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doi:10.15199/48.2016.09.53

Influence of ECG testing errors on Automatic ECG interpretation

***Abstract**. The ECG testing is very common in health diagnose of a patient. Also, in present it is common to apply as many automated technology solutions as possible. Generally, this should insure better quality of gained diagnostic results. On the other hand, complex solutions invoke human error in procedure, which ultimately can provide inaccurate results. The influence of such errors on example of ECG testing is analyzed and compared to normal ECG test in this research, where six scenarios are deliberately forced to provide fault diagnose.*

Streszczenie.** Do analizy sygnałów EKG stosuje się obecnie wiele metod automatyzacji. W artykule analizuje się możliwe błędy w interpretacji sygnałów EKG. **Wpływ błędów na interpretację wyniku EKG w metodach automatycznej diagnozy

Keywords: ECG, resting cardiograph, electrical measuring, automatic
Słowa kluczowe: EKG, automatyczna diagnoza chorób serca..

Introduction

Heart is active muscle which supports circulation of blood in the human body. During this activity heart generates certain flow of electrical charge, e.g. the electrical current dependent to state of the heart. Therefore, if one wants to deduct on heart status and quality, some of necessary input information can be measured trough electrical potential which emerges on the human body skin. Electrocardiography is set of measured electrical voltage gained from heart activity, all available in compact device electrocardiograph. The heart electrical activity was first noticed in 1856 by Koelliker and Muller, while the first capillary electrocardiograph record on a human was made in 1877 by Waller, like described in [1]. The first modern type electrocardiograph was constructed in 1903 by Willem Einthoven, like shown in [2]. Indications for conducting ECG procedure are any suspicions of cardiovascular disease, as provided in [3]. One of human body bioelectrical signals is ECG signal, as described in [4].

The ECG testing is actually a simple procedure and is commonly made by nurses when ordered by the physician, but it needs to be done with great care for details during the preparation and conduction. Therefore, human error is common and can finally result in fault ECG record of heart activity. In this paper Automatic ECG interpretations are analyzed and compared for six of the simplest and most common human errors and how they can affect on the final result on ECG diagnose of a patient. These errors are selected from hospital staff common experience, and have no previous references. The patients used in this research are a healthy male in age of 33 and a healthy female in age of 39.

ECG testing in modern medicine

The heart electrical activity consists of two steps: depolarization and repolarization. In natural state the heart cells are electrically polarized. The cells have extra negative charge relatively to its environment. Such polarity is maintained by transmembrane pumps which insure distribution of ions necessary for interior electronegativity, mainly potassium, sodium, chloride and calcium.The process of depolarization is loss of heart cells electronegativity, while it spreads from cell to cell and produces a wave of depolarization across the heart. In such way an electrical current is generated, which can be measured as electrical potential change on the human body skin surface, presented in Fig.1. The repolarization is process of polarity recuperation in the heart cells, and starts right after the depolarization process ends. The record of such electrical activity generated from the heart is ECG curve called electrocardiogram. It consists of P-wave and QRS complex as a depolarization waves, and T-wave as a repolarization wave, all described in [5] and [6].

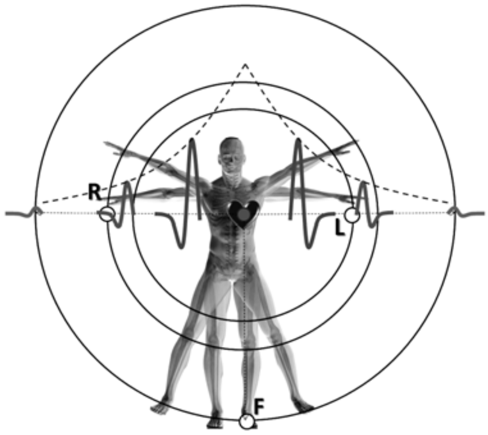

Fig.1. Spreading of depolarisation and repolarisation wave trough the human body

The Standard ECG is collection of record for twelve different vector views of the heart electrical activity, regarding the voltage between certain points of human body. Six vector views are vertical (I, II, III, aVR, aVL and aVF), and six are horizontal (V1 – V6). Standard electrodes are presented in detail in [7], and in Fig.2. and Fig.3.

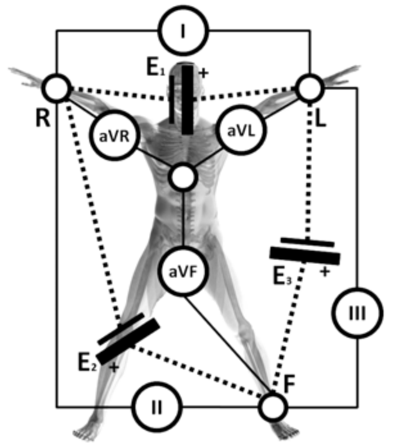

Fig.2. ECG vertical views I, II, III, aVR, aVL and aVF

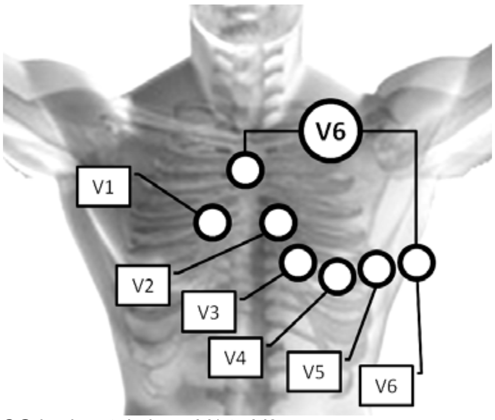

Fig.3. ECG horizontal views V1 to V6

In this research the resting cardiograph CP 50 is used for ECG testing, presented in detail in [8]. It is a compact stand-alone ECG measuring and diagnostic device. It supports test types as Auto ECG, Stat ECG and Rhythm ECG, with possibility to show patient data, measurements and optional interpretation. If necessary, it allows the optional Automatic ECG interpretation, provided from the algorithm developed by the University of Rotterdam in the Netherlands.

Common errors in ECG testing

Case 1 is ECG test conducted with error scenario: precordial electrodes switched side, as in Fig.4. In this scenario placement of precordial electrodes is mirror-switched to right-hand side of a patient chest. Precordial electrodes are placed further from the heart than expected. The difference of distances is increasing while moving from V1 to V6.

Case 2 is ECG test conducted with error scenario: precordial electrodes switched order, as in Fig.4. In this scenario placement of precordial electrodes is mirror-switched from V1 to V6 on the left-hand side of a patient chest. Precordial electrodes are switched in pairs V1/V6, V2/V5 and V3/V4. The distances do not significantly disturb the normal placement of electrodes, but relative signals from V1 to V6 do not match expected relations.

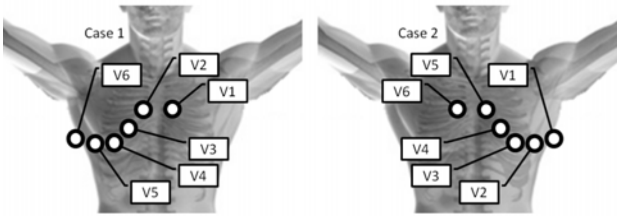

Fig.4. Error placement of precordial electrodes in cases 1 and 2

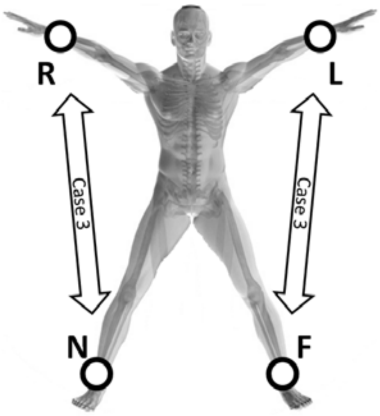

Fig.5. Error placement of standard unipolar electrodes in case 3

Case 3 is ECG test conducted with error scenario: standard unipolar electrodes legs/arms switched, as in Fig.5. In this scenario standard unipolar electrodes for arms are placed on legs and standard unipolar electrodes for legs are placed on arms, while right-hand and left-hand sides are provided correctly. Standard unipolar electrodes for arms are placed further from the heart than expected, while standard unipolar electrodes for legs are placed closer to the heart than expected. Such placement significantly disturbs measured results for I, II, III, aVR, aVL and aVF.

Case 4 is ECG test conducted with error scenario: standard unipolar electrodes arms switched side, as in Fig.6. In this scenario standard unipolar electrodes for arms are each placed on opposite side, right-hand electrode on left-hand side and vice versa. Standard unipolar electrodes for arms are placed to very similar distance from the heart, while the relative relation between potentials on R and L electrodes are switched. Such placement significantly disturbs measured results for I, II, III, avR and aVF.

Case 5 is ECG test conducted with error scenario: standard unipolar electrodes arms/legs switched side, as in Fig.6. In this scenario standard unipolar electrodes for arms and legs are each placed on opposite side, right-hand electrode on left-hand side and vice versa. Standard unipolar electrodes for both arms and legs are placed to very similar distance from the heart, relative relation between potentials on R and L electrodes are switched, while potential of leg electrode is very similar to expected signal since other leg is reference and does not have significant influence on measured results. Such placement significantly disturbs measured results for I, avR and aVF.

Case 6 is ECG test conducted with error scenario: standard unipolar electrodes legs switched side, as in Fig.6. In this scenario standard unipolar electrodes for legs are each placed on opposite side, right-hand electrode on left-hand side and vice versa. Standard unipolar electrodes for legs are placed to very similar distance from the heart, while the relative relation does not exist as a standard view since right-hand leg is only reference for all measurements. Such placement insignificantly disturbs any measured results.

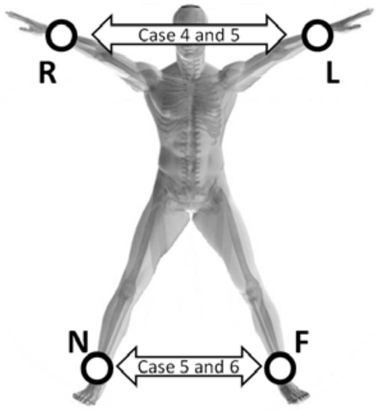

Fig.6. Error placement of standard unipolar electrodes in cases 4, 5, 6

Results of ECG testing with common errors

Case 1 is ECG test conducted with error scenario: precordial electrodes switched side. The difference of distances is increasing while moving from V1 to V6. Therefore, the measured results show decreasing of standard signals when moving from V1 to V6, slight decrease on V1 to significant decrease on V5 and V6. Views V1 to V6 are presented in Fig.7. Standard unipolar electrodes show expected results. Automatic ECG interpretation algorithm concludes to disturbance secondary to infarct due to slight mid- and left- precordial repolarisation.

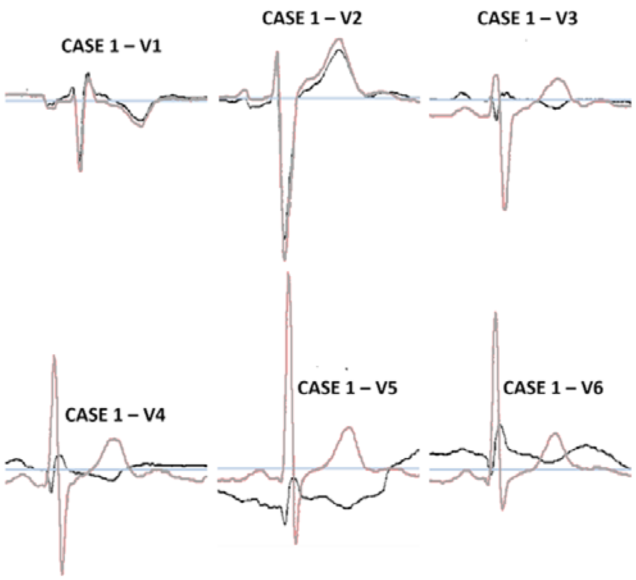

Fig.7. ECG testing error results for Case 1

Case 2 is ECG test conducted with error scenario: precordial electrodes switched order. The distances do not significantly disturb the normal placement of electrodes, but relative signals from V1 to V6 do not match expected relations. Therefore, the measured results show similarity for V1 and V2, while with high positive local maximum and small local minimum. Also the measured result for V6 shows smallest positive local maximum and highest local minimum. Views V1 to V6 are presented in Fig.8. Standard unipolar electrodes show expected results. Automatic ECG interpretation algorithm concludes to borderline ECG due to significant but small deviation to expected relative relation on precordial electrodes.

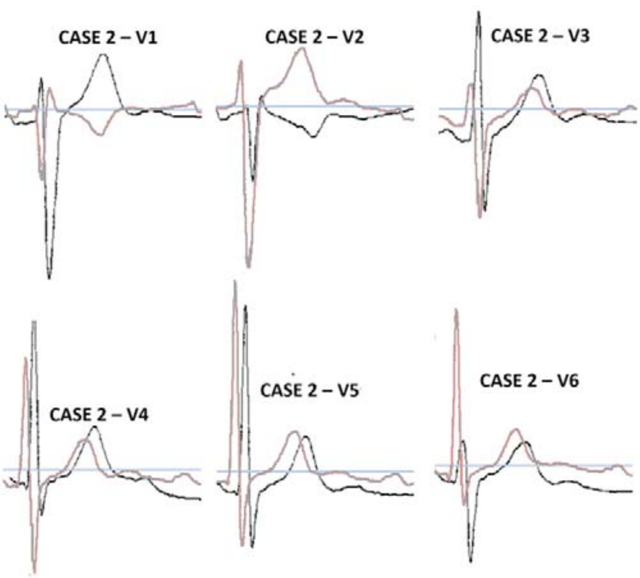

Fig.8. ECG testing error results for Case 2

Case 3 is ECG test conducted with error scenario: standard unipolar electrodes legs/arms switched. Such placement significantly disturbs measured results for I, II, III, aVR, aVL and aVF. Therefore, the measuared results show unexpected results for I and switched polarity from expected response for II and III. Also, the measured result for aVR, aVL and aVF show totally unexpected signals due to wrong interpretation of measured and reference potentials. Views I to aVF are presented in Fig.9. Precordial electrodes show expected results. Automatic ECG interpretation algorithm concludes to borderline ECG due to recognition of high-lateral repolarization disturbance.

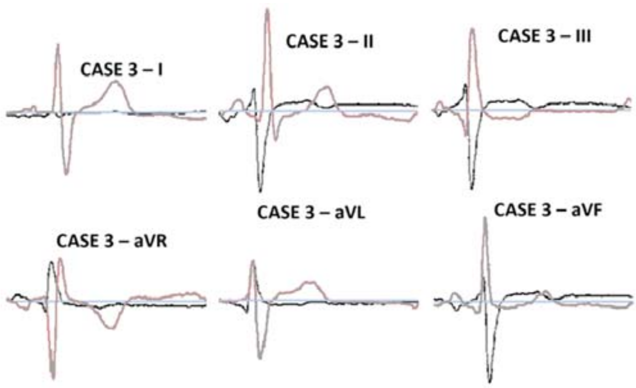

Fig.9. ECG testing error results for Case 3

Case 4 is ECG test conducted with error scenario: standard unipolar electrodes arms switched side. Such placement significantly disturbs measured results for I, II, III, avR and aVF. Therefore, the measured results are reversed for I, and switched between II and III. Also, measured results for aVR and aVL are switched, while aVF is rather expected since leg electrodes are properly placed. Views I to aVF are presented in Fig.10. Precordial electrodes show expected results. Automatic ECG interpretation algorithm concludes to abnormal ECG due to recognition of slight intraventricular conduction delay and high-lateral repolarization disturbance, while advising to consider infarct or recent occurence.

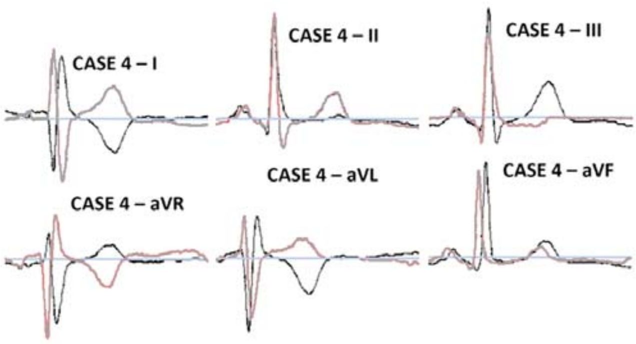

Fig.10. ECG testing error results for Case 4

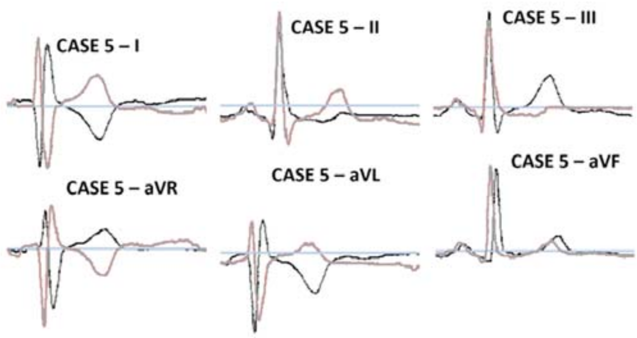

Fig.11. ECG testing error results for Case 5

Case 5 is ECG test conducted with error scenario: standard unipolar electrodes arms/legs switched side. Such placement significantly disturbs measured results for I, avR and aVF. Therefore, the measured results are reversed for I, and switched between II and III. Also, measured results for aVR and aVL are switched, while aVF is rather good although leg electrodes are not properly placed. Views I to aVF are presented in Fig.11. Precordial electrodes show expected results. Automatic ECG interpretation algorithm concludes to abnormal ECG due to recognition of high-lateral repolarization disturbance, while advising to consider infarct or recent occurence.

Case 6 is ECG test conducted with error scenario: standard unipolar electrodes legs switched side. Such placement insignificantly disturbs any measured results. Therefore, the measured results show good similarity to expected results. Views I to aVF are presented in Fig.12. Precordial electrodes show expected results. Automatic ECG interpretation algorithm concludes to normal ECG.

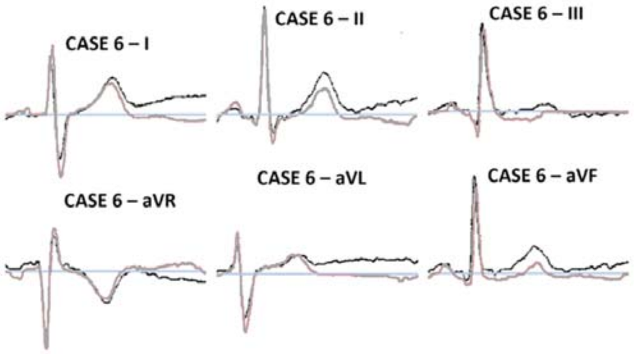

Fig.12. ECG testing error results for Case 6

For these cases it is obvious that any of most common errors will provide bad Automatic ECG interpretation. For three cases the infarct occurrence is assumed, while in two cases the state is considered borderline and suggests further analysis. All other errors while conducting ECG testing will generate even worse Automatic ECG interpretation. The evaluation of measured results and related Automatic ECG interpretations are presented in Table 1.

Table 1. The evaluation of measured results and related Automatic ECG interpretations

View	Case					
	1	2	3	4	5	6
I	G	G	B	B	B	G
II	G	G	B	S	S	G
III	G	G	B	S	S	G
aVR	G	G	S	B	B	G
aVL	G	G	S	S	B	G
aVF	G	G	S	G	S	G
V1	G	B	G	G	G	G
V2	G	B	G	G	G	G
V3	B	S	G	G	G	G
V4	B	S	G	G	G	G
V5	B	S	G	G	G	G
V6	B	S	G	G	G	G
Automatic interpretation	A SI	BL	BL	A I	A I	N

where – *B* is bad, *S* is satisfactorily, *G* is good, *N* is normal ECG, *BL* is borderline ECG, *A* is abnormal ECG, *SI* is secondary to infarct, *I* is infarct.

Conclusion

The ECG testing became irreplaceable since it was introduced in medicine due to its diverse applications. Modern technology solutions made ECG testing and diagnostics very easy, and can even offer some automatic conclusions. However, it also became very easy to make human errors due possibility of relaxation, negligence and/or ignorance of a person which conducts the testing. It can be seen from results of this research that, if some trivial errors appear, a healthy person can be diagnosed heart failure. Also, it can be assumed that there is a possibility that a sick person in similar way can be diagnosed as healthy. The results of ECG testing with high performance automated apparatus must always be verified by an expert cardiologist.

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