Comparison of the new acceleration spectrum analysis with other time- and frequency-domain analyses of the signal-averaged electrocardiogram

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Aim To compare four analysis techniques of the signal-averaged-electrocardiogram, including time-domain, spectral temporal mapping, spectral turbulence analysis and the new acceleration spectrum analysis.

Methods and Results We studied 634 subjects (77 with bundle branch block) divided into three groups. Group 1 comprised 117 post-myocardial infarction patients tested for inducibility of sustained ventricular tachycardia, and which was induced in 54 of them. Group 2 comprised 407 consecutive acute myocardial infarction survivors, followed for 1 year; 29 of them had suffered major arrhythmic events: 15 were cases of sustained ventricular tachycardia, three resuscitated ventricular fibrillation and 11 sudden cardiac death. Group 3 comprised 110 control subjects. The different analysis techniques were compared by their likelihood ratio for the prediction of ventricular tachycardia inducibility (Group 1) or major arrhythmic events (Group 2). The likelihood ratios of spectral-turbulence-analysis, acceleration spectrum analysis, spectral temporal mapping and time-domain were 8·0, 3·3, 1·7, 1·3 in Group 1, and 3·8, 2·1, 1·5, 2·6, in Group 2, while the corresponding false-positive rates in Group 3 (control) were 0·9%, 10·0%, 4·5%, and 3·6%, respectively.

Conclusion Spectral turbulence analysis was the most accurate technique for the prediction of either ventricular tachycardia inducibility or major arrhythmic events after myocardial infarction. It also showed the highest specificity among control subjects.

Key Words: Signal averaged ECG, late potentials, frequency-domain analysis, acceleration spectrum analysis, post-myocardial infarction, ventricular tachycardia.

Introduction

Late potentials detected on the signal-averaged ECG, are non-invasive markers for major arrhythmic events, including sustained ventricular tachycardia, ventricular fibrillation and sudden cardiac death[15–41]. Late potentials correspond to delayed and fragmented signals observed in electrocardiograms registered in post-infarction animal models[5–8], and in patients with ventricular tachycardia[9]. Initial studies used the time-domain analysis exclusively[10,11]. While this is still the most frequently used technique, and has proven highly reproducible[12–14], it nonetheless suffers from significant shortcomings: high-pass filters are required, discrimination between noise and late potentials may be difficult, and its results in patients with bundle branch block are uncertain[15–17]. To overcome these limitations, several frequency-domain techniques have been developed in recent years[18–24]. The first frequency-domain method was the area ratio of the terminal QRS described by Cain et al.[18]; however, the reproducibility of this method is very weak[25]; more recently, Cain et al.[19] proposed another method, spectral and temporal analysis of the entire cardiac cycle. Finally, there are three other frequency-domain techniques commercially available, including spectral temporal mapping[20–21] (with a poor reproducibility, which limits its clinical application[26,27]), spectral turbulence analysis[24] and the new acceleration spectrum analysis[28]. The aim of this study is to compare the four analysis techniques of the signal-averaged electrocardiogram, the conventional time-domain and the three frequency-domain methods, in a sizable group of patients.
Methods

Subject population

This prospective study comprised 634 subjects, divided into three groups (Table 1): Group 1 consisted of 117 remote myocardial infarction patients tested for inducibility of ventricular tachycardia. Group 2 included 407 consecutive patients with acute myocardial infarction who had survived the first week after admission. Group 3 was comprised of 110 healthy volunteers. Exclusion criteria were: (1) atrial fibrillation; (2) noise level >0.3 μV; (3) pacemaker patients; (4) pre-excitation syndromes; and (5) refusal or inability to participate in the protocol. For purposes of comparing analysis techniques, patients with bundle branch block and QRS duration >120 ms, were not excluded. These conduction defects were present in 39 Group 1 patients and 38 Group 2 patients (Table 1).

Left ventricular ejection fraction was assessed by 2D-echocardiography in all patients.

The signal-averaged ECG recording was prospectively recorded the day before programmed ventricular stimulation in Group 1 patients, and during the second week (10.1 ± 2.6 days) post-infarction in Group 2 patients, using the ART-1200 EPX unit. The procedure used for signal-averaging was conventional. At least 200 sinus beats (397 ± 89 beats) were averaged during each recording, until a noise level ≤ 0.3 μV was achieved (mean noise level = 0.2 ± 0.1 μV). The recordings were analysed, using the four methods described below, by different physicians to those who performed the programmed stimulation (Group 1) or clinical follow-up (Group 2), who were blinded to signal-averaging interpretation.

The three classical parameters of time-domain analysis were determined according to the methods of Simson, using a high-pass cut-off frequency of 40 Hz. Time-domain analysis was considered positive for late potentials when at least two parameters reached the standard criteria of abnormality. Patients with conduction defects and QRS duration >120 ms were considered 'not analysable' by this technique.

Spectral temporal mapping was performed according to the methods of Haberl et al., using the FFT-Plus software. The test was considered abnormal if the normality factor was <30% in any of the three leads X, Y, or Z.

The four turbulence parameters of spectral turbulence analysis were calculated according to the methods, definitions, and cut-off values published by Kelen et al. Each recording was scored for spectral abnormality, from 0 (no abnormal parameters) to 4 (all abnormal parameters), and it was considered abnormal when the score was 3 or 4.

Acceleration spectrum analysis was performed with the ART-IntraSpect 1.0 software, according to the method described by Chan. The Blackman-Harris windowed fast Fourier transform of the second derivative signal is calculated for 250 ms of the X, Y and Z leads, commencing 10 ms prior to QRS onset. The increase or decrease in the presence of spectral peaks in the 50 to 300 Hz range is quantified using the spectral change index. This index is derived from calculating the sum of absolute gradients in the acceleration spectrum within the specified band-width. High values of this index should identify electrical fragmentation caused by damaged myocardium (Figs 1 and 2). Following the recommendations of Chan, the maximum of the three values (in X, Y and Z leads) was used as the diagnostic index, and was considered abnormal if ≥ 20.

Programmed ventricular stimulation was performed in all Group 1 patients, with a conventional protocol that consisted of up to three extrastimuli delivered at two right ventricular sites during three ventricular pacing drives. Inducible sustained monomorphic ventricular tachycardia was defined as a repetitive ventricular response (cycle length 200 to 500 ms), with a uniform QRS configuration, lasting ≥ 30 s or requiring termination due to haemodynamic compromise.

Follow-up

All Group 2 patients were followed for 1 year after myocardial infarction. The result of signal averaging did not influence the treatment. Three types of arrhythmic events were defined prospectively as study endpoints, for Group 2 patients: (1) sudden cardiac death as defined by the Cardiac Arrhythmia Pilot Study, as death within 1 h of the onset of new symptoms; the definition also included instantaneous death, death during sleep, as well as unexpected death that occurred within 1 h after the time the patient was last seen alive; (2) sustained ventricular tachycardia, defined as spontaneous ECG-documented ventricular tachycardia, with a rate ≥ 120 beats. min⁻¹ and lasting ≥ 30 s; and (3) documented ventricular fibrillation, requiring defibrillation, not associated with acute myocardial infarction.

Statistical analysis

Continuous variables were expressed as mean ± SD. Comparisons between groups were performed using the Student t-test for normally distributed continuous variables, the Mann-Whitney U test for non-parametric continuous variables and chi-square analysis or Fisher exact test for categorical variables. The type 1 error was fixed at 0.05. The sensitivity, specificity, positive, negative and total predictive values of each test was computed, according to conventional methods. In order to compare the discrimination power of the four techniques between subjects with/without arrhythmic end points, we used the likelihood ratio, computed as: Sensitivity/(1-Specificity). We also calculated the 95% confidence limits for the likelihood ratio, and the
<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
<th></th>
<th>Group 3</th>
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<tr>
<td></td>
<td>All PVS patients</td>
<td>Sust-VT inducible</td>
<td>Non-inducible</td>
<td>P-value (inducib. vs non-inducib.)</td>
<td>All AMI patients</td>
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<tr>
<td>n</td>
<td>117</td>
<td>54</td>
<td>63</td>
<td>0.04554</td>
<td>407</td>
</tr>
<tr>
<td>Age (years)</td>
<td>60.2 ± 10.1</td>
<td>62.1 ± 8.2</td>
<td>59.5 ± 11.2</td>
<td>ns</td>
<td>61.7 ± 11.9</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>89/28</td>
<td>45/9</td>
<td>44/19</td>
<td>ns</td>
<td>32/84</td>
</tr>
<tr>
<td>Anterior MI</td>
<td>63 (53.8%)</td>
<td>28 (51.9%)</td>
<td>35 (55.6%)</td>
<td>ns</td>
<td>183 (45.0%)</td>
</tr>
<tr>
<td>Inferior MI</td>
<td>54 (46.2%)</td>
<td>26 (48.1%)</td>
<td>28 (44.4%)</td>
<td>ns</td>
<td>192 (47.2%)</td>
</tr>
<tr>
<td>Non Q MI</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>ns</td>
<td>32 (7.9%)</td>
</tr>
<tr>
<td>EF &lt;40%</td>
<td>44 (37.6%)</td>
<td>32 (59.3%)</td>
<td>12 (19.0%)</td>
<td>&lt;0.00001</td>
<td>113 (27.8%)</td>
</tr>
<tr>
<td>BBB</td>
<td>39 (33.3%)</td>
<td>27 (50.0%)</td>
<td>12 (19.0%)</td>
<td>0.00082</td>
<td>38 (9.3%)</td>
</tr>
<tr>
<td>TD+</td>
<td>29 (24.8%)</td>
<td>22 (40.7%)</td>
<td>7 (11.1%)</td>
<td>0.0049</td>
<td>91 (22.4%)</td>
</tr>
<tr>
<td>STM+</td>
<td>49 (41.9%)</td>
<td>29 (53.7%)</td>
<td>20 (31.7%)</td>
<td>0.02696</td>
<td>149 (36.6%)</td>
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<tr>
<td>STA+</td>
<td>47 (40.2%)</td>
<td>41 (75.9%)</td>
<td>6 (9.5%)</td>
<td>&lt;0.00001</td>
<td>102 (25.1%)</td>
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<tr>
<td>ASA+</td>
<td>61 (52.1%)</td>
<td>45 (83.3%)</td>
<td>16 (25.4%)</td>
<td>&lt;0.00001</td>
<td>153 (37.0%)</td>
</tr>
</tbody>
</table>

AMI = acute myocardial infarction; ASA = acceleration spectrum analysis; BBB = bundle branch block; EF <40% = % of patients with ejection fraction <40%; MAE = major arrhythmic events; MI = myocardial infarction; PVS = programmed ventricular stimulation; STA = spectral turbulence analysis; STM = spectral temporal mapping; Sust-VT = Sustained ventricular tachycardia; TD = time-Domain analysis.
Results

Clinical characteristics

Group 1
Sustained ventricular tachycardia could be induced in 54 patients, while the remaining 63 subjects were considered non-inducible (Table 1). Inducible patients were older (62.1 ± 8.2 vs 58.5 ± 11.2 years, P < 0.05), and had a higher proportion of subjects with left ventricular dysfunction (59.3% vs 19.0%, P < 0.0001) or bundle branch block (50.0% vs 19.0%, P = 0.01187). No statistically significant differences were found in terms of age, sex, or infarction site (Table 1).

Group 2
During the follow-up period of 1 year post-infarction, major arrhythmic events occurred in 29 patients: 15 had sustained ventricular tachycardia, three resuscitated ventricular fibrillation and 11 sudden cardiac death (three of them with previous documented ventricular fibrillation). The clinical characteristics of the patients, with and without major arrhythmic events, are also displayed in Table 1. In patients with arrhythmic events subjects had higher rates of left ventricular dysfunction (72.4% vs 24.3%, P < 0.00001) and bundle branch block (24.1 vs 8.2%, P = 0.01187). No statistically significant differences were found in terms of age, sex, or infarction site (Table 1).

Group 3 (110 control subjects)
All subjects in this group were free of heart disease, and none of them had bundle branch block or left ventricular dysfunction (Table 1).

Signal-averaged ECG results

Group 1
Comprehensive statistics about the prognostic value of each technique, for the prediction of ventricular tachycardia inducibility, are displayed in Table 2, and only the most relevant data will be repeated here. In the whole group of 117 patients, time-domain had the lowest likelihood ratio (1.3), due to the inclusion of 39 patients with bundle branch block. In the subgroup of 78 patients without conduction defects, the likelihood ratio of time-domain was raised to 5.9, and the
sensitivity, specificity, negative and total predictive values were between 80% and 90%. Spectral temporal mapping showed likelihood ratios of 1·7, 1·0 and 2·0, and low sensitivity values of 53·7%, 51·9% and 55·6%, in the whole group and in the subgroups of patients with and without bundle branch block, respectively. Spectral turbulence analysis showed the highest specificity and the highest likelihood ratio in all three groups of patients: 8·0 (whole group), 2·7 (with bundle branch block), and 16·2 (without bundle branch block); however, in this latter group, the sensitivity of spectral turbulence analysis (63·0%) was much lower than that of time-domain (81·5%). The likelihood ratio of the acceleration spectrum analysis was 3·3, 1·5 and 4·2 in the entire group, and in the subgroups of patients with and without conduction defects, respectively. Acceleration spectrum analysis was the method with the highest sensitivity in all Group 1 subjects (83·3%), and in the subgroup of patients with bundle branch block (100·0%); however, in this latter subgroup, the specificity of the acceleration spectrum analysis was only 33·3%. In summary, comparing the four techniques, the best likelihood ratio was obtained with spectral turbulence analysis, in all three groups of patients with and/or without bundle branch block.

**Group 2**

The overall predictive characteristics of each technique for major arrhythmic events are shown in Table 3. The most remarkable data could be summarized as follows: in the whole group of 407 acute-myocardial infarction patients, the likelihood ratio of time-domain was 2·6, increasing to 4·4 in the subgroup of 369 patients without bundle branch block. In these patients without conduction delays, time-domain showed sensitivity, specificity and a total predictive value between 80% and 90% (as in Group 1). Spectral temporal mapping offered the lowest likelihood ratio: 1·5 (whole group), 0·6 (with bundle branch block), and 1·7 (without bundle branch block); the sensitivity of spectral temporal mapping was also the lowest in the whole group (51·7%), as well as in the subgroups of patients with (42·9%) or without bundle branch block (54·5%). Spectral turbulence analysis showed the highest specificity in all patient subgroups. This technique presented likelihood ratios of 3·8 (whole group), and 4·3 (without bundle branch block), with sensitivity, specificity and a total predictive value very close to 80% in both groups. In patients with conduction defects, the sensitivity of spectral turbulence analysis was 85·7%, but the specificity dropped to 45·2%, and the likelihood ratio to 1·6. Acceleration spectrum analysis
<table>
<thead>
<tr>
<th>Group of patients</th>
<th>n=</th>
<th>Method of SAECG</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive Predictive value (%)</th>
<th>Negative Predictive value (%)</th>
<th>Total Predictive value (%)</th>
<th>Likelihood ratio</th>
<th>95% CL for LR</th>
<th>P-value</th>
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<tr>
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<td>TD</td>
<td>40.7</td>
<td>69.2</td>
<td>78.2</td>
<td>62.7</td>
<td>94.3</td>
<td>66.7</td>
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<tr>
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<td>STM</td>
<td>53.7</td>
<td>68.3</td>
<td>59.5</td>
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<td>1.1–2.7</td>
<td>0.02696</td>
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<tr>
<td>All 117</td>
<td>STA</td>
<td>75.9</td>
<td>90.5</td>
<td>87.2</td>
<td>81.4</td>
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<td>8.0</td>
<td>4.5–14.1</td>
<td>&lt;0.00001</td>
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<tr>
<td>All 117</td>
<td>BBB</td>
<td>78.0</td>
<td>96.1</td>
<td>89.5</td>
<td>83.1</td>
<td>84.6</td>
<td>16.2</td>
<td>6.0–43.7</td>
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<tr>
<td>All 117</td>
<td>ASA</td>
<td>66.7</td>
<td>84.3</td>
<td>69.2</td>
<td>82.7</td>
<td>78.2</td>
<td>4.2</td>
<td>0.8–1.4</td>
<td>&lt;0.00001</td>
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</table>

ASA = acceleration spectrum analysis; BBB = conduction defects with a right or left bundle branch block pattern; CL = confidence limits; LR = likelihood ratio; Not A. = not analysable; SAECG = signal-averaged electrocardiogram; STM = spectral temporal mapping; TD = temporal domain mapping; TIA = spectral turbulence analysis; VT = ventricular tachycardia.
<table>
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<tr>
<th>Group of patients</th>
<th>n=</th>
<th>Method of SAECG</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive Predictive value (%)</th>
<th>Negative Predictive value (%)</th>
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<th>Likelihood ratio</th>
<th>95% CL for LR</th>
<th>P-value</th>
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<tbody>
<tr>
<td>All</td>
<td>407</td>
<td>TD</td>
<td>69.0</td>
<td>73.0</td>
<td>22.0</td>
<td>99.3</td>
<td>72.7</td>
<td>26</td>
<td>2.0-3.3</td>
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<tr>
<td>All</td>
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<td>79.1</td>
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<td>79.1</td>
<td>3.8</td>
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<tr>
<td>With BBB</td>
<td>38</td>
<td>TD</td>
<td>Not A.</td>
<td>Not A.</td>
<td>Not A.</td>
<td>Not A.</td>
<td>Not A.</td>
<td>1.4</td>
<td>1.0-2.7</td>
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<td>0</td>
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<td>STA</td>
<td>85.7</td>
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<td>Without BBB</td>
<td>369</td>
<td>TD</td>
<td>90.9</td>
<td>79.5</td>
<td>22.0</td>
<td>99.3</td>
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<td>1.7</td>
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<td>Without BBB</td>
<td>369</td>
<td>ASA</td>
<td>77.3</td>
<td>82.1</td>
<td>21.5</td>
<td>98.3</td>
<td>81.8</td>
<td>4.3</td>
<td>2.7-6.8</td>
<td>&lt;0.00001</td>
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</table>

ASA = acceleration spectrum analysis; BBB = conduction defects with a right or left bundle branch block pattern; CL = confidence limits; LR = likelihood ratio; MI = myocardial infarction; Not A. = not analysable; SAECG = signal-averaged electrocardiogram; STA = spectral turbulence analysis; STM = spectral temporal mapping; TD = time-Domain analysis.
had a likelihood ratio of 2.1 in the entire group, and also in the subgroup without bundle branch block, with sensitivity, specificity and a total predictive value ranging from 63.6% to 72.4%. Among patients with bundle branch block, the sensitivity of the acceleration spectrum analysis was again 100.0%, but with an extremely low specificity of 12.9%, and a likelihood ratio of 1.1. In summary, comparing the four techniques, the best likelihood ratio was obtained with spectral turbulence analysis, except in the subgroup of patients without bundle branch block, which showed a slightly higher likelihood ratio with time-domain.

Group 3 (control)
The number of false-positive results with time-domain, spectral temporal mapping, spectral turbulence analysis and acceleration spectrum analysis was 4 (3.6%), 5 (4.5%), 1 (0.9%) and 11 (10.0%), and the corresponding specificity of each technique among control subjects was 96.4%, 95.5%, 99.1% and 90.0%, respectively (Table 1).

Discussion

Method used to compare the four signal-averaging analysis techniques

The ideal signal-averaging analysis technique should have high sensitivity and specificity. The likelihood ratio integrates both concepts in a single measurement, and thus facilitates comparisons between different techniques. We did not use the odds ratio, because it was not computable for time-domain, due to non-analyzable results from patients with bundle branch block. On the other hand, the likelihood ratio is less influenced by pre-test risk than the odds ratio[32], and can be used in groups with a very different prevalence of arrhythmic end-points, as is the case with Groups 1 and 2 of the present study.

Comparison with previous studies

Studies on ventricular tachycardia-inducibility
Kelen et al.[24] found that spectral turbulence analysis had a higher predictive accuracy than time-domain for ventricular tachycardia-inducibility. We came to the same conclusion, based on our results in Group 1 (Table 2). Flowers et al.[35] also found that the predictive accuracy of spectral turbulence analysis was superior to time-domain for sustained ventricular tachycardia in post-infarction patients with conduction defects; their criteria for an abnormal time-domain result were the same for all kinds of conduction defects (duration of terminal low-amplitude signals >38 ms or root mean square voltage of the last 40 ms <20 μV). We agree with Flowers et al.[35], that spectral turbulence analysis is clearly superior to time-domain for patients with conduction defects; however, we think, as other authors[16,36] do, that there are no established abnormality time-domain criteria for patients with conduction defects, especially right bundle branch block. Modified criteria have been proposed for left bundle branch block patients with the 25 Hz filter[16,36].

In our study, we used a different filter (40 Hz) and there were too few patients with left bundle branch block in each group. For these reasons, we preferred to codify all cases with bundle branch block as non-analyzable by time-domain. However, we did not exclude these patients from our series, which would have favoured time-domain when this analysis was compared with frequency-domain techniques. Mittleman et al.[37] found that spectral temporal mapping was clearly inferior to time-domain for the discrimination of ventricular tachycardia inducibility in 50 patients (10 having bundle branch block). However, Haberl et al.[20,21] stated that spectral temporal mapping provided a better identification of patients with spontaneous or induced ventricular tachycardia, than time-domain. In our series, the predictive characteristics of spectral temporal mapping were only slightly better than those of time-domain for all of Group 1, of which a third of patients had bundle branch block; excluding these patients, spectral temporal mapping was clearly inferior to time-domain (Table 2). Finally, there are still no other studies comparing acceleration spectrum analysis with any other signal-averaging technique. In a recent paper by Chan[28], where this new method is described, its sensitivity, specificity, positive and negative predictive values, in a group of 50 post-infarction patients (25 of them inducible to ventricular tachycardia), were: 72%, 84%, 82%, and 75%, respectively. Those figures fall within our corresponding results in the whole of Group 1, and in its subgroup of patients without bundle branch block (Table 2), and could be explained by a lower rate of patients with conduction defects, which is not defined in that study.

Studies on the prediction of major arrhythmic events after acute-myocardial infarction
Most of these studies[1,4,38–41] have used the time-domain technique only and have excluded patients with conduction defects. In these studies, the sensitivity and specificity ranged between 63%–93% and 65%–81%, respectively, with a uniformly high negative predictive value (96%–99%) and a very low positive predictive value (10%–27%). As shown in Table 3, our time-domain results in Group 2 fall between the ranges of the previously mentioned studies; obviously, the sensitivity and specificity were much lower in the overall group 2 (69.0% and 73.0%, respectively), than in the subgroup of patients without bundle branch block (90.0% and 79.5%, respectively).

Findings of the study

For the prediction of ventricular tachycardia inducibility, spectral turbulence analysis was the most accurate method, in all patients’ subgroups (with and/or without
bundle branch block). The new acceleration spectrum analysis had a higher sensitivity but a lower specificity than the spectral turbulence analysis which showed a better sensitivity–specificity balance (estimated by the likelihood ratio).

For the prediction of major arrhythmic events, post-infarction, spectral turbulence analysis showed the best predictive statistics, except in the subgroup of patients without conduction defects, where time-domain was the most accurate analysis. In all the subgroups of patients, the predictive characteristics of spectral temporal mapping were worse than any other technique. Among control subjects, spectral turbulence analysis was again the most specific technique (99.1%), while the new acceleration spectrum analysis had the lowest specificity (90.0%). This low specificity is the main pitfall of this new analysis: It had the highest number of positive results in all three groups, including the control group. Therefore, if this method could be modified to obtain more specific results, or if its criteria for abnormality could be readjusted, the usefulness of the technique could increase.

Value and limitations of the study
To our knowledge, this is the first study comparing this new acceleration spectrum analysis, not only with the conventional time-domain method, but also with other currently used frequency-domain techniques. This comparison has been carried out on a substantial number of subjects (n=634), in order to obtain solid conclusions. However, the number of patients with bundle branch block was still low (n=77), and that could represent the main limitation of the present study. Nevertheless, the proportions between the likelihood ratio of the three frequency-domain techniques in patients with bundle branch block were very similar in both Groups 1 and 2: spectral turbulence analysis had the highest likelihood ratio, followed by acceleration spectrum analysis and lastly by spectral temporal mapping. The agreement between our results in both groups does reinforce their validity, despite the limited number of patients with conduction defects.

Conclusions
For the prediction of ventricular tachycardia inducibility, spectral turbulence analysis was the most accurate method, in all patients’ subgroups (with and/or without bundle branch block). For risk stratification after acute myocardial infarction, spectral turbulence analysis showed also the best predictive statistics, except in the subgroup of patients without conduction defects, where time-domain were slightly better. False-positive rates in control subjects was also minimized with spectral turbulence analysis.

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References


