Chest Radiographs Fail to Detect Right Ventricular Enlargement and Right Atrial Enlargement in Patients With a Pure Restrictive Ventilatory Impairment*

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The validity of measurements of the cardiac silhouette on chest radiographs for the evaluation of right ventricular enlargement and right atrial enlargement in patients with a pure restrictive ventilatory impairment was investigated in 19 patients. The forced vital capacity (FVC) percent predicted in these patients was 50 ± 12 percent (mean ± SD) (range, 29 to 79 percent). Right ventricular enlargement, by two-dimensional echocardiography, was defined as a right ventricular area >20.4 cm² and right atrial enlargement was defined as a right atrial area >15.3 cm². Chest radiographic measurements in the posteroanterior (PA) projection included distance from the midline to the farthest point of the right border of the cardiac silhouette, transverse cardiac diameter, and cardiothoracic ratio. Measurements in the lateral projection included the horizontal transverse diameter, ventral portion of the lateral broad diameter, and obliteration of the retrosternal space. Neither the right ventricular area nor the right atrial area correlated with any of these radiographic measurements. There were no differences in these chest radiographic measurements among patients with normal right ventricular and right atrial dimensions, patients with right ventricular enlargement, and patients with right atrial enlargement. We conclude, therefore, that PA and lateral chest radiographs do not reliably detect right ventricular enlargement or right atrial enlargement in patients with a pure restrictive ventilatory impairment.

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CHARACTERISTICS OF POSTEROANTERIOR (PA) CHEST RADIOGRAPHS SUCH AS INCREASED DISTANCE FROM THE MIDLINES TO THE FARNEST POINT OF THE RIGHT BORDER OF THE CARDIAC SILHOUETTE, AND CHARACTERISTICS OF LATERAL CHEST RADIOGRAPHS SUCH AS RETROSTERNAL SPACE OBLITERATION, HAVE BEEN THOUGHT TO RELATE TO RIGHT VENTRICULAR ENLARGEMENT AND RIGHT ATRIAL ENLARGEMENT.

METHODS

Nineteen patients with pure restrictive ventilatory defects, defined as a forced vital capacity (FVC) ≤60 percent predicted and a normal FEV₁/FVC ratio were studied by two-dimensional (2-D) echocardiography, PA and lateral chest radiographs, and spirometry.

Echocardiography

All patients underwent a 2-D echocardiographic study of the right and left heart using a phased array echocardiography system (Hewlett-Packard 500). The images were obtained in the parasternal short axis, parasternal long axis, and apical four-chamber views with the patient in the left lateral decubitus position. All images were stored on VHS videotape using a videorecorder (Panasonic).

For each study, the gain settings and the gray scale were optimized to ensure the endocardial borders were clear for planimetry. Because endocardial definition is influenced by the focal line and center line frequency of the imaging transducer, the highest frequency that allowed adequate penetration was used to optimize the images obtained in each patient.

Right ventricular area was mapped on the screen after the identification of the blood endocardial interface of the right ventricle. The right ventricular area was calculated by planimetry from the apical four-chamber view at end-diastole. The end-diastolic frame was identified as the instant of the onset of the electrocardiographic QRS complex or as the video frame at or before the initial systolic coaptation of the mitral valve. The right ventricle was considered enlarged if the right ventricular area was >20.4 cm².

The right atrial area was measured from the apical four-chamber view by planimetry at end-diastole. The right atrium was considered to be enlarged if the right atrial area was >15.3 cm².

Left ventricular ejection fraction was calculated on the basis of ventricular volumes calculated by the single plane area method using the apical four-chamber view. Left ventricular dimensions in diastole were measured from the apical four-chamber view. Left ventricular wall thickness was measured from the parasternal long axis view in end-diastole.

Spirometry

All patients underwent spirometry on the same day as their
Radiography

Posteroanterior and lateral chest radiographs were obtained in deep inspiration at a distance of 1.8 m with the patient upright. In the PA projection, distance from the midline to the farthest point on the right border of the cardiac silhouette was measured. Normal was defined as $\leq 5.5$ cm. The transverse diameter was measured as the sum of the distance from the midline to the right border of the cardiac silhouette plus the distance from the midline to the left border of the cardiac silhouette. Normal was defined as $\leq 14.5$ cm. The cardiothoracic ratio was defined as the ratio of the transverse diameter of the heart to the transverse diameter of the thorax. The latter was measured as the distance near the level of the diaphragm between the inner surface of the ribs on the left side to the inner surface of the ribs on the right side. A ratio of $\leq 55$ percent was considered normal.

In the lateral projection, the lateral horizontal transverse diameter was measured as a line from the most distal dorsal point of the cardiac silhouette horizontally to the frontal inner-chest contour. Normal was defined as $\leq 11.6$ cm (Fig 1). The ventral portion of the lateral broad diameter was measured as the length of a perpendicular dropped from the farthest ventral contour to a line connecting the caudal end of the trachea with the sterno-diaphragmatic angle (Fig 1). No normal values have been reported. The retrosternal space was measured as the distance between the angle of Louis and the sterno-diaphragmatic angle in the lateral radiograph. The extent of obliteration of this space by the cardiac shadow was expressed as a percentage of the total space. Obliteration of $\leq 33$ percent of this space was considered as the upper limit of normal.

**Patient Characteristics**

The mean age of the patients was 59 ± 18 years (mean ± SD). Underlying disorders that caused the restrictive ventilatory impairments are shown in Table 1. Among these 19 patients, 11 had no associated cardiac disease, 4 had hypertension (2 with mild left ventricular [LV] wall thickening, LV wall thickness $\leq 1.3$ cm, and normal LV dimensions), and 4 had angina with normal LV chamber size. None of the patients had evidence of LV dysfunction by echocardiography. None of the patients with vertebral abnormalities had a deformity that might have invalidated the radiographic measurements.

**Statistical Analysis**

Pearson correlation coefficients were obtained to test the relationship between the right ventricular area and the various chest radiographic dimensions. Unpaired t tests were used to compare continuous variables. A Bonferroni correction for multiple comparisons was applied. A probability of p<0.01 was considered significant.

Sensitivity was defined as the proportion of cases correctly diagnosed. Specificity was defined as the proportion of normal test results among patients in whom enlargement of the right atrium or right ventricle was absent.

**RESULTS**

From the PA projection, distance from the midline to the farthest point on the right border of the cardiac silhouette did not correlate with the right atrial area determined by 2-D echocardiography ($r=0.11$,

**Table 1—Underlying Disorders in Patients With Ventilatory Restriction**

<table>
<thead>
<tr>
<th>Disorder</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstitial lung disease</td>
<td>5*</td>
</tr>
<tr>
<td>Lung tumor</td>
<td>1</td>
</tr>
<tr>
<td>Collagen disease</td>
<td>1</td>
</tr>
<tr>
<td>Morbid obesity</td>
<td>2†</td>
</tr>
<tr>
<td>Respiratory muscle dysfunction</td>
<td>1</td>
</tr>
<tr>
<td>Postthoracotomy chest wall restriction</td>
<td>1</td>
</tr>
<tr>
<td>Ankylosing spondylitis</td>
<td>1</td>
</tr>
<tr>
<td>Scoliosis, corrected surgically</td>
<td>1</td>
</tr>
<tr>
<td>Surgically induced vertebral fusion posttrauma</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
</tr>
</tbody>
</table>

*One with asbestosis, and two with sarcoidosis.
†Two patients with interstitial lung disease also had morbid obesity.
Table 2—Correlation of Right Ventricular Area and Right Atrial Area With Radiographic Measurements*

<table>
<thead>
<tr>
<th>Variables Tested</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midline to right border of cardiac silhouette</td>
<td>0.11</td>
</tr>
<tr>
<td>Transverse diameter</td>
<td>0.30</td>
</tr>
<tr>
<td>Cardiopherac ratio</td>
<td>0.24</td>
</tr>
<tr>
<td>Lateral horizontal transverse diameter</td>
<td>0.14</td>
</tr>
<tr>
<td>Ventral portion of the the lateral broad diameter</td>
<td>0.01</td>
</tr>
<tr>
<td>Obliteration of retrosternal space</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

*RV=right ventricle; RA=right atrium. All probabilities of correlation were not significant.

p=NS) or right ventricular area (r=0.11, p=NS) (Table 2). The transverse diameter did not correlate with the right ventricular area (r=0.30, p=NS) or the right atrial area (r=0.003, p=NS). There was poor correlation between the cardiopherac ratio and the right ventricular area (r=0.27, p=NS) (Table 2).

In the lateral projection, the lateral horizontal transverse diameter did not correlate with the right ventricular area (r=0.14, p=NS) (Table 2). The ventral portion of the lateral broad diameter did not correlate with the right ventricular area (r=0.01, p=NS) (Table 2). The extent of obliteration of the retrosternal space did not correlate with the right ventricular area (r=−0.17, p=NS) (Table 2). None of the measurements from lateral radiographs correlated with right atrial area (Table 2).

When patients with vertebral abnormalities were eliminated, the correlations both in the PA and lateral projections remained not significant. Correlations with right ventricular area and right atrial area of radiographic measurements in the PA and lateral projections, when normalized to body surface area or body weight, also remained not significant.

The patients were divided into groups according to the size of the right atrium and the right ventricle as determined by echocardiography: normal right atrial and right ventricular dimensions (n=7), enlarged right ventricle ± enlarged right atrium (n=6), and enlarged right atrium ± enlarged right ventricle (n=8) (Table 3). There were no significant differences in the chest radiographic measurements among these groups (Table 3). When the patients with vertebral abnormalities were eliminated, the differences remained not significant.

**Discussion**

There was no correlation between the right ventricular area and the measurements made from the PA and lateral chest radiographs. Similarly, there was no correlation between the right atrial area and any of the measurements that were made. Most prior studies that evaluated the accuracy of chest radiographic criteria for right ventricular enlargement were based on clinical studies or pathologic studies using wall thickness measurements of the right ventricle.

Right ventricular areas and right atrial areas were obtained from 2-D echocardiograms using the methods of Bommer and associates. Such measurements have been compared with ventriculography in 25 patients with normal right ventricles. The normal right ventricular area was 18.0±1.2 cm². Measurements were also made at autopsy from casts of the normal right ventricles of eight patients. A good correlation was observed (r=0.95) between the area obtained by 2-D echocardiography of the right ventricular casts and dimensions of the casts measured directly. Right atrial areas obtained by 2-D echocardiography in 25 normal patients were 13.9±0.7 cm² (mean±SD).

Murphy and associates, in a study of 27 patients with isolated right ventricular hypertrophy confirmed by autopsy, showed obliteration of the retrosternal space to be 11 percent sensitive and 91 percent specific. In our study, obliteration of the retrosternal space was 100 percent sensitive and 8 percent specific for right ventricular enlargement. Murphy and associates considered all causes of right ventricular enlargement, including coronary heart disease, valvular heart disease, and chronic obstruc-
tive pulmonary disease. Whether there would have been a difference with pulmonary disease alone is uncertain.

Comeau and White, in 200 patients with normal hearts, showed that 90 percent of the patients had a transverse diameter <13.4 cm. The transverse diameter relates to height and weight. In patients <182 cm in height and <103 kg in weight, the transverse diameter was ≤14.5 cm. We found no investigation that relates transverse diameter to right ventricular or right atrial dimensions measured by independent means.

The lateral horizontal transverse diameter can be increased by right ventricular enlargement due to the site at which the measurement is made. Similarly, the ventral portion of the lateral broad diameter anatomically corresponds to the right ventricular outflow tract and right ventricular infundibulum. We did not find any correlation between these dimensions and the right ventricular area.

In conclusion, the chest radiographic dimensions that are considered to be diagnostically useful for determining right ventricular or right atrial enlargement did not reliably identify such enlargement in patients with pure restrictive lung disease. Direct measurement of cardiac dimensions by 2-D echocardiography in patients with a restrictive ventilatory impairment is more reliable for the assessment of right ventricular and right atrial enlargement than assessment by the plain chest radiograph.

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