CLINICAL SIGNIFICANCE OF $\tilde{X}_{qrs}$, $\tilde{X}_T$ AND VENTRICULAR GRADIENT IN SINGLE VESSEL CORONARY ARTERY DISEASES

MASAKAZU MOTOMURA, M.D., YASUNORI OHBAYASHI, M.D., KENJI HASHIMOTO, M.D.
TAKAMI FURUKAWA, M.D., MAKOTO ITOH, M.D., KENICHI MITSUNAMI, M.D.
MASAHIKO KINOSHITA, M.D., AND KEIZO BITO, M.D.

Deflection area vectors of QRS ($\tilde{X}_{qrs}$) and T ($\tilde{X}_T$) and ventricular gradient ($\tilde{G}$) calculated from vectorcardiographic leads were compared in single vessel coronary artery diseases divided into subgroups of normokinetic, hypokinetic and akinetic by left ventriculography. In the LAD group, $\tilde{X}_{qrs}$ shifted posteriorly, $\tilde{X}_T$ were smaller and shifted to the right and $\tilde{G}$ were smaller and shifted posteriorly or to the right. In the RCA group, $\tilde{X}_{qrs}$ were smaller and shifted upwards, $\tilde{X}_T$ shifted upwards and $\tilde{G}$ were smaller and shifted upwards. In the LCx group, $\tilde{X}_{qrs}$ shifted upwards, $\tilde{X}_T$ shifted anteriorly and upwards and $\tilde{G}$ were smaller and shifted upwards. Decreased magnitude and directional change of $\tilde{G}$ reflect the severity and location of myocardial damage.

The deflection area vectors of QRS ($\tilde{X}_{qrs}$) and T ($\tilde{X}_T$) express the products of the mean electromotive forces and the duration of QRS and T. The ventricular gradient ($\tilde{G}$), first defined by Wilson and his associates in 1934, is the sum of $\tilde{X}_{qrs}$ and $\tilde{X}_T$. These three vectors have already been studied by many other investigators. Chief interest of previous researchers has been to examine the basic problem of whether or not $\tilde{G}$ was changed by alterations in the series of ventricular excitations. Clinical significance of these vectors has not been sufficiently discussed and has rarely been used as a method of clinical diagnosis. One of the reasons generally given for not employing these vectors was the troublesome procedures thought necessary for their measurement. The recent development of sophisticated micro-computers has now made calculation a relatively easy task. In the present study, we examined the diagnostic usefulness of these vectors in single vessel coronary artery diseases in comparison to the findings of coronary angiography and left ventriculography.

MATERIALS AND METHODS

Eighty-two patients with single vessel coronary artery diseases and 15 control subjects without significant obstruction in coronary arteries were selected from 299 patients who were suspected of having coronary artery disease and underwent coronary angiography in more than four projections and left ventriculography in 30-degree right oblique projection. Single vessel coronary artery disease was defined as an obstruction of 75% or more of the luminal diameter in one great vessel without abnormal wall motion of the left ventricle or more than 50% obstruction with abnormal wall motion. Forty-five patients had significant obstruction in the left anterior descending coronary artery (LAD group), 25 in the right coronary artery

---

Key words:
Vectorcardiograms
Myocardial ischemia
Wall motion abnormalities

(Received December 17, 1988; accepted May 27, 1989)
*First Department of Internal Medicine, Shiga University of Medical Science, Otsu, Shiga; **Department of Internal Medicine, Sengoku Hospital, Kaizuka, Osaka, Japan
Mailing address: Masakazu Motomura, M.D., First Department of Internal Medicine, Shiga University of Medical Science, Otsu 530-21, Japan

Japanese Circulation Journal Vol. 33, December 1989 1491
Fig. 1. $\bar{A}_{qrs}$, $\bar{A}_t$ and $\bar{G}$ of control and LAD groups. Left bar graph shows the magnitudes (μV·Sec), center circle graph the azimuths (degrees) and right short bar graph the elevation (degrees). Open bars indicate the control group; bars with oblique lines, the subgroup of LAD group with normal left ventricular wall motion; coarsely dotted bars, with hypokinetic wall motion; and dark shaded bars, with akinetic wall motion. ($^* p < 0.05$, $^{**} p < 0.01$ and $^{***} p < 0.001$)

(RCA group) and 12 in the left circumflex artery (LCx group). Seventy-two men and 10 women ranging in age from 33 to 69 years (mean 55 years) comprised the single vessel coronary artery disease group, and 9 men and 6 women, ranging in age from 32 to 66 years (mean 50 years) were in the control group. Patients were divided into subgroups of normokinetic, hypo-

Fig. 2. $\bar{A}_{qrs}$, $\bar{A}_t$ and $\bar{G}$ of control and RCA groups. Expressions are the same as in Fig. 1.

kinetic and akinetic by left ventriculographic findings. Vectorcardiograms using the Frank system were recorded in the supine position with chest electrodes on the fifth intercostal space. Scaler electrocardiograms of X, Y and Z leads were recorded on magnetic tape by TEAC R-260, digitalized at a rate of 400 Hz with an analogue-digital converter and calculated by micro-computer (TEAC PS-80). $\bar{A}_{qrs}$, $\bar{A}_t$ and $\bar{G}$ were calculated as follows:

$$\bar{A}_{qrs} = \int_{qrs} (X \vec{i} + Y \vec{j} + Z \vec{k}) \, dt$$

$$\bar{A}_t = \int_{t} (X \vec{i} + Y \vec{j} + Z \vec{k}) \, dt$$

$$\bar{G} = \bar{A}_{qrs} + \bar{A}_t$$

myocardial infarction and vaso-spastic angina were excluded. Statistical analysis was performed using Student’s t test to determine whether or not the mean values of the parameters in each subgroup differed significantly from the control group.

RESULTS

Data of $\overrightarrow{A_{qrs}}$, $\overrightarrow{A_t}$ and $\overrightarrow{G}$ in the subgroups are listed in Table I and graphed in Fig. 1 - 3.

1) LAD group (Table I and Fig. 1)

In this group, 6 patients (55%) in the normokinetic group, 10 (77%) in the hypokinetic group and six (29%) in the akinetic group were with positive treadmill exercise tests. Five patients (30%) in the hypokinetic group and 18 (86%) in the akinetic group had an episode of acute myocardial infarction.

a) $\overrightarrow{A_{qrs}}$: Magnitude was significantly smaller in the akinetic group. Azimuth shifted significantly posteriorly in all subgroups, and was especially striking in the akinetic group. Elevation did not shift significantly in all subgroups.

b) $\overrightarrow{A_t}$: Magnitude was significantly smaller in the hypokinetic and akinetic groups. Azimuth in the akinetic group shifted significantly to the right. Elevation shifted significantly inferiorly in the hypokinetic and akinetic groups.

c) $\overrightarrow{G}$: Magnitude was significantly smaller in all subgroups. Azimuth shifted significantly posteriorly in the hypokinetic group and to the right in the akinetic group. Elevation shifted significantly inferiorly in the hypokinetic group.

2) RCA group (Table I and Fig. 2)

Four patients (67%) in the normokinetic, 9 (69%) in the hypokinetic and 4 (67%) in the akinetic groups showed a positive treadmill test. Eight (62%) in the hypokinetic and 5 (83%) in the akinetic groups had an episode of acute myocardial infarction.

a) $\overrightarrow{A_{qrs}}$: Magnitude was significantly smaller in the hypokinetic group and the smallest in the akinetic group. Azimuth tended to shift posteriorly in the hypokinetic group and anteriorly in the akinetic group. Elevation shifted significantly upwards in the akinetic group.

b) $\overrightarrow{A_t}$: Magnitude was significantly smaller in the akinetic group. Elevation shifted significantly upwards in the hypokinetic and akinetic groups.

c) $\overrightarrow{G}$: Magnitude was significantly smaller in the hypokinetic group and smallest in the

---

Fig. 3. $\overrightarrow{A_{qrs}}$, $\overrightarrow{A_t}$ and $\overrightarrow{G}$ of control and LCx groups. Expressions are the same as in Fig. 1.

where $\overrightarrow{i}$, $\overrightarrow{j}$ and $\overrightarrow{k}$ were the unit vectors in the directions of X, Y and Z respectively. The following parameters were calculated:

$$
\text{Magnitude (Mag)} = (X^2 + Y^2 + Z^2)^{1/2} \\
\text{Azimuth (Azi)} = \tan^{-1}(Z/X) \\
\text{Elevation (Ele)} = \cos^{-1}(Y/Mag)
$$

The positive direction of the Z lead was chosen as the forward direction. Azimuth of $\overrightarrow{A_{qrs}}$, $\overrightarrow{A_t}$ and $\overrightarrow{G}$ was expressed from $-180^\circ$ to $180^\circ$, except for the azimuth of $\overrightarrow{A_t}$ expressed from $-90^\circ$ to $270^\circ$ and the azimuth of $\overrightarrow{G}$ from $-270^\circ$ to $90^\circ$ in the LAD group in order to clarify the significance of the shifted mean values. Patients with bundle branch block, acute
TABLE I  MEAN VALUES AND STANDARD DEVIATIONS OF $\vec{A}_{QRS}$, $\vec{A}_T$ AND $\vec{G}$ IN CONTROL, LAD, RCA AND LCx GROUPS

<table>
<thead>
<tr>
<th>Groups</th>
<th>No of cases</th>
<th>Years</th>
<th>$\vec{A}_{QRS}$</th>
<th>$\vec{A}_T$</th>
<th>$\vec{G}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mag</td>
<td>Azi</td>
<td>Ele</td>
<td>Mag</td>
<td>Azi</td>
</tr>
<tr>
<td>Control</td>
<td>15</td>
<td>50</td>
<td>52</td>
<td>-2</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>± 9</td>
<td>± 13</td>
<td>± 15</td>
<td>± 13</td>
<td>± 11</td>
</tr>
<tr>
<td>LAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normo</td>
<td>11</td>
<td>54</td>
<td>46</td>
<td>-29**</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>± 10</td>
<td>± 14</td>
<td>± 27</td>
<td>± 22</td>
<td>± 26</td>
</tr>
<tr>
<td>Hypo</td>
<td>13</td>
<td>56</td>
<td>42</td>
<td>-21*</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>± 7</td>
<td>± 14</td>
<td>± 29</td>
<td>± 12</td>
<td>± 15</td>
</tr>
<tr>
<td>A</td>
<td>21</td>
<td>56</td>
<td>41*</td>
<td>-56***</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>± 7</td>
<td>± 14</td>
<td>± 30</td>
<td>± 17</td>
<td>± 22</td>
</tr>
<tr>
<td>RCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normo</td>
<td>6</td>
<td>54</td>
<td>41</td>
<td>-16</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>± 7</td>
<td>± 22</td>
<td>± 36</td>
<td>± 9</td>
<td>± 14</td>
</tr>
<tr>
<td>Hypo</td>
<td>13</td>
<td>55</td>
<td>34*</td>
<td>-19</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>± 8</td>
<td>± 13</td>
<td>± 31</td>
<td>± 21</td>
<td>± 29</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>56</td>
<td>28**</td>
<td>23</td>
<td>104***</td>
</tr>
<tr>
<td></td>
<td>± 11</td>
<td>± 13</td>
<td>± 46</td>
<td>± 27</td>
<td>± 13</td>
</tr>
<tr>
<td>LCx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normo</td>
<td>4</td>
<td>55</td>
<td>41</td>
<td>-27**</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>± 7</td>
<td>± 13</td>
<td>± 9</td>
<td>± 17</td>
<td>± 32</td>
</tr>
<tr>
<td>Hypo</td>
<td>4</td>
<td>58</td>
<td>29**</td>
<td>23</td>
<td>82*</td>
</tr>
<tr>
<td></td>
<td>± 6</td>
<td>± 9</td>
<td>± 39</td>
<td>± 20</td>
<td>± 12</td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>48</td>
<td>38</td>
<td>-57***</td>
<td>103**</td>
</tr>
<tr>
<td></td>
<td>± 11</td>
<td>± 20</td>
<td>± 21</td>
<td>± 43</td>
<td>± 12</td>
</tr>
</tbody>
</table>

Mag: magnitude, Azi: azimuth and Ele: elevation.
LAD: left anterior descending coronary artery, RCA: right coronary artery and LCx: left circumflex artery.
$\vec{A}_{QRS}$: deflection area vector of QRS, $\vec{A}_T$: deflection area vector of T and $\vec{G}$: ventricular gradient.

akinetic group. Elevation shifted significantly upwards in the hypokinetic and akinetic groups.

3) LCx group (Table I and Fig. 3)
Four patients (100%) in the normokinetic, three (75%) in the hypokinetic and two (50%) in the akinetic groups showed a positive treadmill test. All of the akinetic group had an episode of acute inferior myocardial infarction.

a) $\vec{A}_{QRS}$: Magnitude was significantly smaller in the hypokinetic group. Azimuth tended to shift anteriorly in the hypokinetic group and posteriorly in the akinetic group. Elevation shifted significantly upwards in the hypokinetic and akinetic groups.

b) $\vec{A}_T$: Magnitude was significantly smaller in the hypokinetic group. Azimuth shifted significantly anteriorly in the hypokinetic and akinetic groups. Elevation shifted significantly upwards in the hypokinetic group.

c) $\vec{G}$: Magnitude was significantly smaller in the hypokinetic and akinetic groups. Azimuth shifted significantly anteriorly in the hypokinetic group. Elevation shifted significantly upwards in the hypokinetic and akinetic groups.

4) Seven patients in LAD, one in RCA and two in LCx groups had dysskinetic regions. Patients in the LAD group have more posteriorly shifted $\vec{A}_{QRS}$ and more right-shift $\vec{A}_T$ and $\vec{G}$, but those in RCA and LCx groups did not have shifted $\vec{A}_{QRS}$, $\vec{A}_T$ and $\vec{G}$.

DISCUSSION
Prolonged duration of the action potential of myocardial cells in chronic ischemia due to coronary arterial obstruction has been previously re-
ported. This phenomenon causes a shift of the T wave opposite to the ischemic area. In addition, necrosis of the myocardial cells due to infarction extinguishes the action potential of these cells, which causes a decrease in QRS components directed toward the necrotic area and a T wave shift opposite the necrotic area in electrocardiograms on the body surface.

Obstruction of the anterior descending branch of the left coronary artery causes ischemia or infarction of the septal, anterior and lateral walls of the left ventricle. Obstruction of the right coronary artery causes ischemia or infarction of the right ventricle and the inferior and posterior walls of the left ventricle. Obstruction of the left circumflex branch of the left coronary artery causes ischemia or infarction of the inferior, posterior and lateral walls of the left ventricle.

We divided the subjects into three subgroups by left ventriculography in a 30-degree right anterior oblique view. The normokinetic group exhibited normal wall motion of the left ventricle, the hypokinetic group had one or more regions of hypokinetic wall motion but no akinetic wall motion, and the akinetic group showed regions of akinetic or dyskinetic wall motion. The hypokinetic region was thought to be in ischemia or a state of small infarction. The akinetic or dyskinetic region was thought to be in a state of large infarction.

Differences of $\tilde{A}_{qrs}$, $\tilde{A}$t and ventricular gradient between each group:

1) LAD group

In this group, $\tilde{A}_{qrs}$ was smaller and shifted posteriorly, reflecting a decrease of the electromotive forces with anterior orientation. This phenomenon was most severe in the akinetic group. These findings were considered to be due to the necrosis of the anterior wall of the left ventricle. $\tilde{A}$t was also smaller in the hypokinetic and akinetic groups and shifted to the right in the akinetic group. These changes were thought to reflect the changes in ventricular gradient. Ventricular gradient of this group was smaller in all subgroups and was directed more posteriorly in the hypokinetic group and markedly shifted posteriorly in the akinetic group. These changes express the ventricular gradient receding away from the necrotic area in proportion with the severity of the myocardial damage.

2) RCA group

$\tilde{A}_{qrs}$ in this group was smaller in the hypo-

kinetic and akinetic groups and shifted upwards in the akinetic group. These changes reflect a decrease of electromotive forces with inferior orientation due to the necrosis of the inferior ventricular wall. At shifted upwards in the hypokinetic and akinetic groups, reflecting a necrosis of the inferior wall of the left ventricle. Ventricular gradient was small and shifted upwards in proportion with the severity of the myocardial damage.

3) LCx group

Although there were not enough cases in this group to allow discussion in detail, upwardly shifted $A_{qrs}$ and anteriorly shifted $A$ were thought to be due to the necrosis of the infero-posterior wall of the left ventricle in the hypokinetic and akinetic groups.

Clinical significance of the ventricular gradient ($\tilde{G}$) in single vessel coronary disease

Current popularity of the micro-computer has made it easier to calculate $\tilde{G}$, which has been said to be less influenced by conduction disturbances and reflects the local changes of the action potential of myocardial cells. Thus, magnitude and direction of $\tilde{G}$ are expected to help demonstrate myocardial ischemia or damage. In this study, the magnitude of $\tilde{G}$ became smaller in proportion to the extent of the abnormal wall motion of the left ventricle in all groups. Direction of $\tilde{G}$ shifted posteriorly or to the right in the LAD, upwards in the RCA and upwards and anteriorly in LCx groups. These directional changes express a tendency of $\tilde{G}$ to recede away from the ischemic or necrotic region.

Acknowledgement

We express our appreciation to Leslie I. Brezak for his helpful advice in the preparation of the manuscript.

REFERENCES

1. WILSON FN, MacLEOD AG, BARKER PS, JOHNSTON, FD: The determination and the significance of the areas of the ventricular deflections of the electrocardiogram. Am Heart J 10: 46, 1934


4. BURGER HC: A theoretical elucidation of the notion "Ventricular gradient". Am Heart J 53:
5. BURCH GE, DePASQUALE N: The electrocardiogram and ventricular gradient in atrial septal defect. Am Heart J 58: 190, 1959
9. BURCH GE, DePASQUALE NP: The electrocardiogram, vectorcardiogram and ventricular gradient in combined pulmonary stenosis and interatrial communication. Am J Cardiol 11: 646, 1961
11. MASHIMA S, FU L, FUKUSHIMA K: The normal ventricular gradient determined with Frank’s lead system and its relation to the heart rate change induced by various procedures. Studies on the ventricular gradient I. Jpn Heart J 5: 337, 1964
15. ISHIZAWA K: Mean QRS, ventricular gradient and left ventricular mass in patients with eccentric left ventricular hypertrophy. J Electrocardiol 8: 227, 1975