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Comparison Between Two Classification Systems of the Electrocardiogram in Epidemiologic Investigations

The Minnesota Code and the Washington, D.C., Code

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The electrocardiocardiogram (ECG) is a basic method used in cardiovascular epidemiologic investigations. Its value as a prognostic indicator of future cardiac events has been fully demonstrated, and some ECG items, such as a pattern of left ventricular hypertrophy, are considered as among the definite cardiovascular risk factors.[1]

However, the prevalence rates of various ECG abnormalities in a given population will depend on the true prevalence of cardiac disease as well as on the sensitivity and specificity of the ECG criteria included in the classification system. Different ECG coding systems using different criteria might provide different rates of ECG abnormalities in the same population.

The most widely used and internationally accepted ECG coding system is the Minnesota code (MC), introduced by Blackburn in the 1960s.[2] This system, designed for the standard 12-lead ECG, was developed on an empirical basis, according to generally accepted criteria. More recently, Pipberger et al. proposed a new classification system, developed at the Washington VA hospital.[3] The Washington, D.C. code (WC) is designed for use with the Frank orthogonal lead system. By contrast with the MC, the WC has been validated on a population with well-known cardiovascular status. The purpose of this study was to compare the two coding systems by applying them to the same population sample.

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Material and Methods

The study population consisted of 1,948 subjects equally divided between men and women, among three age groups from 35 to 64 years old. This population sample came from the Province of Luxembourg in Belgium. The screening was performed as partial requirement for the BELLUX MONICA Project.[4] In each individual, a 12-lead ECG immediately followed by a three orthogonal XYZ-lead ECG was recorded by automatic three-channel electrocardiographs (Siemens Mingograph), using a single 14-lead patient cable. The Frank electrodes were placed in the fifth intercostal space as originally described. Both the 12-lead and the 3-orthogonal lead recordings were analyzed visually by two technicians who classified each tracing according to the two methods (ie, the MC for the 12-lead ECG and the WC for the Frank-lead ECG). These technicians had been trained for using the MC in the frame of the MONICA project. Through their clinical work, they also had a good knowledge of the Frank-lead system, and further precisions concerning the WC were provided by the developers. The two technicians worked independent of each other. Differences were first resolved between them, and any remaining disagreement was arbitrated by a cardiologist who had practicing knowledge of both lead systems and of both coding schemes.

In the first stage, the prevalence rates of various ECG categories reported by the two codes were compared and the sources of discrepancies analyzed. To make this comparison, equivalences between the

Table 1. Minnesota Code (MC) Versus Washington Code (WC)

	MC	WC
MI		
Lateral		
Hi spe	1.1.1–1.1.3 *	2.1.A*
Lo spe	1.1.2–1.2.8 or 1.3.1, 1.3.3	2.1.B
Anterior		
Hi spe	1.1.1–1.1.7	2.3.A
Lo spe	1.2.1–1.2.6 or 1.3.1, 1.3.2	2.3.B
Inferior		
Hi spe	1.1.1–1.1.5	2.2.A
Lo spe	1.2.1–1.2.6 or 1.3.1, 1.3.6	2.2.B
Posterior		
Hi spe	—	2.4.A
Lo spe	—	2.4.B
ST-T changes		
Injury/ischemia		
Lateral	4.1.1, 4.1.2	6.1.A, 6.1.B
	5.1 , 5.2	7.1.A, 7.1.B
Anterior	4.1.1, 4.1.2	6.6.A, 6.6.B
	5.1 , 5.2	7.3.A, 7.3.B
Inferior	4.1.1, 4.1.2	6.2.A, 6.2.B
	5.1 , 5.2	7.2.A, 7.2.B
Elevated ST		
Lateral	9.2	6.4.A, 6.4.B
Anterior	9.2	6.3.A, 6.3.B
Inferior	9.2	6.5.A, 6.5.B
LVH		
Hi spe	3.1	3.1.A, 3.2.A, 3.3.A
Lo spe	3.3	3.1.B, 3.2.B, 3.3.B
RVH/COLD		
Hi spe	3.2	4.1.A–4.5.A
Lo spe	—	4.1.B–4.5.B

MI, myocardial infarction; hi spe, high specificity criteria; LVH, left ventricular hypertrophy; lo spe, low specificity criteria; RVH/COLD, right ventricular hypertrophy/chronic obstructive lung disease.

* The actual criteria corresponding to these coding items can be found in the original publications concerning the MC[2] and WC.[3]

two codes were established in the main ECG categories shown in Table 1, taking into account different levels of specificity, when appropriate.

In the second stage, the two ECG codes were evaluated with reference to the clinical information. The prevalence rates of myocardial infarction (MI) and left ventricular hypertrophy (LVH) by the two codes were considered according to the presence or absence of a clinical diagnosis of MI and of high blood pressure (HBP), respectively, following the WHO criteria for these conditions. Differences in the prevalence rates between the two classification methods were expressed by means of the odds ratio and the percentage of concordance. The odds ratio indicates the odds of a subject with a clinical history of MI or HBP for having, respectively, MI or LVH, on the ECG n times those of a subject with no antecedent history of MI or HBP. The concordance rate is the proportion of correct ECG classifications (ie, the sum of true positives and true negatives over the total).

Table 2. Prevalence Rates of ECG Categories by Minnesota Code and Washington Code In a Sample of 1,948 Subjects

ECG Category	Minnesota Code	Washington Code
Normal	72.0%	42.0%
MI	2.5%	14.5%
LVH	3.6%	8.5%
RVH/COLD	0 %	15.4%
Ischemia	6.0%	13.7%

MI, myocardial infarction; LVH, left ventricular hypertrophy; RVH, right ventricular hypertrophy; COLD, chronic obstructive lung disease.

Results

Prevalence Rates, Concordance, and Discrepancies Between MC and WC

Table 2 shows the prevalence rates of the various ECG categories when MC and WC were applied to the same set of 1,948 recordings. The WC reported an excess rate of all abnormalities as compared with the MC. The differences were specially marked in the categories of MI, right ventricular hypertrophy (RVH), and chronic obstructive lung disease (COLD).

Table 3 shows the main areas of discrepancies. The excess rate of abnormalities reported by the WC was striking for anterior MI (AMI) and posterior MI (PMI), in both sexes and all age groups, for anterior ischemia and LVH in women, for RVH/COLD in men. In the category of AMI, 122 cases were diagnosed only by the WC, as compared with only 5 cases di-

Table 3. Concordances and Discrepancies Between Minnesota Code and Washington Code

ECG Category	Concordance (N) (Both Agree)	Discrepancies (N)	
		Minnesota Code	Washington Code
AMI	5	5	122
LMI	1	6	7
IMI	1	13	11
PMI	—	—	120
Total MI	7	24	260
Anterior ischemia	28	21	176
Total ischemic ST-T	66	33	188
LVH	31	36	131
RVH/COLD	0	0	300

AMI, anterior myocardial infarction; LMI, lateral myocardial infarction; IMI, inferior myocardial infarction; PMI, posterior myocardial infarction; LVH, left ventricular hypertrophy; RVH/COLD, right ventricular hypertrophy/chronic obstructive lung disease.

Table 4. Clinical Relevance of the Diagnosis of Myocardial Infarction by the Minnesota Code and the Washington Code

	ECG Diagnosis	Clinical Diagnosis		Odds Ratio	% Concordance
		Positive	Negative		
Men	N = 988	N = 58	N = 930		
MC (%)	3%	21%	2%	11.9	93
WC	15%	36%	14%	3.5	81
Women	N = 959	N = 32	N = 927		
MC	2%	12%	1%	10.9	96
WC	12%	28%	12%	2.8	84

agnosed by both the WC and the MC. Of 57 cases with WC high specifity criteria for AMI, 40 were men, whereas of 65 cases with low specificity criteria, 49 were women. Not surprising was the excess rate of 120 WC cases with PMI, since this category is not considered by the MC. In this PMI category, 51 were detected by high specificity criteria, of whom 39 were men. Among ischemic ST-T changes, the majority of excess codes by WC was found in the category of anterior ischemia in women (150 of 176 cases). The excess rate of 131 LVH cases was more important in women than in men: 47 versus 11 for high specificity criteria and 54 versus 19 for low specificity criteria. By contrast, the excess rate of WC for RVH/COLD was more prominent in men: of 300 cases, there were 95 men and 46 women with high specificity criteria, 83 men and 76 women having low specificity criteria.

Correlation With Clinical Diagnosis of MI and LVH

Table 4 shows the correlation between the ECG codes of MI by the two classification systems and the clinical information related to a history of MI. A clinical diagnosis of MI was present in 58 of the 988 screened male subjects and in 32 of the 959 women. In men, as compared with the MC, the WC had a higher sensitivity for MI (36% vs. 21%), but at the expense of a lower concordance with the clinical diagnosis (81% vs. 93%) due to a higher false positive rate (14% vs. 2%). The odds ratio for the ECG diagnosis of MI was 4 times higher with the MC than with the WC. Similar differences were found in women: higher sensitivity of WC (28% vs. 12%) but lower concordance rate (84% vs. 96%), higher false positive rate (12% vs. 1%), and a fourfold difference in the odds ratio (2.8 vs. 10.9).

Table 5 shows the comparison between MC and WC in the category of LVH. Here, the ECG code was evaluated according to the presence or absence of HBP, assuming that HBP leads to a higher susceptibility of developing LVH on the ECG. The condition of HBP was present in 325 men and 320 women. The concordance rates were similar with the two coding systems. Both ECG codes had a low sensitivity for LVH in male hypertensives. In women, the WC had a higher sensitivity than the MC (18% vs. 5%) at the expense of a higher false positive rate (6% vs. 0.5%). The odds ratios were similar in men and different in women (WC: 3.6, MC: 10.3). In women, the prevalence of HBP among those with LVH on the ECG was higher for the MC (83%) than for the WC (61%).

Discussion

On a theoretical basis, both the MC and the WC have potential advantages and disadvantages.

Table 5. Clinical Relevance of Diagnosis of LVH (According to the Presence or Absence of High Blood Pressure) by the Minnesota Code (MC) and the Washington Code (WC)

	ECG Diagnosis of MI	High Blood Pressure		Odds Ratio	% Concordance
		Positive	Negative		
Men	N = 981	N = 325	N = 656		
MC	5%	6%	5%	1.3	65
WC	5%	7%	4%	1.9	67
Women	N = 951	N = 320	N = 631		
MC	2%	5%	0.5%	10.3	67
WC	10%	18%	6%	3.6	68

The Minnesota code, which applies to the familiar 12-lead ECG, is very popular, in fact the most widely used classification system in epidemiologic investigations. With its many coding items, however, it is cumbersome to use, and practice is needed to reduce the number of coding errors. Moreover, the criteria introduced in the MC were developed on an empirical basis from generally accepted criteria known at that time. The Washington code was developed recently and was presented as a new classification system with the interest of being largely based on actual data distributions of normal and abnormal ECGs from a well-validated clinical data base. The WC also considers sex- and race-related differences in the ECG. Because it has a more limited set of codable items, it is easy to use, requires substantially less coding time, and reduces the number of possible coding errors. However, the prognostic value and reproducibility of the WC in large epidemiologic investigations have not yet been fully demonstrated. Moreover, it is based on a less familiar and less widely available lead system.

After applying the two coding systems to the same population, we observed that the WC reported far more ECG abnormalities than the MC. Some of the differences can be attributed to the design of each coding system (eg, by contrast with the WC, the MC does not consider the category of true posterior MI). The excess rate of abnormalities reported by the WC might be related to some of its criteria. For example, a high percentage of anterior ischemic ST-T wave changes was found in normal women with a posterior orientation of the T loop in the horizontal plane, whereas the WC criterion of T_z amplitude is the same for men and women. The excess rate of PMI and RVH/COLD in men is probably related to an anterior shift of QRS loop as a normal variant: the limit of 1.5 for the Q/R_z ratio was frequently exceeded in our normal male population. The excess rate of low specificity criteria for AMI in women is probably explained by the reduction of initial QRS forces in many normal women. For LVH, the excess rate of WC code, especially in women, might represent a higher true positive rate among patients with systemic hypertension, similar to the findings of De Backer, who compared the MC with a set of orthogonal criteria in middlle-aged men.[5]

After comparing the results obtained by the two coding systems with the clinical information, we found that the excess rate of MI and LVH codes reported by the WC was better explained by a high false positive rate than by a higher sensitivity. The reason for these differences is not clear. It is possible that the WC yields a higher false positive rate because it was designed from a population with a high proportion of cardiac abnormalities, contrary to what is found in most epidemiologic studies. In the set of records used for developing and testing the WC,[3] there were more MI cases (1,100) and LVH cases (1,277) than normal subjects (1,499). By contrast, in our population sample, only 14% of patients had CAD and 33% were hypertensive.

The observed differences and the low concordance between the two classification methods represent a conceptual problem for epidemiologic investigations, but they do not allow us to preclude a possible independent prognostic value of these two coding systems. Both their reproducibility and their independent prognostic value will be assessed by applying them on a new independent sample from the same population, and by following this cohort for CAD incidence by means of the MONICA registry over the next years.

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