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Common errors in computer electrocardiogram interpretation

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Abstract

Objective: The aim of the study was to determine the frequency and nature of errors in computer electrocardiogram (ECG) reading.
Methods: The ECGs were collected in the tertiary care VA Hospital from both inpatients and outpatients. They were read by the electrocardiograph built-in computer software, and then reread by two cardiologists. Statistical analysis was performed using sensitivity, specificity, positive and negative predicted value to analyze the data. An error index was formulated as indicator of diagnostic accuracy.
Results: Out of 2072 ECGs, 776 (37.5%) were normal, and 1296 (62.5%) were abnormal. In 9.9% of all ECGs and in 15.9% of abnormal ECGs there were significant disagreements between the computer and cardiologists. The errors in diagnosis of arrhythmia, conduction disorders and electronic pacemakers accounted for 178 cases, or 86.4% of all errors. The rest was represented by misdetection of chamber enlargement (7 cases, 3.4%), misdiagnosis of ischemia and acute myocardial infarction (16 cases, 7.8%), and lead misplacement (5 cases, 2.4%).
Conclusions: The most frequent errors in computer ECG interpretation are related to arrhythmias, conduction disorders, and electronic pacemakers. Computer ECG diagnosis of life threatening conditions e.g. acute myocardial infarction or high degree AV blocks are frequently not accurate (40.7% and 75.0% errors, respectively). Improvement in the diagnostic algorithms should focus on these areas. Error index is a convenient and informative tool for evaluation of diagnostic accuracy.

Keywords: ECG; Diagnostic errors; Computer

1. Introduction

Part of the regular work of a cardiologist is reading of electrocardiograms (ECGs). Commonly, the reader has a computer generated diagnostic interpretation, which can be accepted or rejected, partially or in full. This analysis by the computer is extremely helpful. It can considerably speed up the process of physician ECG interpretation and help prevent errors [3]. However, frequently inaccuracies are encountered which need manual correction. Certain types of errors are encountered more frequently. The aim of this study was to determine the nature and frequency of errors by computer analysis of ECG.

The reliability and accuracy of computer programs has been previously analyzed. In the setting of an emergency room, the computer made 4% of major errors (2 out of 50) [1]. On a large sample size greater than 5000 ECGs, Thompson et al. [2] concluded that overall sensitivity of computer interpretation was 90.1%, specificity 89.6%, positive predictive accuracy 87.1%, and negative predicted accuracy 92.2%. The readings of ST–T wave changes demonstrated the lowest sensitivity and specificity. A significant observation was that ECGs read as normal by computer did not require further checking.

The nature and frequency of typical errors has not been in the focus of previous studies. This study focuses on the types of errors most commonly encountered. We sought to

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identify areas of weakness which can help refine the ECG reading algorithms.

2. Methods

The ECGs were collected in the tertiary care VA Hospital from both inpatients (36.4%), outpatients (47.6%) and in the emergency room (16.0%). There were 2194 consecutive ECGs recorded on 1856 patients. Patients age ranged from 33 to 96 years, mean 73.5. Nearly all of them (98.3%) were male. The decision to record an ECG was made by the treating health care provider. No ECGs were taken for the purpose of this study or added to the sample to make it more representative.

All ECGs were initially analyzed by the electrocardiograph built-in computer software (12SL). Each tracing was reread sequentially by two independent cardiologists. The first reader was one of the staff cardiologists who did not know that it was part of a study. The ECGs were read for clinical purposes only. The second reader independently analyzed each ECG and was blinded to the final interpretation of the first cardiologist. Computer ECG analysis error was identified if both cardiologist interpretations were in agreement. The final readings were changed accordingly. For the purpose of this study discordance between the two physician readers was excluded as a computer error.

The 12 SL is the only diagnostic algorithm used at our institution. No other algorithms were analyzed.

ECGs read as "borderline", i.e. "normal except borderline left ventricular hypertrophy" (LVH) or "normal except first degree atrioventricular (AV) block", were considered abnormal. All cardiac rhythms except normal sinus rhythm, sinus tachycardia, sinus bradycardia, and sinus arrhythmia were also considered abnormal.

Sensitivity, specificity, positive and negative predicted values were determined. A new concept for diagnostic accuracy, error index (EI) was introduced. To calculate the EI, each final diagnosis was counted, made by either the computer or cardiologists. As a result, each ECG had two diagnoses, one made by the computer, and the other by the cardiologists. The number of diagnoses of any given condition was equal to the sum of computer and cardiologists diagnoses. The percent of erroneous diagnoses (false positive plus false negative) was calculated as a percent of this number.

In accepted terms, error index calculates the ratio of all diagnostic errors (false positive and false negative), which is the numerator of the formula, to all diagnoses for a given condition made by either computer or cardiologists. The denominator includes all diagnoses made by computer, which are true positives and false positives, and all diagnoses made by cardiologists, which include true positives and false negatives. Hence the denominator of the equation becomes 2 true positives plus false positives plus false negatives. Thus the EI was calculated as ratio of $(FP+FN)/(2TP+FP+FN)$. True negatives are not included; therefore, the index does not depend on the prevalence of the disease.

3. Results

A total of 2194 ECGs were included for analysis in the study. One hundred twenty two ECGs with a disagreement between the two cardiologists were excluded from analysis. Out of 2072 remaining cases, 776 (37.5%) were read by the computer as normal, and 1296 were abnormal. In 206 cases, there were discordances between the computer and cardiologists readings (9.9%), which constituted the computer error group. There were no discordances in the ECGs read as normal. Therefore, discordances occurred in 15.9 % of all ECGs read as abnormal. Out of 206 ECGs which computer read incorrectly, the errors in diagnosis of arrhythmia, conduction disorders and electronic pacemakers accounted for 178 cases, or 86.4%. The rest was represented by misdetection of chamber enlargement (7 cases, 3.4%), misdiagnosis of ischemia and acute myocardial infarction (MI) (16 cases, 7.8%), and erroneous interpretation of lead misplacement (5 cases, 2.4%). Primary errors lead to secondary errors, for example, unrecognized electronic pacemaker led to erroneous reading of paced beats as myocardial infarction, bundle branch block or hypertrophy. Therefore, total number of errors exceeded 206. On 52 ECGs there was an artifact which could potentially cause misinterpretation, however disagreements between computer and cardiologists occurred in only six of these ECGs representing less than 0.5% of errors.

Diagnostic errors made by computer for each condition are summarized in Table 1. This data identifies the most frequent errors which mainly included arrhythmias, conduction disorders, and electronic pacemakers.

Within the "arrhythmia" group, the most common misreading was "undetermined rhythm" (23 cases). These were finally interpreted by the cardiologists as atrial fibrillation (AF) in 5 cases, AF with premature ventricular contractions (PVCs) [4], normal sinus rhythm [4], atrial flutter [2], normal sinus rhythm with complete AV block and ventricular escape [2], and also AF with electronic ventricular pacemaker and PVCs, atrial flutter with PVCs, junctional rhythm with PVCs, normal sinus rhythm with first degree AV block, normal sinus rhythm with electronic ventricular pacemaker tracking P waves, and sequential AV pacing, one case of each.

The next most common misinterpretation was "sinus rhythm with sinus arrhythmia", which was, in 22 cases, thought to be a normal sinus rhythm with premature atrial contractions (PACs) by both cardiologists. In 5 cases, atrial flutter was read as normal sinus rhythm. Accelerated idioventricular rhythm (on the tracing with predominantly sinus rhythm) went completely unnoticed by the computer