Correlative Study between Electrocardiographic Findings and Ventricular Wall Thickness based on Cardio-synchronous Angiography (I)

Comparison of Angiocardiographic and Postmortem Thickness of Ventricular Wall in Normal Dogs

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Comparison of angiocardiographic and postmortem measurements of the ventricular wall thickness in dogs was made. Angiocardiographic thickness of the ventricular wall was found to be 7.4% thinner than that proved at autopsy. The notable merits and little demerits of angiocardiographic determination of ventricular hypertrophy as compared with postmortem measurement were briefly discussed.

Various electrocardiographic criteria for LVH appeared to give relatively high positivity but they also showed a high incidence of false positives. New sets of the criteria for LVH are herein proposed to give better results. Only one half of cases with angiocardiographically confirmed RVH was diagnosed with existing criteria for RVH, and the diagnosis of CVH was found to be extremely inaccurate.

It has long been known that ventricular hypertrophy may give rise to certain characteristic alterations in the electrocardiogram. Barnes\(^1\) has described what he called the pattern of left ventricular strain, which consisted of left axis deviation with the ST-T changes in the standard leads. Since then the various sets of electrocardiographic criteria for the diagnosis of left ventricular hypertrophy (LVH), right ventricular hypertrophy (RVH), and combined ventricular hypertrophy (CVH) have been proposed; those of LVH by Gubner and Ungerleider\(^2\), Katz\(^3\), Wilson and co-workers\(^4\), Goldberg\(^5\), Sokolow and Lyon\(^6\), Gould and Kissan\(^7\) and so on, those for RVH by Wilson and co-workers\(^8\), Myers et al.\(^9\), Sokolow and Lyon\(^10\), Braunwald and his associates\(^11\), Scott et al.\(^12\), Milnor\(^13\), Hollman\(^14\), Roman and co-workers\(^15\), and so on, and those for CVH by Katz\(^16\), Soulie et al.\(^17\), Lepeschkin\(^18\), Agnioni and Goodwin\(^19\), etc. It has been pointed out, however, that these criteria are insufficient in both sensitivity and specificity for the clinical diagnosis.

The ideal electrocardiographic criteria for ventricular hypertrophy should indicate all the cases with hypertrophied ventricle and not include any normal case. To test the sensitivity and the degree of the specificity of various criteria, a number of excellent studies of electrocardiographic-clinical or electrocardiographic-pathologic correlation have been made. Many workers\(^20\) have tried to analyse electrocardiographic findings in patients with ven-
tricular hypertrophy proved at autopsy. There were also various investigations from clinical side to this problem. In most cases, however, hypertensive cardiac disease for LVH\textsuperscript{26(27)} and congenital heart disease, such as tetralogy of Fallot\textsuperscript{28(29)}, or cor pulmonale \textsuperscript{11(30)} for RVH have been treated for the purposes assuming that they would have anatomic left or right ventricular hypertrophy. These materials are too generous in accuracy to correlate ventricular hypertrophy to the electrocardiogram. The accuracy of the criteria is best determined by anatomic correlation.

Prior to assess the accuracy of the criteria for the electrocardiographic diagnosis of ventricular hypertrophy by correlating the thickness of the ventricular wall in living body to the electrocardiographic findings, angiocardiographic thickness of the ventricular wall was compared with that of postmortem material.

**Materials and Methods**

Nine mongrel dogs from 6 to 15 kg in body weight were used. The animals anesthetized with morphine hydrochloride were placed in supine position. The contrast medium used in this study was Urokinin M (75\%)\textsuperscript{*} at a dose level of 1.0 to 1.5 cc per kg body weight. The injection was performed into the external jugular vein. The film changer employed was a Toshina's single plane type\textsuperscript{10}, allowing 3 exposures per second. The roentgenographic apparatus operates in the following way. The action potential of the R wave, which is commonly the highest positive deflection on the electrocardiogram, is amplified and shaped, and then this pulse controls both X-ray radiation and the synchronized operation of the film changer. Simultaneous recordings of electrocardiogram are made during angiocardiography to secure the cardiac phase of each exposure and the heart rate during angiocardiography. When the end-diastolic angiogram is needed, one should set up the pulse within 0.02 second after the tip of the R wave by using the phase-shifter. Since the signals of each exposure are recorded on the electrocardiogram, one can know that the radiation has been made exactly at the preset cardiac phase (Fig. 1). The exposure time varied 1/60 to 1/20 second and the voltage between 70 and 75 kV. The roentgen tube was kept at a distance of 88 cm from the film, providing 1.13 $\times$ magnification. Serial angiocardiography was carried out at the end of ventricular diastole and the frontal angiograms were obtained on 12 $\times$ 10 films. The measurements of the width of the ventricular wall were made with an accuracy of $\pm$0.5 mm. The right ventricular wall was measured at the thickest free wall, whereas the left ventricular wall was measured at the thickest wall and at one centimeter above the apex (Fig. 2). The animals were killed immediately after angio-

* mixed solution of Methyl glucamine acetrizoate (80 \%) and Sodium Acetrizoate (20 \%)

![Fig. 1. Direct writing electrocardiographic tracing indicates instant of successive exposure just after the tip of the R wave,](image-url)
Fig. 3. The heart was fixed by two steel needles piercing through the thorax prior to necropsy, in order to avoid the rotation, deviation and distortion of the heart.
Table I  Comparison of Angiocardiographic and Autopsy Findings with Regard to Ventricular Wall Thickness in Normal Dogs

<table>
<thead>
<tr>
<th>Number of Materials</th>
<th>Left Ventricular Wall (mm)</th>
<th>Right Ventricular Wall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 cm above apex</td>
<td>thickest wall</td>
</tr>
<tr>
<td></td>
<td>A  B  C</td>
<td>A  B  C</td>
</tr>
<tr>
<td>3</td>
<td>6.8 6.0 6.7</td>
<td>7.7 6.8 7.8</td>
</tr>
<tr>
<td>4</td>
<td>5.0 4.4 4.5</td>
<td>7.0 6.2 6.4</td>
</tr>
<tr>
<td>5</td>
<td>5.8 5.1 5.3</td>
<td>7.0 6.2 7.0</td>
</tr>
<tr>
<td>6</td>
<td>7.0 6.2 6.6</td>
<td>8.0 7.1 7.0</td>
</tr>
<tr>
<td>7</td>
<td>6.0 5.3 6.0</td>
<td>7.5 6.7 7.0</td>
</tr>
<tr>
<td>8</td>
<td>6.0 5.3 5.5</td>
<td>6.0 5.3 6.0</td>
</tr>
<tr>
<td>9</td>
<td>6.0 5.3 6.0</td>
<td>8.0 7.1 7.0</td>
</tr>
<tr>
<td>10</td>
<td>5.0 4.4 5.2</td>
<td>7.5 6.7 7.7</td>
</tr>
<tr>
<td>11</td>
<td>7.5 6.6 7.0</td>
<td>9.5 8.4 8.8</td>
</tr>
<tr>
<td>Average</td>
<td>B: 5.4±0.82</td>
<td>B: 6.7±0.82</td>
</tr>
<tr>
<td></td>
<td>C: 5.8±0.92</td>
<td>C: 7.2±0.73</td>
</tr>
</tbody>
</table>

Results

Table I showed the values measured on films (A), the values corrected by the magnification factor of 1.13 × (B) and the values measured at autopsy (C). The differences of the values for C minus that for B in 27 pairs as shown in Table I ranged +1.0 mm to −0.2 mm with a mean value of +0.37 mm, and in 5 cases the value for B was greater than that for C. The mean value of the difference between C and B was 0.43 mm at the wall of one centimeter above the apex, 0.47 mm at the thickest wall of the left ventricle, and 0.23 mm at the right ventricular wall, which correspond to 8.0 %, 6.9 % and 7.3 % for the average value of B, respectively. It is concluded that angiocardiographic thickness of the ventricular wall was 7.4% thinner than that obtained at autopsy.

Discussion

As an evidence of ventricular hypertrophy, the thickness of the ventricular wall and the total heart weight proved at autopsy have been used for many years. These quantities vary also with sex, body length and body weight. Therefore most of the electrocardiographic-anatomic studies using total heart weight have concerned with Zeek's criteria, which is related to the body length, but the heart weight exceeds 0.5% of total body weight of the patient has also been employed as an evidence of LVH. With more careful considerations, some pathologists have tried to separate the right ventricle from the left before weighing. Concerning the thickness of the ventricular wall, most workers admit that the greatest thickness of the right ventricular wall must exceed 5 mm to diagnose RVH in an adult and that to diagnose LVH the greatest thickness of the left ventricular wall must be 13 (14) mm or more at autopsy. Almost all of those methods of recognizing the ventricular hypertrophy at autopsy involve the several disadvantages. The postmortem changes of the heart are considered to be serious problem. The heart at necropsy is being free from the intraventricular pressure, but during the life blood is present in the heart. In fact, the ventricular cavity during the life was found to be always larger than those observed at necropsy and the ventricular wall showed thinner than those at necropsy. It is well known that the thickness of the ventricular wall varies throughout cardiac cycle. The point in question is that in what stage of cardiac cycle the ventricular contraction was over and then what kinds of postmortem changes took place in the heart. Accordingly the ventricular wall thickness in living body can only be surmised from the findings at autopsy. Solloff and Lawrence stressed that one should concern with the
thickness of the ventricular wall at end-diastole when depolarization commences.

Ishimi and his associates evaluated the reliability of the electrocardiographic criteria for LVH from the pathological point of view. They classified all the electrocardiograms used into five groups, namely electrocardiograms taken at about a half month, one month, three months, six months and one year before the death, and then they examined the incidence of positivity and false positivity among each group. As a result, they found that the incidence between electrocardiographic and pathologic diagnosis might be due to the stage when the electrocardiograms had been taken. Postmortem hearts are usually obtained from patients with end stage of heart disease. Therefore the data obtained at autopsy are not completely relevant to patients with less severe forms of heart disease, from whom their electrocardiograms are customarily obtained.

Angiocardiographic technique used in the author’s study is more reliable one because the disadvantages mentioned above could be excluded out. However, angiographic determination of ventricular hypertrophy might have two demerits. One is that the thickness of the ventricular wall measured by the angiocardiographic method may involve both the papillary muscles and the subepicardial fatty tissue, but this might not give any serious trouble to the result because they are relatively small at the end of ventricular diastole. The other is still controversial to determine the ventricular hypertrophy only on the basis of the ventricular wall thickness. The thickening of the left ventricular wall is not always observed in the patients with “eccentric” LVH which is often observed in aortic regurgitation, mitral insufficiency or patent ductus arteriosus in lesser degree. The thickness of the free wall of the left ventricle are considered to be normal in the cases mentioned above, even though the total muscle mass is abnormally increased. Thus one should take into consideration of this fact in case to select the material.

It is a well-known fact that the structure of the heart varies throughout cardiac cycle. The thickness of the ventricular wall at end-diastole becomes the smallest and being measured most easily on angiocardiogram. Therefore in order to measure the thickness of the ventricular wall at angiocardiology, the films should be exposed during such cardiac phase.

So far as the present author is aware, no attempt has been made to compare the ventricular wall thickness obtained during the life with that determined at autopsy. In dogs, the right cardiac border in frontal projection is composed of the right ventricle, so that the both ventricular wall thickness could be measured an angiocardiology. The thickness can be measured accurately on the films, but in the cases of the postmortem measurements the errors are inevitably involved to some extent.

In the three different positions measured the average differences between the values obtained angiocardographically and autopsically were found approximately the same, ranging from 6.9% to 8.0% (average 7.4%). In other words, the thickness of the ventricular wall at the end-diastole during the life was 7.4% thinner than that obtained from postmortem material. Although the result herein obtained seems to be reasonable in a qualitative sense, this value of 7.4% is somewhat smaller than expected.

SUMMARY

Angiocardiography at the end of ventricular diastole was carried out in nine mongrel dogs. Measurements of the ventricular wall thickness were made on angiocardiograms and autopsies, and both were compared with each other. The differences between them ranged 0.2 mm to 1.0 mm with a mean value of 0.37 mm. It may be concluded that angiocardographic thickness of the ventricular wall was 7.4% thinner than that obtained at autopsy.

The comparative merits and demerits of postmortem and angiographic measurements of the thickness of the ventricular free wall indicated the presence of ventricular hypertrophy have been discussed.

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