Clinical Studies

Frequency Analysis of QRS Complex with Bundle Branch Block in Patients With and Without Sustained Ventricular Tachycardia

Naoto Yoneda, M.D., Shigeki Itoh, M.D.*, Toshinori Fujimoto, M.D.*, Hiroyuki Kurogane, M.D.* and Yutaka Yoshida, M.D.*

To distinguish patients with bundle branch block (BBB) and sustained ventricular tachycardia (s-VT) from patients with BBB but without s-VT, a frequency analysis of the QRS complex was performed in 71 patients. Frequency analysis of the QRS complex of patients with left bundle branch block (LBBB) showed that patients with s-VT had significantly larger areas and area ratios between 50 and 100 Hz in the X lead than patients without s-VT (area: $-0.905 \pm 0.231$ vs $-1.195 \pm 0.286$, area ratio: $-0.783 \pm 0.230$ vs $-1.125 \pm 0.310$; $P<0.05$). The area and area ratios from 100 to 200 Hz in the Z lead were also larger in patients with s-VT. The highest predictive accuracy using the area ratio from 50 to 100 Hz in the X lead was 86%, with a sensitivity and specificity of 83% and 88%, respectively. In cases with LBBB, time domain analysis showed no significant difference between patients with s-VT and those without s-VT. Frequency analysis of the QRS complex may be useful for distinguishing LBBB patients with s-VT from those without s-VT. (Jpn Circ J 1993; 57: 1027–1037)

Recent experimental and clinical studies1–4 have demonstrated that reentry plays a major role in ventricular tachycardia (VT) and that delayed conduction is a prerequisite for reentry. Using a time domain analysis of signal averaged electrocardiograms (SAEs), Berbari et al.5 successfully documented this delayed conduction from the body surface for the first time in 1978. Low-amplitude and high-frequency potentials in the terminal portion of the QRS complex, i.e., late potentials, have been reported to be closely related to sustained VT (s-VT)6–8. On the other hand, Cain et al.7 reported that patients with s-VT exhibited quantitative differences in the frequency content of SAEs as compared to those in patients without s-VT. In patients with bundle branch block (BBB), late potentials are often difficult to detect in a time domain analysis because they are covered by delayed activation of normal heart muscles. However, a frequency domain analysis may be used to detect such fragmented activity within the QRS complex of BBB patients if the frequency content of the fragmented activity and that of the delayed activation of normal heart muscles are different. This study was performed to determine whether a frequency domain analysis could be used to distinguish patients with BBB and s-VT from patients with BBB but without s-VT. The relationship between the frequency content and s-VT in patients with a narrow QRS complex was also examined.

Key words:
Frequency analysis
Bundle branch block
Sustained ventricular tachycardia
Late potentials
Signal averaged electrocardiogram

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The Department of Internal Medicine, National Sasayama Hospital, Sasayama, Japan
*The Department of Cardiology, Himeji Cardiovascular Center, Himeji, Japan
Mailing address: Naoto Yoneda, M.D., The Department of Internal Medicine, National Sasayama Hospital, Yamauchi-cho, Sasayama, Hyogo 669-23, Japan

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### TABLE I  TYPES OF BUNDLE BRANCH BLOCK AND UNDERLYING CARDIAC DISEASES IN SUBJECTS

<table>
<thead>
<tr>
<th></th>
<th>OMI</th>
<th>DCM</th>
<th>AP</th>
<th>VHD</th>
<th>CPS</th>
<th>HCM</th>
<th>HT</th>
<th>Others</th>
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<tr>
<td>LBBB S-VT</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
<td>No s-VT</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>1</td>
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<td>RBBB S-VT</td>
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<tr>
<td>No s-VT</td>
<td>7</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>RB+LA No s-VT</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>RB+LP No s-VT</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>NIB S-VT</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No s-VT</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Narrow QRS</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>S-VT No s-VT</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>1</td>
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<td>Total (n=103)</td>
<td>39</td>
<td>23</td>
<td>22</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>


### METHODS

**Patients:** The study population consisted of 71 patients (60 males and 11 females, mean age of 63.1±9.0 years) with bundle branch block [QRS > 120 msec]. and 32 patients (23 males and 9 females, mean age of 57.2±13.9 years) with a narrow QRS complex. Types of BBB were diagnosed by the criteria of the WHO/ISFC Task Force.16

Twenty-two patients had complete left bundle branch block (LBBB), 21 patients had complete right bundle branch block (RBBB), 13 patients had RBBB and left anterior fascicular block (RB+LA), 5 patients had RBBB and left posterior fascicular block (RB+LP) and 10 patients had a QRS duration of greater than 0.12 sec which did not meet the criteria for either LBBB or RBBB. These latter 10 cases were classified as nonspecific intraventricular block (NIB). Underlying cardiac diseases and types of BBB are shown in Table I. Thirty-nine patients had old myocardial infarction (OMI), 23 patients had dilated cardiomyopathy (DCM), 22 patients had angina pectoris, 4 patients had valvular heart diseases (VHD), 3 patients had chest pain syndrome (CPS), 2 patients had hypertensive heart disease (HT), 2 patients had hypertrophic cardiomyopathy (HCM), 5 patients had other cardiac diseases and 3 patients had no organic cardiac disease other than s-VT.

Eleven patients with BBB and 10 patients with a narrow QRS complex had documentation of spontaneous s-VT by either standard electrocardiogram or monitoring electrocardiogram. S-VT was defined as a VT which lasted for more than 30 sec or which was associated with hemodynamic collapse within 30 sec. None of the s-VTs of these 21 patients were associated with new myocardial infarction, electrolyte imbalance or drug toxicity. Each patient was in sinus rhythm and received no antiarrhythmic drugs during the study.

**Recording Technique:** All SAE recording and analysis was performed with a model 101 EPX high-resolution electrocardiogram.
Frequency Analysis with Bundle Branch Block

Fig. 1 Representative plots of frequency analysis of the QRS complex (X lead) from DCM patients with (solid line) and without (dashed line) s-VT.

Signals were recorded from bipolar X, Y, and Z leads as described by Simson. Amplified signals were then AD-converted to 16 bit accuracy at 4000 samples/sec. These digitized electrograms were tested against a template made from the 8 initial beats to reject ectopic beats and excessively noisy beats. Data from 250 beats were averaged to reduce the noise level using the steeply sloped portion of the QRS complex in the Z lead as a reference. Reference jitter was reported as ±0.5 msec in Simson's study using the same system. These signal-averaged data were stored to hard disk or floppy disk for later analysis.

Frequency domain analysis was performed on the QRS complex of each signal-averaged X, Y and Z lead. The onset and end point of the QRS complex were determined with the same computer algorithm used to decide the onset and end point of the filtered vector magnitude in Simson's method. This region of interest was multiplied by a Blackman-Harris window and fast-Fourier transformed (FFT). Transformed data in each lead were expressed as a FFT magnitude and plotted on a logarithmic scale. According to the report of Cain et al., the area under the curve between 20 and 50 Hz (A20) was divided by the area under the initial curve between 0 and 20 Hz (A0). This area ratio [AR20 (=A20/A0)] represents the relative contribution of frequencies between 20 and 50 Hz to the entire signal. In the same way, AR50 [ratio of the area under the curve between 50 and 100 Hz (A50) to A0] and AR100 [ratio of the area under the curve between 100 and 200 Hz (A100) to A0] were also computed.

Time domain analysis was performed with the same averaged signals by Simson's method. Averaged signals were filtered with a bidirectional digital filter and then combined into a vector magnitude. The QRS onset and end point in this filtered vector magnitude were the same as in the frequency domain analysis. The duration from the onset to the end point of the filtered vector magnitude (f-QRS) and the voltage of the filtered vector magnitude during the last 40 msec of the QRS complex (V40) were used to ascertain the existence of late potentials in the time domain analysis.

Statistical Analysis: Data were expressed as the mean ± standard deviation. Statistical comparisons were performed with an unpaired Student's t test. Because of the skewed log normal distribution, analysis of area and area ratios were performed after logarithmic transformation. A probability value of P < 0.05 was accepted as significant.

RESULTS

Representative plots of FFT data of the QRS complex in the X lead from a patient with DCM and s-VT (patient A) (solid line) and from a patient with DCM but not s-VT (patient B) (dashed line) are shown in Fig. 1. Amplitude and frequency are both on a logarithmic scale. In both cases, peak amplitude was about 20 Hz. Areas and area ratios of patient A and patient B were 0.593 vs 0.666 (A0), 0.473 vs 0.449 (A20), 0.237 vs 0.076 (A50), 0.069 vs 0.038 (A100), 0.801 vs 0.674 (AR20), 0.402 vs 0.113 (AR50), and 0.117 vs 0.057 (AR100) respectively.
<table>
<thead>
<tr>
<th></th>
<th>X lead</th>
<th>Y lead</th>
<th>Z lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>logAR20</td>
<td>logAR50</td>
<td>logAR100</td>
</tr>
<tr>
<td>LBBB</td>
<td>-0.38 ± 0.26</td>
<td>-1.03 ± 0.33</td>
<td>-1.29 ± 0.22</td>
</tr>
<tr>
<td>RBBB</td>
<td>-0.23 ± 0.14</td>
<td>-0.93 ± 0.22</td>
<td>-1.38 ± 0.24</td>
</tr>
<tr>
<td>RB + LA</td>
<td>-0.34 ± 0.13</td>
<td>-1.06 ± 0.27</td>
<td>-1.33 ± 0.20</td>
</tr>
<tr>
<td>RB + LP</td>
<td>-0.29 ± 0.10</td>
<td>-0.89 ± 0.22</td>
<td>-1.21 ± 0.13</td>
</tr>
<tr>
<td>NIB</td>
<td>-0.27 ± 0.19</td>
<td>-0.91 ± 0.24</td>
<td>-1.23 ± 0.26</td>
</tr>
<tr>
<td>narrow QRS</td>
<td>0.13 ± 0.16</td>
<td>-0.69 ± 0.30</td>
<td>-1.07 ± 0.26</td>
</tr>
</tbody>
</table>

P < 0.01: *15, *22, *23

AR20: ratio of the area under the curve between 20 to 50 Hz to the area under the curve between 0 to 20 Hz.
AR50: ratio of the area under the curve between 50 to 100 Hz to the area under the curve between 0 to 20 Hz.
AR100: ratio of the area under the curve between 100 to 200 Hz to the area under the curve between 0 to 20 Hz.
QRS complexes in patients with s-VT contained relatively more components between 20 to 200 Hz than those in patients without s-VT.

Table II shows area ratios of the 6 groups in the X, Y, and Z leads. The data are means and standard deviations of logarithmic transformed area ratios. Area ratios which show the same superscript numbers were significantly different (the respective P values are shown in the Table legend). In all 3 leads, AR20, AR50 and AR100 of the narrow QRS group were significantly larger than those of the LBBB group (P<0.05~P<0.001). AR20 of the RBBB group was larger than that of the LBBB group (P<0.05~P<0.001). In each lead, area ratios of the 6 groups showed significant differences in various combinations (P<0.05~P<0.001). Comparison of the area ratios of only those patients without s-VT, showed that all of the area ratios of the narrow QRS group were significantly larger than those of the LBBB group. Furthermore, the AR20s of the RBBB group were larger than those of the LBBB group in all leads. However, comparison of the area ratios of only those patients with s-VT showed no such differences.

Therefore, the area ratios within each type of bundle branch block were studied.

Fig. 2 shows the area ratios of the LBBB group in the X, Y and Z leads. Open circles represent cases without s-VT and closed circles represent cases with s-VT. AR50 in the X lead showed a significant difference between patients without s-VT and patients with s-VT (-1.125 ±0.310 vs -0.783±0.230, P<0.05). AR100 in the Z lead also showed a significant difference between patients without s-VT and patients with s-VT (-1.617±0.316 vs -1.222±0.314, P<0.05). There was no significant difference between patients with and without s-VT with regard to any other area ratios.

To assess the contribution of A0 to the differences between the area ratios of patients without s-VT and of those of patients with s-VT in the LBBB group, A0 in both, and in each lead, were examined. There were no significant differences in the A0 in each lead between patients without s-VT and those with s-VT. A50 in the X lead and A100 in the Z lead were significantly different in patients without s-VT and in patients with s-VT (-1.195±0.286 vs -0.905±0.231: A50, -1.673±0.241 vs -1.330±
The highest accuracy \( \frac{\text{number of true positives} + \text{number of true negatives}}{\text{total number}} \) in predicting patients with s-VT in the LBBB group was achieved when log AR50 in the X lead for a positive test was defined as equal to or greater than \(-0.90\). Using this definition, predictive accuracy, sensitivity, and specificity were 86%, 83%, and 88%, respectively. When log AR100 in the Z lead was defined as equal to or greater than \(-1.35\) for a positive test, the predictive accuracy of AR100 was at its maximum, and predictive accuracy, sensitivity, and specificity were 77%, 67%, and 81%, respectively.

Neither the NIB group nor the narrow QRS group showed any significant differences between patients without s-VT and patients with s-VT in any area ratios in any leads. (Figs. 3 and 4)

In the time domain analysis using Simson’s method, f-QRSs of the LBBB, RBBB, RB + LA, RB + LP, NIB, and narrow QRS groups were 149.9 ± 23.8, 140.1 ± 11.5, 154.5 ± 11.6, 139.6 ± 12.1, 151.3 ± 28.7, and 100.7 ± 14.6 msec respectively. The narrow QRS group had a lower value of f-QRS than any of the other 5 groups \((P < 0.001)\). The f-QRS of patients with s-VT in either the NIB group or the narrow QRS group was longer than that of patients without s-VT in each group \((177.0 ± 28.0 \, \text{msec} \, vs \, 134.2 ± 10.8 \, \text{msec}, \, P < 0.05; \, \text{NIB group}, \, 112.0 ± 17.3 \, \text{msec} \, vs \, 95.5 ± 9.5 \, \text{msec}, \, P < 0.005; \, \text{narrow QRS group})\). However, in the LBBB group, the f-QRS of patients with s-VT and that of patients without s-VT showed no significant difference \((137.3 ± 10.1 \, \text{msec} \, vs \, 154.6 ± 25.6 \, \text{msec})\).

V40s of the LBBB, RBBB, RB + LA, RB + LP, NIB, and narrow QRS group were 23.8 ± 12.5, 29.5 ± 19.7, 29.0 ± 15.7, 40.9 ± 17.7, 14.6 ± 7.0, and 53.8 ± 39.4 μV, respectively. The V40 of patients with s-VT in either the NIB group or the narrow QRS group was smaller than that of patients without s-VT in the same group \((8.5 ± 3.5 \, \mu \text{V} \, vs \, 18.7 ± 5.6 \, \mu \text{V}, \, P < 0.05; \, \text{NIB group}, \, 29.9 ± 21.1 \, \mu \text{V} \, vs \, 64.6 ± 40.9 \, \mu \text{V}, \, P < 0.05; \, \text{narrow QRS group})\). However, in the LBBB group, the V40 of patients with s-VT and that of patients without s-VT showed no significant difference \((30.7 ± 12.7 \, \mu \text{V} \, vs \, 21.2 ± 11.4 \, \mu \text{V})\).

*1,2; \( P < 0.05 \)

A0: the area under the spectrum curve between 20 to 50 Hz.
A20: the area under the spectrum curve between 50 to 100 Hz.
A50: the area under the spectrum curve between 100 to 200 Hz.
A100: the area under the spectrum curve between 200 to 400 Hz.

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Fig. 3 Area ratios of 3 frequency bands: AR20, AR50 and AR100 in patients with non-specific intraventricular block (NIB). No significant differences were observed between patients with and without s-VT in any of the leads. Abbreviations are the same as in Fig. 2.

Fig. 4 Area ratios of 3 frequency bands: AR20, AR50 and AR100 in patients with narrow QRS. No significant differences were observed between patients with and without s-VT in any of the leads. Abbreviations are the same as in Fig. 2.

\[ \mu \text{V}. \]

**DISCUSSION**

BBB is often accompanied by s-VT\(^\text{12,13}\) However, in many time domain analyses of SAE\(^\text{7,14,15}\) cases with BBB were excluded from the study. The main reason for this exclusion has been that BBB caused a delay of normal heart muscle activation and cover-
ed late potentials in the QRS complex. Ozawa\(^6\) pointed out that it was more difficult to detect late potentials in RBBB cases that in LBBB cases with ischemic heart disease. Moreover, Simson\(^7\) ascertained the presence of late potentials by the root mean square voltage of the last 40 msec of the filtered QRS complex. In BBB cases, QRS complexes have gentler slopes and are wider that those in narrow QRS cases. Therefore, the criteria for late potentials in narrow QRS complex cases cannot be used in BBB cases.

In applying frequency domain analysis to SAE, several problem areas have been identified, including distortion of higher frequency components in SAE, type of window, length and timing of the analyzed area, and recording site of the electrocardiogram\(^17-21\).

Fluctuation in the signal between the trigger point and the target signal attenuates higher frequency components according to the equation\(^17\):

\[
R(\sigma; f) = 100 \exp\left[-2(\pi \sigma f \times 10^{-3})^2\right]
\]

where \(R(\sigma; f)\): the percent magnitude of the averaged signal, \(\sigma\): standard deviation of fluctuation in msec, and \(f\): component frequency in Hz. If reference jitter is 0.5 msec, as previously reported,\(^7\) and target signals (late potentials) are fixed in every cardiac cycle, then the magnitude of the 370 Hz component after averaging is half of that of the original signal.

A window was applied to the data to reduce spectral leakage caused by the discontinuity of finite-time records selected from infinite-time signals. The simplest window function, i.e., a rectangular window, has the highest frequency resolution, but also the greatest side lobes (Gibb’s phenomenon). Other windows (Hanning, Hamming and Blackman-Harris windows) can be applied to reduce side lobes. In this study, a Blackman-Harris window was applied. While this type of window has a lower frequency resolution than a rectangular window, it also has greatly reduced side lobes\(^18\).

The length of the analyzed area is inversely proportional to the frequency resolution. Since the entire width of the QRS complex was examined in this study (81~231 msec), the frequency resolutions were 12.3~4.3 Hz. Differences in the frequency resolutions in each case produced spectrum curves with different shapes. Equal frequency resolutions would have been ideal, but trimming QRS complexes of different widths to fit a fixed data length did not coincide with our objectives in this study. Using areas or area ratios over a wider frequency range might decrease the effect caused by differences in the frequency resolution. Aliasing caused by sampling continuous signals may have appeared at frequencies greater than 2000 Hz since the sampling interval in this study was 0.25 msec. However, since we did not examine frequencies greater than 200 Hz, aliasing did not affect our results.

Many studies have used the terminal portion of the QRS complex and the ST segment as the region of interest\(^19,20,22\) In this study, we considered the entire width of the QRS complex to be the region of interest because fragmented activities recorded at the endo- and epicardium have been observed in the early portion of the QRS complex\(^23\).

Activation of normal heart muscles distal to the blocked site occurs later in cases with BBB than in cases with a narrow QRS complex. Therefore, fragmented activity may occur during an earlier portion of the QRS complex in cases with BBB than in cases with a narrow QRS complex. However, analyzing areas of different lengths could not be avoided in this study.

Shobuzawa et al\(^19\) reported in simulated electrocardiograms that the area between 25~100 Hz and its area ratio increased when the peak of the S wave was within the analyzed area. In this study, narrow QRS patients had larger area ratios in all 3 leads than LBBB patients (Table II). The steeper peaks observed in narrow QRS patients, as compared to those in LBBB patients are believed to have caused the larger area ratio. Steep peaks produce many higher frequency harmonics even if there is no fragmentation. Therefore, fragmentation in patients with a narrow QRS and s-VT might be concealed by these harmonics. In the LBBB group, the peaks were gentler, and thus generated fewer high frequency components. Therefore, differences in high frequency components are believed to be responsible for the finding that AR50, AR100, A50 and A100 were greater in patients with s-VT than in patients without s-VT. Patients in the NIB group had area ratios which fell between those of pa-
tients in the LBBB and narrow QRS groups. This fact, and the small number of s-VT cases in this group, may explain why the area ratios in NIB cases with s-VT were not significantly different from those in NIB cases without s-VT.

Regarding the electrocardiogram recording site, Soh\textsuperscript{21} noted a dip at 20–40 Hz in electrocardiograms using distant monopolar chest leads. Whether or not a similar phenomenon affects bipolar leads, which were used in this study, is unknown. However, the different degrees to which each frequency signal is conducted through the body may explain why the area ratios in the 3 leads varied. Nakai et al\textsuperscript{23} studied the spatial distribution of time domain late potentials by body surface mapping and reported that anterior OMI and inferior OMI showed different distributions. In this study, although the underlying diseases varied and the distribution of late potentials was unknown, the frequency contents from 50 to 100 Hz in the X lead and from 100 to 200 Hz in the Z lead were significantly different in LBBB patients with and without s-VT. As shown in Fig. 2, AR50 and AR100 tended to have large values in all leads in patients with s-VT. However, the differences between patients with and without s-VT in the Y lead were small because area ratios in patients without s-VT were also relatively large. Some peaks in the QRS complex in the Y lead of cases with LBBB were believed to have produced these large values in patients without s-VT. Further study in a larger number of cases with s-VT may help to explain the difference between patients with and without s-VT in AR50 and AR100 in the X and Z lead. Improvement of the recording site may also provide better separation in the frequency domain analysis.

Some studies\textsuperscript{25,26} have compared time domain analysis and frequency domain analysis in patients with VT. Worley et al\textsuperscript{25} studied patients with OMI using multivariable analysis, and reported that f-QRS was the only independent factor that separated patients with s-VT from those without s-VT. In their study, 44% of the cases with s-VT had BBB while only 7% of those without s-VT had BBB. As shown in our study, time domain analysis is even more useful in cases other than LBBB. Worley’s result is not believed to contradict our result. They also reported that the initial portion of the QRS complex contains many high frequency components caused by normally depolarizing myocardium, while the late portion of the QRS contains high frequency components in patients with OMI and s-VT. Based on this concept, a slight delay in the onset of the sampling interval, which would hopefully exclude high frequency components of normal myocardium and include abnormal fragmentation, might produce a clearer separation of patients with s-VT from those without s-VT. However, the timing of normal depolarization in each patient with BBB may differ and differences in the wave form cut by the sampling interval seem to have a large effect on the area ratio. Therefore, the selection of a suitable sampling interval appears to be difficult. Moreover, it is unclear whether Worley’s results hold true in cases where the underlying disease is other than OMI.

Machac et al\textsuperscript{26} performed a time domain analysis and a frequency domain analysis in the terminal 40 msec of the QRS complex and reported that patients with s-VT have long f-QRSs. Therefore, the terminal 40 msec of the QRS complex in these patients may consist of a great deal of abnormal fragmentation. On the other hand, patients without s-VT have short f-QRSs. Therefore, the terminal 40 msec of the QRS complex in these patients may consist primarily of normally depolarized action potentials. They obtained most of their information using the area from 20 to 50 Hz of the terminal 40 msec of the QRS complex. As they themselves noted, 20 to 50 Hz corresponds to a period of 50 to 20 msec, which does not correspond to the higher frequency oscillations seen in the filtered time domain display. In this study, we observed significant differences in the frequency content from 50 to 100 Hz in the X lead and from 100 to 200 Hz in the Z lead. These frequencies represent a period of 20 to 5 msec and seem to correspond to oscillations observed in the time domain analysis. In cases with LBBB, the time lag of each normally depolarized action potential makes the entire QRS complex wider and more gently-sloped. Since such a QRS complex has fewer high frequency components (Table II), the presence of abnormal fragmented activities in cases with s-VT.
should be detectable in a frequency domain analysis.

In this study, frequency content from 50 to 100 Hz in the X lead and from 100 to 200 Hz in the Z lead showed statistically significant differences between LBBB cases with or without s-VT. However, the differences were not believed to be sufficient for judging the risk of s-VT in each patient. As mentioned above, the selection of a more suitable area for analysis and a better recording site may provide more definitive results. However, as Machac et al.26 showed by simulation, while irregular frequencies can be easily detected in a time domain analysis, they have a very low magnitude in a frequency domain analysis. This phenomenon may be one of the limitations of frequency domain analysis.

In this study, we used s-VT as a marker of ventricular arrhythmias. Several other studies have used non-sustained VT or ventricular premature beats as marker.27,28 However, s-VT has a stronger relationship to SAE. Furthermore, the severity of ventricular arrhythmias as judged by these other markers can be influenced by the duration of Holter monitoring. Therefore we used the documentation of s-VT as an only marker of ventricular arrhythmias.

Frequency domain analysis may also be useful as a marker for reentrant s-VT in patients with RBBB. In our study, however, only one patient showed RBBB with s-VT, and none of the patients showed RBBB+LP or RBBB+LP and s-VT. Therefore, this study could not adequately address this subject.

CONCLUSIONS

We performed a frequency analysis of the entire QRS complex in signal averaged ECGs from patients with bundle branch block. AR50 or A50 in the X lead and AR100 or A100 in the Z lead were useful for distinguishing between LBBB patients with and without s-VT. Time domain analysis was not useful in cases of LBBB.

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