The Minnesota Code Manual of Electrocardiographic Findings: Standards and Procedures for Measurement and Classification

The Minnesota Code Manual of Electrocardiographic Findings

including measurement and comparison with the Novacode

Standards and Procedures *for* ECG Measurement *in* Epidemiologic and Clinical Trials

Second Edition
New and Enlarged

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Dedication:

To our mentors and colleagues, Henry Blackburn,

Pentti Rautaharju, and in memory of Geoffrey Rose

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Preface to the Second Edition

The manual is suitable for training electrocardiographers and technicians and can be accompanied by sets of training ECGs already coded by trainers. It is our expectation that the manual will serve as a reference, guide, and training source for those conducting studies that require objective evidence of cardiac disease, both prevalent and incident, by non-invasive, highly standardized, inexpensive recording of the electrocardiogram. In our own ECG Reading Center, this has included epidemiologic studies among healthy populations, diabetics, psychiatric patients, pregnant women, cohorts of patients with clinical heart disease, populations exposed to environmental contaminants such as arsenic, populations exposed to Chagas disease, and in clinical trials of HIV-infected participants, diabetics, hypertensives, children, the aged, dietary intervention studies and phase I and phase II drug studies.

It is 28 years since the publication of the first edition, which is now out of print. We have produced a second edition because, in the interim, we have received continuous requests over the years for copies of the book that no longer existed and also because there have been refinements and extensions to the Minnesota Code that allow a greater range of abnormalities to be coded; there are even clearer means of demonstrating correct and standardized methods of measurements that are incorporated into this second edition; some minor coding rules have been changed; and now the use of the code has been greatly expanded and is used in countless epidemiologic studies and clinical trials worldwide. Even as far back as 1981 the initial publication describing the Minnesota Code was chosen as a citation classic (*CC/NUMBER 51 of SCI December 21, 1981: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*). It had been cited more than 405 times in published articles. Since then the bibliography has grown many times larger–at the time of writing, over 700 citations were listed in Pub Med. The introduction of digital ECG recordings and analysis has only expanded the role of the Minnesota Code now encompassed in computer programs to analyze digital signals transferred over phone lines or directly on solid digital recording platforms such as CDs. The latter notwithstanding, archival paper tracings are continually mined for data that were collected without digital recording and that are accompanied by other uniquely rich data. Despite my expectations during the 1960s that such archives would cease to be used after the introduction of digital recording, the tide of such treasures has hardly ebbed.

The changes included in this edition arise from more than a quarter of a century of directing central ECG reading and research centers and collectively 60+ large and small epidemiologic studies and multicenter national and international clinical trials. The changes include the description of a new measuring loupe in Chap. 3, developed over the past decade, to better serve a more efficient and a more extensive span for measurement of relevant durations, voltages, and deviations from the isoelectric line. In Chap. 4, the old code 1-2-6 has been removed because of lack of prognostic value, and for a similar reason, code 1-2-8 has been down-coded to 1-3-8 to better represent its place in the hierarchy of Q-wave abnormalities. In addition, a new code 1-3-7 has been added to extend coding of inferior myocardial infarction. In Chap. 7, newer more precise methods of measuring ST-segment and T-wave voltages are presented. Additions to conduction defects in Chap. 9 include measurements for and classification of the Brugada syndrome ECG pattern (code 7-9) and fragmented QRS (code 7-10) – both of the latter codes have been associated with sudden death. The chapter on arrhythmias has minor modifications from the first edition, but, notably, premature beats need no longer be "frequent" by the old definition to be coded in a standard 12 lead ECG, where the presence of any premature beats is significant for prediction of future cardiovascular disease. In Chap. 11, additional codes have been added for lead reversal (with many examples), technical quality, left atrial enlargement (code 9-6), and early repolarization (code 9-7). More detailed criteria are presented in Chap. 12 for the measurement of QT interval, so important in testing all new drugs. New coding forms are presented in Chap. 13, and Chap. 14 on ECG data acquisition has been re-written and expanded to include training of ECG recording technicians and maintenance of recording quality. Chap. 15 on the criteria for significant serial change has been developed in a much more comprehensive manner and has added descriptive tables and new codes for documenting serial change myocardial infarction. Chap. 16 is a new addition on continuous measurements, which can be derived from a standard 12-lead ECG that have independent prognostic value

and includes description of ultrashort heart rate variability. Chap. 17 on quality control is now greatly expanded and includes quality control directions and documentation for both paper (visual) and electronic ECGs. Appendix A has all of the new Minnesota Codes incorporated. Appendix B is new and details the criteria and classification of the Novacode, including significant serial change, MI diagnosis, and comparisons with the Minnesota Code. Finally, Appendix C lists a summary of minor and major code abnormalities that can be used in comparisons of subgroups in experimental studies and analyses.

NC, USA

Ronald J. Prineas

May 2009

Preface to the First Edition

The electrocardiogram (ECG) is mainly used in clinical and hospital practice for diagnosis and for prognosis. But it is also used for systematic population studies and clinical trials in and outside hospital, where a repeatable, valid, and quantitative method is required for classification of ECG findings related to disease. Useful classification depends, in turn, on standardized methods of acquiring the data, on mounting (sampling), and on reading and measurement of the ECG.

In systematic studies the ECG is read centrally, unbiased by clinical information. This blinded classification provides objective criteria for individual events, group differences, and for sequential changes in individuals and groups. Measurement classification criteria and procedural rules for standardized ECG coding were devised and published from this laboratory and became known as the Minnesota Code (Blackburn H, Keys A, Simonson E, Rautaharju P, Punsar S. *Circulation.* 1960;21:1160). Current updated criteria and coding rules are found in the Appendix to this manual.

Since 1960, these criteria and coding rules have been tested and occasionally slightly modified to improve validity and repeatability. The rules are nevertheless continually subject to variation in application because of different quality of recording, baseline trace width, characteristics of the tracing, and the number of beats to be measured. A set of definitions and procedural rules has evolved in this and other laboratories to define more precisely wave onset and offset and wave segments.

Other factors affecting standardized ECG coding include ECG coder training, data acquisition, patient preparation, technician training, and quality control. These are presented in this manual along with unambiguous definitions and measurement procedures.

The current Minnesota Code criteria are found in the Appendix, in sequence from 1–9-codes. In the body of the manual, separate chapters are provided on the exact measurement of continuous ECG variables such as frontal plane axis and heart rate, on standard ECG acquisition and mounting, and on quality control of coding, as well as detailed presentation of the wave classification system.

The codes in the Appendix do not need to be learned by rote for this manual to be used as a training and testing tool. Early in training as ECG findings are recognized, the detailed code may be referred to. It is, however, necessary to develop an efficient personal system for scanning each ECG for all codable findings, and to learn thoroughly *how* to measure the findings detected. While the contents of the coding chapters of this manual need not be mastered in one course, the manual should be used as reference when there is doubt how to measure a particular wave form.

The ECG measurements described here are easily applied by intelligent, trained, and dedicated medical, technical, or lay persons. The manual can be used by electrocardiographers or experienced investigators to teach measurement and coding of the ECG. This laboratory has for two decades trained "ordinary" university students in coding skills as part-time workers for periods of 1–3 years. Nurses, physicians, and technicians have also been successfully trained. Adherence to specific rules and ongoing quality control allow comparisons of results from different observers and centers at different times.

Training requires intensive instruction for a full 10 day course, followed by continual experience. An introductory lecture on electrocardiographic history and physiology imparts understanding of the reasons for the measurements and codes, and is tailored to the sophistication of the students. It explains the current setting of ECG coding for population comparisons and clinical trials and their different requirements from clinical diagnosis. Within 3 months of initial training, further testing for accuracy and speed is carried out.

The introductory lectures also explain the recording of 12 lead ECGs and the expected patterns for each lead, and identify P-, Q-, R-, S- and T-waves. Coders are taken sequentially through the coding material in each of Chapters 3 through 12. At the conclusion of each chapter, sample electrocardiograms are coded for the findings and measurements described in that chapter. The student codings are checked by the instructor before proceeding to the next chapter and remedial work is assigned where needed. Specific codes are sought in each lead separately to recognize the range of normal patterns in each lead.

At the conclusion of instruction with the text material and practice ECGs, a separate test packet of approximately 20 ECGs, as described in Chap. 13, and enriched with examples of major codable findings, is coded for the complete ECG. Results are checked by the instructor. Duplicate coding of actual "unknown" ECGs then starts, initially, with a new coder against a senior experienced coder for

the first three to six months of the program. In this period, misunderstanding of the coding rules is discovered and corrected.

After approximately three months of on-the-job coding, new test packets with approximately 50 ECGs per packet are coded and tabulated according to standard tables of repeatability (Rose G, Blackburn H, Gillum RF, Prineas RJ. *Cardiovascular Survey Methods.* Geneva: WHO; 1982). Coding rates (speed) and test results (accuracy) are compared among coders so that the suitability of coders, or the need for retraining, is determined. Test packets are available from the Director, ECG Coding Laboratory, Laboratory of Physiological Hygiene, School of Public Health, Stadium Gate 27, 611 Beacon Street SE, University of Minnesota, MN 55455, USA.

Was written in Minnesota

Ronald J. Prineas MB, BS, PhD

January 1982

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