Correlation of peak amplitude ECG between leads
Based on the condition of the heart

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Abstract: Non-invasive cardiac examination in standard clinic is still using 12-lead electrocardiograph. The results of the examination are presented on ECG paper or on the monitor screen. A normal electrocardiogram on one lead is not necessarily normal for the other lead, because each lead represents a certain part of the heart so that one by one is necessary. This examination takes time so that it can increase the stage of the disease if the patient turns out to be in an abnormal condition. This paper aims to correlate the peak amplitude of each lead to normal and abnormal heart conditions. If it is known that the peak amplitude is correlated between the leads, the other leads do not need to be checked, so that the diagnosis time will be obtained faster. Cardiac biosignal data that has been sampled with a frequency of 250 Hz is a discrete signal that can be stored digitally in a database. 10 samples of normal conditions and 10 samples of abnormal conditions were analyzed using Saphiro-Wilk so that the data were normally distributed. Spearman correlation analysis is used to get peak amplitude correlation between leads. The results showed that for abnormal conditions with a significance of 0.01 there was a correlation between the peak P lead I with leads III and V5, while for normal conditions there was a correlation between peak P lead I and leads V3 and V4. In abnormal conditions there is a correlation between peak R lead II and V6, while in normal conditions there is a correlation between peak R lead I and aVF.

Keywords: correlation, lead, peak amplitude, heart condition, ECG

1. INTRODUCTION:

Non-invasive cardiac examination by standard clinic generally uses a 12-lead electrocardiograph, namely leads I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5 and V6 [1]. The leads represent an electrocardiogram wave divided into 6 leads for the vertical plane (Extremity) and 6 leads for the horizontal plane (Precordial, Chest) [2]. The lead-lead is attached to the surface of the body as shown in Figure 1. The part of the heart examined is shown in Figure 2 and the morphology of the electrical voltage signal versus time of the heart electrical is shown in Figure 3.
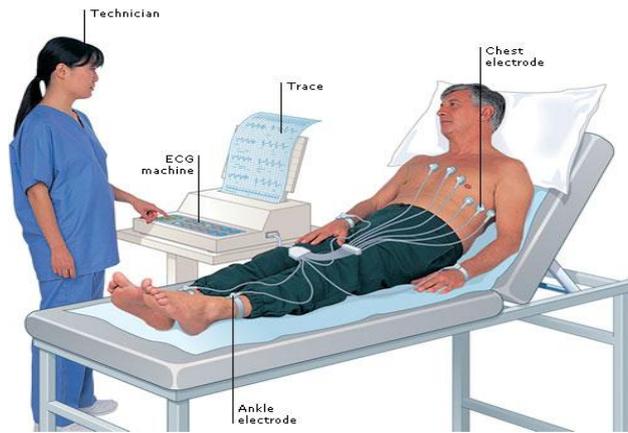
Figure 1. Location of placement of leads on body surface

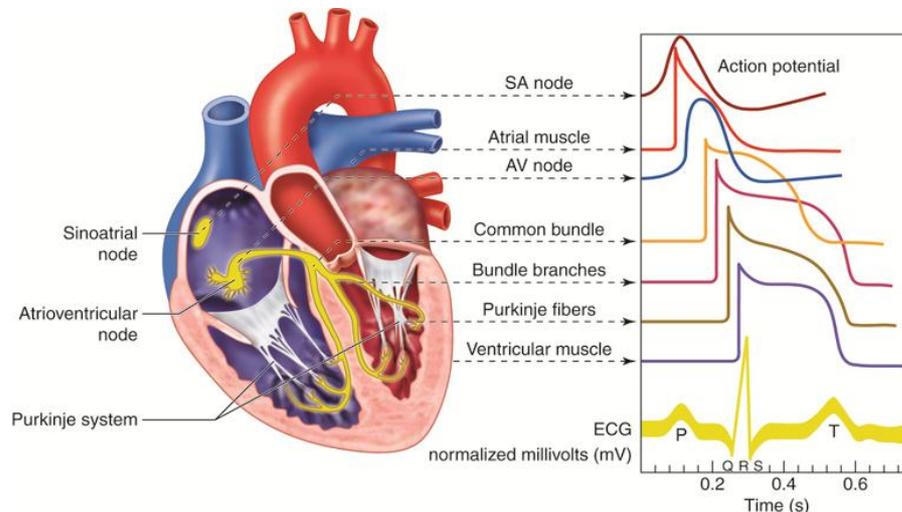| I Lateral	aVR	V1 Septal	V4 Anterior
II Inferior	aVL Lateral	V2 Septal	V5 Lateral
III Inferior	aVF Inferior	V3 Anterior	V6 Lateral

Figure 2. The part of the heart that is examined

Figure 3. Morphology of the voltage wave against time of the heart electricity

Presentation of electrocardiogram on ecg paper or monitor screen is a graphic display obtained from digital data of voltage amplitude as a function of time. Digital data were obtained from the results of cardiac biosignal sampling at certain frequencies using the Analog to Digital Converter (ADC) [3]. Digital data of examination results that are often used by researchers generally are published by Physionet (Massachusetts Institute of Technology-Boston's Beth Israel Hospital, MIT-BIH). Several authors who have examined the correlation associated with the electrocardiogram are [4], [5], [6], [7], [8], [9], [10], [11]. It appears from these references that no one has used 12-lead digital data for their research. This can be due to the limited digital data published by physionet and the difficulty of obtaining digital data from standard clinic cardiac examinations.

This study aims to correlate the digital peak amplitude value on each lead. Data from standard clinic examination for normal and abnormal heart conditions were used as the study sample. It is known that the peak amplitude is correlated between the leads, so that the other leads do not require examination, so that the diagnosis time will be obtained faster.

2. MATERIAL AND METHODS:

Populasi dan Sampel

The object data collection was carried out by standard clinical examinations on 30 people in the Electronica medic laboratory, Faculty of Engineering, Widyagama University, Malang on Friday, August 5, 2019. The criteria for the proposed object were adult men and women (18-55 years), in good health (not sick), married, not disabled and willing to be the object of research (filling in a willingness statement).

Number and Sampling Method

Based on the results of the examination of the patient's object and a letter of willingness to examine, 10 patients with normal conditions and 10 patients with abnormal conditions were selected. In collecting this data, patients were examined by clinical standards using a Discrete Electrocardiograph (ECGd) device at a sampling frequency of 250 Hz for 10 seconds under the supervision of the Cardiovascular Care Unit (CVCU) officer at the Dr. Saiful Anwar Malang Hospital. The variable in this study is time as an independent variable, while the dependent variable is the amplitude of peak P, peak Q, peak R, peak S, peak T and HR. The time variable is expressed as the number of the sampling sequence (N, integer) at a frequency of 250 Hz for which the data scale is the interval scale.

Data Processing and Analysis

The variables in this study were amplitude of peak P, peak Q, peak S, peak R, peak T and HR contained in discrete data records of patient examination results using 12-lead ECGd [12]. The sample used in this study was selected for 2 conditions, namely normal conditions and abnormal conditions. Normal and abnormal conditions correspond to [13].

The duration of the examination is carried out for 10 seconds in a relaxed state. Data normality test used Kolmogorov-Smirnov and correlation analysis of peak amplitude PQRST and HR for each cycle on each lead in 6 cycles using Spearman Correlation.

3. RESULT AND DISCUSSION

In this study, one of the processes to obtain peak amplitude and heart rate (HR) data is shown in Figure 4 for normal patients and Figure 5 for abnormal patient conditions. [14], [15]. Table 1 shows the peak amplitude PQRST results in cycle 1 between normal patient leads and table 2 shows the peak amplitude PQRST results in cycle 1 between patient leads with abnormal conditions. [16],[17].
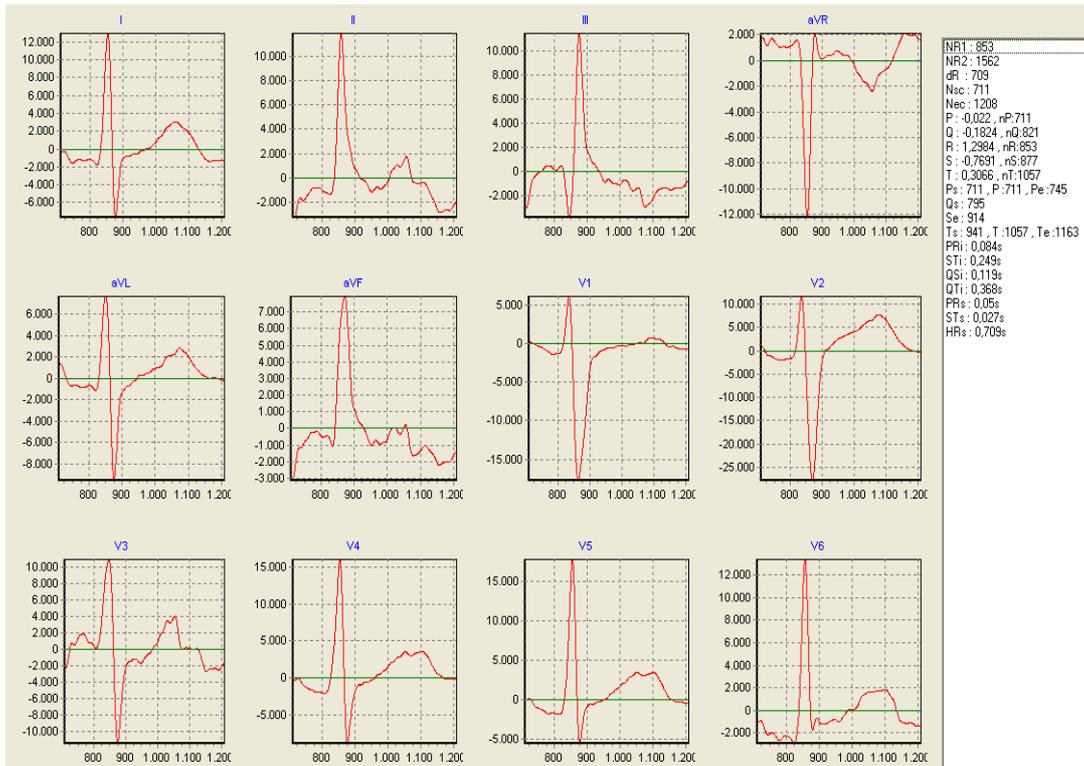
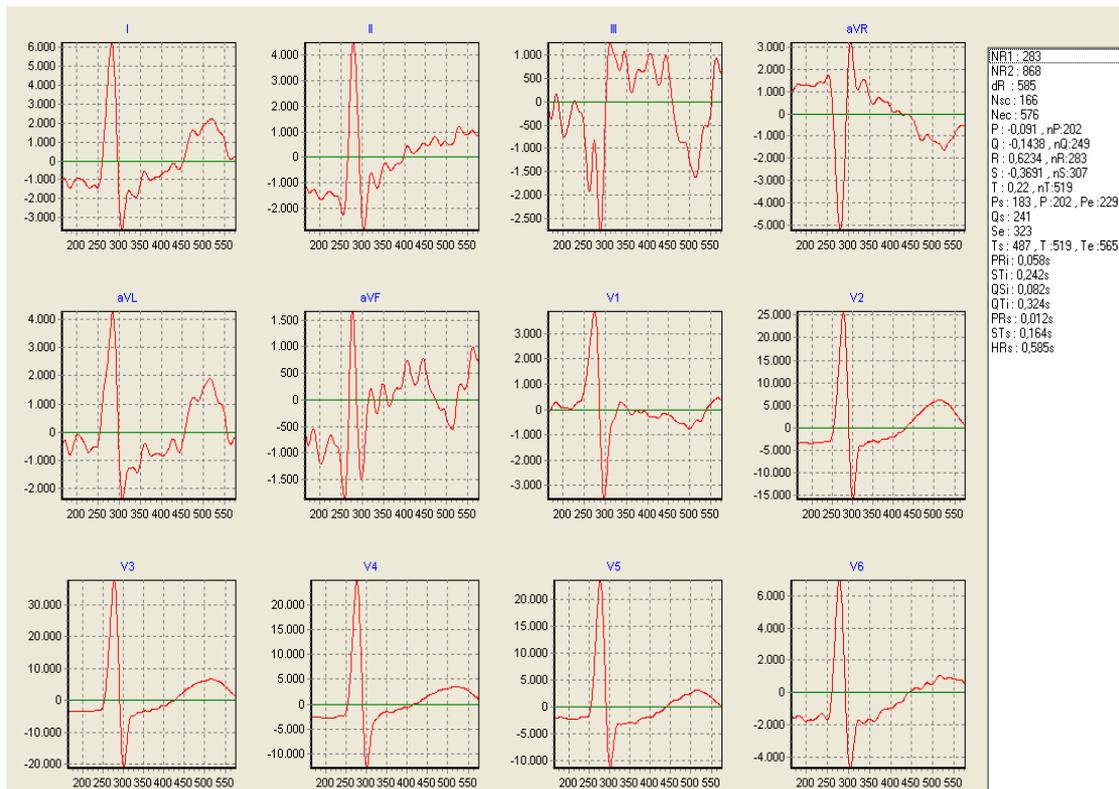Figure 4. Cardiogram 12-lead cycle 1 patient sample 2 Normal condition

Figure 5. Cycle 12-lead cardiogram of 1 patient in a sample of 8 abnormal conditions

Table 1. PQRST results in cycle 1 among Lead Patients in normal condition

Sample	Peak	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
1	P	0.046	-0.035	-0.080	-0.005	0.063	-0.058	-0.245	-0.255	-0.208	-0.116	-0.009	0.056
1	Q	-0.202	-0.315	-0.113	0.259	-0.045	-0.214	0.046	-0.049	-0.143	-0.108	-0.065	-0.072
1	R	1.907	1.327	-0.715	-1.550	1.311	0.238	-1.504	-1.165	1.151	2.969	0.283	2.050
1	S	-0.749	-0.702	0.047	0.726	-0.398	-0.328	-0.533	-1.577	-1.678	-1.360	-0.827	-0.500
1	T	1.098	0.119	-0.672	-1.663	1.335	0.328	-1.402	-0.994	1.299	2.997	2.677	1.917
1	HRs	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824
2	P	0.016	0.051	0.035	-0.033	-0.010	0.043	-0.013	-0.150	-0.175	-0.168	-0.172	-0.151
2	Q	-0.160	-0.110	0.050	0.135	-0.105	-0.030	-0.062	-0.255	-0.273	-0.247	-0.237	-0.215
2	R	1.568	0.992	-0.577	-1.280	1.072	0.208	-0.395	0.768	1.742	1.838	2.591	2.720
2	S	-0.310	-0.547	-0.237	0.428	-0.037	-0.392	-0.776	-1.257	-0.741	-0.650	-0.393	-0.311
2	T	0.500	0.478	-0.021	-0.489	0.260	0.229	0.032	0.818	0.788	0.606	0.748	0.910
2	HRs	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840	0.840
3	P	0.109	-0.123	-0.232	0.007	0.171	-0.177	0.042	-0.072	-0.002	-0.111	0.066	-0.094
3	Q	-0.130	-0.396	-0.266	0.263	0.068	-0.331	0.037	-0.178	-0.182	-0.302	-0.112	-0.224
3	R	0.293	1.570	1.278	-0.932	-0.492	0.142	-0.502	-1.812	1.769	3.316	2.730	0.162
3	S	-0.276	-0.677	-0.401	0.477	0.063	-0.539	-1.856	-2.170	-2.129	-1.500	-1.057	-0.976
3	T	0.395	0.451	0.056	-0.423	0.170	0.254	0.960	1.959	2.018	1.470	3.920	1.077
3	HRs	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824
4	P	0.058	0.144	0.086	-0.101	-0.014	0.115	-0.204	-0.090	-0.033	-0.086	-0.055	-0.046
4	Q	-0.143	-0.089	0.053	0.116	-0.098	-0.018	-0.057	-0.052	-0.113	-0.198	-0.163	-0.208
4	R	1.778	1.174	-0.604	-1.476	1.191	0.285	-1.532	-1.062	0.183	1.496	1.961	0.136
4	S	-0.223	-0.142	0.081	0.182	-0.152	-0.030	-0.399	-0.570	-0.838	-0.631	-0.534	-0.313
4	T	0.487	0.411	-0.075	-0.449	0.281	0.168	-0.376	0.130	0.324	0.454	0.476	0.302
4	HRs	0.924	0.924	0.924	0.924	0.924	0.924	0.924	0.924	0.924	0.924	0.924	0.924
5	P	0.015	-0.188	-0.204	0.086	0.110	-0.196	0.234	0.109	-0.107	-0.044	-0.004	0.076
5	Q	-0.220	-0.222	-0.002	0.221	-0.109	-0.112	0.465	0.444	0.053	-0.104	-0.146	-0.107
5	R	1.280	0.879	-0.401	-1.080	0.840	0.240	-0.515	-0.322	0.895	1.423	1.575	1.267
5	S	-0.745	0.339	1.084	0.203	-0.915	0.711	-1.045	-2.538	-1.239	-0.835	-0.507	0.059
5	T	0.356	0.321	-0.035	-0.338	0.195	0.143	0.586	0.923	0.601	0.372	0.350	0.351
5	HRs	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
6	P	0.019	0.152	0.133	-0.085	-0.057	0.143	-0.062	-0.284	-0.138	0.014	-0.109	-0.216
6	Q	-0.096	-0.116	-0.020	0.106	-0.038	-0.068	0.044	-0.209	-0.250	-0.033	-0.191	-0.287
6	R	0.106	1.601	0.542	-1.330	0.258	1.072	-1.516	-2.725	-1.483	1.166	2.213	1.636
6	S	-0.647	0.476	1.123	0.086	-0.885	0.799	-1.872	-3.541	-3.472	-2.503	-1.754	-0.896
6	T	0.443	0.318	-0.125	-0.380	0.284	0.097	-0.187	0.538	0.371	0.957	0.653	0.221
6	HRs	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780
7	P	-0.147	0.008	0.155	0.070	-0.151	0.081	0.030	-0.475	-0.143	-0.280	-0.540	-0.262
7	Q	-0.264	-0.261	0.003	0.263	-0.134	-0.129	0.052	-0.567	-0.298	-0.404	-0.631	-0.380
7	R	0.122	1.814	0.595	-1.516	0.312	0.120	-1.014	-3.136	0.644	2.163	3.282	3.762
7	S	-0.675	-1.034	-0.359	0.855	-0.158	-0.697	-1.399	-3.196	-2.345	-2.021	-1.960	-1.279
7	T	0.489	0.563	0.074	-0.526	0.207	0.319	0.415	1.021	0.814	0.922	0.963	0.906
7	HRs	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
8	P	0.000	0.158	0.158	-0.079	-0.079	0.158	0.059	-0.151	-0.183	-0.220	-0.100	-0.214
8	Q	0.009	-0.545	-0.554	0.268	0.282	-0.549	0.463	0.815	-0.111	-0.192	-0.439	-0.401
8	R	0.313	2.231	1.918	-1.272	-0.802	2.074	-1.276	-3.535	1.450	1.601	2.224	1.134
8	S	-0.330	-0.581	-0.251	0.455	-0.039	-0.416	-0.991	-1.060	-1.399	-1.051	-0.741	-0.534
8	T	0.326	0.380	0.054	-0.353	0.136	0.217	-0.011	0.687	0.735	0.749	0.462	0.164
8	HRs	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.684
9	P	0.001	-0.244	-0.245	0.122	0.123	-0.244	0.211	-0.012	-0.093	-0.224	-0.147	-0.043
9	Q	-0.227	-0.526	-0.299	0.377	0.036	-0.412	0.392	0.251	0.035	-0.245	-0.237	-0.220
9	R	1.283	1.466	0.183	-1.375	0.550	0.825	0.271	0.251	1.922	2.571	2.943	3.451
9	S	-0.460	-0.867	-0.407	0.663	-0.026	-0.637	-0.735	-1.709	-1.385	-1.164	-0.834	-0.832
9	T	0.664	0.544	-0.120	-0.604	0.392	0.212	0.155	1.691	1.502	1.278	1.247	1.408
9	HRs	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
10	P	0.038	-0.051	-0.089	0.007	0.063	-0.070	-0.019	0.171	0.200	0.024	-0.068	-0.424
10	Q	-0.129	-0.205	-0.075	0.167	-0.027	-0.140	-0.032	0.270	0.232	-0.002	-0.189	-0.615
10	R	0.716	0.582	-0.134	-0.649	0.425	0.224	0.122	0.737	0.951	1.059	1.299	0.835
10	S	-0.357	-1.277	-0.921	0.817	0.282	-0.110	-0.283	-1.445	-1.622	-1.525	-1.237	-1.362
10	T	0.275	0.204	-0.070	-0.239	0.173	0.067	-0.019	0.061	0.492	0.034	0.217	-0.277
10	HRs	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608

Table 2. PQRST results in cycle 1 among Lead Patients with abnormal conditions

Sample	Peak	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
1	P	-0.238	-0.189	0.049	0.214	-0.144	-0.070	0.210	0.117	-0.038	0.173	-0.119	-0.158
1	Q	-0.275	-0.203	0.073	0.239	-0.174	-0.065	0.213	0.115	0.008	0.188	-0.087	-0.149
1	R	1.675	0.196	0.281	-1.815	0.697	1.118	-0.621	-0.857	0.144	-0.459	-0.941	-3.356
1	S	-0.387	-0.316	0.071	0.352	-0.229	-0.123	0.172	0.101	-0.153	0.431	-0.202	0.228
1	T	0.020	0.158	0.137	-0.089	-0.059	0.148	-0.019	-0.111	-0.143	0.350	0.246	0.175
1	HRs	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572
2	P	0.162	0.219	0.057	-0.190	0.053	0.138	-0.180	-0.060	0.142	0.247	0.304	0.380
2	Q	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.429	0.000	0.343
2	R	0.372	0.285	-0.087	-0.329	0.230	0.099	-0.559	-0.322	-0.099	0.344	0.452	0.372
2	S	-0.041	0.045	0.086	-0.002	-0.063	0.066	-0.231	-0.127	-0.143	-0.126	-0.142	-0.139
2	T	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.429	0.000	3.429
2	HRs	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424
3	P	0.099	0.114	0.015	-0.107	0.042	0.065	-0.081	0.042	0.114	0.100	0.094	0.085
3	Q	-0.012	-0.102	-0.090	0.057	0.039	-0.096	-0.135	-0.054	-0.078	0.006	0.168	0.069
3	R	1.066	0.388	-0.678	-0.727	0.872	-0.145	-0.106	-0.571	-0.461	0.966	3.087	1.980
3	S	0.535	-0.263	-0.798	-0.136	0.667	-0.531	-1.537	-1.412	-1.909	-0.936	-0.377	-0.063
3	T	-0.086	0.077	0.162	0.005	-0.124	0.119	0.224	0.142	0.196	-0.112	-0.109	-0.111
3	HRs	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836	0.836
4	P	-0.151	0.167	0.318	-0.008	-0.235	0.243	0.038	0.044	0.082	0.012	-0.064	-0.279
4	Q	-0.097	-0.160	-0.064	0.129	-0.017	-0.112	0.066	-0.009	-0.051	-0.069	-0.167	-0.406
4	R	1.514	0.667	-0.847	-1.090	1.180	-0.090	-0.524	-0.693	-0.094	0.592	1.644	1.749
4	S	-0.066	-0.427	-0.361	0.246	0.147	-0.394	-0.411	-1.365	-1.800	-1.814	-1.569	-1.267
4	T	0.327	0.278	-0.049	-0.302	0.188	0.115	-0.324	0.178	0.315	0.536	0.653	0.102
4	HRs	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868
5	P	0.196	0.010	-0.186	-0.103	0.191	-0.088	-0.073	0.082	0.062	0.063	0.132	0.181
5	Q	-0.035	-0.211	-0.176	0.123	0.071	-0.194	0.163	0.175	0.197	-0.014	-0.053	-0.053
5	R	0.751	0.795	0.044	-0.773	0.353	0.419	-0.890	-0.142	-2.399	1.428	2.509	1.983
5	S	-0.064	-0.346	-0.283	0.205	0.110	-0.315	0.276	0.296	0.402	-0.124	-0.181	-0.108
5	T	0.222	0.054	-0.168	-0.138	0.195	-0.057	0.104	0.373	0.809	0.713	0.584	0.453
5	HRs	0.668	0.668	0.668	0.668	0.668	0.668	0.668	0.668	0.668	0.668	0.668	0.668
6	P	0.133	0.405	0.273	-0.269	-0.070	0.339	0.509	0.065	0.116	0.139	0.194	0.656
6	Q	-0.122	-0.413	-0.291	0.268	0.084	-0.352	0.109	-0.154	0.049	-0.013	0.009	0.406
6	R	0.690	0.618	-0.073	-0.654	0.381	0.273	-0.435	0.309	0.198	1.998	1.615	1.578
6	S	-0.376	-1.234	-0.859	0.805	0.241	-1.046	-1.478	-0.353	-3.239	-2.427	-1.554	-0.431
6	T	0.256	0.834	0.577	-0.545	-0.161	0.705	0.918	0.847	0.670	0.465	0.290	0.641
6	HRs	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780	0.780
7	P	0.171	0.339	0.168	-0.255	0.001	0.254	-0.726	-0.299	-0.046	-0.022	0.079	0.228
7	Q	-0.113	0.093	0.206	0.010	-0.160	0.149	-0.416	-0.158	0.067	-0.004	0.007	0.078
7	R	1.522	0.285	-1.237	-0.903	1.379	-0.476	-1.553	1.607	2.383	1.458	1.190	0.808
7	S	-0.385	-0.273	0.113	0.329	-0.249	-0.080	-0.126	-0.267	-2.209	-1.361	-0.668	-0.051
7	T	0.341	0.190	-0.150	-0.266	0.246	0.020	-0.506	0.804	1.012	0.561	0.515	0.266
7	HRs	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744
8	P	-0.018	-0.182	-0.164	0.100	0.073	-0.173	-0.121	-0.554	-0.419	-0.466	-0.160	-0.242
8	Q	-0.122	-0.223	-0.101	0.172	-0.010	-0.162	-0.104	-0.537	-0.386	-0.418	-0.125	-0.237
8	R	0.507	0.374	-0.133	-0.440	0.320	0.121	0.172	1.390	2.718	0.216	0.194	0.664
8	S	-0.256	-0.287	-0.031	0.272	-0.112	-0.159	-0.290	-1.003	-1.236	-0.102	-0.690	-0.530
8	T	0.245	0.148	-0.097	-0.196	0.171	0.026	-0.330	-0.122	0.342	0.279	0.319	0.062
8	HRs	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.572
9	P	-0.040	0.087	0.127	-0.023	-0.083	0.107	-0.013	-0.145	-0.178	-0.656	-0.640	0.018
9	Q	-0.145	-0.014	0.131	0.080	-0.138	0.059	0.070	-0.068	0.565	0.441	0.986	0.106
9	R	1.619	0.145	-1.475	-0.882	0.000	-0.665	-0.849	-0.501	-0.272	0.385	0.449	0.843
9	S	-0.158	0.053	0.211	0.052	-0.184	0.132	0.051	-0.051	0.383	0.592	1.026	0.135
9	T	0.160	-0.072	-0.232	-0.044	0.196	-0.152	0.058	0.294	-0.150	-0.454	-0.795	-0.064
9	HRs	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804
10	P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.429	0.000	3.429
10	Q	-0.013	-0.203	-0.190	0.108	0.088	-0.197	0.244	0.165	0.009	-0.118	0.031	0.029
10	R	0.285	0.108	-0.177	-0.196	0.231	-0.034	0.109	0.153	0.096	-0.045	0.160	0.130
10	S	-0.125	-0.303	-0.177	0.214	0.026	-0.240	0.430	0.142	0.063	-0.245	-0.074	-0.106
10	T	1.596	0.152	-0.079	-1.556	0.837	0.719	0.000	0.000	0.226	1.808	0.214	1.785
10	HRs	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316

Correlation test under normal conditions

One of the normality test results for normal condition data is shown in table 3 for descriptive statistics and table 4 for test distribution.

Table 3. Descriptive Statistics lead I cycle 1 Normal group

	N	Mean	Std. Deviation	Minimum	Maximum
P (mV) lead I	60	.03048	.067826	-.147	.160
Q (mV) lead I	60	-.15385	.080495	-.271	.133
R (mV) lead I	60	1.13677	.582376	.105	2.120
S (mV) lead I	60	-.49220	.193701	-.845	-.147
T (mV) lead I	60	.49607	.317192	.224	2.015
hr1 (s)	60	.72230	.164881	.102	.988

Table 4. One-Sample Kolmogorov-Smirnov Test lead I cycle 1 Normal group

		P (mV)	Q (mV)	R (mV)	S (mV)	T (mV)	Hr1 (s)
N		60	60	60	60	60	60
Normal	Mean	.03048	-.15385	1.13677	-.49220	.49607	.72230
Parameters[a,,b]	Std. Deviation	.067826	.080495	.582376	.193701	.317192	.164881
	Absolute	.101	.132	.134	.123	.219	.239
Most Extreme	Positive	.070	.132	.084	.101	.219	.124
Differences	Negative	-.101	-.073	-.134	-.123	-.196	-.239
Kolmogorov-Smirnov Z		.784	1.020	1.040	.954	1.696	1.855
Asymp. Sig. (2-tailed)		.570	.249	.229	.323	.066	.082

a. Test distribution is Normal.
b. Calculated from data

A summary of the results of the peak amplitude corelation test for patients in the Normal condition group is shown in table 5a for peak P, table 5b for peak Q, table 5c for peak R, table 5d for peak S and table 5e for peak T.

Table 5a. Summary of peak P correlation test results under normal conditions

P norm condition											
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I		1		1	1		5		5	5		
II	Cor		1	1	1	1	5	5				
III		Cor		1	1	1	5	1		5	5	5
aVR	Cor	Cor	Cor		1	1	1					
aVL	Cor	Cor	Cor	Cor		1		1	5	1	1	5
aVF		Cor	Cor	Cor	Cor		5	1			5	
V1	Cor	Cor	Cor	Cor		Cor						
V2		Cor	Cor		Cor	Cor			1	1	1	
V3	Cor				Cor		Cor			1	1	
V4	Cor		Cor		Cor		Cor	Cor			1	5
V5			Cor		Cor		Cor	Cor	Cor			
V6			Cor		Cor					Cor		

Table 5b. Summary of peak Q correlation test results under Normal conditions

Q norm condition											
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I		1	1		1	1	1	1				
II	Cor		1	1	1	1	1	1		5		
III	Cor	Cor		1	1	1	1	1		5		
aVR		Cor	Cor		1	1	1	5				
aVL	Cor	Cor	Cor	Cor		1	1	1	5	5		
aVF	Cor	Cor	Cor	Cor	Cor		1	1		5		
V1	Cor	Cor	Cor	Cor	Cor	Cor		1	5			
V2	Cor	Cor	Cor	Cor	Cor	Cor	Cor		1	1		
V3					Cor		Cor	Cor		1	1	
V4		Cor	Cor		Cor	Cor		Cor	Cor		1	
V5									Cor	Cor		
V6												

Table 5c. Summary of peak R correlation test results under normal conditions

R norm condition	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I			1	5	1	1		5				
II			1		1	1		1		5		5
III	Cor	Cor			1	1		1				
aVR	Cor						1	1			1	5
aVL	Cor	Cor	Cor			1		1				
aVF	Cor	Cor	Cor		Cor			1		5		
V1				Cor	Cor			1	1			
V2	Cor	Cor	Cor	Cor		Cor	Cor					
V3								Cor				
V4		Cor				Cor						5
V5			Cor									1
V6		Cor		Cor						Cor	Cor	

Table 5d. Summary of peak S correlation test results under normal conditions

S norm condition	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I		5	1		1	1	5	1	1	1	5	
II	Cor		1	1	1	1	5					
III	Cor	Cor		1	1	1	1	5				
aVR		Cor	Cor		1	1			1	5	5	1
aVL	Cor	Cor	Cor	Cor		1	1	1				
aVF	Cor	Cor	Cor	Cor	Cor		1	5				
V1	Cor	Cor	Cor		Cor	Cor		1	1	1	1	1
V2	Cor		Cor		Cor	Cor	Cor		1	1	1	1
V3	Cor			Cor			Cor	Cor		1	1	1
V4	Cor			Cor			Cor	Cor	Cor		1	1
V5	Cor			Cor			Cor	Cor	Cor	Cor		1
V6				Cor			Cor	Cor	Cor	Cor	Cor	

Table 5e. Summary of peak T correlation test results under normal conditions

T norm condition	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I		1	5	1	1	1	1	5	1	1	1	1
II	Cor			1	1	1	5		1	1	1	1
III	Cor				1	1	1	1				
aVR	Cor	Cor			1	1	5		1	1	5	1
aVL	Cor	Cor	Cor	Cor			1	1		1	5	1
aVF	Cor	Cor	Cor	Cor				1	1	1		1
V1	Cor	Cor	Cor	Cor	Cor			1		5		
V2	Cor		Cor		Cor	Cor	Cor		1		5	
V3	Cor	Cor		Cor		Cor		Cor		1	1	1
V4	Cor	Cor		Cor	Cor	Cor	Cor		Cor		1	1
V5	Cor	Cor		Cor	Cor				Cor	Cor		1
V6	Cor	Cor		Cor	Cor	Cor			Cor	Cor	Cor	

Correlation Test Abnormal conditions

One of the normality test results for abnormal condition data is shown in table 6 for descriptive statistics and table 7 for test distribution.

Table 6. Descriptive Statistics lead I cycle 1 Abnormal group

	N	Mean	Std. Deviation	Minimum	Maximum
P (mV) lead I	60	.04385	.189528	-.238	1.097
Q (mV) lead I	60	-.09685	.116343	-.411	.123
R (mV) lead I	60	.96827	.570855	.123	1.949
S (mV) lead I	60	-.17383	.261209	-.698	.692
T (mV) lead I	60	.23425	.390162	-.264	1.709
hr1 (s)	60	.63153	.199581	.020	.912

Table 7. One-Sample Kolmogorov-Smirnov Test lead I cycle 1 Abnormal group

		P (mV)	Q (mV)	R (mV)	S (mV)	T (mV)	Hr1 (s)
N		60	60	60	60	60	60
Normal	Mean	.04385	-.09685	.96827	-.17383	.23425	.63153
Parameters[a,,b]	Std. Deviation	.189528	.116343	.570855	.261209	.390162	.199581
	Absolute	.190	.097	.122	.187	.278	.160
Most Extreme	Positive	.190	.053	.122	.187	.278	.086
Differences	Negative	-.117	-.097	-.113	-.107	-.191	-.160
Kolmogorov-Smirnov Z		1.469	.748	.943	1.449	2.150	1.239
Asymp. Sig. (2-tailed)		.067	.630	.336	.056	.0610	.093

a. Test distribution is Normal.
b. Calculated from data.

A summary of the results of the corelation peak amplitude test for patients in the abnormal condition group is shown in table 8a for peak P, table 8b for peak Q, table 8c for peak R, table 8d for peak S and table 8e for peak T.

Table 8a. Summary of peak P correlation test results for abnormal conditions

P abnorm condition	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I		1	1	1	1		1				1	
II	Cor		5	1		1					5	
III	Cor	Cor			1	1	1	5			1	
aVR	Cor	Cor			1	1	1				1	
aVL	Cor		Cor	Cor		1	1				1	
aVF		Cor	Cor	Cor	Cor			5				
V1	Cor		Cor	Cor	Cor			1			5	
V2		Cor			Cor	Cor			1			
V3								Cor				
V4												1
V5	Cor	Cor	Cor	Cor	Cor		Cor					
V6										Cor		

Table 8b. Summary of peak Q correlation test results for abnormal conditions

Q abnorm condition	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I			1	1	1		1		5			
II			1	1		1				5		
III	Cor	Cor			1	1	1	1				
aVR	Cor	Cor			5	1				5		5
aVL	Cor		Cor	Cor		1	1	1	5			
aVF		Cor	Cor	Cor	Cor			5				
V1	Cor		Cor		Cor							
V2			Cor		Cor	Cor			1			
V3	Cor				Cor			Cor			1	
V4		Cor		Cor							5	1
V5									Cor	Cor		
V6			Cor							Cor		

Table 8c. Summary of peak R correlation test results for abnormal conditions

R abnorm condition	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
I		1	1	1	1		1	5				1
II	Cor		5	1		1	1	1		5		1
III	Cor	Cor			1	1						5
aVR	Cor	Cor			1	1	1	1		5		1
aVL	Cor		Cor	Cor		5	1					
aVF		Cor	Cor	Cor	Cor			5				1
V1	Cor	Cor		Cor	Cor			1	5			
V2	Cor	Cor		Cor		Cor	Cor		1	1		
V3							Cor	Cor		1		
V4		Cor		Cor				Cor	Cor		1	1
V5										Cor		1
V6	Cor	Cor	Cor	Cor		Cor				Cor	Cor	

Table 8d. Summary of peak S correlation test results in abnormal conditions

	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
S abnorm condition												
I		1	1	1	1		5				5	
II	Cor		1	1		1	1	1	1	1	1	1
III	Cor	Cor			1	1	1	1	1	1	1	
aVR	Cor	Cor			1	1		1	1	1	1	1
aVL	Cor		Cor	Cor		1	1					
aVF		Cor	Cor	Cor	Cor		1	1	1	1	1	5
V1	Cor	Cor	Cor		Cor	Cor		1	1	1	1	
V2		Cor	Cor	Cor		Cor	Cor		1	1	1	5
V3		Cor	Cor	Cor		Cor	Cor	Cor		1	1	1
V4		Cor	Cor	Cor		Cor	Cor	Cor	Cor		1	1
V5	Cor	Cor	Cor	Cor		Cor	Cor	Cor	Cor	Cor		1
V6		Cor		Cor		Cor		Cor	Cor	Cor	Cor	

Table 8e. Summary of peak T correlation test results for abnormal conditions

	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
T abnorm condition												
I		1	1	1	1	1	1	1			1	
II	Cor			1	1	1	1	1			1	
III	Cor				1	1	1					
aVR	Cor	Cor			1	1	1	1		1	1	
aVL	Cor	Cor	Cor	Cor			1	1			1	
aVF	Cor	Cor	Cor	Cor				5			1	
V1	Cor	Cor	Cor	Cor	Cor			1	5		1	
V2	Cor	Cor		Cor	Cor	Cor	Cor		1		1	5
V3							Cor	Cor				5
V4												1
V5	Cor	Cor		Cor	Cor	Cor	Cor	Cor				
V6								Cor	Cor	Cor		

The correlation between the amplitude of peak P, peak, Q, peak R, peak S and peak T between the leads in table 5 and table 8 is indicated by the words "Cor" (Correlation) while the significance level is indicated by the number 1 for significance $\alpha = 0.01$ and the number 5 for significance $\alpha = 0.05$

4. CONCLUSIONS

1. The peak amplitude P for abnormal heart conditions is indicated by the correlation of lead I with leads III and V5 at a significance of 0.01
2. The peak amplitude R for abnormal heart conditions is indicated by the correlation of leads II and V6 at a significance of 0.01
3. The peak amplitude P for normal heart conditions is indicated by the correlation between leads I and V3 and V4
4. The peak amplitude R for normal heart conditions is indicated by the correlation between lead I and lead aVF

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