Jackson Heart Study Protocol

Manual 5

Electrocardiography

Visit 1

Version 1.0

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FOREWORD

This manual is one of a series of protocols and manuals of operation for the Jackson Heart Study (JHS). The complexity of the JHS requires that a sizeable number of procedures be described, thus this rather extensive list of materials has been organized into the set of manuals listed below. Manual 1 provides the background, organization, and general objectives of the JHS Study. Manuals 2 and 10 describe the operation of the Cohort and Surveillance Components of the study. Detailed Manuals of Operation for specific procedures, including those of reading centers and central laboratories, make up Manuals 3 through 9 and 11.

JHS Study Protocols and Manuals of Operation

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1	General Description and Study Management
2	Cohort Component Procedures
3	Family Study
4	Blood Pressure
5	Electrocardiography
6	Echocardiography
7	Ultrasound Assessment
8	Pulmonary Function Assessment
9	Specimen Collection and Processing
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1.0 BACKGROUND

1.1 Description of the Jackson Heart Study

The Jackson Heart Study (JHS) is a single-center prospective observational study of African-American residents of Jackson, Mississippi. Recruitment for this project will begin in September, 2000, and continue for a three year period until approximately 6,500 35-84 year old women and men are enrolled. This cohort will be contacted annually for information about their health, including new cardiovascular disease events. Any indication of incident disease will be investigated through physician contact and hospital records. Ascertainment and documentation of incident coronary events is a major goal of the project. The purpose of the JHS ECG Manual of Operations is to specify ECG acquisition procedures, to facilitate training of ECG technicians, to identify "alert" conditions which may require special cautions and to briefly describe ECG coding and quality control procedures for JHS.

Two categories of resting ECGs are collected for the JHS cohort:

1. Standard ECG for every participant at the baseline visit.
   To determine prevalent baseline ECG findings with regard to myocardial ischemia, left ventricular hypertrophy, arrhythmias and conduction delays for each JHS participant.

2. Ancillary ECGs (A-ECGs) for participants having ECGs recorded outside the clinic and including ECGs recorded in-hospital and at local medical facilities.
   To determine if new coronary heart disease event(s) occurred.

ECGs for all participants at baseline, are sent by phone modem to be analyzed by computer at the Minnesota Central Electrocardiographic Laboratory (ECGRC), Division of Epidemiology, School of Public Health, Minneapolis, Minnesota. Wave voltage and duration measurements are automatically determined by the Minnesota Code Modular ECG Analysis System (MC-MEANS)[2], which provides Minnesota Codes[1] (Appendix 1) and other special measurements. A-ECGs recorded at other medical facilities including hospitals are visually coded using standardized procedures and will, so far as possible, be part of a participant's record. These A-ECGs will document the timing, nature and severity of coronary events occurring after baseline. Both baseline and A-ECGs will contribute to the participant's overall cardiac status. A-ECGs will be compared serially to document new CHD events including unrecognized MI, LVH, new bundle branch block and other incident ECG abnormalities specified by the study.

1.2 Electrocardiography in the Jackson Heart Study

A single baseline 12-lead electrocardiogram (ECG) will be recorded digitally on all JHS participants during a three year recruitment period and classified centrally. Enrollees having ECGs recorded for any potential medical problems at outpatient facilities or in-hospital will, so far as possible, have their ECGs visually coded centrally as well.

The major aim of the Minnesota ECG Coding Center (ECGRC) for the JHS is to provide reliable ECG measurements from digital and paper ECG records which will be used to identify prevalent coronary disease (CHD) and new CHD events such as unrecognized myocardial infarction (MI) and in-hospital acute MI. The ECGRC will provide ECG documentation of:

1. Prevalent ECG findings reflecting cardiac disease; such as MI, left ventricular hypertrophy (LVH), bundle branch block, cardiac arrhythmias and other major or minor ECG findings.

2. Other prevalent ECG risk indicators such as low heart rate variability, prolongation of the heart rate corrected QT interval (QTc). These ECG findings are defined by the ECGRC from specific computer measurements and by application of the Minnesota Code[1].
3. Incident myocardial infarction, symptomatic or asymptomatic.
4. Estimated left ventricular mass.

2.0 JACKSON HEART STUDY CLINIC ECG PROCEDURES

2.1 Introduction

At the baseline visit, a standard supine 12-lead resting ECG is recorded after a 12-hour fast and at least one hour after smoking or ingestion of caffeine, followed by a light snack.

2.2 Procedures for Recording ECGs

A supine twelve lead digitized ECG will be the standard for the JHS, and the MAC PC Personal Cardiographic Computer by Marquette Electronics, Inc., is recommended for the study. The MAC PC is a widely used ECG machine that is approved by the Underwriters' Laboratory and has been used extensively in other epidemiologic studies. The MAC is the most advanced cardiograph available today. For the JHS, the function of the MAC PC will be used to obtain and store ECG data prior to transmission to the ECGRC. Complete instructions for operating the MAC PC are provided by the company and are easy to understand. The data acquisition manual will contain complete instructions for successfully recording an electrocardiogram.

The standard configuration for the MAC PC is shown in Appendix 2. A 12-lead resting ECG tracing is obtained consisting of 10 seconds of each of the leads simultaneously (I, II, III, aVR, aVL, aVF, V_I-V_6).

2.3 Electrode Position Measuring and Marking

A standard procedure will be followed for location of chest electrode sites and limb leads. Measurements taken for chest electrodes will be used for quality control. This protocol will mimic that used in the ARIC Study. The electrodes are attached to the lead wires of the acquisition module in the correct order by using the lead wire labels. Simultaneous with the digital recording a paper record is produced that can be inspected for data quality, lead reversal and alert ECG statements.

Because it is essential for the study to be able to compare baseline ECG data with subsequent records, a uniform procedure for electrode placement and skin preparation is required. The method and procedure for standardizing electrode locations are outlined below. The participant, chest bared, is instructed to lie on the recording bed with arms relaxed at the sides. The individual is asked to avoid movements, which may cause errors in marking the electrode locations, but encouraged to converse with the technician. Prior experience with electrocardiograms is discussed, as is the purpose of the ECG recording. The participant should be told this is a research ECG to be used for statistical analysis later in the study. However, the clinic physician can also use it for general diagnostic purposes, and a copy can be sent to the individual's private physician if desired. For best electrode/skin interface, place the electrodes on the skin at least 2-3 minutes before taking the ECG. Participant information can be entered on the MAC PC during this time.

A good felt tip pen is used to mark the six chest electrode positions. Wipe the general area of the following 10 electrode sites with a sterile alcohol prep to remove skin oil and perspiration. It is extremely important that care be taken to locate these positions accurately. Therefore, the procedure given below must be meticulously followed. Electrode positions in women with large, pendulous breasts must be determined in relation to the anatomic points described below, as for all participants. The electrodes must then be placed on **top** of the breast (in the correct position).Figure 1 schematically displays the standard electrode locations.

2.3.1 Limb Leads

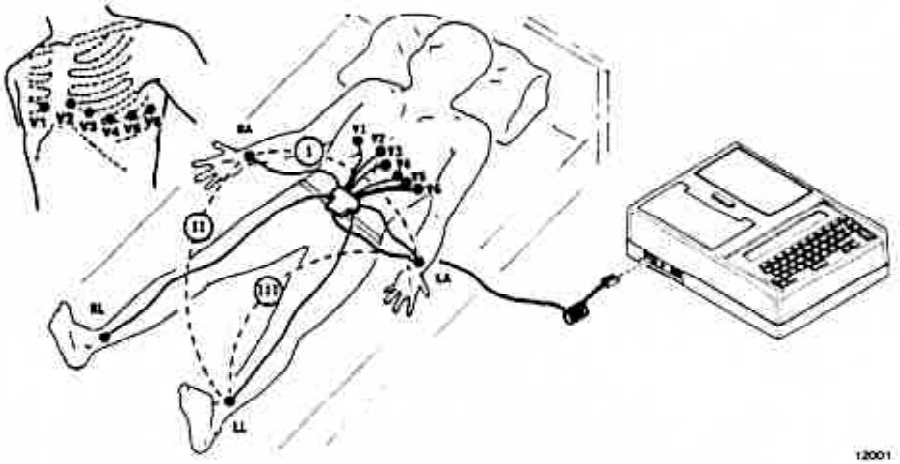
Locate electrode LL on the left ankle (inside).
Locate electrode RL on the right ankle (inside).
Locate electrode LA on the left wrist (inside).
Locate electrode RA on the right wrist (inside).

Figure 1. Electrode and Leadwire Placement

1. Apply limb electrodes, precordial electrodes, plates, suction bulbs, and electrode paste.

2. Connect electrodes to the patient at the locations shown.

NOTE: Don't pull or jerk tangled wires. To untangle wires, disconnect leadwires from electrodes.



NOTE: To avoid interference with adjoining electrodes, rub chest electrode sites with an up and down motion, rather than from side to side.

2.3.2 Electrode V_2

Locate the sternal angle and second left rib between the index and middle fingers of your right hand. Count down to the fourth rib and identify the fourth intercostal space below it. Locate V_2 in the fourth intercostal space immediately to the left of the sternal border.

2.3.3 Electrode V_1

Locate electrode V_1 in the fourth intercostal space at the right sternal border. This should be at the same level as V_2 and immediately to the right of the sternum.

2.3.4 Anterior 5th Interspace Marker (E Point)

Identify the fifth rib and fifth intercostal space below V_2 by counting down ribs as described for V_2. Follow this space horizontally to the midsternal line and mark this point. This is the "E" point.

2.3.5 Electrode V_6

With the chest square held lightly against the body (see Figure 2) locate the V_6 electrode at the same level as the E point in the midaxillary line (straight down from the center of the armpit). If breast tissue is over the V_6 area, mark the V_6 location on the breast. Do not attempt to move the breast in order to mark V_6 on the chest wall.

Figure 2. Location of V_6 Electrode using the Chest Square

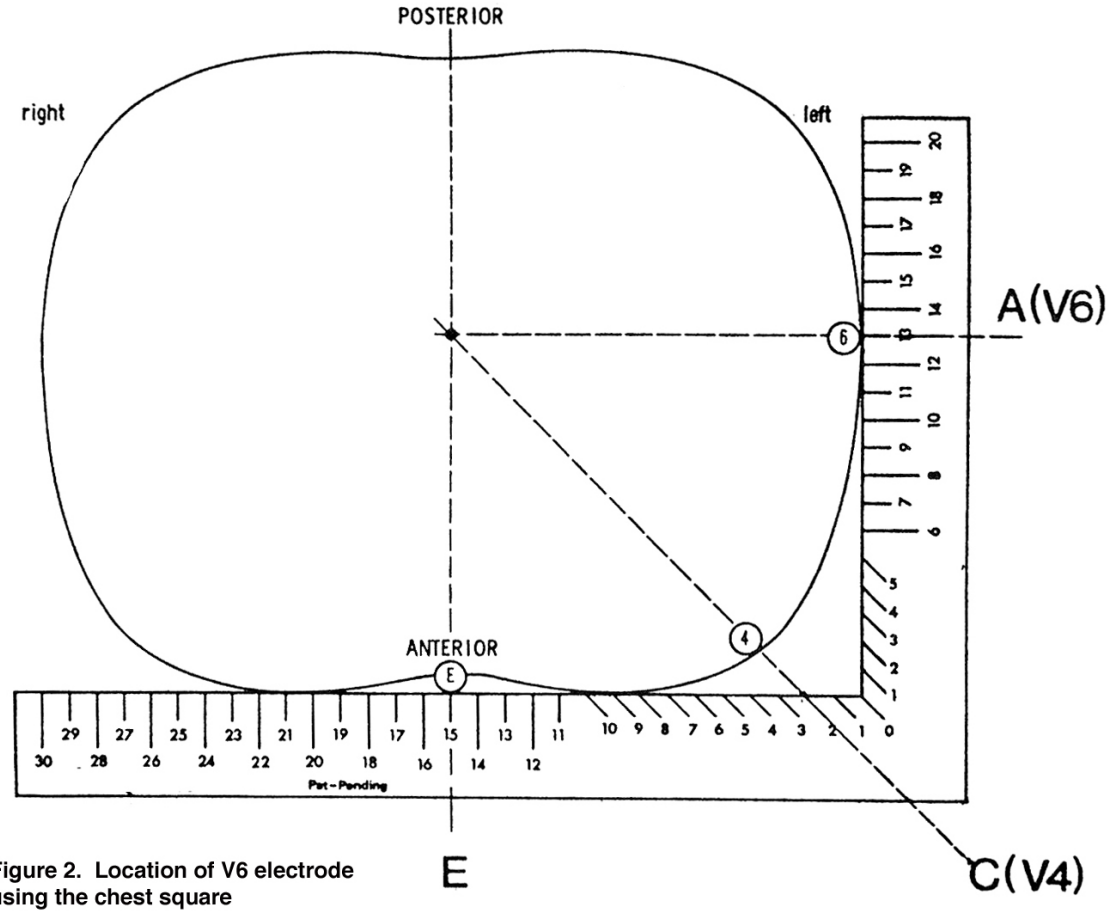


Figure 2. Location of V6 electrode using the chest square

2.3.6 Chest Size Measurements

Place the Chest Square firmly on the lower sternum at location E and at location V_6. Verify that the arms of the square are exactly horizontal and vertical in the horizontal plane of the thorax. Move the

square so that the vertical arm at V_6 is firmly against the ribcage. Use the appropriate length chest square so the horizontal arm rests firmly on the lower sternum.

Now read the distance 0-E and the distance 0-V_6 to the nearest 0.5 cm. Write them down on scratch paper.

Record the 0-V_6 measurement under height and the O-E measurement under weight. Measure to the nearest 0.5 cm. and round up.

e.g., 11.25 cm. would be 11.5 cm.
11.75 cm. would be 12.0 cm.

Enter 3 digits into the MAC PC but do not enter decimal points.

e.g., 11.5 cm enter as 115
11 cm. enter as 110

Use leading zeros.

e.g. 9.5 cm. enter as 095

2.3.7 Electrode V_4

Electrode V_4 is located using the E-V_6 Halfpoint Method[3]. Using a flexible tape measure, measure the distance between the E point and the V_6 marking. The tape should be resting lightly on the skin, not pressing into the flesh. The E and V_6 marks should clearly be seen above the tape. Without moving the tape, mark the location of electrode V_4 midway between E and V_6.

2.3.8 Electrode V_3

Using a flexible tape measure, mark the location of electrode V_3 midway between the locations of V_2 and V_4.

2.3.9 Electrode V_5

Using a flexible tape measure, mark the location of electrode V_5 midway between the locations of V_4 and V_6.

2.4 Skin Preparation

Prepare the skin for applying electrodes by wiping with alcohol, then briskly with a gauze pad. If technical problems are observed due to poor electrode contact, it is necessary to do further preparation as described below:

1. With the participant's consent, remove any excess hair from each electrode site on the chest and legs using an electric or disposable shaver.
2. At each electrode location in turn, the outer horny layer of the epidermis is removed by gentle dermal abrasion with a piece of 6-O (220) sandpaper. Only three passes (in the form of an asterisk) at each site using light pressure are required.

If the skin preparation has removed the felt pen marking at any of the electrode sites, these are accurately reestablished by carefully repeating the procedure described in Electrode Position Measuring and Marking. It is important that the electrode sites be marked using the exact technique described.

2.5 Application of Electrodes

Disposable electrodes are used in the JHS. Adaptors are used with the leadwires to connect the "banana" plug from the MAC PC leadwire to the disposable electrode via a clip.

When placing each electrode, massage it with a small up and down circular motion to maximize the pre-gel contact with the skin but avoid overlap of gel from one electrode to the next.

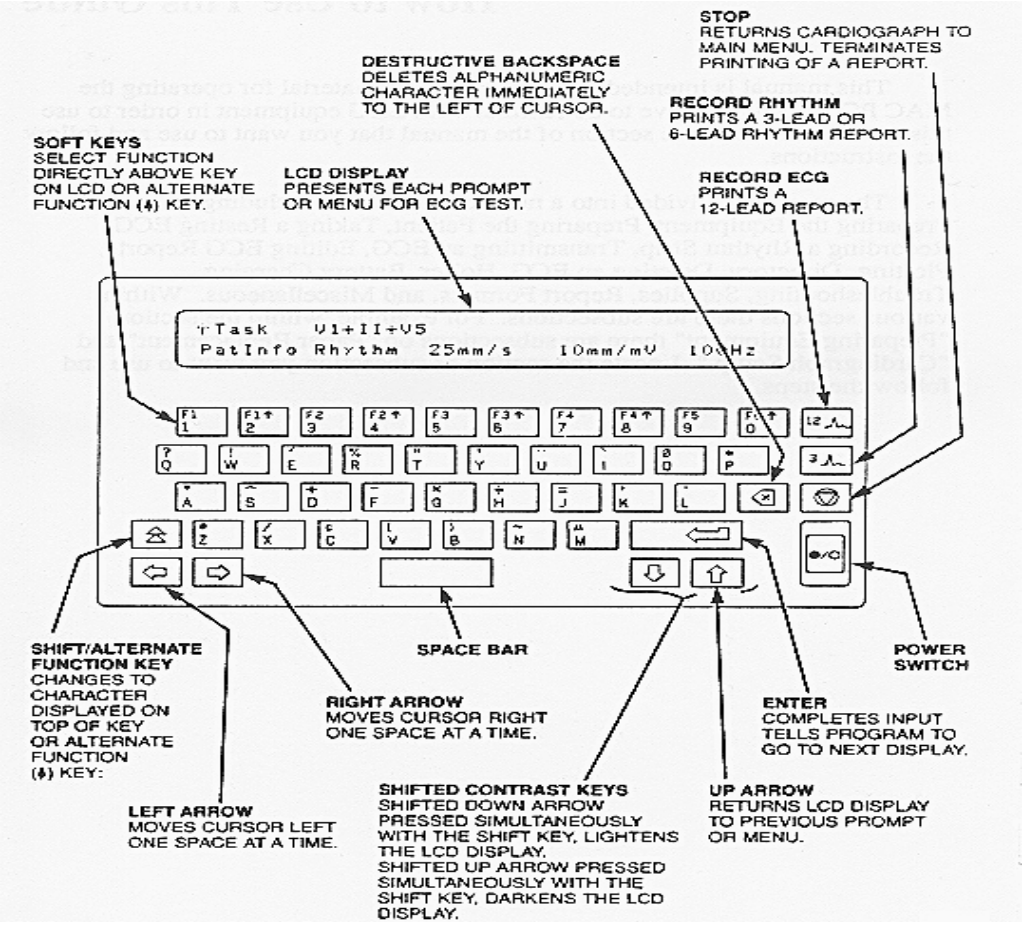
Center the four limb electrodes on the inside of the wrist or ankle with the tab for the clip pointing toward the head. Center the six chest electrodes on the chest markings with the tabs pointing down. Do not let the electrodes overlap or touch each other if possible.

Clip the appropriate leadwire to each electrode. Do not pull or jerk tangled wires. To untangle wires, disconnect lead wires from electrodes.

2.6 Recording the 12-lead ECG

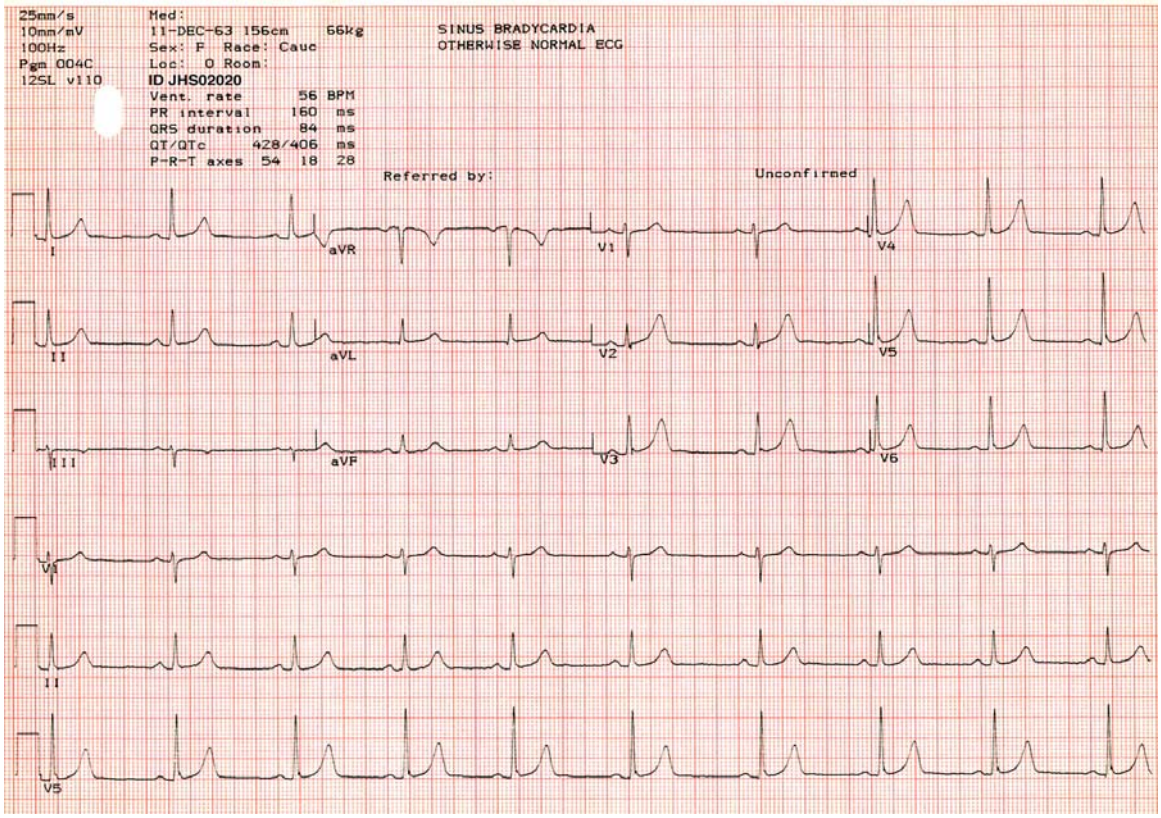
After placing the electrodes on the skin, enter the participant information into the MAC PC (Figure 3) according to Appendix 2. Electrodes must be on the skin for at least 2-3 minutes before taking the ECG. Make a final check of the electrodes and lead wires. Ask the participant to relax and keep still, then press the RECORD key.

Figure 3. The MAC PC Keyboard and LCD Display by Marquette Electronics, Inc.



The machine will display "Acquiring Data" and the left side of the display will show a count. If there are technical problems the display will show which lead is involved and will keep counting until it gets 10 seconds of good data. Check electrode contacts and leadwires, then check the display again. If the display counts past 45, electrodes likely will need to be re-positioned. Push the STOP key and remove the electrodes on limbs first. Prepare the electrode sites as discussed in Skin Preparation and follow the above protocol for exact relocation of electrodes. Press RECORD ECG. The machine will tell you to "enter a new patient or press RECORD." Press RECORD ECG a second time to start the ECG. The machine will automatically print the ECG after it has acquired 10 seconds of good data (Figure 4).

Figure 4. Typical Electrocardiogram Using the MAC PC



Tear the ECG off the machine and file it in your records. Make a copy by pressing "up" arrows with Fl. Press Fl under “Storage”, again press Fl under “Plot”. Choose the desired tracing. Press F5 – “Enter” - then “Print”. A copy can be printed from the machine's memory any time before deletion of the ECG.

2.7 Fault Detection Procedures

Should problems with noise or drift be encountered, electrodes are replaced. The following is a guide for determining which electrodes may be faulty. The underlined electrodes are the predominant determinants of the appropriate lead and therefore are most likely to be the faulty electrodes for a given lead. After adjustment or replacement of suspect electrodes, the electrocardiograph should be able to record 10 seconds of good data.

Table 1. Fault Detection Table

Lead Affected	Possible Faulty Electrode
I	RL, RA, LA
II	RL, RA, LL
III	RL, LA, LL
aVR	RL, RA, LL, LA
aVL	RL, LL, RA, LA
aVF	RL, LL, RA, LA
V_I	RL, LL, RA, LA, V_1
V_2	RL, LL, RA, LA, V_2
V_3	RL, LL, RA, LA, V_3
V_4	RL, LL, RA, LA, V_4
V_5	RL, LL, RA, LA, V_5
V_6	RL, LL, RA, LA, V_6

2.8 Self Evaluation of Technical Performance

This section allows technicians to monitor their own ECG technique. It is intended to help technicians who are having difficulty meeting the quality standards set by the ECGRC. These data are not intended to be collected by the study.

The technician examines the ECG tracing to estimate the noise level and baseline drift. Based on the requirements of the Minnesota Code, acceptable and unacceptable levels of noise and baseline drift have been established. These levels are scored using the following table:

Table 2. Self Evaluation Table

Quality Grade	Noise (mm)	Overall Drift (mm)	Beat-to-Beat Drift (mm)
1	< .25	< 1	< l
2	< .50	< 2	< 1.5
3	< 1	< 3	< 2
4	< 2	< 4	< 3
5	=> 2	=> 4	=> 3

The grade levels given in this table are related to the ability of the analysis program to achieve the required accuracy. Quality Grade 5 is unacceptable. ECGs of Quality Grade 5 must be deleted from the machine's memory and retaken immediately.

1. First, the tracing is examined for obvious errors such as right arm/left arm and other common lead misplacements (see Figure 5, negative p-waves in I indicate lead switch). These ECGs must be deleted from the machine's memory and retaken immediately.

Figure 5. Common Lead Placement Artifacts

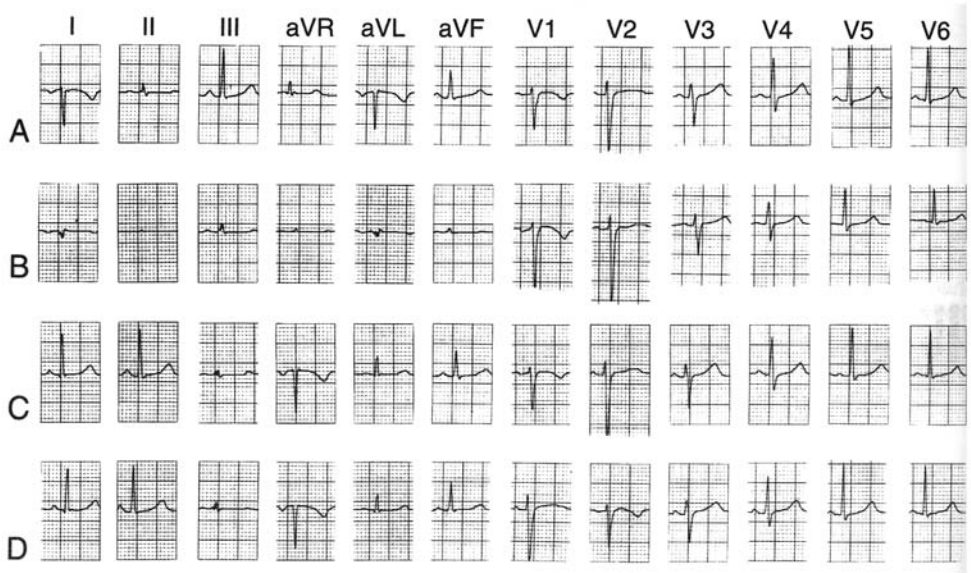


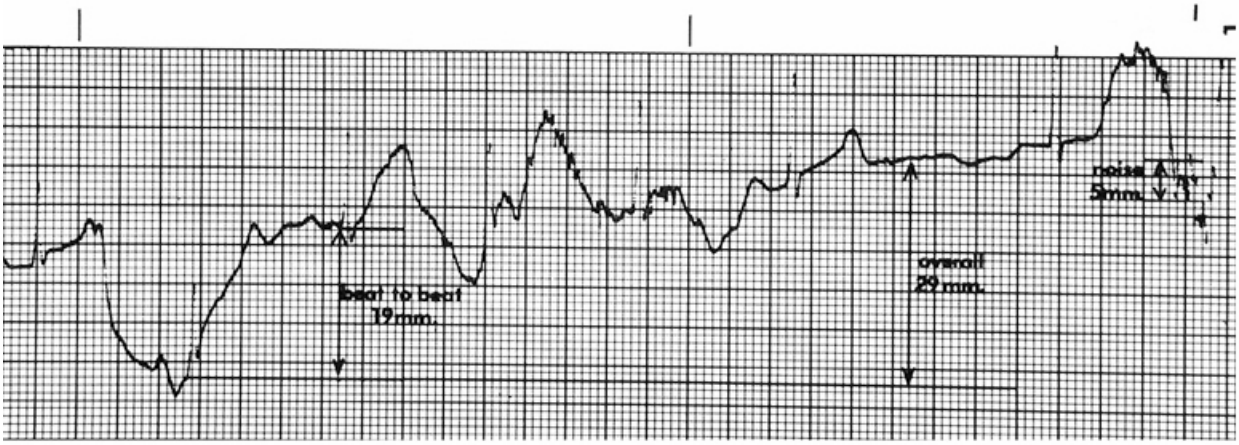
Figure 4. Lead switch artifacts

A. Right arm left arm electrodes reversed.
B. Right arm right leg electrodes switched.
C. Left arm and right leg electrodes switched.
D. Left arm and right leg electrodes switched plus V1 and V2 electrodes reversed.

2. The Quality Grade for noise is obtained by measuring the noise level as vertical peak-to-peak values in terms of number of small paper divisions (smallest grid squares). Note that recording sensitivity is 1 mm per 0.1mv, (one small paper division = 1 mm = 0.1 mv).

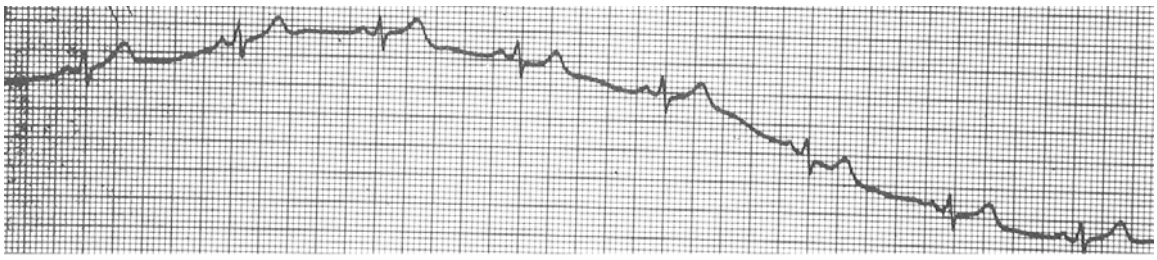
Noise, beat-to-beat drift and overall drift exceed quality level 5 (Figure 6)

Figure 6. Unacceptable ECG Data Quality



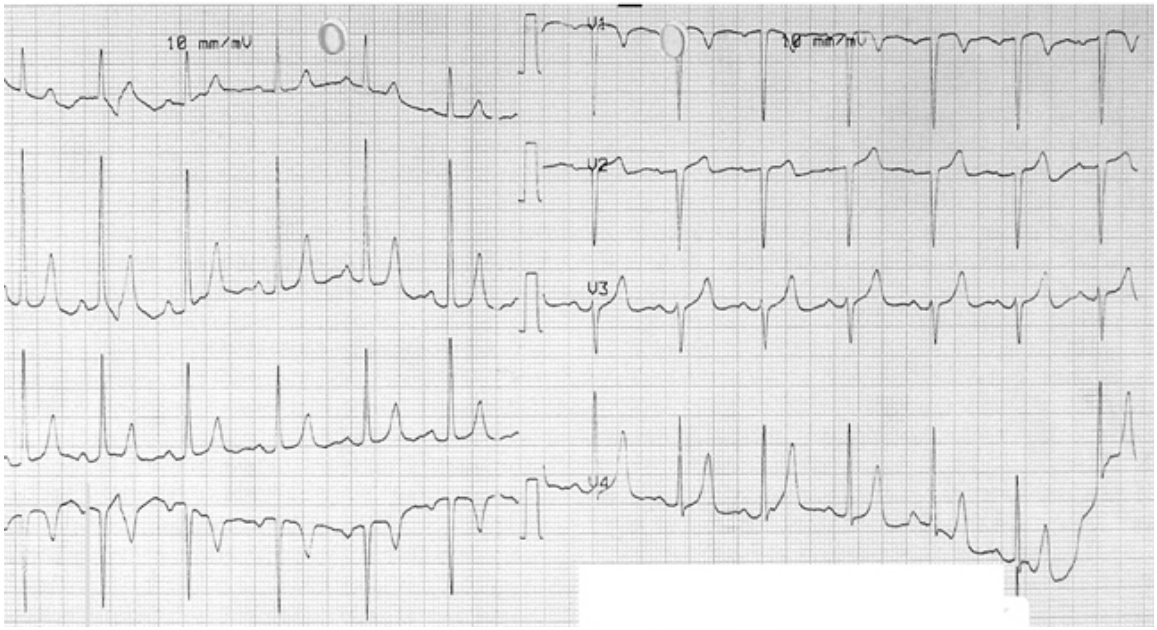
3. The Quality Grade for overall drift is obtained by searching each of the 12-leads for the maximum and minimum baseline levels within that lead (as determined by the PR and/or TP segments) over the 10 second recording and measuring the vertical distance between them. A distance of more than 4 small paper divisions is unacceptable (Figure 7).

Figure 7. Unacceptable Overall Baseline Drift



4. The Quality Grade for beat-to-beat drift is determined by searching for the pair of successive QRS complexes having the largest amplitude difference (vertical distance) between successive PR segments. A difference of more than 3 small paper divisions (>0.3 mm) indicates an unacceptable record (Figure 8).

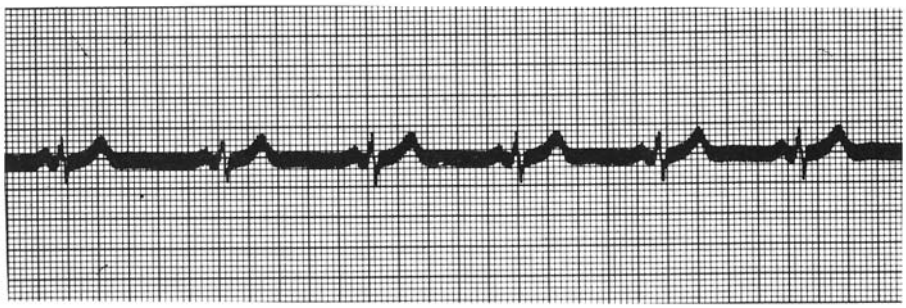
Figure 8. Unacceptable Beat-to-Beat Baseline Drift



Improvement in technical quality will indeed result if the prescribed procedure for electrode position marking, electrode and skin preparation, electrode replacement and equipment use are carefully followed. Baseline drift problems, which are essentially caused by poor electrode-skin contact are particularly easy to remedy, as is 60-cycle interference.

Sixty-cycle interference is characterized by perfectly regular fine oscillations occurring at the rate of sixty per second (Figure 9).

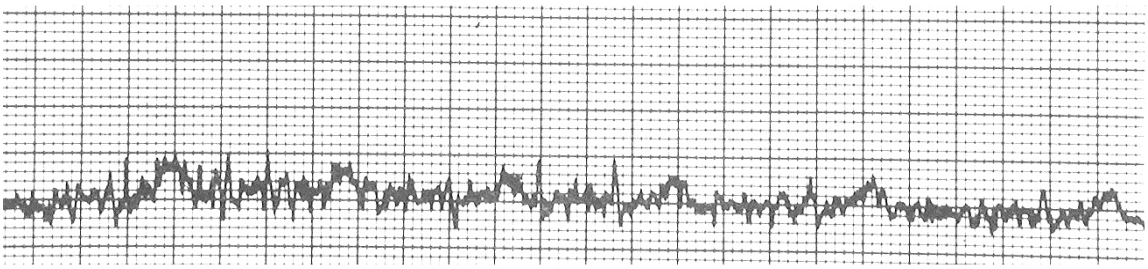
Figure 9. Sixty-Cycle Interference



Electrical equipment of any kind may be the source of AC interference on an ECG in all leads or only certain ones. Check quality of skin preparation and electrode contact. Check leadwires and re-secure attachment of the alligator clip to the electrode. Make sure participant does not touch any metal part of the bed or other equipment. Proximity to a wall with hidden wiring or a partially broken cable may also cause this problem.

Muscle tremor causes irregular oscillations of low amplitude and varying rapidity superimposed upon the ECG waveform (Figure 10). Muscle tremor is the involuntary muscle activity of a participant whose state is tense, apprehensive, or uncomfortable. This is why a clear explanation of the electrocardiogram test and reassurance are necessary for the participant. The participant is asked if the temperature of the room is too low for her/him and is covered with a blanket if so.

Figure 10. Artifact Caused by Muscle Tremor (Possible Shivering)



2.9 Original Hard Copy Record

The original 12-lead ECG record is filed at the field center, and is read locally by clinic physicians for notification and referral if needed. The records are then placed in participants' local data files. Double check that the participant is correctly identified.

2.10 Transmission, Confirmation and Deletion

ECGs are transmitted via the phone and are received by the ECGRC's two MAC 12s. These two machines permit automatic switching to accommodate simultaneous transmission or for backup in the event one becomes non-functioning. In the event both lines are busy, the clinic site is automatically notified and must call back later. The MAC PC indicates when transmission is completed. Each day, the digital ECG information is processed, and transferred to the VAX system. **The ECGRC will acknowledge, on the same day, ECGs received from JHS.** The ECGRC uses an automated system for logging, tracking, and inventory of received ECGs, and for identification of duplicate ID numbers. The status of any or all ECGs can be ascertained in less than five minutes using this approach.

2.10.1 Transmission

The MAC PC will store 11 to 14 12-lead ECGs. The machine will not store another ECG if the memory is full when an ECG is taken. The machine will ask you to delete an ECG from memory or delete the one just taken. For this reason ECGs must be transmitted to the ECGRC every day and deleted the next day after confirmation.

The receiving unit at the ECGRC is usually in the "ready" state to receive ECGs. If you get a "no connection" message when trying to send ECGs, try again in 10-20 minutes. If there continues to be problems with transmitting to the ECGRC, call the ECGRC Coding Supervisor at (612) 626-9681 or the ECGRC Manager at (612) 626-8581 to arrange transmission.

1. The phone number for the ECGRC receiving port **612-626-9685** is already programmed in the setup menu of the electrocardiograph.
2. Make sure the phone line is connected. This can be done by moving the jack from your regular phone to the port in the back of the MAC PC.
3. Print one copy of the directory of ECGs in memory (see Appendix 3). To do this:
    a) From the Main Menu press the shift and Fl keys simultaneously to show the system functions display.
    b) Press the Storage (Fl) key to display the storage functions display.
    c) Press the Directory (F2) key and a directory will be printed.

4. On the directory, put an asterisk by the IDs taken that day which are to be transmitted (see Appendix 3).
5. To complete transmission:
    a) From the Main Menu press the shift and Fl keys simultaneously to show the system functions display.
    b) Press the Storage (Fl) key to display the storage functions display.
    c) Press the More (F5) key to show the second storage functions display.
    d) Press the Transmit (Fl) key to show the transmission type display.
    e) Press the Phone (Fl) key. (The ECGRC phone number will show on the display and should not need to be reentered). Press ENTER.
    f) Patient data for the first ECG in memory will be displayed.
    g) If that ID had already been transmitted earlier, press NO (F2). If the ECG is to be transmitted press YES (Fl).
    h) Each ID on the directory will be displayed. Press NO or YES for each one, referring to the printed directory. Note in Figure 10 that ID 15102402 has two different ECGs in the machine's memory. This would occur if the technician noticed poor quality in the first ECG, and took a second one without deleting the first. Make sure to immediately delete tracings that are of poor quality. In doing so, all tracings not previously sent can be transmitted each time.
    i) The machine will dial the phone and transmit each ECG.
    j) Watch the display as each ECG is transmitted and check the IDs on the Directory List. This way if a problem occurs, the ECG involved can be identified.
    k) After the last ECG to be transmitted is displayed, a message indicating the number of ECGs that were transmitted vs. the number you selected to transmit is displayed. If the numbers are not the same, the problem ECGs will have been identified on the Directory List. These can be retransmitted using the above steps.
    l) Keep the Directory List available for confirmation from Minnesota via electronic mail the next morning.

2.10.2 Confirmation

Every morning the ECGRC in Minnesota notifies the JHS Clinic of the IDs received. Notification is by electronic mail directly to the JHS Clinic Supervisor. The mailing includes the ID, and date and time of each ECG received on the previous evening. Compare the Directory List with the IDs of the mailing. If there is a notice of invalid ID tracing on the E-mail confirmation, it must be corrected and retransmitted before deletion. See Appendix 3 for an example of e-mail confirmation. If there is an ID on the Directory (which had been marked for transmission) that is not on the confirmation mailing, retransmit that ID immediately. If there is an ID on the confirmation mailing that is not on your Directory List, notify Minnesota of this via electronic mail.

Note: Confirmation of transmission from Minnesota has nothing to do with the confirmed/unconfirmed report settings in the MAC PC.

2.10.3 Deletion

To delete ECGs that have been received by Minnesota:

1. From the Main Menu press the shift and Fl simultaneously to show the system functions display.

2. Press the Storage (Fl) key to display the storage functions display.
3. Press the Delete (F4) key.
4. Patient Data for the first ECG in memory will be displayed.
5. If confirmation from Minnesota has been received, press the Delete (Fl) key, otherwise press the Save (F2) key.
6. Each EGG in the directory will be displayed. Press Delete or Save for each one.
7. The machine will count the ECGs and the display will ask if you really want to delete them. If you are sure you have selected only ECGs confirmed by Minnesota and/or bad quality ECGs, press Yes (Fl), otherwise press No (F2) and start over.
8. You may also press Quit (F4) while any ID is being displayed if you have made a mistake and nothing will be deleted.

2.11 Clinic ECG Alerts

The MAC PC has an interpretative program which assigns diagnostic statements to the paper ECG. While the technician is not expected to be able to interpret ECGs, they should be familiar with the interpretative statements printed on the hard copy. The interpretative program should be considered a screening device, which tends to be overly sensitive. The following conditions are suggested as possible alerts that warrant quick review by the study physician:

1. Heart rate $\leq$ 40 beats per minute
2. Heart rate $\geq$ 150 beats per minute
3. Ventricular tachycardia
4. Idioventricular rhythm
5. WPW pattern
6. Atrial fibrillation or flutter
7. Complete heart block
8. Any statement(s) which refers to acute pattern (injury, ischemia, MI or pericarditis).

2.12 MAC PC Maintenance

2.12.1 Paper

Change the roll of paper as needed. Each roll is 75 feet long; and will print approximately 75 ECGs.

2.12.2 Procedures for charging the battery of the MAC PC

The MAC PC runs only from its battery. The machine may be used with the battery or plugged into a wall outlet. The machine must be plugged into an outlet to charge when the battery charge is down to 20 or less. It holds and stores about 14 ECGs. The amount of charge left is displayed for one-half second when the machine is turned on. If the unit is left unplugged, over a period of time it will completely drain and will delete stored ECGs. Leave the unit plugged in over weekends and holidays.

3.0 JACKSON HEART STUDY ANCILLARY ECG PROCEDURES

3.1 Introduction

Ancillary ECGs are obtained for participants having ECGs recorded outside the clinic. This includes ECGs recorded in-hospital and at local medical facilities.

3.2 Procedures for Obtaining Ancillary ECGs

For each JHS participant with an in-hospital or clinic ECG, obtain up to 3 ECGs for each event. For example, a participant has a two-day hospital stay for chest pain. Ideally, the JHS clinic staff will obtain three ECGs; the first ECG upon participant's admission to the hospital/ER/clinic; the last ECG before the participant's discharge; and one in between. Label each ECG with the participant's JHS ID number, and either F (First), T (in between) or L (Last), indicating the order of the ECGs.

Original ECG tracings are best, otherwise a good photocopy should be taken. Obtain two copies, one to keep in the JHS participant's clinic file, and one to send to the ECGRC.

3.3 Transmission of Ancillary ECGs

Monthly, the JHS will send Ancillary ECGs to the ECGRC. Two copies of a shipping form will accompany the shipment, listing the JHS participant IDs. Upon receipt, the ECGRC will initial and date the shipping forms and send one back to the JHS. See Appendix 13 for an example of a shipping form.

ECGs should be shipped to:

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4.0 CENTRAL READING OF BASELINE AND ANCILLARY ECGS

4.1 Resting 12-lead

Reading of 12-lead ECGs by the ECGRC includes the Minnesota Code[1] (Appendix 1) and the Performance Grade Level (Appendix 4). Every other week Minnesota sends these data for the ECGs received to the JHS on diskette. Wave voltage and duration measurements also taken are detailed. An example of the data dictionary created for each study is illustrated in Appendix 5. Established ECG criteria for prevalent myocardial infarction at the baseline ECG recording are:

a) any 1-l-X code AND (no 7-l-l or 7-4)
OR
b) any l-2-X (except 1-2-6 or 1-2-8) **PLUS** (4-1-l or 4-l-2 or 4-2 or 5-l or 5-2) **AND** (no 7-l-l or 7-4).

4.2 Ancillary ECGs

Whenever hospital ECGs for cohort participants are obtained after the baseline examination, photocopies of these records (masked at the field center for all information except ID) are sent to the ECGRC and coded by the Minnesota Code. ECGs are read two times, blinded: if the final codes do not agree they are adjudicated by a senior coder. Minnesota Code criteria are in Appendix 1.

4.3 Serial ECG Comparison of Ancillary ECGs

Non standard ECGs taken at outside JHS clinic facilities including in-hospital ECGs are compared by the Minnesota Serial ECG comparison algorithm. This procedure takes either the baseline ECG or the first A-ECG as reference and compares it to other A-ECGs to determine whether significant change in Q-code, ST-depression code, T-wave inversion code, ST elevation code, LVH code or Conduction code has occurred. Serial comparison results are significant increase, significant decrease, no significant change and technical problem. Serial change triggers, definitions and criteria are shown in Appendix 6 and publications of serial change criteria are in Appendix 7. These objective rules for side-by-side ECG evaluation are used to determine whether a Minnesota code change between ECG pairs is significant.

ECGs that fit the change criteria (i.e., any pattern ED1 through ED7 or EVl through EV8) are examined side by side for Serial ECG change. Simultaneous ECG comparison is performed by a senior coder on the final Minnesota codes using the first ECG of the hospitalization as the reference. Serial change categories are: significant increase, decrease (but not for Q-codes), no change (this implies no increase for Q-codes) or technical problem. These objective rules for side-by-side ECG evaluation are used to determine whether a Minnesota code change between ECG pairs is significant. The ECG findings are combined with presence of chest pain and level of serum enzymes to document definite, probable, suspect or no MI (see Appendix 8).

As an example, the ARIC protocol defines a new Minnesota code 1-2-7 as a potential ischemic event. Persons with this severity of ECG change will have simultaneous ECG comparison. The ECG comparison procedure (for this case) requires a 1 mm R-wave amplitude decrease between corresponding leads of the reference and comparison ECGs.

The criterion for 1-2-7 are QS patterns in V_1 -V_3. If the reference ECG has R-waves that are 1 mm tall in V_3 , then when comparing these ECGs side by side, the R-waves in the event ECG decrease by =>1 mm compared to the reference ECG and a "significant increase" is noted (see Appendix 9).

JHS requires a Minnesota Code change plus agreement by simultaneous ECG comparison before declaring that the ECG pattern change meets JHS criteria for an evolving ECG diagnostic pattern.

5.0 DATA STORAGE AND RETRIEVAL

5.1 Digital Data Storage and Retrieval

Digital ECGs are stored both on the ECGRC's personal computer system and the Division of Epidemiology's VAX system. The latter system uses daily backup and a special server for ECG studies. Either system can retrieve digitized information in about 5 minutes.

5.2 Paper Data Storage and Retrieval

Paper tracings from A-ECGs and those generated from all digital ECGs are stored in locked cabinets for immediate access as needed. Only ECGRC staff have access. The ECGs are filed by ID.

6.0 QUALITY CONTROL

6.1 The 12-lead ECG

6.1.1 Technician

1. All ECG technicians must be certified. See the following section on Training and Certification, and Appendix 10 for Certification forms.
2. Study guidelines on "acceptable" noise levels are given earlier in this protocol under Self Evaluation of Technical Performance.
3. Each technician must take an average of 3 ECGs per week over a two month period to remain familiar with procedures and equipment.
4. Each technician is observed quarterly by the most senior certified technician while taking a participant's ECG. The observer checks whether or not each procedure is performed (Appendix 11) and makes comments on the sheet if necessary. After the ECG is taken, the observer discusses the Procedure Review with the technician, then sends it to the JHS.

6.1.2 JHS Clinic Center

1. Each ECG is checked for quality of data in Minnesota.
2. The technician number and Performance Grade Level (Appendix 6) of each ECG is included in the data file that is sent to the ECGRC each month.
3. The ECGRC reports these findings to the JHS.
4. Each MAC PC is calibrated quarterly. Procedures are in Appendix 12.

6.1.3 ECG Computer Coding at the ECGRC

Blind rereading of baseline ECGs is performed in two ways:

1. The abnormal quality control ECGs that are retransmitted are returned to the ECGRC with the other abnormals. The ECGRC makes no effort to distinguish these returned ECGs from the rest of a normal shipment. They are coded and reported in the usual manner. Thus, the ECGRC continually rereads the quality control ECGs determined to be abnormal. (The quality control ECGs determined to be normal are only sent to the ECGRC if they are chosen to be part of the 10% sample of normals that is included with the abnormals.)

2. A 25% sample of computer defined abnormals are visually overread . A 10% sample of normals are also visually overread. The overreading is done using the same “average” beat used by the computer program.

6.2 Ancillary ECGs

The ECGRC will conduct internal repeat quality control on hospital (ancillary) ECGs.

6.3 Data Acquisition

Quality control of data acquisition will be achieved by initial central training of technicians and subsequent certification of them and all "new" technicians involved during the course of the study. Study guidelines on "acceptable" noise levels are given earlier in this protocol under Self Evaluation of Technical Performance. Feedback of clinic quality of ECG recording will also be reported by the

ECGRC on receipt of ECGs transmitted by modem. The Performance Grade Level is included for every ECG in the monthly diskette sent to the Coordinating Center.

6.4 Training and Certification

The ECGRC will assume responsibility for ECG training and certification. Central training of ECG technical staff will take place in one day. After completion of training, JHS technical staff will know how to reliably position electrodes, how to record and transmit the digital ECG to the ECGRC, how to recognize alert conditions and understand the quality requirements for ECGs recorded in the JHS. Each technician will have a personal ID coded with the transmitted ECG. Upon completion of training, technical staff must transmit three high quality ECGs to the ECGRC to be certified for recording JHS ECGs. Recertification will take place on an annual basis for those already certified and prior to any new technician recording JHS study data.

New technicians hired after central training are trained by the most senior certified technician. Training of new technicians must include observation of at least 6 ECGs being taken by the senior technician. Once training is complete, the technician must be officially certified as capable of recording high quality ECGs by the ECGRC. Certification ECGs must be done by obtaining 3 ECGs on age-eligible participants. Send the ECGs and the certification form (Appendix 10) to the ECGRC. The tracing will be "logged in" and evaluated for ECG quality. The ECGRC will notify the JHS when certification is complete. The JHS will notify the technician of certification status.

7.0 REFERENCES

1. The Minnesota Code Manual of Electrocardiographic Findings; Prineas RJ, Crow RS, Blackburn H. John Wright PSG, Inc., Littleton, MA 1982.

2. Kors JA, van Herpen G, Wu J, Zhang Z, Prineas RJ, van Bemmel JH. Validation of a new computer program for Minnesota coding. J Electrocardiol 1996;29 Suppl:83-88.

3. Rautaharju PM, Wolf HK, Eifler WJ, and Blackburn H. A Simple Procedure for Positioning Precordial ECG and ECG Electrodes Using an Electrode Locator. Journal of Electrocardiology 1976; 9(1):35-40.

APPENDICES

Appendix 1 Minnesota Code 1982

Q and QS Patterns
(Do not code in the presence of WPW code 6-4-1.) To qualify as a Q-wave, the deflection should be at least 0.1 mV (1 mm in amplitude).

Anterolateral site (leads I, aVL, V_6)

1-1-1 Q/R amplitude ratio => 1/3, plus Q duration =>0.03 sec in lead I or V_6.
1-1-2 Q duration => 0.04 sec in lead I or V_6.
1-1-3 Q duration => 0.04 sec, plus R amplitude => 3 mm in lead a VL.
1-2-1 Q/R amplitude ratio => 1/3, plus Q duration => 0.02 sec and < 0.03 sec in lead I or V_6.
1-2-2 Q duration => 0.03 sec and < 0.04 sec in lead I or V_6.
1-2-3 QS pattern in lead I. Do not code in the presence of 7-1-1.
1-2-8 Initial R amplitude decreasing to 2 mm or less in every beat (and absence of codes 3-2, 7-1-1, 7-2-1, or 7-3 between V_5 and V_6. (All beats in lead V_5 must have an initial R > 2 mm.)
1-3-1 Q/R amplitude ratio =>1/5 and < 1/3, plus Q duration => 0.02 sec and < 0.03 sec in lead I or V_6.
1-3-3 Q duration => 0.03 sec and < 0.04 sec, plus R amplitude => 3 mm in lead aVL.

Posterior (inferior) site (leads II, III, aVF)

1-1-1 Q/R amplitude ratio => 1/3, plus Q duration => 0.03 sec in lead II.
1-1-2 Q duration =>0.04 sec in lead II.
1-1-4 Q duration => 0.05 sec in lead III, plus a Q-wave amplitude => 1.0 mm in the majority of beats in lead aVF.
1-1-5 Q duration => 0.05 sec in lead aVF.
1-2-1 Q/R amplitude ratio => 1/3, plus Q duration => 0.02 sec and < 0.03 sec in lead II.
1-2-2 Q duration =>0.03 sec and < 0.04 sec in lead II.
1-2-3 QS pattern in lead II. Do not code in the presence of 7-1-1.
1-2-4 Q duration =>0.04 sec and < 0.05 sec in lead III, plus a Q-wave => 1.0 mm amplitude in the majority of beats in aVF.
1-2-5 Q duration => 0.04 sec and < 0.05 sec in lead aVF.
1-2-6 Q amplitude => 5.0 mm in leads III or aVF.
1-3-1 Q/R amplitude ratio => 1/5 and < 1/3, plus Q duration => 0.02 sec and < 0.03 sec in lead II.
1-3-4 Q duration => 0.03 sec and < 0.04 sec in lead III, plus a Q-wave => 1.0 mm amplitude in the majority of beats in lead aVF.
1-3-5 Q duration => 0.03 sec and < 0.04 sec in lead aVF.
1-3-6 QS pattern in each of leads III and aVF. (Do not code in the presence of 7-1-1.)

Anterior site (leads V_1, V_2, V_3, V_4, V_5)

1-1-1 Q/R amplitude ratio => 1/3 plus Q duration => 0.03 sec in any of leads V_2, V_3, V_4, V_5.
1-1-2 Q duration => 0.04 sec in any of leads V_1, V_2, V_3, V_4, V_5.
1-1-6 QS pattern when initial R-wave is present in adjacent lead to the right on the chest, in any of leads V_2, V_3, V_4,V_5, V_6.
1-1-7 QS pattern in all of leads V_1-V_4 or V_1-V_5.
1-2-1 Q/R amplitude ratio => 1/3, plus Q duration => 0.02 sec and < 0.03 sec, in any of leads V_2, V_3, V_4, V_5.
1-2-2 Q duration => 0.03 sec and < 0.04 sec in any of leads V_2, V_3, V_4, V_5.
1-2-7 QS pattern in all of leads V_1, V_2, and V_3. (Do not code in the presence of 7-1-1).
1-2-8 Initial R amplitude decreasing to 2.0 mm or less in every beat (and absence of codes 3-2, 7-1-1, 7-2-1, or 7-3) between any of leads V_2 and V_3, V_3 and V_4, or V_4 and V_5. (All beats in the lead immediately to the right on the chest must have an initial R > 2 mm.)
1-3-1 Q/R amplitude ratio => 1/5 and < 1/3 plus Q duration => 0.02 and < 0.03 sec in any of leads V_2, V_3, V_4, V_5.
1-3-2 QS pattern in lead V_1 and V_2. (Do not code in the presence of 3-1 or 7-1-1.)

QRS Axis Deviation

(Do not code in presence of low-voltage QRS, code 9-1, WPW 6-4-1, ventricular conduction defects, or 7-1-1, 7-2-1, and 7-4.)

2-1 Left. QRS axis from -30^0 through -90^0 in leads I, II, III. (The algebraic sum of major positive and major negative QRS waves must be zero or positive in I, negative in III, and zero or negative in II.)

2-2 Right. QRS axis from $+120^0$ through -150^0 in leads I, II, III. (The algebraic sum of major positive and major negative QRS waves must be negative in I, and zero or positive in III, and in I must be one-half or more of that in III.)

2-3 Right (optional code when 2-2 is not present). QRS axis from $+90^0$ through $+119^0$ in leads I, II, III. (The algebraic sum of major positive and major negative QRS waves must be zero or negative in I and positive in II and III.)

2-4 Extreme axis deviation (usually S1, S2, S3 pattern). QRS axis from -90^0 through -149^0 in leads I, II, and III (The algebraic sum of major positive and major negative QRS waves must be negative in each of leads I, II, and III.)

2-5 Indeterminate axis QRS axis approximately 90^0 from the frontal plane. (The algebraic sum of major positive and major negative QRS waves is zero in each of leads I, II and III, or the information from these three leads is incongruous.)

High Amplitude R Waves

3-1 Left: R amplitude > 26 mm in either V_5 or V_6, or R amplitude > 20.0 mm in any of leads I, II, III, aVF, or R amplitude > 12.0 mm in lead aVL measured only on second to last complete normal beat.

3-2 Right: R amplitude => 5.0 mm and R amplitude => S amplitude in the majority of beats in lead V_1, when S amplitude is > R amplitude somewhere to the left on the chest of V_1 (codes 7-3 and 3-2, if criteria for both are present).

3-3 Left (optional code when 3-1 is not present): R amplitude > 15.0 mm but => 20.0 mm in lead I, or R amplitude in V_5 or V_6, plus S amplitude in V_1 > 35.0 mm.

3-4 Criteria for 3-1 and 3-2 both present.

ST Junction (J) and Segment Depression

(Do not code in the presence of codes 6-4-1, 7-1-1, 7-2-1 or 7-4. When 4-1, 4-2, or 4-3 is coded, then a 5-code must also be assigned except in lead V_1.)

Anterolateral site (leads I, aVL, V_6)

4-1-1 STJ depression => 2.0 mm and ST segment horizontal or downward sloping in any of leads I, aVL, or V_6.

4-1-2 STJ depression => 1.0 mm but < 2.0 mm, and ST segment horizontal or downward sloping in any of leads I, aVL, or V_6.

4-2 STJ depression => 0.5 mm and < 1.0 mm and ST segment horizontal or downward sloping in any of leads I, aVL, or V_6.

4-3 No STJ depression as much as 0.5 mm but ST segment downward sloping and segment or T-wave nadir => 0.5 mm below P-R baseline, in any of leads I, aVL, or V_6.

4-4 STJ depression => 1.0 mm and ST segment upward sloping or U-shaped, in any of leads I, aVL, or V_6.

Posterior (inferior) site (leads II, III, aVF)

4-1-1 STJ depression =>2.0 mm and ST segment horizontal or downward sloping in lead II or aVF.

4-1-2 STJ depression => 1.0 mm but < 2.0 mm and ST segment horizontal or downward sloping in lead II or aVF.

4-2 STJ depression => 0.5 mm and < 1.0 mm and ST segment horizontal or downward sloping in lead II or aVF.

4-3 No STJ depression as much as 0.5 mm, but ST segment downward sloping and segment or T-wave nadir => 0.5 mm below P-R baseline in lead II.

4-4 STJ depression => 1.0 mm and ST segment upward sloping, or U-shaped, in lead II.

Anterior site (leads V_1, V_2, V_3, V_4, V_5)

4-1-1 STJ depression => 2.0 and ST segment horizontal or downward sloping in any of leads V_1, V_2, V_3, V_4, V_5.

4-1-2 STJ depression => 1.0 mm but < 2.0 mm and ST segment horizontal or downward sloping in any of leads V_1, V_2, V_3, V_4, V_5

4-2 STJ depression => 0.5 mm and < 1.0 mm and ST segment horizontal or downward sloping in any of leads V_1, V_2, V_3, V_4, V_5.

4-3 No STJ depression as much as 0.5 mm, but ST segment downward sloping and segment or T-wave nadir => 0.5 mm below P-R baseline in any of leads V_2, V_3, V_4, V_5.

4-4 STJ depression => 1.0 mm and ST segment upward sloping or U-shaped in any of leads V_1, V_2, V_3, V_4, V_5.

T-Wave Items

(Do not code in the presence of code 6-4-1, 7-1-1, 7-2-1 or 7-4.)

Anterolateral site (leads I, aVL, V_6)

5-1 T amplitude negative 5.0 mm or more in ether of leads V_6 or in lead aVL when R amplitude is => 5.0 mm.

5-2 T amplitude negative or diphasic (positive-negative or negative-positive type) with negative phase at least 1.0 mm but not as deep as 5.0 mm in lead I or V_6, or in lead aVL when R amplitude is => 5.0 mm.

5-3 T amplitude zero (flat), or negative, or diphasic (negative-positive type only) with less than 1.0 mm negative phase in lead I or V_6, or in lead aVL when R amplitude is => 5.0 mm.

5-4 T amplitude positive and T/R amplitude ratio < 1/20 in any of leads I, aVL, V_6; R wave amplitude must be => 10.0 mm.

Posterior (inferior) site (leads II, III, aVF)

5-1 T amplitude negative 5.0 mm or more in lead II, or in lead aVF when QRS is mainly upright.

5-2 T amplitude negative or diphasic with negative phase (negative-positive or positive-negative type) at least 1.0 mm but not as deep as 5.0 mm in lead II, or in lead aVF when QRS is mainly upright.

5-3 T amplitude zero (flat), or negative, or diphasic (negative-positive type only) with less than 1.0 mm negative phase in lead II; not coded in lead aVF.

5-4 T amplitude positive and T/R amplitude ratio < 1/20 in lead II; R wave amplitude must be => 10.0 mm.

Anterior site (leads V_2, V_3, V_4, V_5)

5-1 T amplitude negative 5.0 mm or more in any of leads V_2, V_3, V_4, V_5.

5-2 T amplitude negative (flat), or diphasic (negative-positive or positive-negative type) with negative phase at least 1.0 mm but not as deep as 5.0 mm, in any of leads V_2, V_3, V_4, V_5.

5-3 T amplitude zero (flat), or negative, or diphasic (negative-positive type only) with less than 1.0 mm negative phase, in any of leads V_3, V_4, V_5.

5-4 T amplitude positive and T/R amplitude ratio < 1/20 in any of leads V_3, V_4, V_5; R wave amplitude must be => 10.0 mm.

A-V Conduction Defect

6-1 Complete (third degree) A-V block (permanent or intermittent) in any lead. Atrial and ventricular complexes independent, and atrial rate faster than ventricular rate, with ventricular rate < 60.

6-2-1 Mobitz Type II (occurrence of P-wave on time with dropped QRS and T).

6-2-2 Partial (second degree) A-V block in any lead (2:1 or 3:1 block).

6-2-3 Wenckebach's Phenomenon (P-R interval increasing from beat to beat until QRS and T dropped).

6-3 P-R (P-Q) interval => 0.22 sec in the majority of beats in any of leads I, II, III, aVL, aVF.

6-4-1 Wolff-Parkinson-White Pattern (WPW), persistent. Sinus P-wave. P-R interval < 0.12 sec, plus QRS duration => 0.12 sec, plus R peak duration => 0.06 sec, coexisting in the same beat and present in the majority of beats in any of leads I, II, aVL, V_4, V_5, V_6. (6-4-1 suppresses 1-2-3, 1-2-7, 1-2-8, 1-3-2, 1-3-6, all 3, 4, 5, 9-2, 9-4, 9-5 codes.)
6-4-2 WPW Pattern, intermittent. WPW pattern in => 50% of beats in appropriate leads.
6-5 Short P-R interval. P-R interval < 0.12 sec in all beats of any two of leads I, II, III, aVL, aVF.
6-6 Intermittent aberrant atrioventricular conduction. P-R > 0.12 sec (except in presence of 6-5 or heart rate greater than 100); wide QRS complex > 0.12 sec; normal P-wave when most beats are sinus rhythm. (Do not code in the presence of 6-4-2.)
6-8 Artificial pacemaker.

Ventricular Conduction Defect

7-1-1 Complete left bundle branch block (LBBB). (Do not code in presence of 6-1, 6-4-1, 6-8, 8-2-1 or 8-2-2.) QRS duration => 0.12 sec in a majority of beats (of the same QRS pattern) in any of leads I, II, III, aVL, aVF, *plus* R peak duration => 0.06 sec in a majority of beats (of the same QRS pattern) in any of leads I, II, aVL, V_5, V_6. (7-1 suppresses 1-2-3, 1-2-7, 1-2-8, 1-3-2, 1-3-6, all 2, 3, 4, 5, 9-2, 9-4, 9-5 codes. If any other codable Q-wave coexists with the LBBB pattern, code the Q and diminish the 7-1-1 code to a 7-4 code.)
7-1-2 Intermittent left bundle branch block. Same as 7-1-1 but with presence of normally conducted QRS complexes of different shape than the LBBB pattern.
7-2-1 Complete right bundle branch block (RBBB). (Do not code in the presence of 6-1, 6-4-1, 6-8, 8-2-1 or 8-2-2.) QRS duration => 0.12 sec in a majority of beats (of the same QRS pattern) in any of leads I, II, III, aVL, aVF, *plus*: R' > R in V_1 or QRS mainly upright, *plus* R peak duration => 0.06 sec in V_1 or V_2; or V_2; or S duration > R duration in all beats in lead I or II. (7-1 suppresses 1-2-3, 1-2-7, 1-2-8, 1-3-2, 1-3-6, all 2, 3, 4, 5, 9-2, 9-4, 9-5 codes.
7-2-2 Intermittent right bundle branch block. Same as 7-2-1 but with presence of normally conducted QRS complexes of different shape than the RBBB pattern.
7-3 Incomplete right bundle branch block. QRS duration < 0.12 sec in each of leads I, II, III, aVL, aVF, and R' > R in either of leads V_1, V_2 .(Code as 3-2 in addition if those criteria are met. 7-3 suppresses code 1-2-8.)
7-4 Intraventricular block. QRS duration => 0.12 sec in a majority of beats in any of leads I, II, III, aVL, aVF. (7-4 suppresses all 2, 3, 4, 5, 9-2, 9-4, 9-5 codes.)
7-5 R-R' pattern in either of leads V_1, V_2 with R' amplitude => R.
7-6 Incomplete left bundle branch block. (Do not code in the presence of any codable Q- or QS-wave.) QRS duration => 0.10 sec and < 0.12 in the majority of beats of each of leads I, aVL, and V_5 or V_6.
7-7 Left anterior hemiblock (LAH). QRS duration < 0.12 sec in the majority of beats in leads I, II, III, aVL, aVF, plus Q-wave amplitude => 0.25 mm and < 0.03 sec duration in lead I, plus left axis deviation of -45^0 or more negative. (In presence of 7-2, code 7-8 if axis is $< -45^0$ and the Q-wave in lead I meets the above criteria.)
7-8 Combination of 7-7 and 7-2.

Arrhythmias

8-1-1 Presence of frequent atrial or junctional premature beats (10% or more of recorded complexes).
8-1-2 Presence of frequent ventricular premature beats (10% or more of record complexes).
8-1-3 Presence of both atrial and/or junctional premature beats and ventricular premature beats (so that individual frequencies are < 10% but *combined* premature beats are => 10% of complexes).
8-1-4 Wandering atrial pacemaker.
8-1-5 Presence of 8-1-2 and 8-1-4.
8-2-1 Ventricular fibrillation or ventricular asystole.
8-2-2 Persistent ventricular (idioventricular) rhythm.

8-2-3 Intermittent ventricular tachycardia. Three or more consecutive ventricular premature beats occurring at a rate => 100. This includes more persistent ventricular tachycardia.
8-2-4 Ventricular parasystole (should not be coded in presence of 8-3-1).
8-3-1 Atrial fibrillation (persistent).
8-3-2 Atrial flutter (persistent).
8-3-3 Intermittent atrial fibrillation (code if 3 or more clear-cut, consecutive sinus beats are present in any lead).
8-3-4 Intermittent atrial flutter (code of 3 or more clear-cut, consecutive sinus beats are present in any lead).
8-4-1 Supraventricular rhythm persistent. QRS duration < 0.12 sec; and absent P-waves or presence of abnormal P-waves (inverted or flat in aVF); and regular rhythm.
8-4-2 Supraventricular tachycardia intermittent. Three consecutive atrial or junctional premature beats occurring at a rate => 100.
8-5-1 Sinoatrial arrest. Unexpected absence of P, QRS and T, plus a R-R interval at a fixed multiple of the normal interval, $\pm$ 10%.
8-5-2 Sinoatrial block. Unexpected absence of P, QRS and T, preceded by progressive shortening of P-P intervals. (R-R interval at a fixed multiple of the normal interval, $\pm$ 10%.
8-6-1 A-V dissociation with ventricular pacemaker (without capture). Requires: P-P and R-R occur at variable rates with ventricular rate as fast as or faster than the atrial rate, plus variable P-R intervals, plus no capture beats.
8-6-2 A-V dissociation with ventricular pacemaker (with capture).
8-6-3 A-V dissociation with atrial pacemaker (without capture).
8-6-4 A-V dissociation with atrial pacemaker (with capture).
8-7 Sinus tachycardia (over 100/min).
8-8 Sinus bradycardia (under 50/min).
8-9 Other arrhythmias. Heart rate may be recorded as a continuous variable.

ST Segment Elevation

Anterolateral site (leads I, aVL, V_6)
9-2 ST segment elevation => 1.0 mm in any of leads I, aVL, V_6.

Posterior (inferior) site (leads II, III, aVF)
9-2 ST segment elevation => 1.0 mm in any of leads II, III, aVF.

Anterior site (leads V_1, V_2, V_3, V_4, V_5)
9-2 ST segment elevation =>1.0 mm in lead V5 or ST segment elevation => 2.0 mm in any of leads V_1, V_2, V_3, V_4.

Miscellaneous Items

9-1 Low QRS amplitude. QRS peak-to-peak amplitude < 5 mm in all beats in each of leads I, II, III, or < 10 mm in all beats in each of leads V_1, V_2, V_3, V_4, V_5, V_6. (Check calibration before coding.)
9-3 P-wave amplitude => 2.5 mm in any of leads II, III, aVF, in a majority of beats.
9-4-1 QRS transition zone at V_3 or to the right of V_3 on the chest. (Do not code in the presence of 6-4-1, 7-1-1, 7-2-1 or 7-4.)
9-4-2 QRS transition zone at V_4 or to the left of V_4 on the chest. (Do not code in the presence of 6-4-1, 7-1-1, 7-2-1 or 7-4.)
9-5 T-wave amplitude > 12 mm in any of leads I, II, III, aVL, aVF, V_1, V_2, V_3, V_4, V_5, V_6. (Do not code in the presence of 6-4-1, 7-1-1, 7-2-1 or 7-4.)
9-8-1 Technical problems which interfere with coding.
9-8-2 Technical problems which do not interfere with coding.

Incompatible Codes
The codes in the left column suppress codes in the right column.

Code	Suppress this code(s)
All Q-, QS-codes	7-6
Q > 0.03 in lead I	7-7
3-1	1-3-2
3-2	1-2-8, 7-3
6-1	All other codes except 8-2
6-4-1	All other codes
6-8	All other codes
7-1-1	1-2-3, 1-2-7, 1-2-8, 1-3-2, 1-3-6, all 2-, 3-, 4-, and 5-codes, 7-7, 9-2, 9-4, 9-5
7-2-1	1-2-8, all 2-, 3-, 4-, and 5-codes, 9-2, 9-4, 9-5
7-3	1-2-8
7-4	All 2-, 3-, 4-, and 5-codes, 9-2, 9-4, 9-5
8-1-2	8-2-4
8-1-4	8-1-1, 9-3
8-2-1	All other codes
8-2-2	All other codes
8-2-3	8-1-2
8-3-1	8-1-1, 8-1-2
8-3-2	6-2-2, 8-1-1, 8-1-2
8-3-3	8-1-1, 8-1-2
8-3-4	6-2-2
8-4-1	6-5
8-4-1 + heart rate => 140	All other codes except 7-4 or 6-2
Heart rate > 100	6-5
8-4-2	8-1-1
9-1	All 2-codes

Appendix 2 Marquette MAC PC Setup, Entry and Editing

The Marquette MAC PC Operator's Manual gives detailed instructions for Setup, Entry and Editing. A few helpful tips specific to the JHS are included here.

Setup:

1. Phone Setup. Many institutions require dialing a 9 to place an outside call. The "=" or "," gives a pause for outside call dialing.

2. Confirmed/Unconfirmed. For the JHS, report formats should be configured as Unconfirmed.

Entry:

To begin entry of a participant's data, press F1.

1.	Patient, Last Name:	Enter first 4 letters of last name
2.	Patient, First Name:	Enter complete ID, example J123456
3.	Patient ID:	Enter 9 digit ID, example 00J123456
4.	Referred by:	(always blank)
5.	Location Number:	Enter "01"
6.	Room Number:	Enter your Technician ID number
7.	Date of Birth	Enter the participants date of birth
8.	Height:	Enter O-V_6 measurement in cm (see 2.3.6)
9.	Weight:	Enter O-E measurement in cm (see 2.3.6)
10.	Sex:	Press either F1 (Male) or F2 (Female)
11.	Race:	Press F1 (Caucasian), F2 (Black), F3 (Oriental), F4 (Hispanic), or F5 (More options)
12.	Medication:	(always blank)

Editing:

With Storage on the screen, press:

1. MORE . . . . . followed by
2. EDIT . . . . . followed by
3. PATIENT DATA . .followed by ENTER

The data for each participant in the MAC PC is now displayed, one at a time, on the screen. If you do not wish to Edit the currently displayed participant, respond by pressing . . .

4. NO

If you do wish to Edit the currently displayed participant, respond by pressing . . .

5. YES . . . followed by ENTER

You are now shown the selected participant's Last name.

6. If no change is to be made, press . . . ENTER

7. If you want to change the Last name, use the Backspace key to erase unwanted characters and type in correct ones. Press . . . ENTER. You are now shown the selected participant's First name. Make changes to this field as above. (Remember, the First name is made up of your Center Code character plus ID number.) You are now shown the selected participant's ID number. Make changes to this field as above. To make changes on other participant information, keep pressing ENTER until screen displays information wanted and follow above steps. When the last participant has been displayed and dealt with, you must now instruct the MAC PC to save any changes you have made.

8. You must Press Shift and Fl together . . . followed by

9. PRINT REPORT . . . followed by ENTER

10. Print a directory to be sure correction has been made. You will note corrected ECG moves to bottom of directory. This is useful in the case of deleting every tracing except the one corrected -- which is then transmitted again.

Appendix 3 Example of MAC PC Storage Directory and E-Mail Confirmation of Received ECGS

MAC-PC Storage Directory 13-JAN-87 14:38

ID	Name		Date	Time	Type	U/C	Cart	Loc	Site	Room	Size
000102479	MESS.	J102479	12-JAN-87	14:29	ECG	U	006	001	006	36	5%
000102517	PRIN.	J102517	12-JAN-87	14:31	ECG	U	006	001	006	36	5%
000102376	ANDE.	J104376	12-JAN-87	14:32	ECG	U	006	001	006	36	5%
000102572	CROS.	J102572	12-JAN-87	14:33	ECG	U	006	001	006	41	5%
000109087	JONE.	J109087*	13-JAN-87	14:35	ECG	U	006	001	006	41	5%
000102402	SMIT.	J102402	13-JAN-87	14:36	ECG	U	006	001	006	36	5%
000102402	SMIT.	J102402*	13-JAN-87	14:36	ECG	U	006	001	006	36	5%
000109127	BUCK.	J109127*	13-JAN-87	14:37	ECG	U	006	001	006	41	5%

8 ECG(s) 41% Used 59% Free

Example Of E-Mail Confirmation of Received ECGS

From: "Bernadette Gloeb" <gloeb>
Date: Thu, Apr 27, 2000 11:11 AM
To: gloeb
Subject: Confirmation of ECGs received

The following ECGs were received by the Minnesota ECGRC on Wednesday, April 26, 2000.

ID DATE TIME

J109087 13-JAN-87 14:35
J102402 13-JAN-87 14:36
J109127 13-JAN-87 14:37

Please call the ECG Coding Supervisor, Sean Thomas, at 612-626-9681 if the above list does not match the list of ECGs sent on Wednesday, April 26, 2000.

Appendix 4 Performance Grade Levels

PERFORMANCE GRADE LEVEL	NOISE µvrms	DRIFT Overall (mV)	Beat to Beat (µV) Rest
1	≤ 30	≤ 0.7	≤190
2	≤ 60	≤ 0.8	≤250
3	≤ 90	≤ 0.9	≤ 310
4	≤ 120	≤1.0	≤ 370
5	> 120	> l.0	> 370

Appendix 5 Example Of Record Format For ECG Coding Lab

Column	Length	Description
PDUR	3	P Duration
QRSDUR	3	QRS Duration
TDUR	3	T Duration
QTDUR	3	QT Duration
PAXIS	3	P Axis
QRSAXIS	3	QRS Axis
TAXIS	3	T Axis
QTCDUR	3	QTC Duration
VRATE	3	V Rate
QAMPI	5	Q Amplitude in lead I
QAMPII	5	Q Amplitude in lead II
QAMPIII	5	Q Amplitude in lead III
QAMPAVR	5	Q Amplitude in lead AVR
QAMPAVL	5	Q Amplitude in lead AVL
QAMPAVF	5	Q Amplitude in lead AVF
QAMPV1	5	Q Amplitude in lead V1
QAMPV2	5	Q Amplitude in lead V2
QAMPV3	5	Q Amplitude in lead V3
QAMPV4	5	Q Amplitude in lead V4
QAMPV5	5	Q Amplitude in lead V5
QAMPV6	5	Q Amplitude in lead V6
RAMPI	5	R Amplitude in lead I
RAMPII	5	R Amplitude in lead II
RAMPIII	5	R Amplitude in lead III
RAMPAVR	5	R Amplitude in lead AVR
RAMPAVL	5	R Amplitude in lead AVL
RAMPAVF	5	R Amplitude in lead AVF
RAMPV1	5	R Amplitude in lead V1
RAMPV2	5	R Amplitude in lead V2
RAMPV3	5	R Amplitude in lead V3
RAMPV4	5	R Amplitude in lead V4
RAMPV5	5	R Amplitude in lead V5
RAMPV6	5	R Amplitude in lead V6
SAMPI	5	S Amplitude in lead I
SAMPII	5	S Amplitude in lead II
SAMPIII	5	S Amplitude in lead III
SAMPAVR	5	S Amplitude in lead AVR
SAMPAVL	5	S Amplitude in lead AVL
SAMPAVF	5	S Amplitude in lead AVF
SAMPV1	5	S Amplitude in lead V1
SAMPV2	5	S Amplitude in lead V2
SAMPV3	5	S Amplitude in lead V3
SAMPV4	5	S Amplitude in lead V4
SAMPV5	5	S Amplitude in lead V5
SAMPV6	5	S Amplitude in lead V6
R1AMPI	5	R' Amplitude in lead I
R1AMPII	5	R' Amplitude in lead II
R1AMPIII	5	R' Amplitude in lead III
R1AMPAVR	5	R' Amplitude in lead AVR
R1AMPAVL	5	R' Amplitude in lead AVL

Column	Length	Description
R1AMPAVF	5	R' Amplitude in lead AVF
R1AMPV1	5	R' Amplitude in lead V1
R1AMPV2	5	R' Amplitude in lead V2
R1AMPV3	5	R' Amplitude in lead V3
R1AMPV4	5	R' Amplitude in lead V4
R1AMPV5	5	R' Amplitude in lead V5
R1AMPV6	5	R' Amplitude in lead V6
S1AMPI	5	S' Amplitude in lead I
S1AMPII	5	S' Amplitude in lead II
S1AMPIII	5	S' Amplitude in lead III
S1AMPAVR	5	S' Amplitude in lead AVR
S1AMPAVL	5	S' Amplitude in lead AVL
S1AMPAVF	5	S' Amplitude in lead AVF
S1AMPV1	5	S' Amplitude in lead V1
S1AMPV2	5	S' Amplitude in lead V2
S1AMPV3	5	S' Amplitude in lead V3
S1AMPV4	5	S' Amplitude in lead V4
S1AMPV5	5	S' Amplitude in lead V5
S1AMPV6	5	S' Amplitude in lead V6
R11AMPI	5	R'' Amplitude in lead I
R11AMPII	5	R'' Amplitude in lead II
R11AMPII	5	R'' Amplitude in lead III
R11AMPAV	5	R'' Amplitude in lead AVR
R11AMPAV	5	R'' Amplitude in lead AVL
R11AMPAV	5	R'' Amplitude in lead AVF
R11AMPV1	5	R'' Amplitude in lead V1
R11AMPV2	5	R'' Amplitude in lead V2
R11AMPV3	5	R'' Amplitude in lead V3
R11AMPV4	5	R'' Amplitude in lead V4
R11AMPV5	5	R'' Amplitude in lead V5
R11AMPV6	5	R'' Amplitude in lead V6
QRRATI	5	QR Ratio in lead I
QRRATII	5	QR Ratio in lead II
QRRATIII	5	QR Ratio in lead III
QRRATAVR	5	QR Ratio in lead AVR
QRRATAVL	5	QR Ratio in lead AVL
QRRATAVF	5	QR Ratio in lead AVF
QRRATV1	5	QR Ratio in lead V1
QRRATV2	5	QR Ratio in lead V2
QRRATV3	5	QR Ratio in lead V3
QRRATV4	5	QR Ratio in lead V4
QRRATV5	5	QR Ratio in lead V5
QRRATV6	5	QR Ratio in lead V6
RSRATI	5	RS Ratio in lead I
RSRATII	5	RS Ratio in lead II
RSRATIII	5	RS Ratio in lead III
RSRATAVR	5	RS Ratio in lead AVR
RSRATAVL	5	RS Ratio in lead AVL
RSRATAVF	5	RS Ratio in lead AVF
RSRATV1	5	RS Ratio in lead V1

Column	Length	Description
RSRATV2	5	RS Ratio in lead V2
RSRATV3	5	RS Ratio in lead V3
RSRATV4	5	RS Ratio in lead V4
RSRATV5	5	RS Ratio in lead V5
RSRATV6	5	RS Ratio in lead V6
TRANGI	5	T Range in lead I
TRANGII	5	T Range in lead II
TRANGIII	5	T Range in lead III
TRANGAVR	5	T Range in lead AVR
TRANGAVL	5	T Range in lead AVL
TRANGAVF	5	T Range in lead AVF
TRANGV1	5	T Range in lead V1
TRANGV2	5	T Range in lead V2
TRANGV3	5	T Range in lead V3
TRANGV4	5	T Range in lead V4
TRANGV5	5	T Range in lead V5
TRANGV6	5	T Range in lead V6
PxAMPI	5	P+ Amplitude in lead I
PxAMPII	5	P+ Amplitude in lead II
PxAMPIII	5	P+ Amplitude in lead III
PxAMPAVR	5	P+ Amplitude in lead AVR
PxAMPAVL	5	P+ Amplitude in lead AVL
PxAMPAVF	5	P+ Amplitude in lead AVF
PxAMPV1	5	P+ Amplitude in lead V1
PxAMPV2	5	P+ Amplitude in lead V2
PxAMPV3	5	P+ Amplitude in lead V3
PxAMPV4	5	P+ Amplitude in lead V4
PxAMPV5	5	P+ Amplitude in lead V5
PxAMPV6	5	P+ Amplitude in lead V6
PRDURI	5	PR Duration in lead I
PRDURII	5	PR Duration in lead II
PRDURIII	5	PR Duration in lead III
PRDURAVR	5	PR Duration in lead AVR
PRDURAVL	5	PR Duration in lead AVL
PRDURAVF	5	PR Duration in lead AVF
PRDURV1	5	PR Duration in lead V1
PRDURV2	5	PR Duration in lead V2
PRDURV3	5	PR Duration in lead V3
PRDURV4	5	PR Duration in lead V4
PRDURV5	5	PR Duration in lead V5
PRDURV6	5	PR Duration in lead V6
QRS_I	5	QRS- Amplitude in lead I
QRS_II	5	QRS- Amplitude in lead II
QRS_III	5	QRS- Amplitude in lead III
QRS_AVR	5	QRS- Amplitude in lead AVR
QRS_AVL	5	QRS- Amplitude in lead AVL
QRS_AVF	5	QRS- Amplitude in lead AVF
QRS_V1	5	QRS- Amplitude in lead V1
QRS_V2	5	QRS- Amplitude in lead V2

Column	Length	Description
QRS_V3	5	QRS- Amplitude in lead V3
QRS_V4	5	QRS- Amplitude in lead V4
QRS_V5	5	QRS- Amplitude in lead V5
QRS_V6	5	QRS- Amplitude in lead V6
QRSxI	5	QRS+ Amplitude in lead I
QRSxII	5	QRS+ Amplitude in lead II
QRSxIII	5	QRS+ Amplitude in lead III
QRSxAVR	5	QRS+ Amplitude in lead AVR
QRSxAVL	5	QRS+ Amplitude in lead AVL
QRSxAVF	5	QRS+ Amplitude in lead AVF
QRSxV1	5	QRS+ Amplitude in lead V1
QRSxV2	5	QRS+ Amplitude in lead V2
QRSxV3	5	QRS+ Amplitude in lead V3
QRSxV4	5	QRS+ Amplitude in lead V4
QRSxV5	5	QRS+ Amplitude in lead V5
QRSxV6	5	QRS+ Amplitude in lead V6
JAMPI	5	J Amplitude in lead I
JAMPII	5	J Amplitude in lead II
JAMPIII	5	J Amplitude in lead III
JAMPAVR	5	J Amplitude in lead AVR
JAMPAVL	5	J Amplitude in lead AVL
JAMPAVF	5	J Amplitude in lead AVF
JAMPV1	5	J Amplitude in lead V1
JAMPV2	5	J Amplitude in lead V2
JAMPV3	5	J Amplitude in lead V3
JAMPV4	5	J Amplitude in lead V4
JAMPV5	5	J Amplitude in lead V5
JAMPV6	5	J Amplitude in lead V6
TxAMPI	5	T+ Amplitude in lead I
TxAMPII	5	T+ Amplitude in lead II
TxAMPIII	5	T+ Amplitude in lead III
TxAMPAVR	5	T+ Amplitude in lead AVR
TxAMPAVL	5	T+ Amplitude in lead AVL
TxAMPAVF	5	T+ Amplitude in lead AVF
TxAMPV1	5	T+ Amplitude in lead V1
TxAMPV2	5	T+ Amplitude in lead V2
TxAMPV3	5	T+ Amplitude in lead V3
TxAMPV4	5	T+ Amplitude in lead V4
TxAMPV5	5	T+ Amplitude in lead V5
TxAMPV6	5	T+ Amplitude in lead V6
T_AMPI	5	T- Amplitude in lead I
T_AMPII	5	T- Amplitude in lead II
T_AMPIII	5	T- Amplitude in lead III
T_AMPAVR	5	T- Amplitude in lead AVR
T_AMPAVL	5	T- Amplitude in lead AVL
T_AMPAVF	5	T- Amplitude in lead AVF
T_AMPV1	5	T- Amplitude in lead V1
T_AMPV2	5	T- Amplitude in lead V2
T_AMPV3	5	T- Amplitude in lead V3
T_AMPV4	5	T- Amplitude in lead V4
T_AMPV5	5	T- Amplitude in lead V5
T_AMPV6	5	T- Amplitude in lead V6
T_xI	5	T-+ in lead I
T_xII	5	T-+ in lead II

Column	Length	Description
T_xIII	5	T-+ in lead III
T_xAVR	5	T-+ in lead AVR
T_xAVL	5	T-+ in lead AVL
T_xAVF	5	T-+ in lead AVF
T_xV1	5	T-+ in lead V1
T_xV2	5	T-+ in lead V2
T_xV3	5	T-+ in lead V3
T_xV4	5	T-+ in lead V4
T_xV5	5	T-+ in lead V5
T_xV6	5	T-+ in lead V6
QDURI	5	Q Duration in lead I
QDURII	5	Q Duration in lead II
QDURIII	5	Q Duration in lead III
QDURAVR	5	Q Duration in lead AVR
QDURAVL	5	Q Duration in lead AVL
QDURAVF	5	Q Duration in lead AVF
QDURV1	5	Q Duration in lead V1
QDURV2	5	Q Duration in lead V2
QDURV3	5	Q Duration in lead V3
QDURV4	5	Q Duration in lead V4
QDURV5	5	Q Duration in lead V5
QDURV6	5	Q Duration in lead V6
RPKDI	5	R Peak Duration in lead I
RPKDII	5	R Peak Duration in lead II
RPKDIII	5	R Peak Duration in lead III
RPKDAVR	5	R Peak Duration in lead AVR
RPKDAVL	5	R Peak Duration in lead AVL
RPKDAVF	5	R Peak Duration in lead AVF
RPKDV1	5	R Peak Duration in lead V1
RPKDV2	5	R Peak Duration in lead V2
RPKDV3	5	R Peak Duration in lead V3
RPKDV4	5	R Peak Duration in lead V4
RPKDV5	5	R Peak Duration in lead V5
RPKDV6	5	R Peak Duration in lead V6
MXRDI	5	Maximum R Duration in lead I
MXRDII	5	Maximum R Duration in lead II
MXRDIII	5	Maximum R Duration in lead III
MXRDAVR	5	Maximum R Duration in lead AVR
MXRDAVL	5	Maximum R Duration in lead AVL
MXRDAVF	5	Maximum R Duration in lead AVF
MXRDV1	5	Maximum R Duration in lead V1
MXRDV2	5	Maximum R Duration in lead V2
MXRDV3	5	Maximum R Duration in lead V3
MXRDV4	5	Maximum R Duration in lead V4
MXRDV5	5	Maximum R Duration in lead V5
MXRDV6	5	Maximum R Duration in lead V6
MXSDI	5	Maximum S Duration in lead I
MXSDII	5	Maximum S Duration in lead II
MXSDIII	5	Maximum S Duration in lead III
MXSDAVR	5	Maximum S Duration in lead AVR
MXSDAVL	5	Maximum S Duration in lead AVL
MXSDAVF	5	Maximum S Duration in lead AVF
MXSDV1	5	Maximum S Duration in lead V1
MXSDV2	5	Maximum S Duration in lead V2

Column	Length	Description
MXSDV3	5	Maximum S Duration in lead V3
MXSDV4	5	Maximum S Duration in lead V4
MXSDV5	5	Maximum S Duration in lead V5
MXSDV6	5	Maximum S Duration in lead V6
QRSDI	5	QRS Duration in lead I
QRSDII	5	QRS Duration in lead II
QRSDIII	5	QRS Duration in lead III
QRSDAVR	5	QRS Duration in lead AVR
QRSDAVL	5	QRS Duration in lead AVL
QRSDAVF	5	QRS Duration in lead AVF
QRSDV1	5	QRS Duration in lead V1
QRSDV2	5	QRS Duration in lead V2
QRSDV3	5	QRS Duration in lead V3
QRSDV4	5	QRS Duration in lead V4
QRSDV5	5	QRS Duration in lead V5
QRSDV6	5	QRS Duration in lead V6
QSPTI	5	QS Pattern in lead I
QSPTII	5	QS Pattern in lead II
QSPTIII	5	QS Pattern in lead III
QSPTAVR	5	QS Pattern in lead AVR
QSPTAVL	5	QS Pattern in lead AVL
QSPTAVF	5	QS Pattern in lead AVF
QSPTV1	5	QS Pattern in lead V1
QSPTV2	5	QS Pattern in lead V2
QSPTV3	5	QS Pattern in lead V3
QSPTV4	5	QS Pattern in lead V4
QSPTV5	5	QS Pattern in lead V5
QSPTV6	5	QS Pattern in lead V6
STSLI	5	ST Slope in lead I
STSLII	5	ST Slope in lead II
STSLIII	5	ST Slope in lead III
STSLAVR	5	ST Slope in lead AVR
STSLAVL	5	ST Slope in lead AVL
STSLAVF	5	ST Slope in lead AVF
STSLV1	5	ST Slope in lead V1
STSLV2	5	ST Slope in lead V2
STSLV3	5	ST Slope in lead V3
STSLV4	5	ST Slope in lead V4
STSLV5	5	ST Slope in lead V5
STSLV6	5	ST Slope in lead V6

Appendix 6 Serial Change Triggers, Definitions and Criteria

Minnesota Code Changes which Trigger Serial ECG Comparison

ECG Item	Criteria Number	Minnesota Code on Earlier ECG	Minnesota Code on Later ECG
Q-QS Patterns (major)	1	None of 1-1 to 1-3	1-1 or 1-2 (Except 1-2-8)
	2	1-3 or 1-2-8	1-1
Q-QS Patterns (minor)	3	None of 1-1 to 1-3	1-3 or 1-2-8
	4	1-3 or 1-2-8	1-2*
	5	1-2 (Except 1-2-8)	1-1
T-waves	6	None of 5-1 to 5-3	5-1 or 5-2
	7	5-3	5-2 or 5-1
	8	5-2	5-2 or 5-1
	9	5-1	5-1
ST depression	10	None of 4-1 to 4-2	4-1 to 4-2
	11	4-2	4-2 or 4-1
	12	4-1	4-1
ST elevation	13	No 9-2	9-2

Minnesota Code change of any ECG item may occur within any of the following lead groupings: anterolateral I, aVL, and V_6; posterior II, III, and aVF; anterior V_1-V_5.

Definitions of Electrocardiographic Criteria

The ECG series is assigned the highest category for which criteria are met, i.e., Evolving Diagnostic ECG patterns are greater than Diagnostic ECG patterns are greater than Evolving ST-T patterns are greater than Equivocal ECG patterns are greater than Other are greater than Uncodable.

Evolving ECG Patterns (Evolving Diagnostic and Evolving ST-T):

A. Two or more recordings are needed for these classifications.

B. Changes must occur within lead groups i.e., lateral (I, aVL, V_6), inferior (II, III, aVF), or anterior (V_1- V_5).

C. Changes must be confirmed for codes by Serial ECG comparison.

To be considered Evolving Diagnostic (pattern ED3) both the l-2-4 and the 5-2 must be determined to be Significant Increase by Serial Change rules. If the l-2-4 change is not Significant Increase and the 5-2 change is Significant Increase, then the change would fit Evolving ST-T (pattern EV3). If the 5-2 change is not Significant Increase, then the pattern would be Diagnostic ECG (pattern Dl) because of the 1-2-4,regardless of whether or not the l-2-4 change is Significant Increase. The complexity of this algorithm precludes determination by Minnesota Coders. Determination is made by computer algorithm.

D. The reference ECG for Cohort Field Center Visits is the ECG taken during the first visit. The reference ECG for Cohort Hospital ECGs or Surveillance Hospital ECGs is the earliest ECG of that hospitalization.

E. Serial ECG Significant Decrease is determined only for cohort hospital ECGs and only for 4-, 5- and 9-2 codes.

Definition of Terms:

No Q Code – No 1-x-x or 1-2-6
Diagnostic Q Code – Minnesota Codes 1-1-1 through 1-2-5 plus 1-2-7
Equivocal Q Code – Minnesota Code 1-2-8 or any 1-3-x code
Major ST-Segment Depression – Minnesota Code 4-1-1, 4-1-2, or 4-2
Major T-Wave Inversion – Minnesota Code 5-1 or 5-2
St-Segment Elevation – Minnesota Code 9-2

Evolving Diagnostic ECG:

EDl. No Q-code in reference ECG followed by a record with a Diagnostic Q-code (Minn. code l-l-l through l-2-5 plus l-2-7) OR any code l-3-x in reference ECG followed by a record with any code l-l-x.

ED2. An Equivocal Q-code [(Minn. code l-2-8 in the absence of 7-2-l or 7-4) or any l-3 code] and no major ST-segment depression in reference ECG followed by a record with a Diagnostic Q-code PLUS a major ST-segment depression (Minn. code 4-l-x or 4-2).

ED3. An Equivocal Q-code and no major T-wave inversion in reference ECG followed by a record with a Diagnostic Q-code PLUS a major T-wave inversion (Minn. code 5-l or S-2).

ED4. An Equivocal Q-code and no ST-segment elevation in reference ECG followed by a record with a Diagnostic Q-code PLUS an ST segment elevation (Minn. code 9-2).

ED5. No Q-code and neither 4-l-x nor 4-2 in reference ECG followed by a record with an Equivocal Q-code PLUS 4-l-x or 4-2.

ED 6. No Q-code and neither 5-l nor 5-2 in reference ECG followed by a record with an Equivocal Q-code PLUS a 5-l or 5-2.

ED7. No Q-code and no 9-2 in reference ECG followed by a record with an Equivocal Q-code PLUS a 9-2.

Evolving ST-T Pattern:
(This diagnosis cannot be assigned if a 7-l-l or 7-2-l or 7-4 code is present)

EVl. Either 4-O (no 4-code), 4-4 or 4-3 in reference ECG followed by a record with 4-2 or 4-l-2 or 4-l-l (confirmed by Significant Increase) OR, for hospital ECGs only, 4-2, 4-l-2 or 4-l-l in reference ECG followed by a record with 4-0, 4-4 or 4-3 (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG OR Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV2. Either 4-2 or 4-l-2 in reference ECG followed by a record with 4-l-l (confirmed by Significant Increase) OR, for hospital ECGs only, 4-l-l in reference ECG followed by a record with 4-2 or 4-l-2 (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG OR Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV3. Either S-0, 5-4 or 5-3 in reference ECG followed by a record with 5-2 or 5-l (confirmed by Significant Increase) OR, for hospital ECGs only, 5-2 or 5-l in reference ECG followed by a record with S-0, 5-4 or 5-3 (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG OR Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV4. Code 5-2 in reference ECG followed by a record with 5-l (confirmed by Significant Increase) OR, for hospital ECGs only, 5-l in reference ECG followed by A record with 5-2 (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG OR Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV5. Code 9-O in reference ECG followed by a record with 9-2 (confirmed by Significant Increase) OR 9-2 in reference ECG followed by a record with 9-O (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG OR Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV6. Code 4-l in reference ECG followed by a record with 4-l (confirmed by Significant Increase) OR, for hospital ECGs only, 4-l in reference ECG followed by a record with 4-l (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG or Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV7. Code 5-l-l in reference ECG followed by a record with 5-l-l (confirmed by Significant Increase) OR, for hospital ECGs only, 5-l-l in reference ECG followed by a record with 5-l-l (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG or Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

EV8. Code 5-l-2 in reference ECG followed by a record with 5-l-2 (confirmed by Significant Increase) OR, for hospital ECGs only, 5-l-2 in reference ECG followed by a record with 5-l-2 (confirmed by Significant Decrease),

PLUS

either no Q-code in both the reference ECG and the follow-up ECG or Q-code(s) present in reference ECG or follow-up ECG but no Significant Increase in Q-code found.

Diagnostic ECG:
(any ECG may be used for this classification)

Dl. An ECG record with any Diagnostic Q-code (Minn. code l-l-l through l-2-5 plus l-2-7).

D2. An ECG record with ST-segment elevation code 9-2 PLUS (T-wave inversion code 5-l or 5-2 in the absence of 7-2-l or 7-4).

Equivocal ECG:
(any ECG may be used for this classification)

El. An ECG record with an Equivocal Q-code [(Minn. code l-2-8 in the absence of 7-2-l or 7-4) or (any l-3 code)].

E2. An ECG record with ST-segment depression (code 4-l-x or 4-2 or 4-3 in the absence of 7-2-l or 7-4).

E3. An ECG record with T-wave inversion (code 5-l or 5-2 or 5-3 in the absence of 7-2-l or 7-4).

E4. An ECG record with ST-segment elevation code 9-2.

Other ECG:

01. Reference ECG coded 7-l-l.

02. Any ECG coded 7-l-l.

03. Normal ECG(s), defined as 1 in "clear" field of all ECGs.

04. Other findings including l-2-6.

Uncodable ECG:

Ul. Technical errors coded 9-8-l by Minnesota Code.

Absent ECG:

Al. No ECG available for coding.

Criteria for Determining Significant ECG Pattern Change

Event ECG
Minnesota Code
Q-Code Comparison Rules for Determining Significant ECG Pattern Change

1-1-1 Requires => 50% increase in event Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-1-2 Requires => 50% decrease in event ECG Q/R ratio and => 1.5 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q- wave. New appearance of QS complex in leads to the left of V_1 when V_1 does not show change will also be judged as positive evidence of new infarction.

1-1-3 Required > 75% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q wave in baseline ECG, event record must have codable Q-wave.

1-1-4 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-1-5 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If no Q-wave in baseline ECG, event record must have codable Q-wave.

1-1-6 Requires => 1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG. If *no* QS-wave in baseline ECG, event record must have codable QS-wave.

1-1-7 Requires => 1 mm decrease in event ECG initial R-wave compared with corresponding lead(s) of baseline ECG. If *no* QS-wave in baseline ECG, event record must have codable QS-wave.

1-2-1 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event records must have codable Q-wave.

1-2-2 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-2-3 Requires => 1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG. If *no* QS-wave in baseline ECG, event record must have codable QS-wave.

1-2-4 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-2-5 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-2-6 Requires => 75% increase in event ECG Q/R ratio plus the appearance of a codable and new Q-wave in aVF *OR* => 1 mm initial R-wave amplitude decrease in event ECG plus the appearance of a new codable Q-wave in aVF compared with corresponding lead(s) of baseline ECG.

1-2-7 Requires => 1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG. If *no* QS-wave in baseline ECG, event record must have codable QS-wave.

1-2-8 Requires => 1 mm decrease in event ECG initial R-wave amplitude in the "lead to the left" compared with corresponding lead(s) of baseline ECG.

1-3-1 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-3-2 Requires => 1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG. If *no* QS-wave in baseline ECG, event record must have codable QS-wave.

1-3-3 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have codable Q-wave.

1-3-4 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave i baseline ECG, event record must have a codable Q-wave.

1-3-5 Requires => 50% increase in event ECG Q/R ratio or => 1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG. If *no* Q-wave in baseline ECG, event record must have a codable Q-wave.

1-3-6 Requires => 1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG. If *no* QS-wave in baseline ECG, event record must have a codable QS-wave.

<u>ST Elevation Code</u>

9-2 Requires baseline record have no 9-2 code, or there is 100% change in event ECG ST elevation compared with corresponding lead(s) of baseline ECG.

<u>ST Depression Code</u>

4-1 Requires baseline record have no 4-1 or 4-2, or there is a 100% change in event ECG ST segment depression.

OR

4-2 Requires baseline record have no 4-1 or 4-2 codes, or there is 100% *change* in event ECG ST segment depression.

T-wave Inversion Code

5-1 Requires comparison record have no T-wave inversion codes, or there is 100% *change* (as in 9-2 codes) in T-wave inversion.

OR

5-2 Requires comparison record have no T-wave inversion codes, or there is 100% change (as in 9-2 codes) in T-wave inversion.

Conduction Delay Codes

7-1-1, 7-2-1, 7-4 Requires new 7-1-1, 7-2-1 or 7-4 code in event ECG with a QRS duration increased by 0.02 sec in event ECG compared with baseline ECG.

Appendix 7 Crow Papers on Serial Comparison 1989 and 1997

American Journal of Epidemiology

Vol. 151, No. 8
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Comparison of Computer-assigned Minnesota Codes with the Visual Standard Method for New Coronary Heart Disease Events

Jan A. Kors,[1] Richard S. Crow,[2] Peter J. Hannan,[2] Pentti M. Rautaharju,[3] and Aaron R. Folsom[2]

The Minnesota Code is the most widely used electrocardiogram (ECG) classification system for epidemiologic studies and has been incorporated into several computer algorithms. The authors compared the Modular ECG Analysis System (MC-MEANS) and NOVACODE computer ECG findings with the Visual coding standard for agreement and prognostic associations with coronary heart disease (CHD) events occurring during follow-up from 1987 to 1995 in 2,116 individuals participating in the Atherosclerosis Risk in Communities (ARIC) Study. The exact agreement between Visual and computer findings was greater than 90% for all Minnesota Code categories except Q-code, which was 77% for MC-MEANS and 81% for NOVACODE. Approximately 60% of all Q-codes were assigned by computer methods only. Among the 2,116 participants, there were 246 (11.6%) new coronary events. Unadjusted relative risks for codes assigned by the three methods were similar. When computer methods disagreed on code severity, the CHD occurrence rates for MC-MEANS-detected severer code versus NOVACODE-detected severer code were 21% and 7%, respectively. This study provides clear evidence that computers assign more and severer Minnesota Codes with similar prognostic importance as does the Visual method; it also alerts researchers to potential problems in pooling Minnesota Code data read by different methods. *Am J Epidemiol* 2000;151:790–7.

computing methodologies; coronary disease; electrocardiography; prognosis

Prognostic Associations of Minnesota Code Serial Electrocardiographic Change Classification With Coronary Heart Disease Mortality in the Multiple Risk Factor Intervention Trial

Richard S. Crow, MD, Ronald J. Prineas, MD, PhD, Peter J. Hannan, MSTAT, Greg Grandits, MS, and Henry Blackburn, MD

A central requirement for epidemiologic studies and clinical trials is a bias-free, objective determination of cardiac incidence rates between comparison groups. Epidemiologic studies and clinical trials frequently use changes in the Minnesota Code to document incident ischemic events. An electrocardiographic (ECG) classification system was developed to document significant ECG pattern change using objective comparison rules for side-by-side annual ECG comparison. Previously, we showed that major evolving Q waves were strongly and independently associated with total and coronary disease mortality. Using baseline-to-annual ECG comparisons in the Multiple Risk Factor Intervention Trial, we evaluated major evolving Q waves, minor evolving Q waves combined with major evolving ST-T waves *and* major evolving ST-T waves alone for their prognostic associations with coronary, cardiovascular, and total mortality during 16 years of follow-up. The 16-year coronary mortality rate in men with evolving minor Q waves plus evolving ST-T waves had an average adjusted relative risk of 4, equivalent to that of a major evolving Q wave. These risk ratios held whether a clinical infarction had occurred. Silent evolving ST-T waves without Q-wave change had an average adjusted relative coronary mortality risk of 1.6. Serial comparison methodology documents additional incident ischemic ECG events beyond the traditional major Minnesota Q-code change used in older epidemiologic studies. The procedure is standardized, quantitative, and repeatable. It is applicable for any study, present or past, that used Minnesota coding. The method is also well suited for incorporation in computer analysis programs.

(Am J Cardiol 1997;80:138–144)

A New Epidemiologic Classification System for Interim Myocardial Infarction from Serial Electrocardiographic Changes

Richard S. Crow, MD, Ronald J. Prineas, MBBS, PhD, David R. Jacobs, Jr., PhD, and Henry Blackburn, MD

Many clinical trials or population studies have used change in Minnesota Q code, ST-segment depression code or T-wave inversion code as evidence of new myocardial infarction or new coronary heart disease event. Direct electrocardiogram (ECG) waveform comparison is a new standardized procedure for diagnosing interim myocardial infarction from ECGs classified according to the Minnesota code (serial Q-wave pattern change). This procedure was investigated for its application in epidemiologic studies. Use of this procedure in the Multiple Risk Factor Intervention Trial resulted in a 50% increase in the positive predictive accuracy, improved agreement with clinically defined myocardial infarction and a strong independent prognostic association with total and coronary heart disease mortality. Among those with major Minnesota Q-code findings, there was substantial variation in mortality. The 5-year coronary heart disease death rates estimated by life table analysis were 8.5% for those with major serial Q-wave pattern change, 5.1% for those with minor serial Q-wave pattern change and 1.5 to 2.6% for those with major or minor Minnesota Q-code change not substantiated by direct waveform comparison, compared with 2.4% for those with no Minnesota Q-code findings. The coronary heart disease death rate for those with major serial Q-wave pattern change was greater than that for the other ECG groups ($p < 0.01$). Adjustment for age and other risk factors did not qualitatively alter these findings. This new approach is eminently suitable for export to other investigators, for incorporation into computer analysis programs and for statistical analysis.

(Am J Cardiol 1989;64:454–461)

A central requirement for epidemiologic studies and clinical trials is a bias-free, objective measurement of cardiovascular occurrence rates between comparison groups. The electrocardiogram (ECG) is well suited to central standardized measurement and handling by blinded, repeatable procedures, thus providing an objective method to document study endpoint information without bias of ascertainment.

The Minnesota code was originally developed for determining prevalence information in epidemiologic studies and it functions well in that capacity.[1] Later, criteria for documenting significant change between Minnesota codes were developed from "armchair rationale" with general knowledge of the classification error in ECG coding, and then modified after testing against an autopsy-proven sample from Mayo clinic records and a normal sample.[2] However, criteria for significant change between Minnesota code classifications, used as an index of incidence rates for new myocardial infarction (MI), tended to produce high false positive misclassifications as judged by clinical assessment.[3] Because ECGs are continuous and "infinitely gradable," whereas Minnesota code items are categorical, a minor amplitude or duration change can sometimes produce a significant Minnesota code change. In spite of these limitations, criteria based on change in Minnesota code were routinely used for ischemic endpoint determination in many epidemiologic studies in the United States and abroad since the 1960s.[4–8]

During the Multiple Risk Factor Intervention Trial (MRFIT), we introduced a new approach to classification of ECG changes. First, computer-generated Minnesota Q codes were identified for all baseline or annual ECG recordings. Second, for each participant with a new major Minnesota Q code detected at an annual visit, 2 cardiologists directly compared the baseline ECG with the annual ECG to determine whether or not the new Q code represented a major serial Q-wave pattern change. The cardiologists followed predefined rules for serial ECG change that mimic the physician's clinical reading approach. These rules were developed in the Minnesota ECG Coding Center and provide categorization of new MI or coronary heart disease event without the limitations of the original procedure, which compared only Minnesota Q codes. This comparison procedure is based on direct comparison of ECG waveforms. It was incorporated into the Minnesota ECG Center's standardized training procedures and taught to all cod-

From the Division of Epidemiology, University of Minnesota, Minneapolis, Minnesota. This work was supported by grant R01HL29187 from the National Institutes of Health, Bethesda, Maryland. Manuscript received January 23, 1989; revised manuscript received May 18, 1989, and accepted May 19.

Address for reprints: Richard S. Crow, MD, Division of Epidemiology, University of Minnesota, Stadium Gate 27, 611 Beacon Street Southeast, Minneapolis, Minnesota 55455.

Appendix 8 Proposed JHS Dx Criteria for Hospitalized MI Incl. Chest Pain, ECG & Enzymes

Cardiac Pain	ECG Findings	Enzymes	Diagnosis
Present	Evolving Diagnostic ECG Pattern (ED1-ED7)	Abnormal	Definite MI
		Equivocal	Definite MI
		Incomplete	Definite MI
		Normal	Definite MI
	Diag. ECG Pattern	Abnormal	Definite MI
		Equivocal	Probable MI
		Incomplete	Suspect MI
		Normal	No MI
	Evolving ST-T Pattern (EV1 - EV9)	Abnormal	Definite MI
		Equivocal	Probable MI
		Incomplete	Suspect MI
		Normal	No MI
	Equivocal ECG Pattern	Abnormal	Definite MI
		Equivocal	Probable MI
		Incomplete	No MI
		Normal	No MI
	Absent, Uncodable, or other	Abnormal	Probable MI
		Equivocal	Suspect MI
		Incomplete	No MI
		Normal	No MI
Not Present, Unknown or Missing	Evolving Diagnostic ECG Pattern (ED1-ED7)	Abnormal	Definite MI,
		Equivocal	Definite MI
		Incomplete	Definite MI
		Normal	Definite MI
	Diag. ECG Pattern	Abnormal	Definite MI
		Equivocal	Suspect MI
		Incomplete	No MI
		Normal	No MI
	Evolving ST-T Pattern (EV1 - EV9)	Abnormal	Probable MI
		Equivocal	Suspect MI
		Incomplete	No MI
		Normal	No MI
	Equivocal ECG Pattern	Abnormal	Suspect MI
		Equivocal	Suspect MI
		Incomplete	No MI
		Normal	No MI
	Absent, Uncodable or other	Abnormal	Suspect MI
		Equivocal	No MI
		Incomplete	No MI
		Normal	No MI

Diagnostic ECG:
(any ECG may be used for this classification)

D1. An ECG record with any Diagnostic Q-code (Minn. code 1-1-1 through 1-2-5 plus 1-2 7).

D2. An ECG record with ST-segment elevation code 9-2 PLUS (T-wave inversion code 5-1 or 5-2 in the absence of 7-2-1 or 7-4).

Equivocal ECG:
(any ECG may be used for this classification)

E1. An ECG record with an Equivocal Q-code [(Minn. code 1-2-8 in the absence of a 7-1-1 or 7-3 or (any 1-3-code)].

E2. An ECG record with ST-segment depression (code 4-1-x or 4-2 or 4-3 in the absence of 7 2-1 or 7-4).

E3. An ECG record with T-wave inversion (code 5-1 or 5-2 or 5-3 in the absence of 7-2-1 or 7-4).

E4. An ECG record with ST-segment elevation code 9-2.

Other ECG:

01. Reference ECG coded 7-1-1.

02. Any ECG coded 7-1-1.

03. Normal ECG(s), defined as 1 in “clear” field of all ECGs.

04. Other findings including 1-2-6.

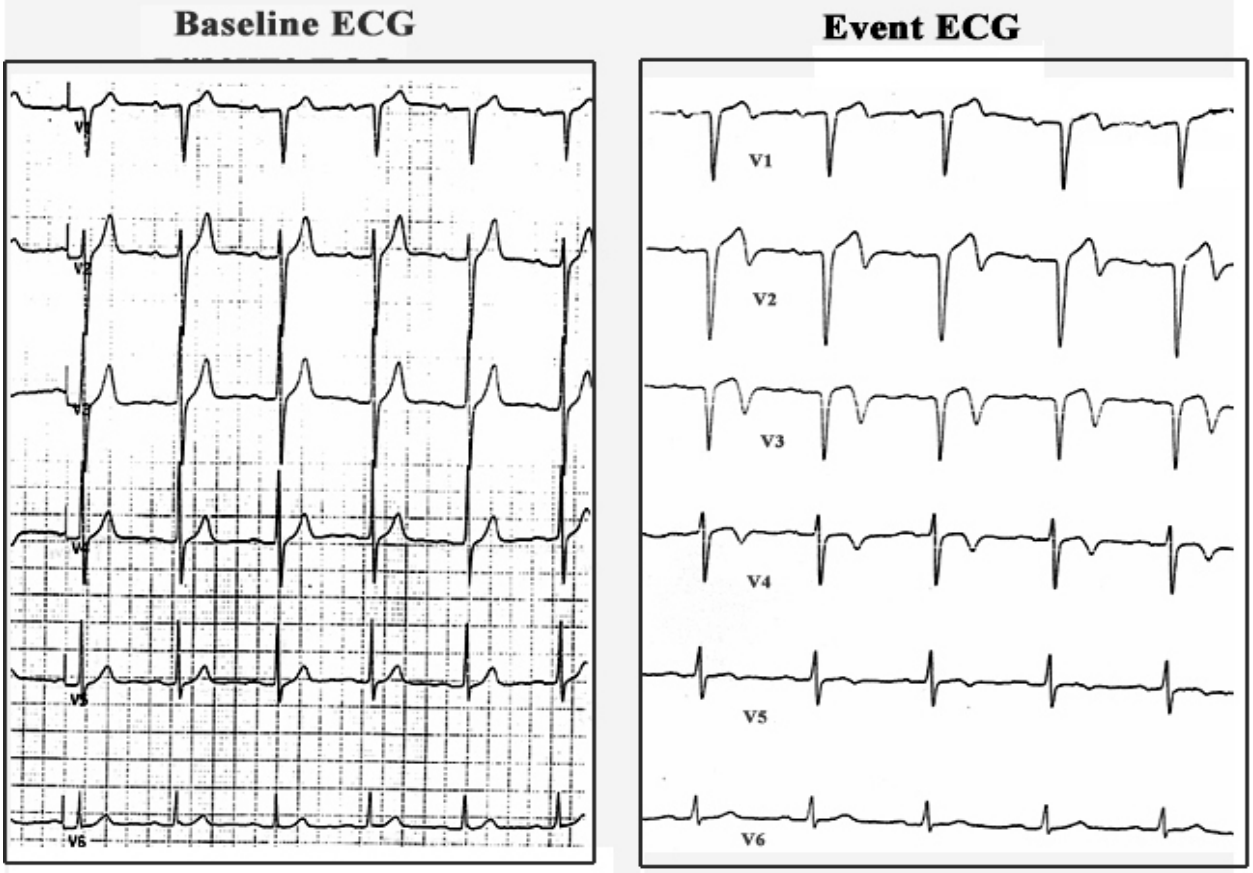
Uncodable ECG:

U1. Technical errors coded 9-8-1 by Minnesota Code.

Absent ECG:

A1. No ECG available for coding.

Appendix 9 Serial Change Example of Minnesota Code 1-2-7



New Minnesota Code 1-2-7 occurs after baseline

Baseline ECG shows normal R-waves V_1-V_3; event ECG shows a QS pattern in the corresponding leads. The event ECG has a Minnesota Code 1-2-7. Serial comparison rules document this as a significant change because the event V_3 R-waves have decreased by ≥ 1mm compared with the baseline V_3.

Appendix 10 ECG Technician Certification

(TO BE FILLED IN BY JACKSON HEART STUDY)

ECG Technician: _____Technician No._____

Date Certification Tracings Taken: _____

INSTRUCTIONS:
• Obtain three 12-lead resting ECGs as specified in the JHS ECG Procedures. Write the Technician name on the ECG, the Technician number must be printed by the MAC PC next to the word ROOM.

• Send the ECGs and one copy of this form to the JHS ECG Coding Center:

University of Minnesota
Division of Epidemiology
JHS Study Coding Center
1300 South Second Street, Suite 300
Minneapolis, MN 55454-1015

• Notification of the technician's certification status is made upon receipt of this completed form at the MN ECG Coding Center.

(TO BE FILLED IN BY THE MINNESOTA ECG CODING CENTER)

Date Tracings Received:

Comments:

Certified: YES ( ) NO ( )

_____ _____
Signature of Certifying Agent Date

Appendix 11 ECG Technician Procedure Review

This form is required for ECG technician certification, recertification, and quality control. It is to be completed by the ECG training supervisor by observing the ECG technician taking an ECG recording. Quality control observations should occur every six months.

The ECG training supervisor should not make any comments during the recording.

Identifying Information

ECG Technician:_____ Technician No._____

ECG Supervisor:_____ Technician No._____

Date:_____ Biannually: _____January_____July

	YES	NO	COMMENTS
Subject asked to disrobe to waist only if back-opening gown worn	( )	( )	
Subject instructed to lie on the recording bed with arms relaxed at the sides.	( )	( )	
Limb leads correctly marked.	( )	( )	
Electrode areas wiped with alcohol, then with a gauze pad.	( )	( )	
V2 position correctly marked.	( )	( )	
V1 position correctly marked.	( )	( )	
E point position correctly marked.	( )	( )	
V6 position correctly marked using chest square.	( )	( )	
E point to V6 measured with tape measure and noted on scratch paper.	( )	( )	

ECG Technician Procedure Review (continued)

	YES	NO	COMMENTS
Participant information entered into the V4 position correctly marked using tape measure.	( )	( )	
V3 position correctly marked using a flexible ruler.	( )	( )	
V5 position correctly marked using a flexible ruler.	( )	( )	
Electrodes applied as in steps 3-6.	( )	( )	
Appropriate lead wire clipped to each electrodes.	( )	( )	
MAC PC	( )	( )	
Electrodes and lead wires checked.	( )	( )	
Subject asked to relax, lie quietly.	( )	( )	
Electrodes on skin 2-5 minutes before taking ECG.	( )	( )	
MAC PC display watched for error messages.	( )	( )	
If error message(s): electrode contacts and lead wires checked, display observed again.	( )	( )	
If display counts past 45: repeat skin preparation using 2 strokes with fine sandpaper. Replace with new electrodes on limb leads first, if necessary, replace all electrodes.	( )	( )	
ECG tracing removed from the MAC PC.	( )	( )	
ECG examined for baseline drift, noise, 60-cycle interference and muscle tremor.	( )	( )	
When technically inadequate, ECG re-recorded until an acceptable recording is achieved.	( )	( )	
Electrodes removed.	( )	( )	

Appendix 12 Procedures for MAC PC Calibration Check

1. Minnesota ECG Coding Center Procedures

The ECGRC Coding Supervisor manages the sending and receiving of the Marquette ECG simulator. The JHS Clinic receives the simulator once every three months. The simulator is sent via Certified Mail, return receipt requested.

Upon receiving a calibration ECG from a Field Center, the Coding Supervisor measures the waves required in the Calibration Check form. If there is wave distortion compared to the ECG taken at the ECG Coding Center on February 20, 1987, the Coding Supervisor contacts the Clinic about appropriate action.

The Coding Supervisor enters the data and graphs comparisons of wave height at the end of every calendar quarter. These results are sent to the JHS.

2. Jackson Heart Study Procedures

Within two days of receiving the simulator, take one noise-free 12-lead ECG following the instructions below.

Instructions for taking a 12-lead ECG using the Marquette ECG Simulator:

1. Make sure the ECG Simulator switch is above "off" unless actually in use. Leaving it "on" drains the battery.
2. Check the battery: push the switch to "test". The yellow light should go on. If it doesn't, unscrew the back of the simulator and replace the old battery with the new battery included in the mailing.
3. Remove the adaptor wires (clips) from the lead wire plugs.
4. Plug each lead wire into the simulator in its proper hole.
5. Turn the Heart Rate knob all the way to the left so the white line is at the number 68 (as in 'beats per minute'). Don't try to line up the line with the dot, just turn it all the way left.
6. Press Fl (PatInfo).
7. For Last Name: CALIBRATION TEST.
8. For First Name: Site Number (MN = 5, NC = 6, MD = 7, MS = 8)
9. For ID number put Technician ID.
10. Press Return.
11. Press the STOP symbol when it asks for Referred by: -_
12. Now the screen is back to the Main Menu.
13. Turn on the ECG Simulator or else you will get a flat line!
14. Press the 12-lead Record key. Machine will take, print and store an ECG.
15. Turn off the ECG Simulator.

If you have trouble getting a noise-free ECG, try twisting the plugs in their holes and take another ECG. Otherwise, there might be something wrong with your Acquisition Module (the white box with all the lead wires coming out of it).

1. Phone the ECG Coding Center and we will send you our Acquisition Module.
2. Try taking another ECG using our module.
3. If the tracing is better, contact Marquette about replacing your module.
4. If you are still getting lots of noise, take the appropriate steps to have your machine serviced..

Do not take a 2-minute rhythm strip using the simulator.

Transmit the Calibration ECG with your next batch to Minnesota. Delete it upon confirmation.

Return the simulator and ONLY ONE 12-lead ECG (the best one if you took more than one) immediately via Certified Mail, return receipt requested to:

Mr. Sean Thomas
ECG Coding Center
Division of Epidemiology, School of Public Health
1300 South 2nd Street, Suite 300
Minneapolis, MN 55454

PLEASE PACK THE SIMULATOR VERY CAREFULLY!

Calibration Check Form

Marquette ECG Simulator Measurements

Study: _____

Location of Clinic: _____ Date of ECG: _____

Type of Electrocardiograph: _____

Simulator used (circle one): ARIC TOMHS

PAPER SPEED:

Overall: Measure from the peak of the R of the first complete R-wave in Lead I to the peak of the 6th R-wave, (5 intervals).

_____mm / 5 intervals = _____ = _____

mm/interval Overall HR

Short Term: Measure interval between first and second complete R-waves.

_____ mm = _____

1st interval Short Term HR

PR Duration: Measure the PR duration of 3 beats in Lead II to the nearest 0.25 mm.

_____ + _____ + _____ / 3 = _____ average PR duration

VOLTAGE CALIBRATION:

Measure the last 3 complete waves of the lead in question. If there are only 2 complete waves then divide by 2, instead of 3, to get the average. The beats themselves do not have to be complete.

R-wave in I: _____ + _____ + _____ / 3 = _____

R-wave in II: _____ + _____ + _____ / 3 = _____

R-wave in III: _____ + _____ + _____ / 3 = _____

Calibration: _____ + _____ + _____ / 3 = _____

T-wave in II: _____ + _____ + _____ / 3 = _____

S-wave in V1: _____ + _____ + _____ / 3 = _____

FREQUENCY RESPONSE:

Compare closely with the ECG taken by the same simulator on the Floater MAC PC on Feb. 20, 1987. Note especially ST segment distortion.

Satisfactory? (circle one) YES NO (show to Dr. Crow)

Comment:

_____

_____

Appendix 13 Sample Shipping Form

JACKSON HEART STUDY SHIPPING FORM
ANCILLARY ECGs

Date shipped: _____ Prepared by: _____

Total number of ECGs in shipment: _____ Telephone: _____

Instructions:
Please complete this shipping form and include it with your ECG shipment to the Minnesota ECG Coding Center. Enter each participant ID, the date shipped, total number of ECGs in the shipment, the name and phone number of the person preparing the shipment. Only accurate shipping forms will be accepted, others will be returned for correction.

Once the ECGs are received and verified, ECG Coding Center staff will initial and date the form and return a copy to the JHS to verify receipt.

#	Patient ID
1	00J123456 – F
2	00J123456 – T
3	00J123456 – L
4	00J567890 – F
5	00J567890 – L
6	00J135792 - F
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

#	Patient ID
26	
27	
28	
29	
30	
31	
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34	
35	
36	
37	
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Shipment received by: _____ Date: _____