Vectorcardiographic Evaluation of Myocardial Infarct Size
— Departure Parameters are Superior to Conventional Spatial Parameters —

Yoshihiko Watanabe, MD; Jianhua Wang, MD; Takeshi Kondo, MD; Mamoru Tokuda, MD; Hitoshi Chikamatsu, MD; Tadashi Yasui, MD; Tamao Yamaguchi, MD; Masaru Kinoshita, MD; Sinichi Kamide, MD; Nobue Nagai, MD; Yasuhiro Abo, MD; Hiroatsu Yokoi, MD; Hitoshi Hishida, MD

To determine whether the departure parameters derived from a “departure loop” of a vectorcardiogram are more accurate than conventional spatial parameters in evaluating myocardial infarct size, 74 patients with first-onset myocardial infarction (MI) were studied. The correlation between the departure parameters (amplitudes in scalar leads of the departure loop) and the percent defect volume of thallium myocardial scintigrams (%DV) was compared with that of the spatial parameters (magnitude, azimuth, and elevation of the original QRS loop). In anteroseptal MI, the amplitude of a 20-msec vector in the z-axis and the azimuth of a 30-msec vector (H30) were significantly correlated with %DV (r=0.783, p<0.001 and r=0.572, p<0.05). In anteroseptal MI with involvement of the lateral wall, the amplitude of a 30-msec vector in the x-axis and H30 showed significant correlation with %DV (r=0.802, p<0.001 and r=0.772, p<0.01). In inferior and inferoposterior MI, the amplitude of a 30-msec vector in the y-axis and the elevation of a 30-msec vector were significantly correlated with %DV (r=0.920, 0.891, p<0.001 and r=0.871, 0.678, p<0.01, respectively). In conclusion, the departure parameters are more accurate than the spatial parameters for evaluation of myocardial infarct size. (Jpn Circ J 1998; 62: 473–478)

Key Words: Myocardial infarction; Vectorcardiogram, Thallium-201 myocardial scintigram; Departure index

Myocardial infarct size has been proved to be closely associated with the occurrence of serious ventricular arrhythmia, the recovery of left ventricular function, and, consequently, the mortality rate of myocardial infarction (MI). Accordingly, the management of acute MI has focused on reducing myocardial infarct size, and many methods such as thrombolytic therapy and various kinds of invasive revascularization have been shown to be effective in limiting infarct size and as a result improving both short- and long-term survival.

To evaluate the effects of treatment and to predict the prognosis of the patients, it is essential to establish an easy and accurate method of assessing infarct size for clinical application. Although several techniques, including the 12-lead electrocardiogram (ECG), body surface mapping (BSM), measurement of released serum myocardial enzymes, and single-photon emission computed tomography of myocardium (SPECT), have been proposed; they are not very satisfactory in clinical settings because of limitations such as low accuracy of ECGs, complexity of BSM, high cost of and radiation produced by SPECT, and repeated blood samplings and the length of time required for biochemical measurement. Vectorcardiography (VCG) has been showed to be superior to ECG for the diagnosis of MI in that it can provide more detailed spatial information, and it has recently been used to estimate the myocardium at risk and the final infarct size. However, like BSM, there is a variety of individual difference, and, the more information it contains, the more difficult it is to explain the results correctly, especially in the situation of quantitative analysis. Therefore, in the present study, a “departure loop” was made from MI patients’ and normal subjects’ VCGs, and we sought to determine whether the departure parameters derived from the departure loop were more accurate than the conventional spatial parameters for evaluating myocardial infarct size.

Methods

Subjects

The study population consisted of 74 patients (66 men and 8 women with a mean age of 61.7±11.4 years). All patients were suffering from acute MI for the first time, and the diagnosis of MI was established from the ECG findings, peak creatine kinase (CK)-MB, echocardiography, and coronary artery angiography (CAG). VCG examination was performed 26.6±5.3 days and thallium-201 SPECT myocardial scintigraphy 26.9±6.8 days after the onset. Based on McConahay et al’s diagnostic criteria for MI, the patients were classified into 5 groups according to a consensus of 3 experienced VCG cardiologists who were blinded to other clinical findings: (1) anteroseptal MI (AS MI); (2) anteroseptal MI with involvement of lateral wall (ASL MI); (3) anteroseptal MI with involvement of apex (ASAp MI); (4) inferior MI (Inf MI); and (5) inferoposterior MI (IP MI). Patients with conduction abnormality or left
Ventricular hypertrophy were excluded from the study.

**VCG and Departure Loop**

The computerized VCG was recorded using the Frank orthogonal lead system (VCM3000, Fukuda-Denshi). The sampling intervals were 1 msec and the data were stored on floppy disks for off-line analysis.

From the original QRS loop, the following spatial parameters were measured: the magnitude, the azimuth, and the elevation of the maximal vector, the vector at 20 msec and 30 msec (abbreviated to $M_{20}$, $H_{20}$, $V_{20}$, $M_{30}$, $H_{30}$ and $V_{30}$, respectively).

To estimate the deviation of patients’ data from the normal values, the departure index was calculated as follows.

Departure index = ($x$ – mean)/SD

where $x$ represents individual values of QRS loop at 1-msec intervals for each patient and the mean and SD represent the corresponding mean values and standard deviations of QRS loop with age and gender corrections obtained from 608 normal subjects (376 men and 232 women with a mean age of 42 years, range 17–81) provided by the Japanese Circulation Society Task Force Committee on Criteria for Body Surface Potential Mapping (these data include the Frank VCG data recorded simultaneously with 87-lead mapping data). Based on the departure index acquired, a departure loop of QRS was reconstructed as shown in Fig 1. As the initial 0- to 40-msec components of QRS are the most sensitive portions predisposing to changes in MI, the amplitudes of 20- and 30-msec vectors at $x$, $y$, and $z$ scalar leads derived from the departure loop were taken as the departure parameters, which were abbreviated as $[X_D]_{20}$, $[Y_D]_{20}$, $[Z_D]_{20}$, $[X_D]_{30}$, $[Y_D]_{30}$, and $[Z_D]_{30}$, respectively.

**Thallium-201 Myocardial Scintigraphy**

Thallium (74 MBq) was injected iv at rest, and the myocardial SPECT images were acquired within 40 min after injection using a 2-headed gamma-camera with low-energy, parallel-hole collimators (RC-2600-I, Hitachi, Japan). A total of 60 projection images were obtained over 360° in 6° increments with 30 sec per view, and the energy discriminator was centered on 70 keV for thallium-201. The data were recorded in 64×64 matrices into the magnetic disk and the reconstruction and analysis of the SPECT images were performed with a dedicated computer for nuclear medicine (RW3000, Hitachi, Japan).

For quantitative analysis, the bull’s-eye of patients reconstructed from short-axis images was compared with the bull’s-eye of a normal file obtained from 20 normal volunteers (10 men and 10 women) with gender correction. The defect volume of myocardium was defined as the volume of myocardium in which the counts per pixel were less than ±2 SD of departure index. The patient had a total occlusion at segment 1 of RCA, and revascularization was obtained by intravenous thrombolysis within 6 h after the onset. The abnormal parameters were as follows: %DV = 22.44%; $V_{20}$ = 153.8°; $V_{30}$ = 109.5°; $[Y_D]_{20}$ = –5.3; $[Y_D]_{30}$ = –3.6.

Table 1: General Characteristics of the Study Population

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Male/Female</th>
<th>CK-MB (&lt;24 U/L)</th>
<th>%DV (%)</th>
<th>Culprit CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS MI (n=15)</td>
<td>64.4±12.7</td>
<td>13/2</td>
<td>271.3±275.3</td>
<td>15.4±12.61</td>
</tr>
<tr>
<td>ASL MI (n=14)</td>
<td>63.1± 9.89</td>
<td>14/0</td>
<td>550.6±194.3*</td>
<td>23.8±11.58</td>
</tr>
<tr>
<td>ASAp MI (n=10)</td>
<td>63.4±13.5</td>
<td>8/2</td>
<td>343.0±205.6</td>
<td>23.02± 7.24</td>
</tr>
<tr>
<td>Inf MI (n=10)</td>
<td>60.9± 9.98</td>
<td>9/1</td>
<td>200.3±104.8</td>
<td>4.96± 4.32*</td>
</tr>
<tr>
<td>IP MI (n=25)</td>
<td>59.0±11.2</td>
<td>22/3</td>
<td>301.1±209.6</td>
<td>12.2±11.25</td>
</tr>
<tr>
<td>Total (n=74)</td>
<td>61.7±11.4</td>
<td>66/8</td>
<td>334.3±234.3</td>
<td>15.54±12.02</td>
</tr>
</tbody>
</table>

AS, anteroseptal MI; ASL, anteroseptal MI with involvement of lateral wall; ASAp, anteroseptal MI with involvement of apex; Inf, inferior MI; IP, inferoposterior MI; CA, coronary artery; LAD, left anterior descending artery; RCA, right coronary artery; LCX, left circumflex artery; %DV, percent defect volume of thallium myocardial scintigrams.

*Significantly higher or lower than other groups (p<0.05).
than the mean counts – 2SD of normal subjects. In this study, the percent defect volume (%DV), defined as (defect volume of myocardium/total volume of myocardium) × 100%, was taken as the normal parameter for measuring myocardial infarct size.

Statistical Analysis
Continuous variables were expressed as mean±SD and categorical data as absolute values and percentages. Linear regression analysis was performed to determine the correlation of VCG parameters with the %DV of thallium myocardial scintigrams. Unpaired Student’s t test was used to investigate differences in each parameter between 2 groups. A p value <0.05 was considered statistically significant.

Results
Clinical Characteristics of the Study Population
The baseline characteristics of the patients are summarized in Table 1. There were no significant differences in age and gender among the groups. The value of peak CK-MB in anteroseptal MI with involvement of lateral wall was significantly higher than in the other groups (p<0.0001–0.05). The %DV of thallium myocardial scintigrams of inferior MI was significantly lower than in the other groups (p<0.0001–0.05), whereas the %DV of inferoposterior MI, although not significantly different from that of anteroseptal MI, was significantly lower than those of anteroseptal MI with involvement of either the lateral or apical portion (p<0.001).

A weak but significant correlation was observed between peak CK-MB and the %DV of thallium myocardial scintigrams when all patients were taken into account, as illustrated in Fig 2, although no such correlation was present in individual groups.

The culprit coronary arteries included left anterior descending artery (LAD) in 39, right coronary artery (RCA) in 50, and left circumflex artery (LCX) in 5 patients.

The patients received routine treatments randomly on admission, which included intravenous thrombolysis in 28, intracoronary thrombolysis in 3, percutaneous transluminal coronary angioplasty (PTCA) in 28, and thrombolysis with adjunctive PTCA in 15 patients.

Conventional VCG Parameters and Their Correlation With the %DV of Thallium Myocardial Scintigrams
The averages of conventional spatial parameters are listed in Table 2. The azimuth of the 30-msec vector showed a significant correlation with the %DV of thallium myocardial scintigrams in anteroseptal MI with and without involvement of the lateral wall (r=0.572, p<0.05, and r=0.772, p<0.01, respectively), whereas no significant correlation with the %DV was found in anteroseptal MI with involvement of apex. In patients with inferior MI, the elevation of the 30-msec vector demonstrated an excellent correlation with the %DV of thallium myocardial scintigrams (r=0.835, p<0.05, and r=0.678, p<0.001, respectively).

Departure VCG Parameters and Their Correlation With the %DV of Thallium Myocardial Scintigrams
The averages of departure parameters are summarized in Table 3. In anteroseptal MI, [YD]30 showed a high correlation with the %DV of thallium myocardial scintigrams (r=0.835, p<0.001), whereas a weak correlation between [ZD]30 and [YD]30 and the %DV was indicated (r=0.569, p<0.05, and r=0.615, p<0.05, respectively). In anteroseptal MI with involvement of lateral wall, [XD]30 showed an excellent correlation with the %DV (r=0.802, p<0.001), whereas [ZD]30 and [ZD]30, although abnormally high, did not cor-

Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AS MI (n=15)</th>
<th>ASL MI (n=14)</th>
<th>ASAp MI (n=10)</th>
<th>Inf MI (n=15)</th>
<th>IP MI (n=25)</th>
<th>ASL MI (n=14)</th>
<th>ASAp MI (n=10)</th>
<th>Inf MI (n=15)</th>
<th>IP MI (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[XD]30</td>
<td>0.52±0.77</td>
<td>0.48±0.61</td>
<td>0.51±0.35</td>
<td>0.25±0.70</td>
<td>0.50±1.05</td>
<td>0.76±1.52</td>
<td>0.00±1.00</td>
<td>0.00±1.00</td>
<td>0.04±0.78</td>
</tr>
<tr>
<td>[YD]30</td>
<td>0.26±0.67</td>
<td>0.21±0.25</td>
<td>0.26±0.50</td>
<td>0.09±0.50</td>
<td>0.26±0.50</td>
<td>0.56±0.90</td>
<td>0.61±0.92</td>
<td>0.61±0.92</td>
<td>0.06±0.70</td>
</tr>
<tr>
<td>[ZD]30</td>
<td>0.68±2.50</td>
<td>0.58±1.00</td>
<td>0.54±1.25</td>
<td>0.42±0.80</td>
<td>0.62±0.77</td>
<td>0.56±1.00</td>
<td>0.56±1.00</td>
<td>0.56±1.00</td>
<td>0.56±1.00</td>
</tr>
</tbody>
</table>

*Correlated with the %DV of thallium scintigrams with a p value <0.05, 0.01, 0.001, respectively.
Fig 3. Comparison of correlations with the %DV of thallium myocardial scintigrams between the azimuth of the 30-msec vector and \([ZD]_20\) in anteroseptal MI.

Fig 4. Comparison of correlations with the %DV of thallium myocardial scintigrams between the azimuth of the 30-msec vector and \([XD]_30\) in anteroseptal and lateral MI.

Fig 5. Comparison of correlations with the %DV of thallium myocardial scintigrams between the elevation of 30-msec vector and \([YD]_30\) in inferior MI.

Fig 6. Comparison of correlations with the %DV of thallium myocardial scintigrams between the elevation of 30-msec vector and \([YD]_30\) in inferoposterior MI.
relate with the %DV. In patients with anteroseptal MI with
involvement of apex, no significant correlation with the
%DV was obtained, although [YD]20, [ZD]20, [XD]30, and
[YD]30 were high abnormally high. In inferior MI, [YD]20
and [YD]30 in particular correlated strongly with the %DV
of thallium myocardial scintigrams (r=0.632, p<0.05 and
r=0.920, p<0.001, respectively). In inferoposterior MI,
[YD]30 showed a strong correlation (r=0.795, p<0.0001)
compared with [YD]20, [XD]20, and [XD]30, which were
found to be weakly but significantly correlated with the
%DV of thallium myocardial scintigrams (r=0.421, 0.421,
and 0.419, respectively, p<0.05).

Comparison Between Conventional and Departure
Parameters
As mentioned above, a significant correlation was found
between the %DV of thallium myocardial scintigrams and
different parameters of VCG, both conventional and depar-
ture, according to different locations of MI. To determine
whether the departure parameters are superior to the con-
ventional parameters, both conventional and departure
parameters that showed the highest correlation with the
%DV of thallium myocardial scintigrams for each location
of MI were compared. In anteroseptal MI, [ZD]20 had a
higher coefficient of correlation and a lower p value than
the azimuth of the 30-msec vector, as shown in Fig 3.
Similarly, in patients with anteroseptal MI and involvement
of the lateral wall, [XD]30 also showed a higher coefficient
of correlation and a lower p value than the azimuth of the
30-msec vector, as illustrated in Fig 4. For patients with
inferior MI or inferoposterior MI, [YD]30 indicated a higher
coefficient of correlation and a lower p value than the
elevation of the 30-msec vector, as shown in Figs 5 and 6.

Discussion
Although myocardial infarct size is of prognostic signifi-
cance, its accurate evaluation is not easy in clinical prac-
tice. Thallium SPECT myocardial scintigraphy has been
accepted as the most accurate method for evaluating quan-
titatively the extent and the severity of myocardial infarc-
tion, and therefore in the present study it was used as a
“gold standard” to assess the accuracy of other param-
ters.17,18 However, as mentioned previously, the necessity of
special apparatus, the high cost, and the radiation preclude
its routine clinical application.

The conventional 12-lead ECG, the most simple and fea-
sible method for clinical practice, has been used most wide-
ly for qualitative diagnosis of MI. For quantitative estima-
tion, the Selvester QRS scoring system was developed in
the prethrombolytic era, and the score system has been val-
ified against anatomic measurement of infarct size in both
antero and inferior MI. Clinical studies have shown
that the QRS score is inversely correlated with left ventric-
ular systolic function after myocardial infarction.22,23
However, with the use of reperfusion therapy such as
thrombolysis, the validity of the QRS score as an index of
infarct size has been questioned.24 Studies with [18F]2-
deoxyglucose and positron emission tomography show that
viable myocardium may persist within the infarct region
despite Q waves on the surface ECG, and residual viability
is more likely after thrombolysis.25 Although the QRS score
is scaled according to the size of Q-wave and R- and S-
wave amplitudes, the score might be an unreliable measure
of infarct size nowadays with reperfusion therapy having
come a routine treatment for acute myocardial infarction.
In addition, the measurement and the calculation of the
score are performed manually, and this may not be as con-
venient and objective in some ways.

VCG, theoretically, contains more information than 12-
lead ECG, and it should be more accurate and more suit-
able for quantitative analysis. In fact, a few studies have
shown VCG to be more sensitive than 12-lead ECG for
qualitative diagnosis of MI based on its unique spatial
information.11-13 Recently, with widespread use of the
computer, continuous on-line VCG monitoring has become
available and the dynamic changes in QRS and ST were
used to evaluate the myocardium at risk and the final
infarct size. In an animal experiment, Tseng et al27
described a slight correlation between VCG changes and
histological myocardial infarct size, whereas, in a clinical
study, Juhlin et al28 demonstrated a good correlation
between the changes in QRS complex configuration and
the perfusion level of myocardial scintigrams. It may be
difficult to evaluate the extent of ischemia and then to pre-
dict the final infarct size at acute phase by observing the
changes in electrical activity of the myocardium as it is so
unstable and the changes are so remarkable. That is why we
used the VCG obtained about 1 month after the onset of
MI.

In the present study, a significant correlation was found
between the %DV of thallium myocardial scintigrams and
the spatial VCG parameters in various locations of MI
except anteroseptal MI with involvement of apex. For
anteroseptal MI with or without involvement of lateral
wall, the 30-msec azimuth manifested a significant inverse
correlation with the %DV of thallium myocardial scinti-
grams, whereas, for inferior and inferoposterior MI, the 30-
msec elevation demonstrated an excellent correlation with
the %DV of thallium myocardial scintigrams. Moreover,
the departure parameters [ZD]30 for anteroseptal MI,
[XD]30 for anteroseptal MI with lateral involvement, and
[YD]30 for inferior and inferoposterior MI, showed a higher
coefficient of correlation and lower p values with the %DV
of thallium myocardial scintigrams than the conventional
spatial parameters as expected, indicating that the departure
parameters are more accurate for assessing infarct size.

Unfortunately, regardless of the conventional or the
departure parameters, no significant correlation was found
between VCG and the %DV of thallium myocardial scinti-
grams in anteroseptal MI with involvement of apex,
although there seemed to be a weak correlation of the
azimuth of the maximal vector [ZD]30 (r=0.429 and 0.308,
respectively). Several factors may account for this. The
most important one may be a cancellation of electrocardio-
graphic changes between the anterior wall and the apical
portion of inferior wall, an explanation similar to the results
of Sevilla et al28 study in which he found that patients
with multiple infarcts showed a lower degree of correlation
than those with anterior or inferior MI only. Another reason
may be the small sample of the patients enrolled. From this
result, it is quite reasonable to assume that in patients with
multiple myocardial infarction it may be difficult to use the
VCG parameters to evaluate the infarct size because what
VCG changes reflect is the change in the sum of electric
forces of myocardial cells and the cancellation, an innate
limitation of VCG, is unavoidable.

Although biochemical markers such as creatine kinase
(CK) and CK-MB have also been used to evaluate the
infarct size factors such as the amount of time taken for
measurements and repeated blood samplings make it less clinically practicable and, furthermore, the influence of the enzymes released from other organs such as skeletal muscle and the impact of different methods of revascularization may render the measurements less accurate nowadays with reperfusion therapy having become a standard treatment for acute myocardial infarction. As a result, it is not surprising to find that no significant correlation was present between the CK-MB and the %DV of thallium myocardial scintigrams in individual groups and that only a weak correlation was found when all patients were enrolled in the present study because the patients underwent various kinds of revascularization treatments, including thrombolysis, PTCA, or both. On the contrary, the parameters of VCG, especially the departure parameters, seemed to be less affected by the treatments.

The following conclusions may be drawn: (1) the VCG parameters show a significant correlation with the %DV of thallium myocardial scintigrams, and, therefore, it is possible to use VCG to predict myocardial infarct size easily and non-invasively; (2) with a higher coefficient of correlation with the %DV of thallium myocardial scintigrams than the spatial parameters, the departure parameters are more accurate for evaluating the myocardial infarct size than the spatial parameters.

References