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Accuracy of general practitioners' readings of ECG in primary care

Research Article

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Abstract: Background. The electrocardiogram (ECG) is a diagnostic test commonly used in daily Primary Care practice. General Practitioners (GP) often feel unsure about their interpretation of ECGs, so they engage external services to provide it. Aim. To evaluate accuracy of ECG readings done by GPs by comparison with those done by a cardiologist as the gold standard. Methods. We studied 195 ECGs collected consecutively during first semester of 2010 in an urban Health Centre of Portugal. Each ECG was read by each physician and inter-observer agreement was evaluated. After coding by Novacode, sensitivity and specificity of GP's readings were calculated. Results. Inter-observer agreement between GP readings was "good" with an intraclass correlation coefficient of 0.727 (CI 95%: 0.670–0.779). When compared with gold standard, GP achieved a "good" agreement with an intraclass correlation coefficient of 0.712 (CI 95%: 0.659–0.762). The overall accuracy of GP for detecting abnormalities was 81.0% (95%CI: 75.7–85.6%), with a sensitivity of 84.8% (95%CI: 77.3–90.6%) and a specificity of 77.5% (95%CI: 69.7–84.2%). For normal tests, accuracy was 79.9% (95%CI: 74.7–84.3). In the most prevalent classes of abnormalities, accuracy was higher than 90%. Conclusion. GP showed good skills in reading ECGs in their practice of Primary Care. Better attention should be given to ischemic abnormalities present on ECGs. Key message: General Practitioners demonstrate good skills for reading the ECGs of patients on a primary care centre when compared to the gold standard defined by a cardiologist reading.

Keywords: *Cardiovascular Disorders / Hypertension / DVT / Atherosclerosis • Continuing Medical Education • Diagnostic Tests • Graduate Medical Education / Fellowship Training • Physician Competency Primary Care • Quality of Care • Measurement/ Psychometric Analyses • Observational Research*

1. Introduction

Since 1902, when Einthoven described the human utilization of heart electric registry technology [1], the electrocardiogram (ECG) has assumed an important role in the study and follow-up of patients with cardiovascular diseases. Although it is considered a bedside test that any doctor should understand, the real practice shows that skills on reading and interpretation among General Practitioners (GPs) are significantly different from those of other specialists, namely cardiologists, commonly considered the gold standard of electrocardiogram interpretation [2–5]. Better individual experience [6] and working with specific conditions [7] may improve accuracy of ECG readings but consensus about the way of assessing and ensuring that skill have not yet been established [8,9].

In Portugal, the establishment of the universal National Health Service thirty years ago introduced the historical need of ensuring rapid access for the population

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to primary care. Physicians came to General Practice / Family Medicine from several academic and scientific sources and they brought a very interesting diversity that valued global skills, although leading sometimes to controversy over the package of basic services that GP should provide as part of their practice.

The "*São João*" Health Centre is the most visible face of "Test-Tube Project" where the General Practice Department of Faculty of Medicine of University of Porto took on the responsibility for developing innovative lines of management and care on Primary Health Care, since 1999 [10], testing the foundations for a national reform of Primary Care services. The usual practice at time in Portugal was to engage external services providing ECG readings, usually cardiologists. A project to institute performing ECGs in the Health Centre started soon after the project was begun, to avoid unnecessary dislocation of patients to hospitals or external clinics. ECGs were done by trained nurses and sent to a cardiologist for reading. Since 2005, readings have been made by three experienced GPs. Until now, this activity has not been evaluated.

The aim of this study was to evaluate accuracy of GPs' readings of ECGs as evaluated by the gold standard defined as the cardiologist's reading.

2. Methods

2.1. Electrocardiograms

The ECGs performed consecutively in "*S. João*" Health Centre during the first semester of 2010 were collected from patients' clinical files. Two hundred eight tests were done and 195 were available for analysis. Tests were requested by doctors in their regular medical activity in the Primary Care setting and performed by trained nurses on an electrocardiograph (Cardiet start 100 H), providing 12 classic derivations with a speed of 25 mm/second and a sensitivity of 10 mm/mV.

The motives for the request for an ECG included global health examinations of patients, follow-up of cardiovascular or cardiac conditions, and the presence of cardiac-related symptoms in a consultation.

Sample size was calculated on a minimum of 151 tests, providing values for sensitivity of 67.5% [2,5,11], and prevalence of abnormalities of 9.3% for a confidence interval of 95% and a maximum error of 3.5%.

2.2. Physicians

The ECGs were sent for reading to three GPs that commonly report these tests in Health Centre (MV, PP and PS), blinded from each other. The gold standard was defined by the reading of the cardiologist who set the current diagnosis of ECG.

Information about age and gender of patients was available to all participants, and all other clinical or demographic data were removed from the ECG before they were copied and distributed to participants.

All ECGs were read by each physician and written reports were collected for analysis. The physicians were asked to classify degree of complexity of tracings using a Likert scale of 5 points ranging from 1 (very easy) to 5 (very complicated).

2.3. Classification of ECG

Reports were classified by Novacode [12] criteria in normal, with minor abnormalities or with major abnormalities. Detected abnormalities were further classified in eleven categories: a) rhythm abnormalities, b) atrio-ventricular conduction abnormalities; c) prolonged ventricular excitation; d) prolonged ventricular repolarization; e) ECG categories associated with myocardial infarction/ischemia; f) left ventricular hypertrophy; g) left atrial enlargement; h) right ventricular hypertrophy; i) right atrial enlargement; j) fascicular blocks; and k) other clinically significant abnormalities.

2.4. Ethical considerations

ECGs copies were anonymized, making nominal identification elements concealed for all participants. Procedures were consistent with the Helsinki Declaration and the Oviedo Convention. Study protocol had supervision and acceptance of Ethical Committee of *S. João* Health Centre.

2.5. Statistical analysis

Inter-observer reliability was studied using intraclass correlation coefficient in GP group and between these and gold standard defined as Cardiologist reading. A two-way mixed for absolute agreement type model was used after testing additivity by Tukey's test. Analysis was performed on the basis of individual readings. Proportion of agreement and weighted kappa values between different GP and Cardiologist were calculated after classification by Novacode. The agreement strength was classified as follows: 0.01–0.2 slight, 0.21–0.4 fair, 0.41–0.6 moderate, 0.61–0.8 good, 0.81–1.0 almost perfect [13]. Sensitivity and specificity were determined by considering valid the agreement of at least 2 of 3 GPs. An *alpha* error of 0.05 was accepted. Microsoft Office Excel ® 2007 and SPSS ® 17.0 software (IBM

SPSSIStatistics) were used for data collection and analysis.

3. Results

One hundred and ninety five electrocardiograms were evaluated from 191 patients (50.8% females) with the mean age of 56.6 years (SD: 18.5 years). Mean age for males was 54.3±19.6 years and 58.8±17.1 years for females. During the six month period, 13 ECG records were lost; they were excluded from analysis.

Sixty percent of the ECGs (n=117) were normal and in all, 127 abnormalities were reported, divided by 37 different codes. The most common were ST-T abnormalities (17.3%), left anterior fascicular block (14.2%), right bundle block (10.2%), sinus bradycardia (5.5%), and sinus tachycardia (5.5%). The global perception of complexity on reading an ECG were pointed in 2.1 out of 5.0 (95% CI: 2.0–2.2) by GP.

When compared with gold standard after codification by Novacode, GPs showed an intraclass correlation coefficient of 0.712 (95% CI: 0.659–0.762). Inter-observer agreement of GPs was accessed by intraclass correlation coefficient of 0.727 (95% CI: 0.670–0.779). Table 1 shows proportion of agreement and weighted kappa values of each GP compared with cardiologist readings. There was a "good" agreement in two cases and an "almost perfect" in the other one.

When analyzed by identification categories of abnormalities, the weighted kappa value was 0.708 (95% CI: 0.638–0.778), classified as a "good" agreement strength. The overall sensitivity of GP group in detecting abnormalities was 84.8% (95% CI: 77.3–90.6%), with a specificity of 77.5% (95% CI: 69.7–84.2%) and an accuracy of 81.0% (95% CI: 75.7–85.6%)

Table 2 shows the sensitivity and specificity of GP readings for the most 4 prevalent categories of abnormalities. These four diagnostic codes represented 88.1% of total abnormalities. Higher values of sensitivity were found in prolonged ventricular excitation with 94.7% (95% CI: 79.8–99.0) and lower in ECG categories associated with myocardial infarction/ischemia (59.5%; 95% CI: 49.1–63.4). Specificity was higher than 98% for the detection of abnormalities. GP accuracy for normal tests was 79.9% (95% CI: 74.7–84.3). For the most prevalent abnormalities, accuracy was higher than 90%.

The analysis of sensitivity and specificity for most prevalent diagnosis representing 55.1% of total is shown in Table 3. The higher values for sensitivity were found in atrial fibrillation (100%; 95% CI: 71.3–100.0) and the lower values for ST-T minor abnormalities (56.8%; 95% CI: 39.5–72.9). Specificity varied between 99.2% (95% CI: 97.1–99.9) for left anterior fascicular block and 100% (95% CI: 98.5–100.0) for atrial fibrillation.

Table 1. Proportion of agreement (PAg) and weighted Kappa with confidence intervals of 95% (95% CI) for ECG readings by GP in comparison with cardiologist reading after codification by Novacode in normal /minor or major abnormalities.

	PAg 95% CI	Kappa 95% CI	Complexity 95% CI	Concordance strength
GP 1	0.862 0.803–0.903	0.772 0.688–0.857	1.92 1.79–2.06	Good
GP 2	0.903 0.850–0.939	0.845 0.774–0.915	1.81 1.70–1.92	Almost perfect
GP 3	0.810 0.747–0.861	0.700 0.610–0.789	2.54 2.42–2.65	Good

Table 2. Sensitivity, specificity and accuracy of GP readings after codification by identification categories with 95% confidence intervals (95% CI)

	Sensitivity (95% CI)	Specificity (95% CI)	Accuracy (95% CI)
Normal (n=117)	80.7 (75.6–85.0)	79.1 (73.7–83.6)	79.9 (74.7–84.3)
1. Rhythm abnormalities (n=38)	94.6 (86.2–98.2)	98.7 (97.3–99.3)	98.1 (95.7–99.1)
3. Prolonged ventricular excitation (n=22)	94.7 (79.8–99.0)	98.4 (97.2–98.7)	98.1 (96.0–98.7)
5. ECG categories associated with myocardial infarction/ischemia (n=28)	59.5 (49.1–63.4)	99.1 (97.1–99.8)	92.8 (89.5–94.0)
10. Fascicular blocks (n=19)	89.5 (74.8–95.9)	99.2 (98.0–99.7)	98.5 (96.4–99.4)

Table 3. Sensitivity and specificity of most prevalent ECG diagnosis of GP readings (95% CI: confidence interval of 95%)

	Prevalence (%) (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)
ST-T abnormalities	11.28 % (7.21–16.58)	56.8 (39.5–72.9)	99.6 (97.6–99.9)
Left anterior fascicular block	9.23 % (5.56–14.20)	89.5 (66.8–98.4)	99.2 (97.1–99.9)
Right bundle block	6.67 % (3.60–11.13)	91.7 (61.5–98.6)	99.2 (97.2–99.9)
Atrial fibrillation	5.64 % (2.85–9.87)	100 (71.3–100)	100 (98.5–100)
Myocardial infarction (acute or previous)	2.56 % (0.84–5.88)	80.0 (34.2–98.2)	99.6 (98.7–100)

4. Discussion

The data show that these GPs are competent to read ECGs in a primary care setting.

Skills on reading and interpretation of ECGs have been largely discussed and the 2001 consensus of American Cardiology Academy and American Heart Association defined methods for its appraisal [8]. Academy of American Family Physicians adapted this rules to particular environment of Primary Care services [14], establishing a set of requirements for recognition of these skills: undergraduate instruction; a residency program; experience on reading ECGs; and participating in quality control processes. In Portugal, undergraduate instruction and residency training are firmly established, and ECG reading experience, although not generalized, is a skill possessed by many GPs. To date, however, there has been no description of quality control processes applicable to this practice.

In this article, we evaluated the skills of a group of GPs with respect to reading ECGs collected on daily practice of a Health Centre, ensuring quality by comparison with a gold standard defined by cardiologist evaluation. Although the choice of cardiologist reading as gold standard is controversial, due to the variability among doctors, it remains as the most widely used method of assessment – as seen in many articles [2–5].

There are two major aspects to take into account: on the one hand, ECGs come from regular consultations as part of a Primary Care Service, which explains the great number of normal tests and apparent lack of rare diagnosis, which are less prevalent in General Practice patients. On the other hand, GPs recruited to participate have a role in undergraduate instruction and residency training programs of General Practice / Family Medicine, and it is known that there is a positive correlation between higher academic achievement and ability to interpret ECGs [3].

Several articles had been published about GP skills with respect to reading ECGs. Macallan et al in 1990 [3] considered the ability of ECG interpretation as an important skill in professional practice for GPs, despite having found poor results on the accuracy of readings of 15 previously chosen ECGs. Denise Sur, in 2000 [4], applied an identical design to residents in Family Medicine and found an overall hit rate of 67%. She interpreted that as within acceptable ranges for inter-observer variability, but considered it as an inspiration for improvement.

In 1992, Woolley [15] found a proportion of agreement for family doctors of 67%. Mant, in 2007, studied the diagnostic accuracy of atrial fibrillation of primary care physicians and found a sensitivity of 80% and a specificity of 92% compared to the gold standard set by cardiologists' reading [5]. Jensen in 2004 found a sensitivity of 70% and a specificity of 86% in the detection of abnormalities by GPs [2].

In this study, we found an agreement proportion of over 0.8 between GPs and cardiologists with kappa values above 0.7, which are slightly higher than those reported in the literature, allowing us consider as defining a high quality standard.

The experience of having read many ECGs over several years of practice and the intrinsic interest of GPs involved in cardiovascular diseases are factors to take into account in the discussion of these data, knowing that the accuracy of readings will increase with greater experience [16], but this characteristic is present in many physicians all over the country, making us believe that it's possible to extrapolate these results for Portuguese reality: each Health Centre may have at least one physician with expertise in reading and interpretation of ECGs, decreasing financial costs and improving patients' accessibility.

In this study, methodological restrictions forced us to conceal the participants' clinical history and other patient data when the GPs interpreted the tracings. It is known that the knowledge of the clinical data may increase accuracy of readings up to 25% [17–19]. As reports are

usually recorded directly on the patient's electronic clinical file, integration with medical history is possible, and accuracy of readings may thereby be improved. This may be important in the case of abnormalities associated with minor ST-T ventricular repolarization, where results showed lower sensitivity.

The subject of rare diagnoses is an important question that is not clearly answered in this study. The high value of sensitivity for detection of normal ECG makes the prospect of the ease of identifying abnormal tests versus normal ones. When doubt arises, it is always possible to refer to a cardiologist for further clarification [20]. This point is corroborated by the tendency to correlation, although not significant, between self-perception of the degree of difficulty by GP and the proportion of agreement with the reading of the cardiologist. This makes it credible that the greater complexity of the ECG will correspond to a higher use of support tools. Finally, greater experience in reading and interpretation of ECGs will lead to better training and competence of GPs.

5. Conclusions

GPs showed good ability on reading ECGs from a daily Primary Care practice. The possibility of integrating readings from patients' medical history may improve accuracy of reports, especially in abnormalities related to minor ST-T abnormalities.

This study demonstrates Portuguese GPs can be competent to evaluate their patients' ECGs. Continuing medical education programs focused on ECG interpretation, emphasizing clinical cases in daily practice, are important tools to implement quality standards, making it possible to generalize General Practitioners' readings of electrocardiograms.

Ethical considerations

Study protocol had supervision and acceptance of Ethical Committee of *S. João* Health Centre.

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Conflict of interests

Authors disclose any conflict of interests

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