

This Week's Citation Classic

Blackburn H, Keys A, Simonson E, Rautaharju P & Punsar S. The electrocardiogram in population studies: a classification system. *Circulation* 21:1160-75, 1960. [Lab. Physiol. Hygiene, Univ. Minnesota, Minneapolis, MN]

The Minnesota Code meets a need in population studies and clinical trials for discrete, quantitative criteria, numerical codes, and detailed procedures for classification, training, and quality control. It is based on validated clinical-pathological criteria for electrocardiogram (ECG) items related to major cardiac conditions. [The SCI® indicates that this paper has been cited over 405 times since 1961.]

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"In the 1950s, systematic population studies began on heart disease. They eventually demonstrated large population differences in the frequency of coronary and other major cardiovascular diseases. They established the influence of personal behavior and characteristics on future risk. Fresh from a residency in internal medicine, I joined the group of Ancel Keys and the laboratory of physiological hygiene at Minnesota. An immediate research need was to compare disease rates in populations and I was charged with development of clinical criteria and procedures to reduce random and systematic error in cardiac diagnoses. The ECG suggested obvious advantages for objective population comparisons. It represents relevant endpoints of ischemia, infarction, hypertension, and arrhythmia and is independent of other measures. In graphic form, it is amenable to standardized acquisition and bias-free measurement and classification. It is simple, inexpensive, and feasible for population studies and clinical trials. But nowhere to be found were agreed upon ECG criteria or any format for quantitative classification and coding. I thus set about to assemble the best criteria available and, where not available, worked with Ernst Simonson, Pentti Rautaharju, Gunnar Blomqvist, and Sven Punsar to develop and test sensitivity and specificity of new criteria among defined populations.

"The goal was to avoid impressionism and terminology—to stay strictly descriptive and quanti-

tative. Findings were assembled according to Q-waves, representing scar, axis, and wave amplitudes reflecting hypertrophy, ST segment and T-wave findings reflecting ischemia, atrioventricular conduction defects, and arrhythmias. Within items, findings were arranged by magnitude, but without probability labels and were tested anew in independent populations. Finally, criteria were circulated among cardiologists and epidemiological experts for use and criticism. The whole was assembled in the late-1950s, assigned codes, and published in the *Circulation* reference cited. Within days it happily became known as the Minnesota Code, reflecting well the far-flung collaborative researches of this laboratory.

"Designed primarily for our own comparisons of disease prevalence, the Minnesota Code showed considerable systematic and random variation in others' hands. So we set about to develop standard procedures, training, testing, and quality control. And we found, simultaneously with Geoffrey Rose at the University of London, that students and technicians could be trained to code ECGs routinely as reliably, and with greater incentive, than young physicians.

"Over the years, the need for ECG coding has increased for longitudinal population studies, and for objective classification of events and serial records in clinical and preventive trials. The needed modifications were first published in the manual *Cardiovascular Survey Methods*,¹ then for the Coronary Drug Project Trial,² and finally as a complete training and testing manual prepared by Ronald Prineas and Richard Crow of this laboratory.³

"The Minnesota Code met a need at a propitious time in the expansion of major population studies and preventive trials in cardiovascular diseases, and met further notoriety by WHO endorsement and publication. More sophisticated computerized ECG systems are now available and we are collaborating in this development to replace the Minnesota Code. But the economics of small studies, the necessity for comparison with past studies, and the persistent absence of an internationally agreed upon diagnostic computer ECG program have resulted in continued use of the Minnesota Code as the standard manual-visual ECG system for population studies.⁴ It is not, however, recommended by us for clinical diagnostic use."

1. Rose G A & Blackburn H. *Cardiovascular survey methods*. Geneva: World Health Organization, 1968. p. 98-105; 137-54.
2. Selected CDP study forms. (Coronary Drug Project Research Group) *The coronary drug project: design, methods, and baseline results*. New York: American Heart Association, 1973. p. I-50-I-79.
3. Prineas R, Crow R & Blackburn H. *The Minnesota Code manual: procedures for measurement and classification of electrocardiographic findings in clinical trials and population studies*. Littleton: Wright-PSG. To be published, 1982.
4. Prineas R & Blackburn H. The resting electrocardiogram in epidemiological studies. Description and prediction. (van Bemmel J H & Willems J L, eds.) *Trends in computer-processed electrocardiograms*. Amsterdam: North-Holland, 1977. p. 339-44.