Anne Groot, Michiel L Bots, Frans H Rutten, Hester M den Ruijter, Mattijs E Numans and Ilonca Vaartjes

Measurement of ECG abnormalities and cardiovascular risk classification:

a cohort study of primary care patients in the Netherlands

Abstract

Background
GPs need accurate tools for cardiovascular (CV) risk assessment. Abnormalities in resting electrocardiograms (ECGs) relate to increased CV risk.

Aim
To determine whether measurement of ECG abnormalities on top of established risk estimation (SCORE) improves CV risk classification in a primary care population.

Design and setting
A cohort study of patients enlisted with academic general practices in the Netherlands (the Utrecht Health Project [UHP]).

Method
Incident CV events were extracted from the GP records. MEANS algorithm was used to assess ECG abnormalities. Cox proportional hazards modelling was applied to relate ECG abnormalities to CV events. For a prediction model only with SCORE variables, and a model with SCORE+ECG abnormalities, the discriminative value (area under the receiver operator curve [AUC]) and the net reclassification improvement (NRI) were estimated.

Results
A total of 2370 participants aged 38–74 years were included, all eligible for CV risk assessment. During a mean follow-up of 7.8 years, 172 CV events occurred. In 19% of the participants at least one ECG abnormality was found (Lausanne criteria). Presence of atrial fibrillation/flutter (AF) and myocardial infarction (MI) were significantly related to CV events. The AUC of the SCORE risk factors was 0.75 (95% CI = 0.71 to 0.79). Addition of MI or AF resulted in an AUC of 0.76 (95% CI = 0.72 to 0.79) and 0.75 (95% CI = 0.72 to 0.79), respectively. The NRI with the addition of ECG abnormalities was small (MI 1.0%; 95% CI = –3.2% to 6.9%; AF 0.5%; 95% CI = –3.5% to 3.3%).

Conclusion
Performing a resting ECG in a primary care population does not seem to improve risk classification when SCORE information — age, sex, smoking, systolic blood pressure, and total cholesterol/HDL ratio — is already available.

Keywords
cardiovascular risk assessment; ECG; primary care, SCORE chart.

INTRODUCTION

At present, cardiovascular (CV) risk management of patients in primary care is based on estimates of the absolute risk of getting a serious CV event in the next decade. Individuals with increased risk are identified and hence can be treated with lifestyle optimisation, blood pressure control, and lipid-lowering drugs.[1] The final goal is to lower the risk and to prevent disability and death from CV disease.

GPs estimate the CV risk of their patients following the Dutch guideline on CV risk management.[1] In those who have never experienced a symptomatic CV event, the estimate of the risk is based on age, sex, cigarette smoking status, systolic blood pressure, and total cholesterol/high-density lipoprotein cholesterol (TC/HDL) ratio using the Systematic Coronary Risk Evaluation (SCORE) charts. The guideline uses the SCORE risk function,[2] which has been adjusted using national data. The risk function predicts the risk of fatal and non-fatal CV events over 10 years. The 10-year risk is expressed by a percentage, and classified as low (<10%), intermediate (10–19%), or high (≥20%).[1] In the Dutch guidelines, when a patient has diabetes or rheumatoid arthritis, the patient's age used for risk estimation is increased by 15 years.

Low-risk patients are offered lifestyle advice and support. This includes advice to quit smoking, take adequate physical exercise, eat healthily, aim for an optimal bodyweight, and limit the consumption of alcohol. Drug therapy, such as blood pressure-lowering and cholesterol-lowering drugs, is recommended for high-risk patients, depending on the levels of the risk factors (systolic pressure >140 mmHg and/or low-density lipoprotein cholesterol >2.5 mmol/l). Intermediate-risk patients may be offered drug therapy, in addition to lifestyle support. In this intermediate group drug therapy is recommended when additional risk factors are present, such as the presence of a family history of cardiovascular disease, renal impairment, lack of exercise, or obesity. The final judgement is made by the GP.

In a recent review, Chou and colleagues indicated that, out of the 63 prospective studies into the relation of electrocardiogram (ECG) abnormalities and future CV events, no studies provided evidence on how accurately ECG abnormalities classified participants into high-, intermediate-, or low-risk groups, compared with traditional risk factor assessment alone. Thus the clinical implication of a resting ECG remained undetermined.[3] Furthermore, the European Society of Cardiology (ESC) study group

A Groot, MSc, MD, GP; **ML Bots**, PhD, MD, professor of epidemiology of cardiovascular disease; **FH Rutten**, MD, PhD, researcher and GP; **I Vaartjes**, PhD, researcher, cardiovascular epidemiology, Julius Center for Health Sciences and Primary Care; **HM den Ruijter**, PhD, researcher, Department of Experimental Cardiology, University Medical Center Utrecht, Utrecht, the Netherlands. **ME Numans**, PhD, MD, professor of general practice, Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, and Department of General Practice, Free University Amsterdam, Amsterdam, the Netherlands.

Address for correspondence
Ilonca Vaartjes, Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht (STR 6.131), PO Box 85500, 3508 GA Utrecht, the Netherlands.
E-mail: c.h.vaartjes@umcutrecht.nl

Submitted: 22 April 2014; **Editor's response:** 6 June 2014; **final acceptance:** 29 July 2014.

How this fits in

It has long been known that electrocardiogram (ECG) abnormalities are significantly associated with increased risk of cardiovascular (CV) disease. The ECG is easily performed, low in cost, and applicable in primary care, and therefore may be of use for prediction of CV risk. This study showed however that adding ECG information to SCORE information (age, sex, smoking, systolic blood pressure, and total cholesterol/HDL ratio) does not improve risk classification.

of sports cardiology has recommended use of the Lausanne criteria to assess an individual risk on sudden cardiac event. Yet evidence on the relation with CV events and its potential role in risk classification is not established.[4]

The ESC's recent CV disease prevention guidelines[5] recommend managing subjects with a low (<4%) CV mortality risk based on SCORE, but with left ventricular hypertrophy (LVH) on the ECG as individuals at intermediate risk (5–9%) for CV events. However, guidelines such as the Joint British Societies' guidelines on prevention of CV disease in clinical practice[6] and the clinical practice guideline for CV risk management in the Netherlands[7] do not recommend an ECG. In addition, ECG findings such as right and left bundle branch blocks (BBBs), ST-segment, and/or T-wave abnormalities and second- and third-degree atrioventricular (AV) blocks have been found to consistently predict future CV events in the population at large.[8–10] These ECG findings have not been mentioned in the guidelines even though the relative risk of CV disease in these latter abnormalities is of similar magnitude to that of LVH.

Since many abnormalities found on routine resting ECGs have prognostic and potential therapeutic consequences they may be of clinical relevance. The resting ECG is easily made, low in cost, and applicable in primary care. Therefore, this study examined whether measurement of ECG abnormalities on top of established risk factor measurement (SCORE risk factors) improved CV risk classification.

METHOD

Study population

This study used data derived from the Utrecht Health Project (UHP). This is an ongoing primary care-based cohort study among patients enlisted with academic general practice centres affiliated with the Julius Center, University Medical Center Utrecht, the Netherlands. Patients from a newly-developed residential area, near the city of Utrecht, were invited to come in for an 'individual health profile' (IHP). The study was described more extensively elsewhere.[11] Inclusion of participants in the UHP started in 2000. ECGs were collected from 6526 subsequent participants recruited from April 2000 to January 2007.

The present analysis was restricted to those participants eligible for SCORE estimation according to the Dutch guideline.[1] Participants with already established CV disease at inclusion were excluded (n = 192). Those aged <38 years and ≥73 years were excluded (n = 3605). Participants with a systolic blood pressure >180 mmHg (n = 50) and with a cholesterol ratio >8 (n = 226) were excluded. Of the remaining 2453 participants complete information on both SCORE risk factors and ECG parameters was available for 2370 (96.6%), who constitute the current study population. Considering the low percentage of missing data no attempt was made to impute missing values.

Risk factor measurements

All participants went through a general health questionnaire with a trained nurse, and information was obtained on medical history, current drug use, and lifestyle. Height and weight were measured. Serum cholesterol and serum glucose were measured on a Synchron LX20 (Beckman Coulter). Blood pressure was measured on the dominant arm with an Omron M4 device. The cuff sizes were adjusted to the arm circumference. Blood pressure measurements were taken twice in the sitting position, with a 2-minute gap, on a single occasion. The mean of both measurements was used for risk estimation. Using the SCORE algorithm, each individual was categorised into a risk category based on the individual's age, sex, cigarette smoking status, systolic blood pressure, and TC/HDL ratio. The estimated 10-year CV risk groups were low (<10%), intermediate (10–19%), or high (≥20%).[1,2]

ECG measurements

The 12-lead ECG, taken in the resting condition, was digitally stored and analysed by the Modular ECG Analysis System (MEANS), as described in detail elsewhere.[12] MEANS is a scoring system that can be used by a GP resulting in a diagnosis. Measurements were derived from the representative complex that results from selective averaging of dominant beats. The

measurement and classification parts of MEANS have been extensively evaluated, both by the developers themselves and by independent observers.[13] Based on the MEANS classification, abnormalities were classified into myocardial infarction (MI), LVH, AF, left and right BBBs, ST-segment and/or T-wave abnormalities, and second- and third-degree AV blocks. A previous study showed that sensitivity and specificity for having the diagnosis correct is similar when using the MEANS scoring system or having the diagnosis set by a cardiologist.[14] However, another study has reported less specificity.[15]

In addition to the MEANS classification, all ECG patterns were evaluated according to the Lausanne criteria for ECG evaluation, as recommended by the ESC (Appendix 1).[16]

Cardiovascular events

In April 2012 incident CV events since baseline were assessed. Newly-diagnosed CV diseases were identified using the International Classification of Primary Care (ICPC) codes in the GP records.[17,18]

A CV event was defined as the occurrence of MI (K75), angina pectoris (K74), stroke (K90), transient ischaemic attack (K89), atherosclerosis (K91), heart failure (K77), aortic aneurysm (K99.1), peripheral arterial disease (K92.1), or vascular dementia (P70.2) during follow-up. For participants who died during follow-up, it was determined if the cause of death had been of CV origin.

Statistical analysis

For every individual the 10-year CV risk was calculated according to the SCORE risk classification and individuals were classified into risk categories of low (<10%), intermediate (10–20%), or high (≥20%).[1,2] General characteristics were presented as proportions or means with corresponding standard deviations, when appropriate. Data were presented for the total group and by risk category. The ECG abnormalities were evaluated using Cox proportional hazard models. Each ECG abnormality was evaluated separately. Those ECG abnormalities that were related to CV events in the Cox model with a *P*-value <0.157 were combined in a more extended multivariable Cox model, including the SCORE variables.

The area under the operating curve and the net reclassification improvement. The original variables of SCORE — age (adapted in the presence of diabetes mellitus and/or rheumatoid arthritis), sex, smoking status, systolic blood pressure, and cholesterol/HDL ratio — were refitted using a multivariable Cox proportional-hazards model. This baseline model was extended by those ECG abnormalities that were related to CV events in the Cox model with a *P*-value <0.157. The discriminative value of both models was expressed with the area under the receiver operator curve (AUC). The 10-year absolute risk to develop

Table 1. General characteristics of the study population, categorised by risk according to Dutch Score, 2011

	Total	Risk <10%	Risk 10–20%	Risk ≥20%
n (%)	2370	1920 (81)	230 (9.7)	220 (9.3)
Age, years ± SD	48.0 ± 9.6	44.9 ± 7.3	58.2 ± 6.7	63.8 ± 6.2
Male, %	47	44	64	62
Current smoker, %	27.2	25.5	39.1	29.5
Systolic blood pressure, mmHg ± SD	128.1 ± 18.3	124.3 ± 15.8	140.7 ± 18.3	149.4 ± 17.9
Cholesterol ratio ± SD	4.4 ± 1.3	4.3 ± 1.3	4.9 ± 1.3	4.8 ± 1.3
Diabetes mellitus, %	5.1	1.2	8.7	35.0
Rheumatoid arthritis, %	2.4	0.8	8.3	10.5
BMI, kg/m^2	26 ± 10.6	26 ± 4.2	27 ± 4.2	27 ± 4.1
Medication use, %				
Diuretics	3.3	2.3	5.7	7.3
Beta-blockers	4.3	3.0	7.4	13.2
Calcium antagonists	1.2	0.6	2.6	4.5
ACE inhibitors	4.2	2.9	5.2	14.5
Statins	1.2	2.0	10.4	11.8
BP lowering	9.8	6.7	15.2	30.9
Diabetic medication	1.6	0.3	2.6	11.8
CVD events during follow-up, %	7.3	4.6	15.2	22.3

BMI = body mass index. BP = blood pressure. CVD = cardiovascular disease. SD = standard deviation.

a CV event was calculated for both models and was used to classify individuals into risk categories of low (<10%), intermediate (10–20%), or high (≥20%) risk according to SCORE risk classification. The net reclassification improvement (NRI)[18–20] was calculated. The NRI quantifies the percentage of correct movement across categories for those with and without events. Correct movement is upward classification by a new marker in those with events and downward classification in those without events. This study's risk prediction model was based on time-to-event data, which contain not only events and non-events but also individuals who discontinue prematurely. Therefore, the number of individuals reclassified due to a change in risk category was then described using the NRI taking survival time into account. The corresponding 95% confidence intervals (CIs) were obtained with bootstrapping.

SPSS (version 20) was used for the statistical calculations. All NRI analyses were performed in the statistical environment R (version 2.10.0). The model was not validated with ECG measurements because the aim was not to create and validate a new prediction rule, but to assess the actual improvement in risk prediction. All statistical testing was two-sided and $P<0.05$ was considered statistically significant.

RESULTS

The study population comprised 2370 participants. Of all participants, 81% had a low risk and 9.7% had an intermediate risk; 9.3% was considered high risk (Table 1). The mean follow-up was 7.8 years during which 172 new CV events occurred. The incidence of CV events ranged from 4.6% in the low-risk group, to 15.2% in the intermediate group, up to 22.3% in the high-risk group (Table 1). In general, the prevalence of single ECG abnormalities was low except for prolongation of heart rate-corrected QT interval (7.3%), whereas the prevalence of an abnormal ECG based on the presence of any of the Lausanne criteria was high (19.0%) (Table 2).

Of all the ECG abnormalities evaluated, atrial fibrillation/flutter (AF), and MI were statistically significant related to CV events after adjustment for SCORE risk factors

Table 2. Prevalence of ECG abnormalities in the study population

	ECG abnormalities	Model 1 HR (95% CI)
Lausanne criteria	**P-wave**	
	Left atrial enlargement	[a]
	Right atrial enlargement	[a]
	QRS complex	
	QRS axis deviation	4.8 (3.9 to 5.7)
	Increased voltage	0.4 (0.2 to 0.7)
	Pathological Q-waves	0.5 (0.3 to 0.8)
	Right or left bundle branch block	0.9 (0.5 to 1.0)
	R or R' wave in lead V1	0.3 (0.1 to 0.6)
	ST-segment, T-waves, and QT-interval	
	ST-segment depression, T-wave flattening, or inversion in two or more leads	3.1 (2.4 to 3.8)
	Prolongation of heart rate-corrected QT interval	7.3 (6.2 to 8.3)
	Rhythm and conduction abnormalities	
	Premature ventricular beats or more severe ventricular arrhythmias	1.9 (1.4 to 2.5)
	Supraventricular tachycardias, atrial flutter, or atrial fibrillation	0.6 (0.3 to 0.9)
	Short PR interval	2.8 (2.1 to 3.4)
	Sinus bradycardia	[a]
	First-, second-, or third-degree atrioventricular block	1.6 (1.1 to 2.2)
	Any Lausanne abnormality	19.0 (17 to 21)
MEANS diagnosis	Myocardial infarction	2.0 (1.4 to 2.5)
	Left ventricular hypertrophy	0.2 (0.0 to 0.4)
	Atrial fibrillation/flutter	0.6 (0.3 to 0.9)
	Left and right bundle branch block	0.9 (0.5 to 1.3)
	ST-segment and/or T-wave abnormalities	3.1 (2.4 to 3.8)
	Second and third atrioventricular blocks	0.2 (0.0 to 0.4)

[a] *Not calculated because fewer than five individuals. HR = hazard ratio.*

Table 3. Relation of ECG abnormalities with CV events: univariable (model 1), and adjusted for SCORE risk factors (model 2)

	ECG abnormalities	Model 1, HR (95% CI)	Model 2,[a] HR (95% CI)
Lausanne criteria	**P-wave**		
	Left atrial enlargement	[b]	
	Right atrial enlargement	[b]	
	QRS complex		
	QRS axis deviation	1.5 (0.8 to 2.7)	
	Increased voltage	1.1 (0.2 to 8.1)	
	Pathological Q-waves	4.3 (1.6 to 11.6)	2.2 (0.8 to 6.0)
	Right or left bundle branch block	2.6 (0.8 to 8.2)	1.5 (0.5 to 4.8)
	R or R' wave in lead V1	2.2 (0.3 to 16.0)	
	ST-segment, T-waves, and QT-interval		
	ST-segment depression, T-wave flattening, or inversion in two or more leads	2.2 (1.2 to 4.2)	1.4 (0.8 to 2.7)
	Prolongation of heart rate-corrected QT interval	1.7 (1.0 to 2.7)	0.9 (0.6 to 1.6)
	Rhythm and conduction abnormalities		
	Premature ventricular beats or more severe ventricular arrhythmias	1.6 (0.6 to 3.8)	
	Supraventricular tachycardias, atrial flutter, or atrial fibrillation	6.3 (2.3 to 16.9)	4.4 (1.6 to 11.9)
	Short PR interval	0.9 (0.3 to 2.4)	
	Sinus bradycardia	[b]	
	First-, second-, or third-degree atrioventricular block	1.7 (0.6 to 4.7)	
	Any Lausanne abnormality	1.6 (1.2 to 2.3)	1.2 (0.8 to 1.6)
MEANS diagnosis	Myocardial infarction	3.3 (1.7 to 6.2)	2.3 (1.2 to 4.3)
	Left ventricular hypertrophy	0.5 (0.0 to 16.8)	
	Atrial fibrillation/flutter	6.3 (2.3 to 16.9)	4.4 (1.6 to 11.9)
	Left and right bundle branch block	2.6 (0.8 to 8.2)	1.5 (0.5 to 4.8)
	ST-segment and/or T-wave abnormalities	2.1 (1.6 to 4.2)	1.4 (0.8 to 2.7)
	Second and third atrioventricular blocks	4.1 (0.6 to 29.0)	

[a]Cox model (model 1) with a P-value <0.157 was combined in a more extended multivariable Cox model (model 2).
[b]Not calculated as fewer than five individuals.

(Table 3). A positive Lausanne score was not significantly related to CV event risk (1.2; 95% CI = 0.8 to 1.6).

Based on this analysis it was possible to predict CV events using only the SCORE risk factors with an AUC of 0.75 (95% CI = 0.71 to 0.79). Addition of the information on the presence of MI or the presence of AF resulted in an AUC of 0.76 (95% CI = 0.72 to 0.79) and 0.75 (95% CI = 0.72 to 0.79), respectively. As the Lausanne score was not related to event risk, the AUC for the Lausanne criteria was not assessed.

This analysis of reclassification improvement showed a small increase of the NRI for SCORE plus MI of 1.0% (95% CI = –3.2% to 6.9%). The NRI for SCORE plus AF was 0.5% (95% CI = –3.5% to 3.3%). Both results indicated no significant improvement of the model with ECG abnormalities.

DISCUSSION

Summary

This study's results show that, in the general population with a mean age of 48 years and from whom information on established risk factors is available, there is no added value in performing a resting ECG to improve CV risk classification. More specifically, the Lausanne criteria evaluation, the presence of a MI, and the presence of AF did not improve the risk classification.

Strengths and limitations

Most studies on ECG abnormalities used manual readings from printed ECGs and/or applied the Minnesota Codes for the ECG diagnoses, although specificity has been shown to be less favourable. A less effective performance may lead to an underestimation of the relations under study, and may explain the small magnitude of the NRI. Therefore confirmation of these results in a larger sample of the population is needed. In addition, the number of events was reasonably high for the overall evaluation, but too small for detailed, valid, and precise subgroup analyses (for example, by sex or by SCORE risk category).

Comparison with existing literature

At present, as indicated by the most recent review, there is no evidence that assesses the degree to which performing resting ECG in an individual participant more accurately moves them from one risk category to another.[3] Two studies have reported on the change in the AUC.[19,20] These studies showed slight improvements in AUC, of a similar magnitude as in the current study. Yet the change in the AUC is of limited clinical usefulness. It does not provide information about the actual predicted risks, or the proportion of participants classified (or reclassified) as high, intermediate, or low risk.[21] This study expands the current evidence by showing that the NRI was small, not statistically significant, and most likely of limited clinical value.

The currently available studies are mainly directed towards assessing the relation

between ECG abnormalities and risk of future events. It has been consistently shown that abnormalities on a resting ECG (such as ST-segment or T-wave abnormalities, AF, LVH, BBB, left axis deviation, or Q-waves) are associated with increased risk of subsequent CV events with relative risk estimates ranging from 1.4 to 2.1. This study confirmed that for some of these parameters. The evidence was expanded by showing that an assessment of the ECG using the Lausanne criteria was not related to event risk. The importance of this finding is in the fact that these criteria were set up to identify individuals at high risk of a cardiac event.[15]

Implications for practice

These results suggest that there is no use in performing an ECG for improvement of risk classification. The findings are in line with several guidelines that recommend refraining from a routine resting ECG for CV risk stratification.[5,6] In the November 2013 guideline on the assessment of CV risk, issued by the American Heart Association in collaboration with the American College of Cardiology, an ECG is not recommended in risk assessment. However, this guideline does indicate that an ECG may be of value when it is meant for diagnostic purposes.[22]

The latter is an important addition, since one of the reasons for an ECG may be the detection of conditions (that is, diagnosis) that require different treatment options than in increased CV risk assessment. In the study population, a reasonable number of unrecognised MIs were found (2.0%). AF was found in 0.6%, whereas changes in repolarisation were observed in 3.1%. Yet this is not the topic of current analyses. For a formal recommendation of the diagnostic yield, a different approach is needed in which balancing prevalence of the condition, number needed to screen to detect one case, options for treatment, and costs need to be discussed. Indeed a previous report, from the current study's group, supported an ECG measurement in individuals with hypertension, as the prevalence of abnormalities was higher than in the non-hypertensive population and thus the number needed to screen was acceptably low, with a potential to prevent future CV events that was relatively high.[23] In conclusion, performing a resting ECG does not improve CV risk classification when information on age, sex, smoking, systolic blood pressure, and TC/HDL ratio is already available.

Funding

The Utrecht Health Project received grants from the Ministry of Health, Welfare and Sports (VWS), the University of Utrecht, the Province of Utrecht, the Dutch Organisation of Care Research, the University Medical Centre of Utrecht, and the Dutch College of Healthcare Insurance Companies. Ilonca Vaartjes is supported by a grant from the Dutch Heart Foundation (project facts and figures).

Ethical approval

The Utrecht Health Project was approved by the medical ethical committee of the University Medical Center of Utrecht and all participants gave written consent, including for linkage of their data from their routine primary care electronic medical records with baseline data gathered at inclusion.

Provenance

Freely submitted; externally peer reviewed.

Competing interests

The authors have declared no competing interests.

Discuss this article

Contribute and read comments about this article: **bjgp.org/letters**

REFERENCES

1. Nederlands Huisartsen Genootschap. *Multidisciplinaire richtlijn cardiovasculair risicomanagement* [Multidisciplinary guideline cardiovascular risk management]. Houten: Bohn Stafleu van Loghum, 2011.
2. Conroy RM, Pyörälä K, Fitzgerald AP, *et al*. Estimation of ten-year risk of fatal cardiovascular disease in Europe; the SCORE project. *Eur Heart J* 2003; **24(11):** 987–1003.
3. Chou R, Bhaskar A, Dana T, *et al*. *Screening asymptomatic adults for coronary heart disease with resting or exercise electrocardiography: systematic review to update the 2004 U.S. Preventive Services Task Force recommendation*. Rockville, MD: Agency for Healthcare Research and Quality (US), 2011. http://www.ncbi.nlm.nih.gov/books/NBK63671/ (accessed 29 Oct 2014).
4. Corrado D, Pelliccia A, Heidbuchel H, *et al*.; Section of Sports Cardiology, European Association of Cardiovascular Prevention and Rehabilitation. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. *Eur Heart J* 2010; **31(2):** 243–259.
5. Graham I, Atar D, Borch-Johnsen K, *et al*. European guidelines on cardiovascular disease prevention in clinical practice: full text. Fourth Joint Task Force of the European Society of Cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of nine societies and by invited experts). *Eur J Cardiovasc Prev Rehabil* 2007; **14(Suppl 2):** S1–S113.
6. JBS3 Board. Joint British Societies' consensus recommendations for the prevention of cardiovascular disease (JBS3). *Heart* 2014; **100(Suppl 2):** ii1–ii67.
7. Smulders YM, Burgers JS, Scheltens T, *et al*. Clinical practice guideline for cardiovascular risk management in the Netherlands. *Neth J Med* 2008; **66(4):** 169–174.
8. De Bacquer D, De Backer G, Kornitzer M, Blackburn H. Prognostic value of ECG findings for total, cardiovascular disease, and coronary heart disease death in men and women. *Heart* 1998; **80(6):** 570–577.
9. Schillaci G, Pirro M, Pasqualini L, *et al*. Prognostic significance of isolated, non-specific left ventricular repolarization abnormalities in hypertension. *J Hypertens* 2004; **22(2):** 407–414.
10. Ström Möller C, Zethelius B, Sundström J, Lind L. Persistent ischaemic ECG abnormalities on repeated ECG examination have important prognostic value for cardiovascular disease beyond established risk factors: a population-based study in middle-aged men with up to 32 years of follow-up. *Heart* 2007; **93(9):** 1104–1110.
11. Grobbee DE, Hoes AW, Verheij TJ, *et al*. The Utrecht Health Project: optimization of routine healthcare data for research. *Eur J Epidemiol* 2005; **20(3):** 285–287.
12. van Bemmel JH, Kors JA, van Herpen G. Methodology of the modular ECG analysis system MEANS. *Methods Inf Med* 1990; **29(4):** 345–353.
13. Willems JL, Arnaud P, Van Bemmel JH, *et al*. A reference data base for multilead electrocardiographic computer measurement programs. *J Am Coll Cardiol* 1987; **10(6):** 1313–1321.
14. de Bruyne MC, Kors JA, Visentin S, *et al*. Reproducibility of computerized ECG measurements and coding in a nonhospitalized elderly population. *J Electrocardiol* 1998; **31(3):** 189–195.
15. Whitman M, Layt D, Yelland M. Key findings on ECGs: level of agreement between GPs and cardiologists. *Aust Fam Physician* 2012; **41(1–2):** 59–62.
16. Bille K, Figueiras D, Schamasch P, *et al*. Sudden cardiac death in athletes: the Lausanne Recommendations. *Eur J Cardiovasc Prev Rehabil* 2006; **13(6):** 859–875.
17. Hofmans-Okkes IM, Lamberts H. The International Classification of Primary Care (ICPC): new applications in research and computer-based patient records in family practice. *Fam Pract* 1996; **13(3):** 294–302.
18. Leening MJ, Kavousi M, Heeringa J, *et al*. Methods of data collection and definitions of cardiac outcomes in the Rotterdam Study. *Eur J Epidemiol* 2012; **27(3):** 173–185.
19. Denes P, Larson JC, Lloyd-Jones DM, *et al*. Major and minor ECG abnormalities in asymptomatic women and risk of cardiovascular events and mortality. *JAMA* 2007; **297(9):** 978–985.
20. Aktas MK, Ozduran V, Pothier CE, *et al*. Global risk scores and exercise testing for predicting all-cause mortality in a preventive medicine program. *JAMA* 2004; **292(12):** 1462–1468.
21. Janes H, Pepe MS, Gu W. Assessing the value of risk predictions by using risk stratification tables. *Ann Intern Med* 2008; **149(10):** 751–760.
22. Goff DC Jr, Lloyd-Jones DM, Bennett G, *et al*. 2013 ACC/AHA guideline on the assessment of cardiovascular risk: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol 2013*; DOI: 10.1016/j.jacc.2013.11.005.
23. Scheltens T, de Beus MF, Hoes AW, *et al*. The potential yield of ECG screening of hypertensive patients: the Utrecht Health Project. *J Hypertens* 2010; **28(7):** 1527–1533.

Appendix 1. Lausanne criteria for a positive 12-lead ECG

P-wave
Left atrial enlargement: negative portion of P-wave in lead V1 of ≤0.1 mV depth and duration of ≥0.04 seconds
Right atrial enlargement: peaked P-wave in leads II and III or V1 of ≥0.25 mV amplitude
QRS complex
QRS axis deviation: right 120° or more or left –30° to –90°
Increased voltage: amplitude of R-wave or S-wave in a standard lead of ≥2 mV, S-wave in lead V1 or V2 of ≥3 mV, or R-wave in lead V5 or V6 of ≥3 mV
Pathological Q-waves: duration ≥0.04 seconds, or ≥25% of the height of the ensuing R-wave, or QS pattern in two or more leads
Right or left bundle branch block with QRS duration of ≥0.12 seconds
R or R' wave in lead V1 ≥0.5 mV in amplitude and R/S ratio of ≥1
ST-segment, T-waves, and QT-interval
ST-segment depression, T-wave flattening, or inversion in two or more leads
Prolongation of heart rate-corrected QT interval of >0.44 seconds in males and >0.46 seconds in females
Rhythm and conduction abnormalities
Premature ventricular beats or more severe ventricular arrhythmias
Supraventricular tachycardias, atrial flutter, or atrial fibrillation
Short PR interval (<0.12 seconds) with or without 'delta' wave
Sinus bradycardia with resting heart rate ≤40 beats/minute
First- (PR 0.21 seconds), second-, or third-degree atrioventricular block