrocardiographic monitoring and gating electrodes were affixed to the precordium outside the scintillation camera field of view. The following protocol was followed for each patient (fig. 1). Three control measurements of heart rate, systemic arterial pressure (cuff sphygmomanometer) and 2-D echocardiographic views of the right ventricle were recorded at 4-minute intervals. This was followed by an i.v. injection of human serum albumin (HSA) labeled with 20 mCi of technetium-99m. After equilibrium, a control radionuclide angiogram (Medical Data Systems, Inc.) was performed. Subsequently, each patient was given a 5-mg sublingual isosorbide dinitrate tablet, and measurements of heart rate, systemic arterial pressure and 2-D echocardiographic views of the right ventricle were repeated 4, 8, 12 and 16 minutes later. Ten to 14 minutes (mean 12 minutes) after isosorbide dinitrate was given, a second (post-drug) equilibrium radionuclide angiogram was obtained. All patients completed this protocol without complications.

Two-dimensional Echocardiography
Two-dimensional echocardiographic images of the right ventricle were obtained in all patients using a commercially available, phased-array ultrasonograph and a 1.2 × 1.3-cm transducer composed of 32 piezoelectric crystals in a tight linear array operating at 2.25 MHz. The transducer was controlled electronically through an 84° sector arc at 30 sweeps/sec and a depth of 21 cm.

Two mutually perpendicular planes through the right ventricle were obtained in each patient from the subcostal transducer position described by Tajik et al.21 Briefly, the transducer was placed in the left subcostal region or beneath the xiphoid process. The right ventricular inflow view (figs. 2A and 2B) was provided by a plane transecting the heart from the apex to the base perpendicular to the intraventricular septum and below the aortic valve. The tricuspid and mitral valves were visualized simultaneously. Without altering the transducer position, the right ventricular outflow view (figs. 2C and 2D) was obtained by rotating the transducer 90° clockwise. In this position, the sector arc transected the right ventricle from the inferior base through the right ventricular outflow tract, pulmonary valve and main pulmonary artery. These two planar views of the right ventricle were chosen for volume calculations because (1) the frequency of obtaining high-quality right ventricular images in both planes was good in our chronic obstructive pulmonary disease patients from this single transducer position (64%); (2) the right ventricular inflow view provided a cross-sectional triangular area measurement of the right ventricle similar to that shown by Bommer and co-workers20 to correlate highly with right ventricular cast volumes; and (3) the right ventricular outflow view provided a long-axis (height) measurement of the right ventricle that was nearly perpendicular to the right ventricular inflow view area measurement. The clarity

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**Table 1. Pulmonary Function Data**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patient values</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal midexpiratory flow rate (l/sec) (n = 19)</td>
<td>0.23–0.66</td>
<td>2.6–3.7</td>
</tr>
<tr>
<td>Forced expiratory volume in 1 second (l/sec) (n = 19)</td>
<td>0.6–1.3</td>
<td>2.8–3.5</td>
</tr>
<tr>
<td>Total lung capacity (l) (n = 14)</td>
<td>7.31–12.72</td>
<td>5.7–6.7</td>
</tr>
<tr>
<td>Residual volume (l) (n = 14)</td>
<td>4.78–10.25</td>
<td>1.6–2.5</td>
</tr>
<tr>
<td>Residual volume:total lung capacity ratio (n = 14)</td>
<td>0.65–0.85</td>
<td>0.24–0.38</td>
</tr>
</tbody>
</table>

n = number of patients completing each test.

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**Figure 1.** The study protocol. Three control (C) measurements of heart rate, systolic arterial pressure and two-dimensional echocardiographic views of the right ventricle were performed 4 minutes apart (0, 4 and 8). After injection of human serum albumin labeled with 20 mCi of technetium-99m, a control radionuclide angiogram (RNA) was performed. Each patient received 5 mg of sublingual isosorbide dinitrate (ISD), and measurements of heart rate and systolic arterial pressure and two-dimensional echocardiographic views of the right ventricle were repeated 4, 8, 12 and 16 minutes after drug administration (D). An average of 12 minutes after drug administration, a second radionuclide angiogram was obtained.
of all right ventricular endocardial images in both views was optimized by grey scale adjustment before image recording on a video cassette recorder. All images were recorded in real time simultaneously with vertical and horizontal 1-cm calibration grids and an ECG.

Images were processed by a microprocessor-controlled video light pen system. The video light pen system was calibrated for each two-dimensional right ventricular image being analyzed using the simultaneously recorded grid system. All images were viewed in real-time, slow-motion and stop-frame formats. Using the stop-frame mode and the reference ECG, an observer used the light pen to identify right ventricular end-diastolic endocardial borders and long-axis measurements at the peak of the R wave on the ECG, and to define end-systolic borders and long-axis measures near the end of the T wave at maximal inward motion of the right ventricle. Significant variations in right ventricular size were observed in some patients during quiet respiration. Because it would be impractical to make multiple measurements over several respiratory cycles from the 2-D echocardiogram, we averaged measurements from three beats during expiration just before inspiration. In tracing the 2-D echocardiographic endocardial borders of the right ventricle with the light pen from the right ventricular inflow view, minor irregularities due to a decrease in visual integrity of the right ventricular endocardium were interpolated from the previously reviewed real-time and slow-motion images. The end-diastolic and end-systolic endocardial borders identified by the light pen system in the right ventricular inflow view inscribed a triangular cross-sectional area bordered by the intraventricular septum, right ventricular free wall and tricuspid valve (figs. 2A and 2B). The end-diastolic and end-systolic long axis were measured from the pulmonary valve to the inferobasilar right ventricular free wall in the right ventricular outflow view (figs. 2C and 2D). The end-diastolic and end-systolic area and the long-axis measurements were calculated individually and averaged for a minimum of three sinus beats using the programs.
in the microprocessor. These measurements can be completed within 20 minutes by a trained observer. From these measurements, a pyramidal volume formula was used to estimate end-diastolic and end-systolic volumes: volume = area × height/3, where area represents that calculated from the right ventricular inflow view and height represents the long-axis measurement obtained from the right ventricular outflow view. The right ventricular EF was calculated in the standard manner. Also, the percent change in cross-sectional area was calculated from the right ventricular inflow view image as: 
\[
\frac{(area_d - area_s)}{area_d} \times 100 = \text{end-diastole and s = end-systole.}
\]

Radionuclide Angiography

Radionuclide angiography was performed in the 45° left anterior oblique 10° caudal tilt position after the i.v. injection of HSA labeled with 20 mCi of technetium-99m. Images were acquired under ECG control for 10 minutes with a 37-photomultiplier tube gamma scintillation camera equipped with a low-energy, multipurpose, parallel-hole collimator. Count information was summed and stored as images in consecutive corresponding 40-msec segments of each cardiac cycle in the computer core memory, which resulted in each image containing approximately 300,000 counts. Nine-point spatial smoothing was performed on each image of the composite cycle. The right ventricular EF was calculated using the RNA processing technique of Maddahi and associates. Briefly, a background-subtracted right ventricular time-activity curve was generated from a right ventricular end-diastolic region of interest defined by light pen. From the right ventricular time-activity curve, the end-systolic frame was identified as that containing the fewest counts. From this end-systolic frame, right ventricular end-systolic counts were obtained from an end-systolic region of interest, defined by light pen, over the right ventricle, excluding the right atrium. To compare changes in end-diastolic and end-systolic counts, equilibrium counts obtained during the postnitrate study were adjusted proportionally to the number of cardiac cycles processed during each corresponding control study to take into account heart rate changes. Since no study has compared right ventricular RNA count data directly with cineangiographic volume measures, right ventricular volume estimates were assumed to be approximated by RNA background-corrected end-diastolic and end-systolic counts. Data from several studies suggest that this assumption is valid. Right ventricular EF was calculated by subtracting end-systolic from end-diastolic counts and dividing by the end-diastolic counts.

Data Analysis

Both noninvasive techniques were analyzed independently by different investigators. In addition, 2-D echocardiograms were analyzed by one of the authors on two different occasions and the same echocardiograms were analyzed independently by another investigator to assess intra- and interobserver variability. Also, the mean values for the three control 2-D echocardiographic calculations of right ventricular cross-sectional areas, percent change in area, volumes and EF were compared with the corresponding control RNA count and EF data by least-squares linear regression analysis; and 95% confidence intervals for the data and standard errors of the estimate were obtained. The mean values for the 2-D echocardiographic data obtained 12 and 16 minutes after nitrate were compared with the postnitrate RNA data in a similar manner. These echocardiographic values were averaged because heart rate and systemic arterial pressure changes stabilized after nitrate administration. Differences between the control and postnitrate echocardiographic and RNA mean data were compared by paired t-test. The serial heart rate and systolic blood pressure changes were assessed by an analysis of variance with repeat measures and Dunnet’s t-test. A p value of 0.05 or less was considered significant.

Results

Control Echocardiographic and Radionuclide Measurements

The 2-D echocardiographic right ventricular inflow view end-diastolic area measurements correlated with the RNA end-diastolic count data (r = 0.73) (fig. 3A). The estimated right ventricular end-diastolic volumes calculated from the 2-D echocardiographic images correlated with the RNA end-diastolic counts (r = 0.76, fig. 3B), and the 2-D echocardiographic right ventricular end-systolic area measurements and volume estimates correlated with the RNA end-systolic counts (r = 0.76 and 0.82, respectively) (figs. 4A and 4B). The values for the percent change in area of the right ventricle obtained from the echocardiographic right ventricular inflow view correlated with the RNA right ventricular EF estimates (r = 0.80) (fig. 5A). The actual 2-D echocardiographic right ventricular EF estimates also correlated with the corresponding RNA measures (r = 0.83) (fig. 5B). The average 2-D echocardiographic and RNA right ventricular EF estimates (42 ± 11% and 40 ± 12%) did not differ significantly.

Reproducibility

The intraobserver variability for the control 2-D echocardiographic right ventricular end-diastolic and end-systolic volume and EF measures was negligible (r = 0.99, 0.99 and 0.95, respectively). The interobserver variability was greater for these volume and performance measurements (r = 0.89, 0.90 and 0.70, respectively). Also, the average intra- and interobserver mean difference values were 3% and 22% for right ventricular end-diastolic volumes, 6% and 18% for end-systolic volumes and 11% and 14% for EF measures, respectively.

Hemodynamic Response to Isosorbide Dinitrate

After sublingual isosorbide dinitrate, the mean heart rate increased from a resting value of 99 ± 11 to 108 ± 14 beats/min (p < 0.001), and reached a plateau 8–16 minutes after the drug was administered. Also, the average systolic arterial pressure decreased from the mean control value of 139 ± 23 mm Hg to 120 ± 22
mm Hg ($p < 0.001$), and reached a stable nadir 8–16 minutes after the drug was administered.

**Echocardiographic and Radionuclide Measurements After Isosorbide Dinitrate**

The percent change from control after isosorbide dinitrate in echocardiographic and RNA right ventricular volume estimates and EF measurements is shown in figure 6. The average decrease in 2-D echocardiographic end-diastolic volume was $22 \pm 16\%$, and in RNA end-diastolic counts was $33 \pm 17\%$. The mean decrease in 2-D echocardiographic end-systolic volume was $18 \pm 12\%$, and the mean decrease in RNA end-systolic counts was $32 \pm 22\%$. All of these changes were significant ($p < 0.001$). The mean 2-D echocardiographic and RNA right ventricular EF values decreased $4 \pm 12\%$ and $4 \pm 24\%$, respectively. The average right ventricular EF measurements obtained using these two methods after isosorbide dinitrate administration did not differ significantly from control. However, changes in individual right ventricular EF values were variable (fig. 7). In four patients, the RNA right ventricular EF increased by at least 0.05 EF units; in three of these four patients, the 2-D echocardiographic right ventricular EF also increased. Nevertheless, after isosorbide dinitrate, the 2-D
graphic and RNA right ventricular EF values (40 ± 10% and 37 ± 12%, respectively) did not differ significantly.

**Discussion**

Our data from selected patients with chronic obstructive pulmonary disease indicate that right ventricular inflow view area measurements and volume estimates from 2-D echocardiograms at end-diastole and end-systole correlate with the corresponding RNA counts as an estimate of right ventricular volumes.7,10 Also, the 2-D echocardiographic right ventricular EF estimates correlate with the RNA right ventricular EF measures. Moreover, the 2-D echocardiographic right ventricular volume and EF estimates correlated more closely with the radionuclide count and EF data than did the echocardiographic area and percent change in area measures. Therefore, our echocardiographic method of estimating right ventricular volumes and performance appears to be feasible and more accurate than echocardiographic area measures alone for assessing right ventricular size and performance in selected patients with chronic obstructive pulmonary disease.

Previous 2-D echocardiographic and contrast cineangiographic investigations provided the precedent for using the echocardiographic views and the pyramidal volume formula we used in this study to estimate right ventricular volumes.5,20 Bommer and co-workers20 evaluated several 2-D echocardiographic length and area measurements of right ventricular cast preparations to determine whether these measures demonstrated a relationship to actual right ventricular cast

**Figure 5.** (A) The two-dimensional echocardiographic (2DE) percent change in area measurements from the right ventricular inflow view plotted against the control radionuclide angiographic (RNA) right ventricular ejection fraction. (B) The relationship between the control two-dimensional echocardiographic right ventricular ejection fraction estimates plotted against the corresponding RNA measures.

echocardiographic right ventricular end-diastolic area and volume estimates continued to correlate with the RNA end-diastolic count measures (r = 0.70 and 0.76, respectively). The 2-D echocardiographic end-systolic area and volume estimates continued to correlate with the RNA end-systolic count data (r = 0.76 and 0.79, respectively). Furthermore, the percent change in area and the actual right ventricular EF measures using 2-D echocardiography continued to correlate with the corresponding RNA right ventricular EF measures after drug administration (r = 0.68 and 0.75, respectively). The average 2-D echocardiographic and RNA right ventricular EF values (40 ± 10% and 37 ± 12%, respectively) did not differ significantly.

**Figure 6.** The percent change from control of the two-dimensional echocardiographic (2DE) end-diastolic volume (EDV), end-systolic volume (ESV) and ejection fraction (EF) measures in the open bars, and the radionuclide angiographic (RNA) end-diastolic counts (EDC), end-systolic counts (ESC) and ejection fraction in the hatched bars. The mean ± SD are shown beneath each bar. Asterisk indicates significant difference from control.
volumes. They observed that the cross-sectional area measurements made from the approximated apical transducer position correlated with the actual right ventricular cast volumes measured by water displacement. Also, this correlation was better than that for any of the length measurements assessed. Our cross-sectional area measurements of the right ventricle obtained from the subcostal right ventricular inflow view provided a planar image of the right ventricle similar to that described by Bommer and co-workers. Moreover, the approximate anatomic correlation between these two views of the right ventricle has been depicted by Tajik and co-workers. In addition, by rotating the transducer into the right ventricular outflow view, a right ventricular long-axis (height) measurement was obtained, and a simple pyramidal volume calculation was used to estimate right ventricular volume. Ferlinz and co-investigators used a pyramidal volume formula similar to ours to calculate right ventricular volumes from biplane contrast cineangiographic images. They observed a close correlation between these cineangiographic volume estimates and actual volumes measured from right ventricular cast preparations ($r = 0.98$). Therefore, these data provide a reasonable precedent for the 2-D echocardiographic technique we used to estimate right ventricular volumes in patients. Moreover, our data in patients with chronic obstructive pulmonary disease, which show a good relationship between 2-D echocardiographic volume estimates and RNA background-corrected counts, further substantiate the potential of this echocardiographic approach for assessing right ventricular size.

A comparative assessment of right ventricular performance measures is difficult because of the lack of a clearly defined standard against which newer techniques can be compared. Contrast cineangiographic estimates of right ventricular EF have been validated in vivo by comparing calculated cineangiographic right ventricular stroke volumes to other determinations of stroke volume.3,4 Steele and co-workers22 reported a correlation ($r = 0.80$) between right ventricular EF estimates obtained from contrast biplane cineangiography and first-transit RNA. Subsequently, Maddahi and co-workers19 observed a correlation ($r = 0.95$) between right ventricular EF estimates using a dual region-of-interest processing technique for gated equilibrium radionuclide images and the first-transit radionuclide method. The 2-D echocardiographic right ventricular EF values we obtained correlated closely and demonstrated no difference in mean values from gated equilibrium RNA right ventricular EF measures. Therefore, these data suggest that our 2-D echocardiographic method may be an accurate noninvasive technique for assessing right ventricular performance in selected patients.

After isosorbide dinitrate, there was a significant decrease in end-diastolic and end-systolic 2-D echocardiographic right ventricular volume estimates and in RNA counts. Although there was no significant change in mean right ventricular EF values after nitrate administration, changes in individual right ventricular performance measures were more variable. The majority of our patients had no change or a decrease in right ventricular EF values after isosorbide dinitrate. Nevertheless, some patients increased their right ventricular EFs in association with a greater increase in their heart rates. These observations are consistent with the effects of nitrate administration on global left ventricular performance assessed by RNA in normal subjects and patients with coronary artery disease.23,24 In addition, the right ventricular EF values by both techniques demonstrated similar directional changes and continued to correlate closely after drug administration. Therefore, the 2-D echocardiographic technique we used may provide data on right ventricular performance similar to those obtained by RNA after interventions in selected patients.

Certain limitations of our 2-D echocardiographic technique of analyzing right ventricular size and performance must be recognized. First, high-quality echocardiograms of the right ventricle in both planes from the subcostal transducer position cannot be obtained in all patients. We obtained high-quality views of the right ventricle in 64% of our patients, whereas RNA images of the right ventricle can be obtained in nearly all patients. Since the cross-sectional area measurement from the right ventricular inflow view is the most difficult to acquire, this yield might be increased by using the apical transducer position to record a similar cross-sectional area measurement.20,21 or by

![Figure 7](http://circ.ahajournals.org/)

**Figure 7.** The individual right ventricular ejection fraction estimates by two-dimensional echocardiography (2DE) and radionuclide angiography (RNA) during the control period and after isosorbide dinitrate (post ISD). Variability in individual ejection fraction responses to ISD is evident. The mean ± so are shown.
obtaining right ventricular images from the subcostal approach during held inspiration. Second, we evaluated selected patients who had chronic obstructive pulmonary disease and no evidence of cardiac problems that might have affected right ventricular segmental wall motion to obtain a spectrum of right ventricular size and performance measures unrelated to segmental dysfunction. However, the high correlation between the echocardiographic and RNA performance measures may not be observed in patients who have had a myocardial infarction that affects right ventricular segmental wall motion. Third, the echocardiographic measurements were made only during expiration, while the RNA data were averaged throughout the respiratory cycle. This may have accounted for some of the scatter between the 2-D echocardiographic and RNA data. Finally, the identification of right ventricular endocardial images by 2-D echocardiography, particularly in the subcostal right ventricular inflow view, is difficult because of extensive trabeculations. However, in patients with cor pulmonale and enlarged ventricles, trabeculations are less apparent and endocardial targets are more clearly identifiable. Therefore, one observer can make reproducible serial measurements, but two observers may disagree on the interpretation of the endocardial image in a given study.

The RNA technique we used is dependent upon enddiastolic and end-systolic region-of-interest selections, which might introduce systematic errors in volume and performance estimates. In patients with enlarged ventricles, chamber silhouettes may overlap, particularly at end-systole, such that right ventricular EF values could have been underestimated. This may explain why the right ventricular EF estimates by 2-D echocardiography were greater than those obtained by RNA in the low EF range (fig. 5B). Consequently, the 2-D echocardiographic technique may give a more accurate estimate of global right ventricular performance than the RNA technique in patients with right ventricular enlargement due to chronic obstructive pulmonary disease. Also, because similar right ventricular data are obtained by both noninvasive methods, the 2-D echocardiographic technique may have an additional advantage for these patients, as the potential hazard of radiation exposure can be avoided during repeat studies. Finally, we did not correct the background-subtracted equilibrium radionuclide count data for radioactive decay between the control and postnitrate studies as other investigators have done for the left ventricle. However, it is unlikely that decay had a significant effect on our results, as the time between the two radionuclide acquisitions was short (12 minutes) compared with the half-life of the technetium radioisotope (360 minutes), and the nitrate effect on RNA counts was substantial.

Therefore, we conclude that in selected patients with chronic obstructive pulmonary disease, 2-D echocardiographic estimates of right ventricular size and performance compare favorably with similar determinations by the RNA method at rest and after isosorbide dinitrate. In addition, the echocardiographic technique may have advantages over the RNA technique for assessing right ventricular performance in selected patients with chronic obstructive pulmonary disease, cor pulmonale and enlarged, poorly functioning ventricles. Because 2-D echocardiography is less expensive and widely available, it can be used when RNA is unavailable. However, caution must be exercised in applying this 2-D echocardiographic method in patients who may have right ventricular segmental wall motion abnormalities. Further studies are necessary not only to confirm and further validate this 2-D echocardiographic technique for estimating right ventricular size and performance by comparison to actual values quantified by contrast cineangiography, but also for evaluating its efficacy for assessing therapeutic interventions in patients with severe chronic obstructive pulmonary disease and cor pulmonale.

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Circulation. 1982;66:612-620
doi: 10.1161/01.CIR.66.3.612

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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