CLINICAL SIGNIFICANCE OF NORMAL CARDIAC SILHOUETTE
IN DILATED CARDIOMYOPATHY
— Evaluation Based Upon Echocardiography and
Magnetic Resonance Imaging —

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It is generally believed that patients with dilated cardiomyopathy have a large cardiac silhouette on chest roentgenography. Contrary to this general belief, we have recently examined several patients with a dilated left ventricle (LV) on echocardiography but in whom the cardiothoracic ratio (CTR) was within normal limits. To investigate this apparent discrepancy, we evaluated the relationship between LV dimensions, measured on M-mode echocardiography, and CTR in 49 patients with dilated cardiomyopathy. Among these patients, 11 (22%) had a CTR less than 50% and 38 (78%) had a CTR greater than 50%. The spatial orientation (cardiac rotation) of the LV within the thorax was evaluated by magnetic resonance imaging (MRI) in 5 patients with a CTR less than 50% and in 7 patients with a CTR greater than 50%, in comparison with 7 normal controls. In each of these patients, cardiac rotation was assessed from both a transverse and a frontal MRI section. In both groups, LV end-diastolic dimension was greater than 5 cm. Transverse cardiac rotation was $32 \pm 8$ degrees in patients with a CTR less than 50%. This was significantly lower than in the 7 normal controls ($43 \pm 7$ degrees) ($p<0.05$). In patients with a CTR greater than 50%, however, transverse cardiac rotation ($55 \pm 5$ degrees) was significantly greater than in normal controls ($p<0.01$). No differences in frontal cardiac rotation was observed between the 2 groups. These data indicate that a normal cardiac silhouette in patients with dilated cardiomyopathy can be explained on the basis of a counterclockwise transverse rotation of the heart within the thorax, and it cannot always rule out the dilatation of the LV.

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THE advent of new technologies has made it possible to accurately evaluate both cardiac size and volume with a variety of invasive and noninvasive methods. The chest roentgenogram in the posterior-anterior projection, however, remains the most commonly used approach for the detection of cardiomegaly and the evaluation of cardiothoracic ratio (CTR). The latter is the most commonly used index of cardiac size!

We have recently examined an 18 year old male with dilated cardiomyopathy in whom echocardiography showed a markedly dilated and poorly contracting left ventricle (LV). At the time of admission, his CTR was 59%.

Key words:
Dilated cardiomyopathy
Cardiothoracic ratio
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Fig. 1. Measurement of indexes of frontal and transverse rotation (α and β angles, respectively) of the left ventricle within the thorax using MRI in a normal subject (normal controls No 1 in Table I).
Left panel: in the frontal section of the left ventricle (LV) using MRI, an angle, α, formed between the vertical axis of the body, and the long axis of the LV projected from the center of aortic annulus to the most infero-lateral point of the LV cavity, was used as an index of frontal rotation of the LV within the thorax.
Right panel: in the transverse section of the LV at the level of the papillary muscle, an angle, β, formed between the antero-posterior axis of the body and the transverse line bisecting the LV cavity parallel to the interventricular septum and the LV free wall, was used as an index of transverse rotation of the LV within the thorax.

![Diagram showing relationship between LVEDD and CTR in the entire patient cohort.](image)

Fig. 2. Relationship between LVEDD and CTR in the entire patient cohort.
Among the 49 patients, 11 had a LVEDD greater than 5 cm but a CTR less than 50%.

After 2 months of therapy with diuretics and vasodilators, his CTR decreased to 40%. Despite reduction of CTR, his LV end-diastolic dimension (EDD), as assessed by echocardiography, remained unchanged in comparison to pretreatment levels. The apparent discrepancy between the CTR and LVEDD values in this particular patient was the impetus for the present investigation. The present study, therefore, was performed to 1) assess the overall incidence of normal or small cardiac silhouette in the presence of a dilated LV and 2) determine a possible mechanism for this apparent discrepancy.
### TABLE 1  CARDIOTHORACIC RATIO, CAVITY SIZE AND INDEXES OF ROTATION OF THE LEFT VENTRICLE WITHIN THE THORAX, AND LEFT ATRIAL AND RIGHT VENTRICULAR SIZES IN PATIENTS WITH DILATED CARDIOMYOPATHY WHO HAVE NORMAL CARDIAC SILHOUETTE, THOSE WITH LARGE ONE, AND NORMAL CONTROLS

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>CTR (%)</th>
<th>LVEDD (cm)</th>
<th>α (°)</th>
<th>β (°)</th>
<th>LAD (cm)</th>
<th>RVEDD (cm)</th>
</tr>
</thead>
</table>
a. CTR ≤ 50%  
EDD ≥ 5.0 cm  
1. T. M. | 37  | 43      | 7.3        | 52    | 29    | 3.4      | 1.0        |
2. T. I. | 39  | 44      | 6.1        | 52    | 20    | 3.9      | 1.5        |
3. I. K. | 18  | 40      | 6.4        | 31    | 38    | 1.7      | 0.8        |
4. T. M. | 40  | 50      | 6.6        | 47    | 40    | 3.3      | 2.2        |
5. T. N. | 44  | 45      | 6.9        | 48    | 35    | 3.3      | 1.5        |
Mean ± SD | 44±4 | 6.7±0.5 | 46±9       | 32±8  | 3.1±0.4 | 1.4±0.2  |
b. CTR > 50%  
EDD ≥ 5.0 cm  
6. H. H. | 61  | 62      | 6.1        | 51    | 55    | 4.8      | 2.5        |
7. M. S. | 58  | 63      | 6.6        | 53    | 59    | 4.2      | 1.7        |
8. N. H. | 52  | 53      | 6.7        | 73    | 52    | 4.3      | 2.2        |
9. C. I. | 68  | 64      | 6.8        | 70    | 65    | 4.0      | 1.2        |
10. K. I. | 52  | 54      | 6.7        | 59    | 50    | 5.0      | 2.5        |
11. S. T. | 52  | 67      | 7.1        | 52    | 54    | 5.0      | 2.0        |
12. T. Y. | 51  | 62      | 7.4        | 48    | 50    | 3.5      | 2.4        |
Mean ± SD | 61±5 | 6.8±0.4 | 58±10      | 55±5  | 4.4±0.2 | 2.1±0.2  |
c. normal controls  
1. K. K. | 47  | 48      | 4.4        | 42    | 36    | 3.0      | 1.5        |
2. S. F. | 65  | 48      | 4.5        | 60    | 51    | 3.3      | 1.8        |
3. Y. K. | 40  | 49      | 4.8        | 60    | 40    | 3.2      | 2.0        |
4. K. M. | 43  | 48      | 4.7        | 56    | 35    | 3.3      | 2.0        |
5. M. T. | 26  | 46      | 4.9        | 37    | 48    | 3.1      | 1.9        |
6. T. M. | 26  | 48      | 4.6        | 46    | 41    | 3.1      | 2.0        |
7. S. F. | 29  | 49      | 4.9        | 57    | 52    | 3.4      | 1.9        |
Mean ± SD | 48±1 | 4.7±0.2 | 51±9       | 43±7  | 3.2±0.1 | 1.9±0.1  |

**groups**  
<table>
<thead>
<tr>
<th>CTR</th>
<th>EDD</th>
<th>α</th>
<th>β</th>
<th>LAD</th>
<th>RVEDD</th>
</tr>
</thead>
</table>
a vs b | p<0.01 | ns  | 0.10>p>0.05 | p<0.01 | p<0.01 | p<0.05  |
a vs c | ns  | p<0.01 | ns  | p<0.05 | ns  | ns  |
b vs c | p<0.01 | p<0.01 | ns  | p<0.01 | ns  | ns  |

Angle α = an index of frontal rotation of the LV, angle β = an index of transverse rotation of the LV, CTR = cardiothoracic ratio, LAD = left atrial dimension, LVEDD = left ventricular end-diastolic dimension, RVEDD = right ventricular end-diastolic dimension.

**METHODS**

**Patient population**
A total of 49 patients, age 18 to 68 years, with dilated cardiomyopathy were entered in the study. The diagnosis of dilated cardiomyopathy was based upon the criteria established by the World Health Organization/International Society and Federation of Cardiology Task Force.
Among the 49 patients, 15 had a history of alcohol abuse, 2 had a history of hyperten-
sion and 1 patient was diagnosed postpartum cardiomyopathy. The remaining 31 patients had cardiomyopathy of unknown etiology. Upon admission, 21 patients were New York Heart Association functional class I or II and the remaining 28 patients were class III or IV. Seven healthy volunteers served as normal controls.

**Chest Roentgenography and Echocardiography**

A posterior-anterior chest roentgenogram was obtained on admission in all patients and the CTR was evaluated with the standard formula. M-mode echocardiograms were obtained in all patients within one week of the chest roentgenogram using standard commercially available equipment. Echocardiograms were recorded and analyzed in accordance with recommendations of the American Society of Echocardiography. LVEDD was used as an index of LV size. To evaluate the influence of other cardiac chambers to cardiac silhouette, right ventricular end-diastolic dimension (RVEDD) and left atrial dimension (LAD) were measured using the same recommendations.

In 38 of the 49 patients, a follow-up chest roentgenogram and M-mode echocardiogram were obtained one year later.

**Magnetic Resonance Imaging (MRI)**

To evaluate the spacial orientation of the LV within the thorax, an MRI study was performed in 12 of the 49 patients and 7 normal controls using a General Electric Signa 1.5 tesla imaging magnet. Transverse and frontal thoracic sections were obtained in all patients using an ECG gated algorithm. A multiple slice technique consisting of sequential 5 mm thick slices was used to obtain the frontal and transverse sections used in the analyses (Fig. 1). The transverse section at the level of the papillary muscle at end-diastole and the frontal section through the center of the aortic annulus were used in the analyses. In all instances, a spin-echo pulse sequence was used with an echo time of 20 ms.
20 msec. Images were reconstructed using a 2-dimensional Fourier transformation technique.

The spacial orientation of the LV within the thorax was quantitated as follows. The frontal section was used to calculate the angle, alpha, formed between the vertical axis of the body and the long axis of the LV as depicted in Fig. 1. The long axis of the LV was defined as the projection from the center of the aortic annulus to the most infero-lateral point of the LV cavity (Fig. 1). The angle, alpha, was used as an index of the frontal rotation of the LV within the thorax, namely if alpha increases the CTR increases leading to the impression of a larger cardiac size. If alpha decreases the CTR decreases leading to an impression of a smaller cardiac size. The transverse section was used to calculate the angle, beta, formed between the antero-posterior axis of the body, that is, the line passing through the groove in anterior chest wall and the center of the spinal canal, and the line bisecting LV parallel to the interventricular septum and the LV free wall as seen in Fig. 1. The angle, beta, was used as an index of the transverse rotation of the LV within the thorax. Thus, if beta increases the CTR increases leading to an impression of a larger cardiac size. The opposite would be true if beta decreases.

Data Analysis

The 49 patients admitted into the study were used to examine the frequency of occurrence of a normal cardiac silhouette in the presence of a dilated LV. MRI studies were performed in 12 of the 49 patients (5 with CTR less than 50%, and 7 with CTR greater than 50%) at the steady state by conventional therapy and in 7 normal controls. A one way analysis of variance was used to compare the angles alpha and beta, LVEDD, RVEDD and LAD in these 3 groups of patients. If statistical significance (p<0.05) was achieved, multiple comparisons were performed among groups using Duncans test.

RESULTS

Among the 49 patients studied, all of whom had a LVEDD greater than 5 cm, 11 had a CTR less than 50% and 38 had a CTR greater than 50%. The incidence of a normal cardiac silhouette in patients with dilated cardiomyopathy was, therefore, 22%. Fig. 2 shows the relationship between LVEDD and CTR in the entire patient cohort.

There was no difference between patients with a CTR less than 50% and those with a CTR greater than 50% with respect to LVEDD. However, the angle beta defining the transverse rotation of the LV within the thorax was lower in patients with a CTR less than 50% in comparison to the angle measured in the 7 normal subjects (p<0.05) (Table I) (Fig. 3 and 4). In contrast, the angle beta was greater in patients with a CTR greater than 50% than in normal subjects (p<0.01) (Table I). Even though there appeared to be a tendency towards a small angle alpha in patients with a CTR less than 50% in comparison to those with a CTR greater than 50%, this difference between the 2 groups was not statistically significant.
(Table I) (Fig. 3 and 4). Also, RVEDD and LAD were smaller in patients with a CTR less than 50% than in those with a CTR greater than 50% (p<0.05 and p<0.01, respectively).

Roentgenographic and echocardiographic studies were obtained in 38 of 49 patients one year after the initial studies. Among these 38 patients, 6 had a CTR less than 50% on the initial examination and 32 had a CTR greater than 50%. In the 6 patients with an initial CTR less than 50%, follow-up studies showed a reduction of LVEDD and no change in CTR. Among the 32 patients with an initial CTR greater than 50%, 28 showed concordant improvement of both CTR and LVEDD upon follow-up. In the remaining 4 patients, follow-up studies showed a reduction of CTR without a change in LVEDD (Table II). Comparison between the initial and follow-up echocardiograms in these 4 patients showed a marked reduction of both RVEDD and LAD (Table II).

DISCUSSION

Cardiomegaly in patients with dilated cardiomyopathy is conventionally evaluated using a postero-anterior chest roentgenogram. This chest film can be used to determine accurately cardiac size through a calculation of the relative cardiac volume as previously described? This tedious calculation, however, is not routinely employed because its practical value remains questionable. CTR remains the most commonly used index for ascertaining cardiomegaly, which is considered present when CTR is greater than 50%! The present data shows that nearly 22% of patients with dilated cardiomyopathy have a CTR within normal limits (normal CTR) despite marked LV dilatation. The apparently normal cardiac silhouette in these patients was associated with a counterclockwise rotation of the LV within the thorax in comparison to patients with a dilated LV in whom the CTR was abnormally high (large CTR). Because the CTR represents essentially the relative transverse length of the sum of the right atrium and LV to that of the thorax, its value can be influenced not only by the absolute size of the heart but also by the orientation (rotation) of the heart within the thorax.

In the present study, the angle beta was significantly smaller in patients with a large CTR than in normal subjects or in patients with a normal CTR. On the contrary, the angle alpha was not statistically different between patients with a large CTR and those with a normal CTR, but the angle alpha may be another index to differentiate them by the further evaluation. The present data, however, suggests that counterclockwise rotation of the heart within the thorax is more important than frontal rotation in the etiology of the so-called “normal heart” in patients with a dilated LV due to cardiomyopathy. The influence of other cardiac chambers may be considered as another factor contributing to these rotations. In the present study, right ventricular and left atrial size were smaller in patients with a normal CTR in comparison with those with a large CTR, and showed no distiction between patients with normal CTR and normal subjects. These data may indicate that patients with a normal CTR keep in dry status by various medications despite marked LV dilatation, as compared with those with a large CTR. Right ventricular and right atrial enlargement, resulted from the progression of heart failure, can displace the heart to the left leading to clockwise rotation of the LV and a more horizontal position of the heart, resulting in a subsequent increase of CTR. Other factors may also influence these rotations. 1) Elevation of the diaphragm either due to poor inspiration or obesity can place the heart in a more horizontal position leading to an increase of CTR. 2) A slender body structure associated with lowering of the diaphragm can place the heart in a more vertical position leading to a decrease of the CTR.

In conclusion, the present data indicate that 22% of patients with LV dilatation due to dilated cardiomyopathy have a so-called “normal cardiac silhouette” on chest roentgenography. In these patients, the usually normal CTR can be explained on the basis of counterclockwise rotation of the heart within the thorax. An important conclusion of this study, therefore, is the recognition that a normal cardiac silhouette by chest roentgenography does not always rule-out the presence of a dilated LV. These cares must
be taken in the evaluation and follow-up of patients with dilated cardiomyopathy.

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