THE EFFECT OF COMPUTER REPORTED CLINICAL INFORMATION ON THE CARDIOLOGIST'S BEHAVIOR IN THE INTERPRETATION OF ELECTROCARDIOGRAMS

by

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SUPERVISORY COMMITTEE APPROVAL

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ABSTRACT

The effect of computer-reported clinical information on the cardiologist's behavior in the interpretation of electrocardiograms (ECGs) was studied using 100 inpatient ECGs. Using an automated medical record system (HELP), the pertinent demographic and clinical information was printed on a clinical label. Two cardiologists independently read these 100 ECGs twice, once without the label and once with the label provided. A sample of twenty-five ECGs was chosen from the 100 ECGs for estimation of intraobserver variability. These twenty-five ECGs were independently read again with and without the clinical label. An appropriate time delay between the readings was allowed to insure independence of the readings.

The following results were observed: (a) The myocardial infarction (MI) and chamber enlargement interpretations, the intraobserver variability of one cardiologist was reduced from 25 percent to 14.7 percent and a corresponding decrease from 22.7 percent to 6.7 percent for the other cardiologist. Statistically, the decreases in both cases were found to be significant. (b) The overall interobserver variation showed statistically insignificant reduction (16.3 percent to 13 percent). However, for MI interpretation, the corresponding reduction from 24 percent to 13 percent might be clinically significant. (c) For MI, chamber enlargement and repolarization change interpretations; the frequency of agreement between

the cardiologists was approximately 2.00 times that of the disagreement in the diagnoses. (d) For the interpretation of repolarization changes in the twenty-five ECGs, the frequency of changes from nonspecific to a specific interpretation increases from 2 percent to 36 percent after the introduction of the clinical label. Therefore, it was concluded that the availability of demographic and clinical information in a total hospital information system provides useful data to the cardiologist for the interpretation of ECGs.

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CHAPTER I

BACKGROUND AND OBJECTIVES

Background

In spite of recent achievements in the field of medicine, cardiac disease remains the leading cause of death in the United States. One study showed that the mortality rate from myocardial infarction (MI) during hospitalization ranges from 10 to 16 percent (Weinblatt, Shapiro, and Frank, 1968; Bigger, Heller, Wenger, and Weld, 1978). In another study (Friedman, Klatsky, and Siegelaub, 1977), it was found that 61.4 percent of the 1,077 sudden deaths investigated in the forty to sixty-four age group were due to coronary heart disease. In a separate study (Yanushekickus, Bluzhas, and Milashauskene, 1977), it was found that the overall proportion of out-of-hospital sudden deaths due to acute MI and acute coronary insufficiency was as high as 54.2 percent in 1975. The high percentages of out-of-hospital deaths due to cardiac disease in this study indicate that a more meticulous examination of the problem may be rewarding.

One of the many reasons for the high number of cardiac deaths outside the hospital is inaccurate diagnosis. In a necropsy study (Johnson, Achor, Burchell, and Edwards, 1959), it was found that 50 percent of the patients with healed infarcts had no record of clinical diagnosis of MI during their lifetime; 40 percent of the

patients with acute MI, including some with healed infarcts, also had no clinical diagnosis of MI during their lifetime. These high percentages of inaccurate or incomplete diagnoses of cardiac disease indicate that the procedure needs improvement.

Cardiac disease, if not diagnosed and treated, is very often fatal. In order to reduce the number of deaths due to cardiac disease, it is essential to minimize the number of patients who have an unrecognized cardiac problem. To achieve an accurate diagnosis, a good diagnostic method is needed. Ever since the nineteenth century a series of invasive and noninvasive diagnostic methods have been explored to assess the status of the cardiac function. This thesis will concentrate on one such noninvasive diagnostic method--the electrocardiogram (ECG).

An ECG is a graphical recording of electrical potentials produced in association with the cardiac cycle. By applying electrodes at various positions on the body and connecting these electrodes in various combinations to an electrical potential recording device, the ECG can be recorded. The development of electrocardiography dates back to the eighteenth century. In 1787, Professor Aloysio L. Galvani (1737-1798) at the University of Bologna introduced the concept that living tissues have electrical properties. Efforts were then made to record the activity of the human heart, but it was not until 1887 that Augustus D. Waller, an outstanding physiologist in London, first demonstrated at St. Mary's Hospital Medical School how to record the electrical activity with a capillary electrometer. The recording was then called a cardiogram.

Willem Einthoven of Leiden University in Holland developed a procedure for recording the electrical activity of the heart. After working for a number of years with a capillary electrometer, Einthoven became dissatisfied with the records obtained with this instrument. This led him to develop the string galvanometer in 1903. The recording was then called an elektrokardiogram (EKG). Since then, Einthoven's string galvanometer has been refined and modified. It was not until 1909 that the electrocardiograph was first introduced in the United States by Alfred E. Cohn. In 1913, Einthoven and his associates introduced "Einthoven's Triangle," which formed the foundation of clinical electrocardiography. A three-lead system was developed from this concept. Later, however, Einthoven's original three leads were recognized as inadequate for the study of electrical forces in planes other than the frontal plane. In the early 1930s, Frank N. Wilson and his group published their first observation concerning a central terminal of zero potential. By assuming the concept of Einthoven's Triangle, they constructed a lead system which could determine a point whose electrical potential could be defined as zero. Potential variations at any point on the body could be measured against this point which is called the Wilson terminal. Using this concept, he developed a six-lead system to measure the electrical activity of the heart in the horizontal plane. This finding later formed the basis for the Wilson lead system.

During the 1930s, the changes in theories and lead configurations were too rapid. Finally in 1938, the American Heart Association and the Cardiac Society of Great Britain and Ireland spent a

considerable amount of effort to bring order to the field by agreeing on six positions for the chest electrode. The positions were defined on the basis of the landmarks of the bony thorax.

By the mid-1940s, Wilson's "V" leads were widely accepted. Later, Dr. Emanuel Goldberger suggested a modification of Wilson's "V" lead configuration. He observed that in Wilson's lead system, the potential variation at an extremity is fed into both sides of the galvanometer at the same time, once through inclusion in the central terminal connected to the negative pole and once through the exploring electrode connected to the positive one. He reasoned that if the connection of an extremity to the central terminal was interrupted, there would be an increase in amplitude of the deflection with no change in configuration. From this discovery, he developed an additional three leads. By the end of World War II, Dr. Goldberger's three-lead configuration was added to the existing lead system. These configurations have evolved into today's twelve-lead system.

During the period between the two world wars, a better clinical understanding of coronary artery disease, especially MI, was obtained. Hence, the value of electrocardiography in the diagnosis of cardiac disease had increased. Meanwhile, the recording system has been refined and modified to a more stable, dependable, and sensitive system. Amplifiers were built into the system; direct-writing and oscilloscope-display electrocardiographs were developed. At present, the twelve-lead tracing continues to be the standard for recording electrocardiograms. Efforts continue to be made to improve instrumentation with a view to better electrocardiographs.

Instrumentation in any recording system is important. However, the clinical application of the recording is more important. The intelligence that is built into the organization and interpretation of the recorded information is the essence of the diagnostic method. Therefore, the diagnoses that rely on the interpretation of an ECG are the prime reasons for the existence of electrocardiography. The ECG is especially valuable in clinical conditions, such as atrial or ventricular hypertrophy, MI, arrhythmias, pericarditis, systemic diseases that affect the heart, the effect of cardiac drugs, and disturbances of the metabolism of electrolytes. The ECG has been shown to be both useful and accurate. It was demonstrated (Zinn and Cosby, 1950) in one study that the twelve-lead ECG used in diagnosing MI was correct 80 percent of the time. In another study (Paton, 1957), the electrocardiographic diagnosis of confirmed MI was found to be correct in ninety-one out of ninety-seven cases (93.81 percent). Nevertheless, electrocardiography is an imperfect diagnostic tool for the presence of acute or residual cardiac diseases or arrhythmia. One of the limitations lies in the interpretation of the recorded information. The interpretation of the ECG depends not only on the past experiences of the cardiolgoist, but also upon the definition of a "normal" ECG. Kossman (1959) said, "One of the most difficult tasks which confronts the worker in life sciences is to define a normal. This difficulty is compounded when the measurement to be made is affected by many variables which differ in importance from time to time" (p. 920). This statement is very appropriate for the discussion of an ECG.

With the difficulty in defining a "normal," there is

considerable variation in the interpretation of the same ECG among cardiologists. One of the reasons that contributes to this variation may be the nonavailability of specific demographic and clinical information associated with the patient to the reader of the ECG. In most instances, the cardiologist does not have this information when the ECG is interpreted. Hence, the cardiologist, using past experiences, compares the patient's ECG to a standard "normal" ECG. Thus, the interpretation is not patient specific. Nevertheless, all cardiologists know that demographic information of the patient, such as age, body weight, height, chest configuration, anatomic position of the heart, and race, do have an effect on the electrocardiographic tracing. That is to say, every patient has his or her own "normal" ECG. Clinical information on the patient also helps to define the patient's normal ECG. For instance, the laboratory findings, such as creatinine phosphokinase, become invaluable to a cardiologist when a patient is suspected to have had a heart attack, but the ECG shows no abnormalities. Moreover, echocardiography, chest X-ray, and cardiac catherization are additional diagnostic tools being employed to evaluate the cardiac status. Information which may be unobtainable from the patient's electrocardiographic tracing may show up in the echocardiogram, the chest X-ray film, or the cardiac catherization result. This information may be revealing to a cardiologist when the ECG shows a borderline case of cardiac abnormality. Also, the medical history of the patient can provide clues which may elicit a better comprehension of the patient's health status. For example, a history of hypertension is generally suggestive that the patient has

some underlying cardiovascular disease. Indeed, most patients who develop ventricular fibrillation have a history of hypertension. In addition, knowing which cardiac medication the patient is taking allows the cardiologist to recognize some of the abnormal electrocardiographic findings that may result from the medications and not from physiological abnormalities. Thus, it seems that a complete clinical picture of the patient is essential for a cardiologist to make an accurate interpretation of an ECG.

Above all, providing the best health care to hospitalized patients is the prime interest of the hospital medical team. It is unfair to a patient if some pertinent clinical information is absent when the ECG is interpreted. On the other hand, it is currently not practical for every cardiologist to search the patient's chart to retrieve the pertinent clinical information for every ECG read. Presently at the LDS Hospital located in Salt Lake City, Utah, the patient's clinical information is recorded on his or her chart, but is not available to the cardiologist when the interpretation is made. In an attempt to solve this problem, the automated medical record system (HELP), which was developed by Dr. Homer L. Warner and his associates, was employed. The system enables pertinent information for interpretation of the ECG to be provided to the cardiologist. With the clinical information made available to the cardiologist, the change in ECG interpretive behavior may be observed and evaluated.

Objectives

The objectives of this study are to observe and to evaluate any changes in the cardiologist's interpretation of the ECG after the clinical label, which contained pertinent demographic and clinical information, was provided. It is also the purpose of this study to evaluate the type of changes that took place.

CHAPTER II

DESIGN AND METHODOLOGY

Introduction

Currently, there is a tremendous amount of demographic and clinical information recorded in the patient's chart. It is impractical for a cardiologist to retrieve the information from the patient's chart for every ECG read. However, the method and the time needed for the retrieval of this information can be improved if a computerized medical record system is employed. Therefore, the automated medical record system (HELP) at the LDS Hospital is ideal for this study.

This chapter describes the overall design of the study, describes the type of information to be retrieved and printed on the clinical label, justifies the choice of the information, describes the protocol used for data collection, and gives the definitions of changes of diagnoses.

Overall Design

When an ECG was ordered by the attending physician, a copy of the order was automatically printed out at the ECG laboratory. A technician recorded the patient's tracing at bedside and used a questionnaire, which consisted of five questions, to obtain the patient's past medical history. The five questions used are shown

in Table 1.

After returning to the ECG laboratory, the recorded information was stored in the patient data file through data entry. A computer program, which was encoded in the TAL language, was invoked to retrieve and print the demographic and clinical information on a one and three-fourths inches by ten and one-half inches clinical label which was then attached to the ECG of the patient. Thus, the information was made available to the cardiologist when the ECG was interpreted. Figure 1 summarizes the flow of information and Figure 2 depicts the overall logic of the computer program.

Type of Information To Be Retrieved

Speed of retrieval of pertinent information from the patient's chart is essential for efficient medical care of the patient, but the content of the retrieved information is even more important. If the retrieved clinical information is irrelevant to the context of the interpretation, it serves no purpose and may confuse the ECG reader. Therefore, an experienced and competent cardiologist (Dr. Arthur Hagan) was chosen to select a group of demographic and clinical information from the patient's data file. Table 2 shows a list of the demographic and clinical information retrieved.

The retrieval of the interpreted results of cardiac catherization required twenty-six HELP sector decisions to provide the data of interest in the study. These HELP sector decisions are listed in Appendix A. The length of the text in the HELP sector results was too long to be printed out on the clinical label, so a list of

TABLE 1

QUESTIONNAIRE USED TO OBTAIN PAST MEDICAL HISTORY OF THE PATIENT

Questions	Responses
1. Any previous heart attack?	If YES, state the year of occurrence. If it happened in the current year, state the month of occurrence also.
2. Any past coronary artery bypass graft?	If YES, give the year of occurrence. If it happened in the current year, state the month of occurrence also.
3. Any history of hypertension?	YES or NO
4. Any past valvular surgery?	YES or NO
5. Any history of rheumatic valvular disease?	YES or NO

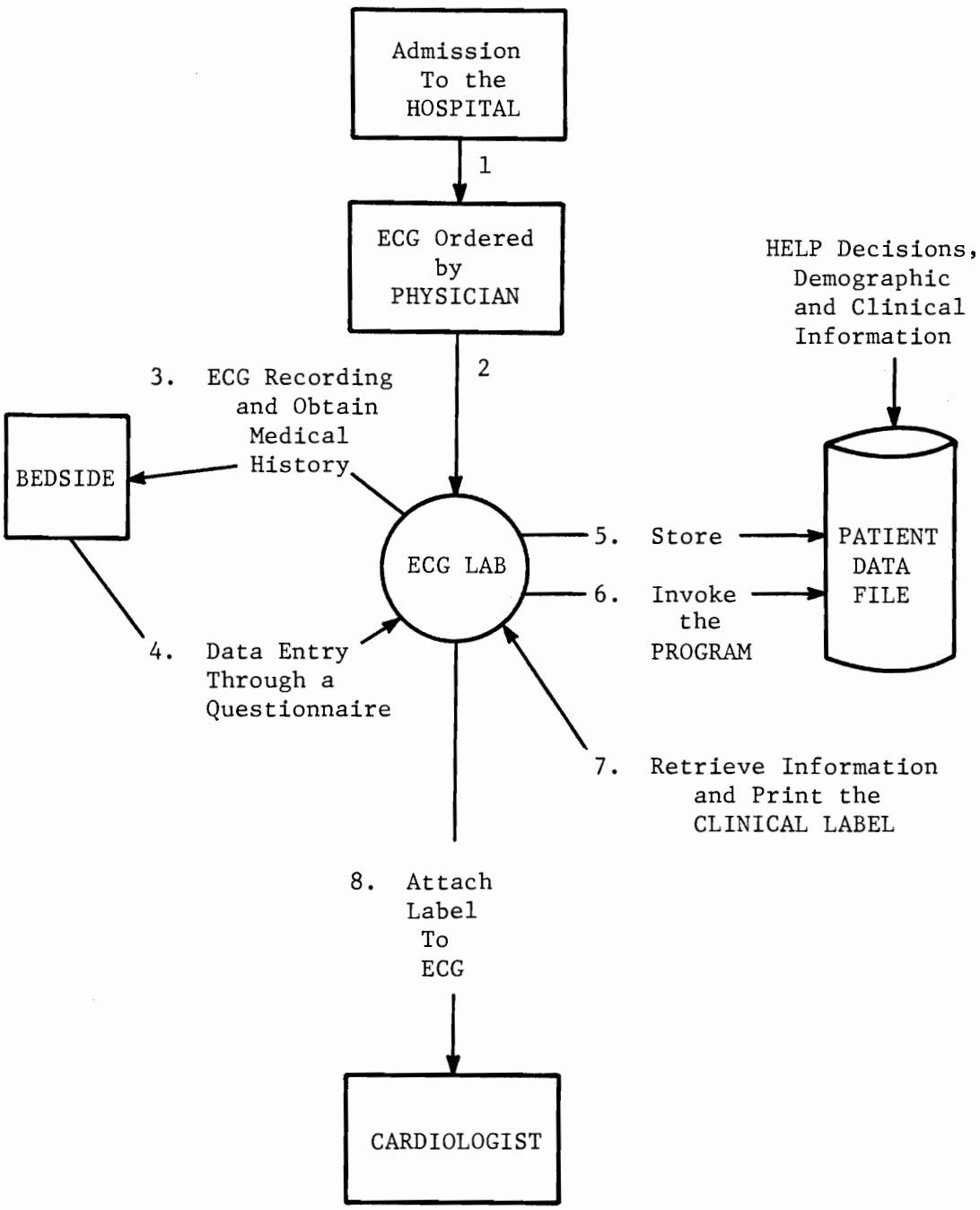

Fig. 1. Information flow diagram.

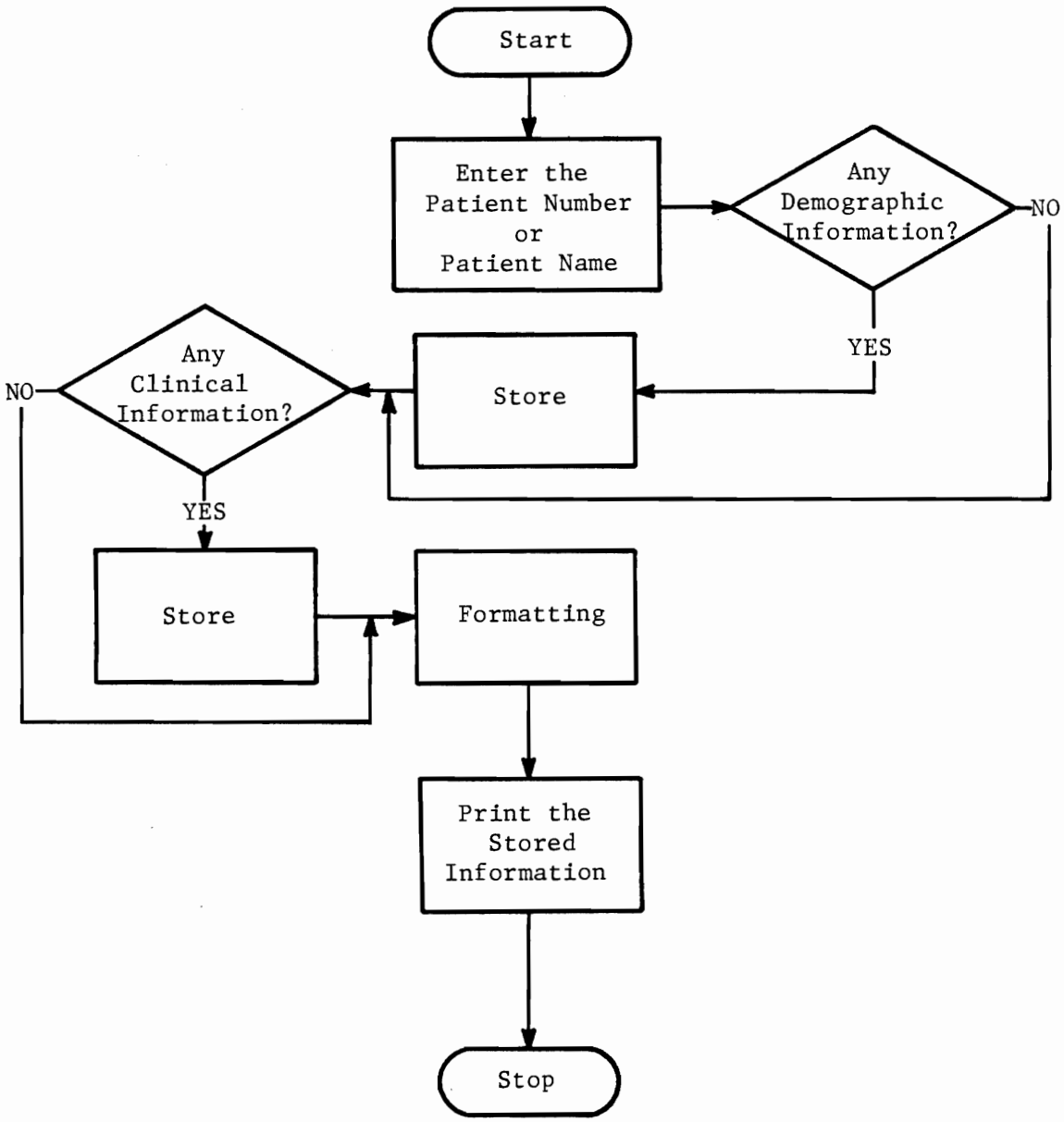

Fig. 2. Overall logic of the computer program.

TABLE 2

LIST OF DEMOGRAPHIC AND CLINICAL INFORMATION TO BE RETRIEVED FROM THE PATIENT DATA FILE

A. Admitting Diagnosis

B. Demographic Information:
   1. Patient's Name
   2. Patient's Age
   3. Patient's Weight
   4. Patient's Height

C. Medical History of the Patient:
   1. Previous Heart Attack (Month and Year of Occurrence)
   2. Past Coronary Artery Bypass Graft (Month and Year of Occurrence)
   3. Past History of Hypertension
   4. Past Valvular Surgery
   5. Past Rheumatic Valvular Disease

D. Current Cardiac Medications of the Patient:
   1. Digitalis-Type of Medications
   2. Diuretic-Type of Medications
   3. Quinoidine or Procainamide

E. Laboratory Findings:
   1. Enzymes:
      a. Creatinine Kinase
      b. Creatinine Kinase MB Isoenzymes
   2. Electrolytes:
      a. Potassium Level
      b. Calcium Level

F. HELP Decisions:
   1. Chest X-ray Diagnoses in Four Areas:
      a. Cardial or Pericardial Enlargement
      b. Obstructive Pulmonary Disease or Emphysema
      c. Pulmonary Artery Hypertension
      d. Congestive Heart Failure
   2. Cardiac Catherization Diagnosis from Twenty-two HELP Sectors
   3. Echocardiographic Diagnoses in Free Text Form

abbreviations was compiled. The list is described in Appendix A.

The peak values of cardiac enzymes were of interest to the cardiologist. Hence, the maximal values of creatinine kinase and its MB isoenzyme level were printed. In the retrieval of chest X-ray diagnoses, there were four HELP sector decisions which were relevant to the study. In addition, along with the test results or HELP sector decisions, the time at which the information was stored was also recorded on the clinical label.

Justification of the Clinical Information

Table 3 shows the information that might affect the interpretation of ECGs in three categories of diagnoses. The following is a brief justification for the inclusion of each item (a more detailed description of the justification is beyond the scope of this review):

1. Admitting diagnosis: It provides some knowledge of the patient's symptoms.

2. Age: With advancing age, the amplitudes of the P waves, QRS complex, and ST-T segment are reduced significantly (Simonson, 1972); the duration of P wave is increased; the QRS axis shifts left.

3. Weight: There is a reduction of amplitudes in the QRS complex and T waves with increasing weight (Simonson, 1952, 1972).

4. Height: The correlation of electrocardiographic changes with height is comparatively less significant than weight.

5. Medical history: The information of previous infarction and coronary artery bypass graft assists the cardiologist to

TABLE 3

INFORMATION THAT FACILITATES THE INTERPRETATION OF ECGs

Information	Myocardial Infarction	Chamber Enlargement	Repolarization Abnormalities
A. Admitting Diagnosis	X	X	X
B. Demographic Information:			
1. Patient's Age	X	X	X
2. Patient's Weight		X	
3. Patient's Height		X	
C. Medical History of the Patient:			
1. Previous Infarction	X	X	X
2. Past Rheumatic Valvular Disease		X	
3. Past History of Hypertension		X	X
4. Past Coronary Artery Bypass Graft	X		
5. Past Valvular Surgery	X	X	X
D. Current Cardiac Medications:			
1. Digitalis			X
2. Diuretics			X
3. Quinoidine or Procainamide			X
E. Laboratory Findings:			
1. Enzymes:			
a. Creatinine Kinase	X		X
b. Creatinine Kinase MB	X		X
2. Electrolytes:			
a. Potassium			X
b. Calcium			X

TABLE 3--Continued

Information	Myocardial Infarction	Chamber Enlargement	Repolarization Abnormalities
F. HELP Diagnoses:			
1. Chest X-ray:			
a. Cardial/Pericardial Enlargement	X	X	
b. Chronic Obstructive Pulmonary Disease	X	X	
c. Pulmonary Artery Hypertension		X	
d. Congestive heart failure	X	X	
2. Echocardiographic Diagnoses	X	X	
3. Cardiac Catherization	X	X	X

NOTE: X = this information facilitates the ECG interpretation of myocardial infarction, chamber enlargement, or repolarization abnormalities.

recognize electrocardiographic findings of old infarction; the information of history of valvular surgery, rheumatic valvular surgery, or hypertension may suggest the presence of chamber enlargements.

6. Cardiac medications: Digitalis causes a gradual downward sloping of ST segment. Diuretic types of medication may cause hypokalemia which is manifested as flattening of the T wave and the appearance of a U wave. Quinoidine and procainamide may cause depression of the ST segment and prolonged QT interval.

7. Cardiac enzymes: Creatinine kinase and its isoenzyme of MB have a higher sensitivity (98 percent and 100 percent, respectively) than ECG (66 percent) in the detection of acute MI (Wagner, Roe, Limbird, Rosati, and Wallace, 1973).

8. Electrolyte levels: In hyperkalemia, the P wave is flattened, the QRS complex is widened, and the T wave becomes peaked; in hypokalemia, the T wave becomes flattened and the U wave appears; in hypercalcemia QT interval is shortened; and in hypocalcemia, it is prolonged.

9. Chest X-ray: It provides helpful information in the recognition of chamber enlargements.

10. Echocardiogram and the interpreted results of cardiac catherization: These provide information concerning the cardiac function.

Design and Methods for Data Collection

The 100 patients in the sample were chosen randomly and consecutively from the coronary care unit of the hospital by the technicians of the ECG laboratory. The patients' electrocardiographic tracings were recorded and collected. In addition, the corresponding clinical labels were printed and gathered. A protocol was followed to distribute the ECGs to the cardiologists to read. The study was conducted in two parts. The first part compared the ECG interpretations before and after the clinical label was provided. The changes in the interpretations of the 100 ECGs after the introduction of the label were evaluated. The second part of the study was an estimation of the intraobserver variation. The protocol for distributing ECGs to both cardiologists in the two parts of the study is described as follows:

1. Part I: (a) One hundred ECGs were read by the two cardiologists independently without the clinical label. (b) A month delay was allowed to ensure independence of the readings. (c) The 100 ECGs were then read by them again for the second time with the clinical label provided. (d) The changes in the interpretations of the 100 ECGs were evaluated for both cardiologists. (e) Another month delay was allowed.

2. Part II: (a) A sample of twenty-five ECGs (already read once twice by both cardiologists, once without the label and once with the label) was randomly chosen from the 100 ECGs; these ECGs were read by the cardiologists again without the clinical

label. (b) A time delay of one month was allowed. (c) The twenty-five ECGs were read again for the last time with the clinical label provided. (d) The changes in the interpretations in the four readings of the twenty-five ECGs were evaluated in order to estimate the interobserver variation of both cardiologists.

Definition of a Change in Diagnosis

In an attempt to evaluate the changes in the cardiologists' behavior in the interpretations of ECGS, four categories of electrocardiographic diagnoses were chosen to be considered. They are listed as follows:

1. Myocardial infarction (MI)
2. Atrial enlargement
3. Ventricular enlargement
4. Repolarization abnormalities.

During the development of the algorithm for the computerized interpretation of ECGS at the LDS Hospital, computer codes were developed for the representation of many abnormalities which may appear in the electrocardiographic tracings. For the purpose of our study, this computerized coding system makes it easier to measure any difference(s) between two sets of interpretations. Thus, the study employed this computerized coding system to represent the interpretations and to define the difference between two ECG diagnoses.

The corresponding computer codes for the four categories of diagnoses described above are listed in Appendix B. In addition,

modifiers were also used in the study to provide more descriptive information of the diagnoses. The list of modifiers is described in Appendix B also.

The same computer codes may be interpreted differently by the two cardiologists. On the other hand, two different codes may actually have equivalent context. Hence, the groups of equivalent codes must be identified. In other words, computer codes which are considered equivalent should be classified under a group. Significant changes in the diagnosis are defined by a change in diagnostic group. The description of the equivalent groups and the definition of a change in diagnosis are described in Appendix C.

CHAPTER III

RESULTS AND EVALUATION

Introduction

In order to have a thorough evaluation of the data, several areas are considered. They are listed as follows:

1. Due to problems in data entry and incomplete database, some of the information is not present on the label. The frequency of the presence of the information on the clinical label indicates the availability of data in the patient data file. The frequency with which the clinical label is informative relative to each category is counted.

2. The intraobserver variation is estimated in order to assess the percentages and frequency of changes which might be attributable to the clinical label.

3. The interobserver variation is used to evaluate the extent of disagreement between the two cardiologists both before and after the clinical label was made available to them.

4. The directions of the changes in the cardiologists' interpretations are tabulated to provide information concerning their reading of the ECGs. Convergent behavior means their diagnoses do not agree with each other in the first reading of the ECGs; but after the second reading, their diagnoses agreed. Divergent means the exact opposite. In addition, if the changes

are in the opposite directions (disagree both before and after the label was provided), it is classified as divergent behavior.

5. The changes in the specificity of the ECG interpretations of the repolarization changes are considered to suggest how the clinical label may affect the cardiologists' interpretive behavior.

6. The type and frequency of some clinical information when there are changes in the interpretations are counted to assess the relationship between the changes and the presence of the specific clinical information. This is especially relevant in the cases where both cardiologists changed their diagnoses in the same direction.

It should be noted that the changes in the modifiers in the ECG diagnoses would reflect the interpretive behavior of the cardiologists. However, because one of the cardiologists misunderstood the study design with respect to the use of modifiers, the analysis of the changes in modifiers was not done.

This chapter gives an account of the overall results of the study and describes the results and evaluations pertaining to the six areas mentioned.

Overall Changes in the Four Categories of ECG Diagnoses after the Clinical Label Was Made Available To the Cardiologists

The protocol, which was described in Chapter II, for the first two readings of the 100 ECGs was followed. The frequency of MIs, atrial enlargements, ventricular enlargements, and repolarizing abnormalities was counted both before and after the clinical label

was made available to the two cardiologists. The results of the frequency count and the net difference between the frequency counts before and after the label are shown in Table 4. The frequency count for infarction was based on specific sites; in other words, if there were diagnoses of more than one infarction at two different locations in one patient, it was counted as two infarctions. The frequency of chamber enlargements was counted in a similar manner. Because in most instances both cardiologists agreed or disagreed that there was some form of repolarization abnormality, the presence of any form of abnormality was counted regardless of the number of interpretations present. In counting the total number in each category of ECG diagnosis, if both cardiologists had the same interpretation, only one diagnosis was counted.

It should be remembered that the changes shown in Table 1 are net changes, and hence the actual changes which took place are not represented. In the category of MI, three observations are notable. The first observation is the small net increase in the total number of positive diagnoses after the label was provided. Individual changes by each cardiologist are greater. This suggests that the overall net changes in the total number of diagnoses does not truly reflect the actual changes that took place. The second observation is the net difference in the frequency counts for Doctor 1 and Doctor 2, which indicate that the changes were in opposite directions. The latter observation may suggest that the cardiologists' ECG interpretive behavior is discordant. However, if the number of infarcts identified by each cardiologist are compared, there is a difference of

TABLE 4

TOTAL NUMBER OF DIAGNOSES IN INFARCTION, ATRIAL ENLARGEMENT, VENTRICULAR ENLARGEMENT, AND REPOLARIZATION ABNORMALITIES BOTH BEFORE AND AFTER THE CLINICAL LABEL WAS AVAILABLE

	Frequency Count		
	Before Clinical Label	After Clinical Label	Net Difference
Total Number of Infarcts	53	54	+ 1
Number of Infarcts by Doctor 1	43	48	+ 5
Number of Infarcts by Doctor 2	49	46	- 3
Total Number of Atrial Enlargements	29	32	+ 3
Number of Atrial Enlargements by Doctor 1	21	32	+11
Number of Atrial Enlargements by Doctor 2	21	13	- 8
Total Number of Ventricular Enlargements	18	19	+ 1
Number of Venticular Enlargements by Doctor 1	15	16	+ 1
Number of Ventricular Enlargements by Doctor 2	12	16	+ 4
Total Number of Repolarizing Abnormalities	72	71	- 1
Number of Repolarizing Abnormalities by Doctor 1	40	51	+11
Number of Repolarizing Abnormalities by Doctor 2	39	40	+ 1

six (forty-three and forty-nine) before the label was provided, and the difference decreases to two (forty-eight and forty-six) after the introduction of the label. The reduction may suggest a decrease in the interobserver variation between the cardiologists. Similar results are observed in the interpretation of ventricular enlargement and repolarization changes except in the category of atrial enlargement. In the interpretation of atrial enlargement, the net increase in the total number of diagnoses is small, while the individual changes are relatively greater. Observation of the net differences contributed by both cardiologists suggests that their changes in the ECG interpretations are in opposite directions. In addition, the difference in the frequency of atrial enlargement diagnoses contributed by both cardiologists is zero (twenty-one and twenty-one) before the label was provided, which increased to nineteen (thirty-two and thirteen) after the introduction of the label. The last two observations strongly suggest that their changes in the interpretations of atrial enlargement tend to be in opposite directions. However, this conclusion can only be made if the actual changes reflect the same changes.

Based on the above observations, no conclusive statement can be made as to how the clinical label would affect the cardiologists' ECG interpretive behavior. The changes in the frequency of diagnosis in the four categories of ECG interpretations may be due to factors other than the effect of the clinical label. Also, the actual changes, which better display the cardiologists' behavior, are not shown. Hence, a more meticulous examination of the data is essential.

Last, the results show that there is a large number of infarctions present. The sample was chosen randomly in a consecutive fashion from the coronary care unit. This sample, therefore, does not represent the hospital population. Nevertheless, it is the changes in the interpretive behavior of the cardiologist that are of interest in this study.

Availability of the Clinical Information in the Patient Data File

The frequency count of the presence of the demographic and clinical information on the 100 labels is shown in Table 5. In the second column, the table also shows the frequency of informative clinical labeling. The latter statement needs further explanation. For instance, in the category of current cardiac medications, a second digitalis medication on thirty-three labels indicates that the label is informative in this respect in thirty-three cases out of the 100 cases. Nevertheless, the absence of this information in sixty-seven cases also means that these sixty-seven patients are not currently taking digitalis. Hence, the clinical label is informative in all 100 cases with respect to current cardiac medications. This also applies to the category of past medical history. With respect to other categories, the label is informative only in the cases where the information is present.

The demographic information including height, weight, and age should be present on all of the labels. However, only 49 percent of the labels have the height and weight information. This was a data entry problem at the admitting office. In addition, during the

TABLE 5

FREQUENCY OF THE AVAILABILITY OF THE CLINICAL INFORMATION

Information	Frequency of Clinical Information Present On the Clinical Label	Frequency that the Clinical Label Is Informative
A. Demographic Information:		
1. Height	49	49
2. Weight	49	49
3. Age	100	100
B. Clinical Information:		
1. Admitting Diagnosis	100	100
2. Past Medical History:		
a. Myocardial Infarction	46	100
b. Hypertension	50	100
c. Coronary Artery Bypass Graft	20	100
d. Valvular Surgery	6	100
e. Rheumatic Fever	21	100
3. Current Cardiac Medications:		
a. Digitalis	33	100
b. Diuretics	39	100
c. Procainamide	3	100
d. Quinoidine	2	100
4. Echocardiogram Diagnosis	0	0
5. Cardiac Catherization Diagnosis	0	0
6. Chest X-Ray	16	16

TABLE 5--Continued

	Frequency of Clinical Information Present On the Clinical Label	Frequency that the Clinical Label Is Informative
7. Enzymes and Isoenzymes:		
a. Creatinine Kinase	34	34
b. Creatinine Kinase MB	9	9
8. Electrolytes:		
a. Potassium	57	57
b. Calcium	56	56

period of data collection, there were no personnel in the Department of Cardiology to enter data on echocardiographic diagnosis. Hence, the echocardiographic diagnosis is absent on all the labels.

The interpreted results of cardiac catherization are also absent from labels, because at the time the sample was collected only a few patients in the hospital had this information on file, and none of these patients was included in this study.

The high frequency of positive past medical history reflects the type of patients in the sample. It suggests that close to 50 percent of the patients in the sample had a history of hypertension or MI. It is not a coincidence to find that there are fifty-three to fifty-four infarction diagnoses (see Table 4). In addition, the high frequency of the presence of digitalis and diuretics medication indicate that these patients has some form of cardiac problems. Hence, their ECGs most likely manifest some form of abnormality.

Intraobserver Variations of the Two Cardiologists

It is known that if a cardiologist interprets the same ECG twice, there is a significant possibility that the interpretations will differ. This section examines how often the cardiologists make conflicting diagnoses before and after the introduction of the clinical label. The protocol described in Chapter II for the intraobserver variation study was followed. The analysis of the interpretations from the twenty-five ECGs is described below.

In order to estimate the intraobserver variation before the clinical label was provided, the interpretations from the first

reading without the clinical label are compared to that of the second reading without the label. This comparison is conducted separately for each cardiologist.

In order to estimate the intraobserver variation after the clinical label was provided, the interpretations from the first reading with the clinical label are compared to that of the second reading with the clinical label. Again, this comparison is conducted separately for each cardiologist.

The results are displayed in Tables 6, 7, 8, and 9. Table 6 shows the overall intraobserver variation of Doctor 1 in interpreting ECGs. There is an overall decrease in the disparity between diagnoses after the clinical label was provided. In interpreting ventricular enlargement, the decrease is as high as 50 percent. However, by the observation from Table 6 alone, it is inconclusive whether the reduction is significant or not. Hence, the three categories of ECG diagnoses are segmented into site specific diagnoses for further examination.

Table 7 shows the frequency of disagreement in the diagnoses within a given category. Again, it shows a general trend of reduction after the clinical label was provided. In order to examine whether the reduction is statistically significant, the hypothesis that the frequency of disagreement was not affected by the presence of the clinical label was tested. A nonparametric one-tailed significance test was applied to test this hypothesis. The computed significance level ($p \leqslant 0.02$) suggests that there was an effect.

The statistical result suggests that there is a difference.

TABLE 6

OVERALL INTRAOBSERVER VARIATION OF DOCTOR 1 BEFORE AND AFTER THE INTRODUCTION OF THE CLINICAL LABEL

Group of Diagnoses	Percent of Discordant Diagnoses Before the Clinical Label	Percent of Discordant Diagnoses After the Clinical Label
Myocardial Infarction	40	24
Atrial Enlargement	28	16
Ventricular Enlargement	8	4
Average	25	14.7

NOTE: Sample size = twenty-five.

TABLE 7

INTRAOBSERVER VARIATION OF DOCTOR 1 IN INTERPRETING ECGs

Categories of ECG Diagnoses	Count of Discordant Diagnoses Before the Clinical Label	Count of Discordant Diagnoses After the Clinical Label
Myocardial Infarction:		
18.1, 18.2, 18.6	1	0
18.3, 18.4, 18.9	4	3
18.5	1	1
18.7	3	2
18.10	1	0
Left Atrial Enlargement	7	4
Left Ventricular Enlargement	1	1
Right Ventricular Enlargement	1	0

NOTE: Sample size = twenty-five.

TABLE 8

OVERALL INTRAOBSERVER VARIATION OF DOCTOR 2 BEFORE AND AFTER THE INTRODUCTION OF THE CLINICAL LABEL

Group of Diagnoses	Percent of Discordant Diagnosis Before the Clinical Label	Percent of Discordant Diagnoses After the Clinical Label
Myocardial Infarction	32	12
Atrial Enlargement	12	8
Ventricular Enlargement	24	0
Average	22.7	6.7

NOTE: Sample size = twenty-five.

TABLE 9

INTRAOBSERVER VARIATION OF DOCTOR 2 IN INTERPRETING ECGs

Categories of ECG Diagnoses	Count of Discordant Diagnoses Before the Clinical Label	Count of Discordant Diagnoses After the Clinical Label
Myocardial Infarction:		
18.1, 18.2, 18.6	0	0
18.3, 18.4, 18.9	5	3
18.5	2	0
18.7	1	0
18.10	0	0
Left Atrial Enlargement	3	2
Left Ventricular Enlargement	5	0
Right Ventricular Enlargement	1	0

NOTE: Sample size = twenty-five.

However, the number of categories of ECG diagnoses and the sample size is small, so the conclusion drawn is weak. Clinically, the statistical result indicates that Doctor 1 became more consistent in the interpretation of the three categories of ECG diagnoses after the introduction of the clinical label.

Table 8 shows the overall intraobserver variation of Doctor 2 in interpreting the three categories of ECG diagnoses. The decrease in discordant diagnosis (22.7 percent to 6.7 percent) is large in the presence of clinical labeling. In interpreting ventricular enlargement, the reduction is as high as 100 percent. Based on this finding, the significance of this reduction is inconclusive. Hence, the three categories of ECG diagnoses are segmented into site specific diagnoses for further examination.

Table 9 shows the frequency of discordant diagnoses under each category. To examine whether the decreases are statistically significant, the null hypothesis of no change in the interpretations was tested. A nonparametric one-tailed significance test was applied to test the null hypothesis. The computed significance level was 0.02 which again suggests that the null hypothesis can be rejected.

The statistical result suggests that the two sets of data are different. Again, because the number of categories of ECG diagnoses and the sample size were small, the conclusive statement is weak. Nevertheless, the statistical result indicates that Doctor 2 became more consistent in interpreting the four categories of ECG diagnoses after the label was made available.

Above all, the intraobserver variation study shows that there

was an overall decrease in the intraobserver variation of each cardiologist in interpreting the three categories of ECG diagnoses. The decrease is statistically significant and comparatively greater in Doctor 2 than in Doctor 1. Clinically, it helps the cardiologist to make more consistent ECG interpretations and thus provide more consistent ECG interpretations to the attending physicians.

Interobserver Variation between the Two Cardiologists

It is known that very often cardiologists disagree among themselves in the interpretations of the same ECGs. Table 10 shows the overall results of the interobserver variation study. It should be noted that there is a large reduction in the frequency of disagreement between the cardiologists in interpreting myocardial infarctions after the introduction of the label. In Table 4, there are fifty-three and fifty-four total number of infarction diagnoses before and after the clinical label was provided, respectively. Out of these fifty-three diagnoses, they disagreed twenty-four times or 45 percent before the label was available to them; the frequency of disagreement decreased to thirteen times (24 percent) after the introduction of the label. The decrease of forty-seven percent seems to strongly suggest that the reduction of the interobserver variation for MI is clinically important. For interpreting chamber enlargement, the changes in the frequency of disagreement are small. However, in order to test whether the changes are statistically significant, the three categories of ECG diagnoses are segmented into site-specific diagnoses for further examination.

TABLE 10

INTEROBSERVER VARIATION IN THE INTERPRETATION OF ECGs
BETWEEN DOCTOR 1 AND DOCTOR 2 BEFORE AND AFTER
THE CLINICAL LABEL WAS PROVIDED

	Percent Count of the Differences in Computer Codes Before the Label	Percent Count of the Differences in Computer Codes After the Label
Myocardial Infarction	24	13
Atrial Enlargement	16	18
Ventricular Enlargement	9	8

NOTE: Sample size = 100.

Table 11 shows the interobserver variation for the specific categories of ECG diagnoses. In order to test whether the two sets of data are identical, the hypothesis of no change in behavior was tested. A nonparametric one-tailed significance test was applied to test the null hypothesis. The computer significance level was 0.11 which is inconclusive since it is not significant. This lack of significance is probably attributable to lack of sample size.

However, one important point which needs to be addressed is the fact that the frequency of disagreement in interpreting MI decreased from twenty-four to thirteen after the introduction of the label. The overall statistical results obtained from the two sets of data in Table 11 do not reflect this change because it is masked by the opposite effect in the category of atrial enlargement. On closer examination, one sees that the reduction of disagreement is especially great (see Table 11) in interpreting inferior infarctions (18.3, 18.4, and 18.9). Since the clinical information, which was available on the clinical label, is more helpful in interpreting infarction than chamber enlargements, it is logical to believe that the clinical label may be more helpful in reducing the frequency of disagreement between the cardiologists in interpreting infarctions. Indeed, the results are in agreement with the latter expectation.

Finally, it must be noted that the changes in the interpretations may have been due to factors other than the effect of the clinical label, such as chance.

TABLE 11

INTEROBSERVER VARIATION IN THE INTERPRETATION OF ECGs BETWEEN DOCTOR 1 AND DOCTOR 2 UNDER THE SEGMENTED CATEGORIES OF ECG DIAGNOSES

ECG Diagnoses of Specific Sites	Frequency of Disagreement Before the Clinical Label	Frequency of Disagreement After the Clinical Label
Myocardial Infarction:		
18.1, 18.2, 18.6	4	3
18.3, 18.4, 18.9	11	4
18.5	4	4
18.7	4	2
18.10	1	0
Left Atrial Enlargement	16	18
Left Ventricular Enlargement	6	6
Right Ventricular Enlargement	3	2
Total	49	39

NOTE: Sample size = 100.

Analysis of the Concurrent ECG Interpretive Behavior of Doctor 1 and Doctor 2

The concurrent behavior of the two cardiologists in interpreting ECGs shows whether their interpretations converge or diverge. If the cardiologists read the same ECGs twice without the clinical label, the interpretations of the first reading and that of the second reading should be the same. However, if there are any changes in their interpretations, it may be due to chance variation. The direction of concurrent changes in their interpretations determines the frequency of convergent or divergent diagnoses after the second reading. Since no other factor contributes to the changes except chance variance, these changes are presumably random, and it is logical to expect that the ratio of the frequency of convergent diagnoses to that of the divergent diagnoses will be ideally one. In addition, this ratio serves as a reference point for further comparative study of this ratio after the clinical label was introduced to the cardiologists. Furthermore, by this comparison, the effect of the clinical label on the cardiologists' ECG interpretive behavior may be uncovered.

Table 12 shows the frequency of convergent and divergent diagnoses of the twenty-five ECGs (the twenty-five ECGS in the intra-observer variation study) in the four categories of ECG diagnoses. The ratio of the total number of convergent diagnoses to that of the divergent diagnoses is twenty-eight to twenty-four and the result is 1.17. As was expected, the ratio is very close to one.

In order to observe the effect of the clinical label on the cardiologists' ECG interpretive behavior, the twenty-five ECGs, which

TABLE 12

THE REFERENCE POINT OF THE CONVERGENT AND DIVERGENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE INTERPRETATION OF ECGs

Categories of ECG Diagnoses	Count of Concurrent Convergent Diagnoses	Count of Concurrent Divergent Diagnoses
Myocardial Infarction	6	10
Atrial Enlargement	6	3
Ventricular Enlargement	5	1
Repolarization Abnormalities	11	10
Total	28	24

NOTE: Sample size = twenty-five. The cardiologists were not provided with the clinical label in the first and second time of the ECG readings.

were read four times by both cardiologists, are again examined. The first reading without the label is compared to that of the second time with the label provided, and changes in their interpretations are observed. These changes may be due to chance variation or the effect of the clinical label. The directions of changes in the interpretations determine the number of convergent and divergent diagnoses. In Table 13, the overall results of the concurrent behavior of both cardiologists in the interpretations of the twenty-five ECGs are shown. The total frequency of convergent and divergent behavioral patterns is recorded under four categories of ECG diagnoses. It is observed that in the four categories of ECG diagnoses considered in the study, all show more convergent than divergent interpretations. The changes in interpreting repolarization changes (eighteen to eleven) are the greatest.

Quantitatively, the ratio of the frequency of convergent diagnoses to that of the divergent diagnoses is thirty-eight to nineteen, indicating that there are two times more convergent diagnoses than divergent diagnoses with the clinical label.

Chance variance is probably the factor which contributes to the changes besides the effect of the clinical label. However, if this ratio is compared to the ratio of the reference point (1.17), the effects of chance variation may be eliminated. Hence, what remains is the effect of the clinical label. The result of the ratio (2.00 to 1.17) was 1.71. It is reasonable to say that the clinical label caused approximately 1.71 times more convergent diagnoses than divergent diagnoses for the four categories of ECG diagnoses. This

TABLE 13

CONVERGENT AND DIVERGENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE INTERPRETATION OF ECGs

Categories of ECG Diagnoses	Count of Concurrent Convergent Diagnoses	Count of Concurrent Divergent Diagnoses
Myocardial Infarction	8	5
Atrial Enlargement	5	2
Ventricular Enlargement	7	1
Repolarization Abnormalities	18	11
Total	38	19

NOTE: Sample size = twenty-five. Convergent means both cardiologists agree in the diagnosis of the same ECG after the clinical label is available to them. Divergent means both cardiologists disagree in the diagnosis of the same ECG after the clinical label is available to them. The cardiologists were provided with the clinical label only in the second time of the ECG reading.

finding shows that the clinical label has some effect on the cardiologists' ECG interpretive behavior and the effect seems to be in a positive direction. In simpler words, the clinical label seems to help both cardiologists to agree more in their interpretations. Clinically, this is important because it may make the interpretations less dependent on which cardiologist was reading the ECGs.

It is appropriate at this time to examine each of the four categories of ECG diagnoses separately in order to observe the details of the behavior of both cardiologists before and after the clinical label was made available to them. Above all, the general trend in the details of the ECG interpretive behavior of both cardiologists is the same as that of the overall trend. The tables displaying the detailed examination of each category of the diagnoses in the twenty-five ECGs are shown in Appendix D.

Changes in the Specificity of ECG Diagnoses Before and After the Introduction of the Clinical Label

The changes in the repolarization portion of an ECG may be attributable to numerous conditions. Thus, the interpretations of the repolarization changes vary in the degree of specificity. The data analysis in the study for repolarization changes emphasizes the changes in the specificity of the interpretations. In Table 14, the total frequency of changes in the specificity and the corresponding frequency of changes by the individual cardiologist is recorded. In the cases where there are concurrent changes of specificity, two changes are recorded.

TABLE 14

CHANGES IN THE SPECIFICITY OF THE INTERPRETATIONS OF REPOLARIZATION CHANGES

Type of Changes	Frequency Count
Nonspecific Diagnosis -> Specific Diagnosis:	
Total Number by Both Cardiologists	47
Total Number by Doctor 1	20
Total Number by Doctor 2	27
Specific Diagnosis -> Nonspecific Diagnosis:	
Total Number by Both Cardiologists	1
Total Number by Doctor 1	1
Total Number by Doctor 2	0

NOTE: Sample size = 100.

-> = Direction of changes.

Table 14 shows that there are a large number of changes in the specificity (23.5 percent) of the interpretations after the introduction of the label. In the one case where Doctor 1 changed interpretation from specific to nonspecific diagnosis, Doctor 2 changed interpretation in the same direction. More information relating to the changes in the specificity of the ECG diagnoses may be uncovered if the twenty-five ECGs selected for the intraobserver variation study are examined closely. The examination and its results are described below.

Ideally, if the same ECGs are interpreted twice under the identical circumstances (without the clinical label), there should be no change in the specificity of the interpretations for the repolarization changes. Indeed, the results of the examination show that out of the twenty-five ECGs (the twenty-five ECGs from the intraobserver variation study), there is only one case (2 percent) where one of the cardiologists changed interpretation from a nonspecific diagnosis to a specific one.

When the interpretations of the first reading without the clinical label are compared to that of the second reading with the clinical label, it is found that there are in total eighteen out of twenty-five ECGS (36 percent) where at least one of the cardiologists changed diagnoses from nonspecific ones to specific ones. Out of these eighteen times, there were seven times where both cardiologists changed their diagnoses concurrently. However, these changes again may be due to the effects of chance variance or the clinical label. If the effects of chance variance are eliminated, the major

effect of the clinical label may be uncovered. The reference point denotes the extent of the effect of chance variance. If subtracted from the total number of changes (eighteen) in the specificity of the interpretation after the introduction of the clinical label, the changes which are contributed by the effect of the label may be identified. The result of the subtraction is seventeen; this means that the label causes approximately seventeen times more specific ECG interpretations of the repolarization changes.

Above all, the overwhelming number of cases where the specificity of the interpretations changes could not be explained by the effects of chance variation alone. The result indicates that there is some clinical information which may affect the interpretive behavior of the cardiologists. Therefore, it may be concluded that the clinical label does have a certain effect on the cardiologists' interpretation of the repolarization changes in ECGs.

Type and Frequency of Clinical Information Present when Convergent or Divergent Behavior Was Observed

It may be informative to observe the frequency with which certain clinical information appears on the clinical label when the convergent or divergent behavior of the cardiologists is present. If a specific piece of information appears frequently when their diagnoses converge or diverge, it may suggest that the clinical information may have some influence on the cardiologists' ECG interpretive behavior. The frequency of clinical information in the four categories of ECG interpretations is described below.

Myocardial Infarction (MI)

Table 15 shows that the past medical history of MI appears quite frequently when there are convergent or divergent diagnoses of MI observed. For interpreting MI, it is known that a history of past infarction is an important piece of information.

Also, the laboratory results of creatinine kinase and its MB isoenzymes are important information in the confirmation of infarctions. The enzyme information appears more often (21 percent) in the cases where convergent diagnoses are present, as compared to 12.5 percent in the cases where divergent diagnoses are observed.

In addition, the information of past coronary artery bypass graft may be useful in diagnosing old infarcts. However, the information is not specific enough because the site of the graft is not known. Hence, its usefulness may be limited.

The high frequency of appearance of the clinical information on the clinical label when convergent diagnoses are present does not indicate any cause-effect relationship. For instance, the information of height and weight is present in high frequency, but it is hardly useful in verifying the presence of infarcts. On the other hand, it is known that the knowledge of past MI may help a cardiologist to identify an old infarction. In addition, creatinine kinase (CK) and CK-MB levels are important clinical information for detecting infarcts especially when the infarctions are patchy and the electrocardiographic tracing does not show any abnormalities. The frequent appearance of these two types of clinical information, when convergent diagnoses of infarction are observed, suggest that the clinical

TABLE 15

FREQUENCY THAT THE CLINICAL INFORMATION WAS PRESENT WHEN THE DIAGNOSES OF MYOCARDIAL INFARCTION WERE CONVERGENT OR DIVERGENT AFTER THE CLINICAL LABEL WAS PROVIDED

Clinical Information	Frequency Count	
	Convergent Diagnoses	Divergent Diagnoses
Height	11	3
Weight	11	3
Past Medical History:		
Past Myocardial Infarction	16	5
Hypertension	10	2
Coronary Artery Bypass Graft	6	1
Valvular Surgery	0	0
Rheumatic Fever	4	0
Current Cardiac Medications:		
Digitalis	9	1
Diuretics	8	4
Procainamide/Quinoidine	0	0
Chest X-Ray	5	0
Enzymes:		
Creatinine Kinase	6	2
Creatinine Kinase-MB	3	0
Electrolytes:		
Potassium	10	4
Calcium	10	4

NOTE: Sample size = fifty-four. Count of convergent diagnoses = twenty-one; count of divergent diagnoses = eight.

information may have an influence in the interpretive process. Nevertheless, based on the findings in Table 15, there is not sufficient sample size to conclude that the three types of clinical information will help the two cardiologists to make better interpretations on the ECGs.

Atrial Enlargement

Table 16 shows the frequency of the clinical information appears when there are convergent or divergent diagnoses of atrial enlargement present. It is important to remember that the crucial information which may help in interpreting atrial enlargement are echocardiographic diagnoses and interpreted results of cardiac catherization. However, this information is absent in all the labels.

The information of past infarction and hypertension may be useful information. Nevertheless, the data in the table suggest the contrary. In other words, the frequency of the presence of this information is higher when divergent diagnoses are present.

The sample size is too small to conclude a relationship between the convergence or divergence in interpreting atrial enlargement and the appearance of the corresponding clinical information.

Ventricular Enlargement

Table 17 shows the frequency of the clinical information in the presence of convergent or divergent diagnoses of ventricular enlargement present. However, as in the case of atrial enlargement, the crucial information which may help the diagnostic process is absent on the clinical label. It seems that there is no association

TABLE 16

FREQUENCY THAT THE CLINICAL INFORMATION WAS PRESENT WHEN THE DIAGNOSES OF ATRIAL ENLARGEMENT WERE CONVERGENT OR DIVERGENT AFTER THE CLINICAL LABEL WAS PROVIDED

Clinical Information	Frequency Count	
	Convergent Diagnoses	Divergent Diagnoses
Height	4	4
Weight	4	4
Past Medical History:		
Past Myocardial Infarction	3	10
Hypertension	3	6
Coronary Artery Bypass Graft	0	4
Valvular Surgery	1	0
Rheumatic Fever	1	2
Current Cardiac Medications:		
Digitalis	3	5
Diuretics	3	4
Procainamide/Quinoidine	1/1	1/1
Chest X-Ray	0	0
Enzymes:		
Creatinine Kinase	2	5
Creatinine Kinase-MB	1	1
Electrolytes:		
Potassium	3	5
Calcium	3	4

NOTE: Sample size = thirty-two. Count of convergent diagnoses = eight; count of divergent diagnoses = eleven.

TABLE 17

FREQUENCY THAT THE CLINICAL INFORMATION WAS PRESENT WHEN THE DIAGNOSES OF VENTRICULAR ENLARGEMENT WERE CONVERGENT OR DIVERGENT AFTER THE CLINICAL LABEL WAS PROVIDED

Clinical Information	Frequency Count	
	Convergent Diagnoses	Divergent Diagnoses
Height	4	5
Weight	4	5
Past Medical History:		
Past Myocardial Infarction	3	3
Hypertension	1	3
Coronary Artery Bypass Graft	0	1
Valvular Surgery	3	1
Rheumatic Fever	3	1
Current Cardiac Medications:		
Digitalis	3	3
Diuretics	4	5
Procainamide/Quinoidine	2/2	0/0
Chest X-Ray	2	4
Enzymes:		
Creatinine Kinase	2	2
Creatinine Kinase-MB	0	2
Electrolytes:		
Potassium	4	5
Calcium	4	5

NOTE: Sample size = nineteen. Count of convergent diagnoses = eight; count of divergent diagnoses = six.

between the diagnoses of ventricular enlargement and the clinical information.

Repolarization Abnormalities

The interpretations of repolarization changes in an ECG vary in specificity. In order to identify which clinical information is most likely to affect the changes, a frequency count of the appearance of the clinical information when there are changes in the specificity of the ECG diagnoses is compiled in a tabulated form.

Out of the 100 ECGs, there are thirty-one instances where at least one of the cardiologists changed interpretations of the repolarization changes from nonspecific diagnoses to specific ones. There are forty-seven changes by both cardiologists; of these forty-seven cases, there are forty-one cases (see Table 18) which have the clinical information of digitalis (85 percent) present. There are sixteen cases where both cardiologists had concurrent changes in the specificity of their diagnoses from nonspecific diagnoses to specific ones. In these sixteen cases, all (100 percent) have the clinical information of digitalis present on the clinical label. On close examination, it is found that in these forty-seven cases where the specificity of their diagnoses changed, the related changes in the computer codes are changed from 13.4 (Nonspecific ST-T Wave Abnormalities) to 13.2 (Suspected Digitalis Effect) or 13.1 (Repolarizing Abnormalities Secondary to Digitalis Effect). It is known that digitalis mainly causes repolarization changes in an ECG. By the nature of these changes in the computer codes and the large number of cases where this

TABLE 18

FREQUENCY THAT THE CLINICAL INFORMATION WAS PRESENT WHEN THE DIAGNOSES OF REPOLARIZATION ABNORMALITIES WERE CHANGED FROM NONSPECIFIC TO A MORE SPECIFIC ONE AFTER THE CLINICAL LABEL WAS PROVIDED

	Frequency Count	
Clinical Information	Nonspecific -> Specific	Concurrent Nonspecific -> Specific
Height	37	14
Weight	37	14
Past Medical History:		
Past Infarction	22	9
Hypertension	18	5
Coronary Artery Bypass Graft	14	5
Valvular Surgery	5	2
Rheumatic Fever	12	5
Current Cardiac Medications:		
Digitalis	41	16
Diuretics	32	13
Procainamide/Quinoidine	3/0	1/0
Chest X-Ray	12	5
Enzymes:		
Creatinine Kinase	20	7
Creatinine Kinase-MB	7	3

TABLE 18--Continued

Clinical Information	Nonspecific -> Specific	Concurrent Nonspecific -> Specific
Electrolytes:		
Potassium	38	15
Calcium	35	15

NOTE: Sample size = thirty-one. Count of changes from nonspecific to specific diagnoses = forty-seven; count of concurrent changes from nonspecific to specific diagnoses = sixteen.

-> = Direction of change of the ECG diagnoses after the clinical label was provided.

clinical information is present when there are changes in the specificity of the diagnoses, it is logical to suspect that this clinical information definitely has an associated effect on the cardiologists' behavior in interpreting the repolarization changes in an ECG.

On the contrary, there are totally 182 interpretations of the repolarization changes which do not involve any changes in the specificity of the diagnoses. Of these 182 interpretations, only thirty-five (20 percent) cases have the clinical information of digitalis type of medications.

These findings strongly suggest that the changes in the specificity of ECG diagnoses are due to the appearance of the clinical information of digitalis. Thus, it may be concluded that the label has some clinical information which affects the cardiologists' interpretation of the repolarization changes in ECGs.

CHAPTER IV

DISCUSSION AND SUMMARY

Discussion

In analyzing the intraobserver and interobserver variation of the cardiologists, the basic hypothesis is that the clinical information improves the consistency of the cardiologists in interpreting ECGs. This hypothesis is supported by the general trend of the results shown in Chapter III.

It should be noted that the sample size of 100 ECGs is too small for strong inferences. However, the results suggest that the clinical label has a positive effect on the interpretations of the ECGs by the cardiologists. It is logical to believe that if the sample size is increased, the general trend would most likely continue.

The medical history shows that about 50 percent of the patients in the sample have a past history of MI. Actually, most of the patients in the sample are from the coronary care unit. By choosing more patients with cardiac problems, more interpretations of abnormalities are found. Thus, more changes in their interpretive behavior may be observed in each category of diagnoses and the general trend deduced from these changes may be more substantial.

In the cases where no changes in the interpretations are observed, it could be that the electrocardiographic findings were so convincing that no other information was necessary to verify the

diagnoses. Thus, the label is of limited use in these instances.

Availability of Clinical Information on the Clinical Label

The more pertinent the information provided to the cardiologists, the better the cardiologist would understand the patient and most likely, the more specific interpretations of the ECGs might be. In evaluating the availability of the clinical information, it is observed that the information is available in the patient data file. Most of the clinical information is likely to be more helpful to the cardiologists for MI interpretation than for diagnosing chamber enlargement. For instance, in interpreting infarction, the inter-observer variation between the cardiologists decreased by 45.8 percent after the introduction of the clinical label. On the other hand, the frequency of disagreement in diagnosing atrial enlargement actually increased by 12.5 percent. The latter result may be due to the effect of chance variance or the clinical label. However, more consistency in the diagnoses of chamber enlargement may be observed if the pertinent information is present. In our study, information including echocardiographic diagnoses, interpreted results of cardiac catherization, and the chest X-ray diagnoses were either absent or present in low frequency (16 percent for chest X-ray diagnoses) on the label. This information is crucial for the interpretation of chamber enlargements. Clinically, the echocardiogram is more sensitive than ECG for detecting chamber enlargement. Cardiac catherization can provide hemodynamic information which is important in the

assessment of cardiac function. The latter two diagnostic techniques provide important cardiac function information, which is related to chamber enlargement, that the ECGs do not show. Hence, it is logical to expect more consistency in interpreting chamber enlargement if this information is present.

Besides the demographic, electrolyte levels, and medical history information, current cardiac medications are recorded with moderate frequency. Most cardiac medications cause repolarization changes in ECGs, and hence, the effect of the presence of this information may be seen in the interpretations of the repolarization changes in the ECGs.

Intraobserver Variation

After the introduction of the clinical label, there was a reduction in the intraobserver variation for both cardiologists. For the interpretations of infarctions and chamber enlargements before the introduction of the clinical label, the overall average intraobserver variation of Doctor 1 and Doctor 2 were 25 percent and 22.7 percent, respectively. After the clinical label was made available to them, the corresponding average values were 14.7 percent and 6.7 percent. A reduction of 10.3 percent and 16.0 percent for Doctor 1 and Doctor 2, respectively, was observed. The computed significant level of 0.02 in the one-tailed significance test infers that the reductions are statistically significant. Chance variance alone could not account for the changes. Hence, it suggests that the clinical label had an effect on the interpretations of the

cardiologists and the effect seems to be in a positive direction. The label seems to have a greater effect on Doctor 2 than on Doctor 1 because the reduction is greater on Doctor 2 after the introduction of the label. Clinically, the cardiologists became more consistent in their interpretations of the ECGs after the label was provided.

Interobserver Variation between the Cardiologists Before and After the Introduction of the Clinical Label

The study accomplished by Davis (1957) showed that the ten experienced cardiologists only agreed unanimously on the ECG interpretations in one-third of the 100 tracings. In half of the tracings, there was some disagreement while they had considerable dispute over twenty tracings. In other words, the interobserver variation among the cardiologists was more than 20 percent. In this study, it was found that the overall interobserver variation between the two cardiologists was 12.3 percent before the clinical label was provided and decreased to 9.8 percent after the introduction of the label. The overall reduction was 2.5 percent.

The small overall reduction masks the large decrease (45.8 percent) in interpreting MI. This is expected because the clinical label has more information which may be helpful to the cardiologists in interpreting infarction. On the other hand, the interobserver variation is actually increased by 4 percent in interpreting chamber enlargement. Partially, it is probably attributable to the absence from the label of the echocardiographic diagnoses and the interpreted results of the cardiac catherization. In addition, the information of

chest X-ray diagnoses, which may be helpful in interpreting chamber enlargement, is not present on the label on most occasions (16 percent). Clinically, this extent of reduction may be significant because if they disagree less, it makes the interpretations less dependent on which cardiologist is interpreting the ECGs for infarctions. Conversely, this study also showed (computed significance level of 0.11) an overall statistically insignificant decrease in the frequency of disagreement after the label was provided. Based on this finding, it is suggestive but not conclusive that the clinical label helps to decrease the overall frequency of disagreement between the two cardiologists.

Concurrent Changes by Doctor 1 and Doctor 2 After the Label Is Provided

In the evaluation of the concurrent changes by the two doctors, it is found that the frequency of converging diagnoses is approximately 1.71 times that of the divergent diagnoses after the introduction of the clinical label. It is also found that this finding is mainly attributable to the effect of the label. In other words, in interpreting infarctions, chamber enlargements, and repolarizing abnormalities, the clinical label seems to help the two cardiologists to agree with each other more. This is logical because the cardiologists would probably have a better understanding of the patient's condition after the label was provided. Clinically, the label increases the consistency in the interpretations of ECGs by the cardiologists and makes the interpretations less dependent on which cardiologist is

reading the ECGs.

Change in the Specificity in Interpreting Repolarization Changes in an ECG

In the twenty-five ECGs selected for the intravariation study, there are sixteen cases where both cardiologists concurrently changed their diagnoses to be more specific. The changes that took place are changes from nonspecific interpretations of the repolarization changes to a specific diagnosis of definite digitalis effect. In all these sixteen cases, the clinical information of digitalis is present on the label. When the information is absent from the label, it informs the cardiologists that the patient is not currently taking digitalis-type medication. Hence, the effect of digitalis on the ECGs could be ruled out. Indeed, in the cases where this information was absent, the percent change in the specificity of ECG diagnoses was low.

Above all, the results of this evaluation indicate that the clinical label has some clinical information which helps the cardiologists to make a more specific interpretation of the repolarization changes. Clinically, this is significant because there are numerous conditions which may contribute to the nonspecific changes in the repolarizing portion of an ECG.

Type and Frequency of Clinical Information Present When There Is a Convergent or Divergent Behavior Observed

Based on the frequency of the presence of a specific type of clinical information, no association can be made between the

information and the convergence of the diagnoses. However, in the cases where changes in the specificity of the diagnoses are involved, the nature of the changes in the computer codes indicates that digitalis is the information which contributes to the changes in the specificity. Thus, the clinical label helps the cardiologists to make a more specific interpretation of the repolarization changes in an ECG.

Summary and Conclusion

The results of the study show that the clinical information was available in the patient data file. After the clinical label is introduced to the cardiologists, there was a significant decrease (10.3 percent for Doctor 1 and 16.0 percent for Doctor 2) in their intraobserver variation for infarction and chamber enlargement interpretations. The interobserver variation between them was reduced by 45.8 percent for MI interpretations; the extent of decrease may be clinically significant. On the contrary, the overall interobserver variation for the interpretations of MI, atrial enlargements, and ventricular enlargements did not show a statistically significant decrease (16.3 percent to 13 percent), although there was a trend of reduction in the frequency of disagreement after the introduction of the label. After the clinical label was made available to them, there tended to be more concordant interpretations in diagnosing the four categories of cardiac diseases. The changes in the specificity of the ECG diagnoses were probably the effect of the clinical information of digitalis.

In conclusion, although the sample size is small, the results of the study suggest that the clinical label contained some clinical information which had an effect on the cardiologists' interpretations of the ECGs. The results seem to suggest that with the help of the clinical label, the cardiologist may become more consistent in interpreting the four categories of abnormalities in the ECGs, will be more likely to agree in their diagnoses, and may make a more specific interpretation in the repolarizing portion of an ECG. Clinically, these findings suggest that the clinical label helps to make the interpretations less dependent on which cardiologist is reading the ECGs because of less intraobserver variation and less interobserver variation in diagnosing infarction.

The conclusion of the findings is expected because the cardiologists have a better understanding of the patient's health condition after gaining the knowledge of the patient's clinical information. Instead of comparing the patient's ECG to the "normal ECG," the cardiologist considers each attribute on the label and makes adjustments in the interpretations. Hence, the interpretations become more specific to the patient.

CHAPTER V

FUTURE EFFORT

The study is by no means complete. Further effort seems to be needed to improve this study and to make the results more conclusive. The recommendations for further development of this study are described as follows:

1. One of the cardiologists misunderstood the design of the study. Hence, the analysis for the modifiers was not finished. In order to complete this study, the analysis of the modifiers should be incorporated into the study.

2. If the sample size is increased, the frequency count in each category of the diagnoses will most likely increase, and hence, the power of the statistical tests will also be increased. Furthermore, if the statistical tests are more powerful, the inferences that are drawn from these tests will be stronger.

3. The echocardiographic diagnoses and the interpreted results of cardiac catherization should be made available in the patient data file. Comparing the electrocardiographic interpretations, this information provides the "Gold Standard" in diagnosing some abnormalities including atrial enlargement and ventricular enlargement.

4. Presently, the technician from the ECG laboratory obtains the necessary medical history for this study at bedside and enters

this information into the computer through a questionnaire after returning to the laboratory. This procedure is tedious and creates a sizeable workload, especially when the volume of ECG recording is high. However, it is possible to employ the existing equipment to transfer the information through the phone line to the patient data file when the ECG is recorded at bedside. This will reduce the present tedious procedure as well as the chance of error in transporting the information manually from the bedside to the computer terminal in the laboratory. Besides, it will improve the efficiency of the system by speeding up the data entry process.

5. One weakness in this study is the failure to identify which clinical information was being used when there was a change in the diagnosis. In future study, if there is some way that this information can be identified, the amount of information on the label can be reduced to a minimum because providing useful and concise clinical information is the prime purpose of this clinical label.

6. Clinically, the real value of the label is the effect of the more specific interpretations on the management of the patient's health care. However, this effect was not studied and is unknown at present. A separate study may have to be done to assess the extent of this effect.

APPENDIX A

HELP SECTOR DECISIONS FROM CHEST X-RAY AND CARDIAC CATHERIZATION PROCEDURE

Description of HELP Sector Decisions

Appendix A comprises three lists. The first and the second lists show all the possible HELP sector decisions from chest X-ray and cardiac catherization procedure, respectively. The last list is a list of abbreviations for the text in the HELP sector decisions from cardiac catherization procedure.

Only four HELP sector decisions in chest X-ray were pertinent to the study. They are sectors 8, 9, 10, and 27. In the case of cardiac catherization, there were twenty-six HELP sector decisions which were of interest in this study: 1, 3, 5, 7, 9, 11, 12, 17, 18, 20, 23, 25, 29, 30, 31, 34, 40, 43, 48, 50, 51, 52, 53, 55, and 57.

List One

```
BLOCK #20.1  ********** CHEST **********          [ANY SECTOR]
        BLK MOD 1:    INITIAL FINDING
        BLK MOD 2:    NO CHANGE
        BLK MOD 3:    INCREASED
        BLK MOD 4:    DECREASED

SOURCE FILE:  $DATA.HELP.RESEARCH
OWNER:  RADIO.CHIP    SECURITY:  AAAAA
ALWAYS SEND DESTINATION LIST:  TO CALLING PROGRAM, TO INFA FOR DEBUGGING
SEND (PRINT) ORDER:  66

SECTOR  1  ===NORMAL POST OPERATIVE STATE=
SECTOR  2  ===INFILTRATE/PNEUMONIA=
SECTOR  3  ===PLEURAL EFFUSION=                    L/R
SECTOR  4  ===HYPOAERATION/A1ELECTASIS=            L/R
SECTOR  5  ===NO SIGNIFICANT ABNORMALITIES=
SECTOR  6  ===RIB FRACTURE/S=
SECTOR  7  ===PNEUMOTHORAX=
SECTOR  8  ===CARDIO/PERICARDIAL ENLARGEMENT=
SECTOR  9  ===OPD/EMPHYSEMA=
SECTOR 10  ===CONGESTIVE HEART FAILURE=
SECTOR 11  ===METASTASES=                          L/R
SECTOR 12  ===LYMPHOMA=
SECTOR 13  ===CHRONIC TUBERCULOSIS=
SECTOR 14  ===COPD=
SECTOR 15  ===NODULES=
SECTOR 16  ===MASS=                                L/R
SECTOR 17  ===CONTUSION=                           L/R
SECTOR 18  ===INTERSTITIAL/ALVEOLAR EDEMA=
SECTOR 20  ===ACTIVE TUBERCULOSIS=
SECTOR 21  ===RESPIRATORY DISTRESS SYND=
SECTOR 22  ===TACHYPNEA OF THE NEWBORN=
SECTOR 23  ===HYALINE MEMBRANE DISEASE=
SECTOR 24  ===PRE-SEC 2 INFILTRATE/PNEUMONIA=
SECTOR 25  ===RIB LESION=
SECTOR 26  ===HILAR MASS=
SECTOR 27  ===PULMON ARTERY HYPERTENSION=
SECTOR 28  ===ATRIAL ENLARGEMENT=
SECTOR 29  ===OBSTRUCTION=                         L/R
SECTOR 31  ===CALCIFIED CAROTID PLAQUES=
SECTOR 32  ===PNEUMOPERITONEUM=
SECTOR 33  ===NORMAL TUBE/CATHETER PLACEMENT=
SECTOR 34  ===ANEURYSM=
SECTOR 35  ===TUBE/LINE/CATHETER-SEE REPORT=
SECTOR 40  ===HIATIAL HERNIA=
SECTOR 41  ===BRONCHIECTASIS=                      L/R
SECTOR 45  ===FLEURAL THICKENING=
SECTOR 46  ===MEDIASTINUM WIDENING=
```

```
SECTOR 50  ===FRACTURE/S=
SECTOR 51  ===TUMOR=
SECTOR 52  ===PACEMAKER PLACEMENT-SEE REPORT=
SECTOR 53  ===NORMAL WIRE PLACEMENT=
SECTOR 56  ===NORMAL PACEMAKER/WIRE PLACEMENT=
SECTOR 58  ===NOUN FC1
SECTOR 61  ===PNEUMOCONIOSIS=
SECTOR 62  ===SEE DEPT. OF LABOR REPORT=
SECTOR 63  ===SIGN. OTHER DIS-SEE BELOW=
SECTOR 64  ===WIRE PLACEMENT-SEE REPORT=
SECTOR 65  ===HEMATOMA=
SECTOR 66  ===FOREIGN BODY IN CHEST=
```

List Two

```
BLOCK #32.1  CATH LAB HELP DECISION SECTORS [ANY SECTOR]
        BLK MOD 1:     MILD
        BLK MOD 2:     MODERATE
        BLK MOD 3:     MODERATELY SEVERE
        BLK MOD 4:     SEVERE
        BLK MOD 5:     SUSPECT
        BLK MOD 6:     PROBABLE
        BLK MOD 7:     DEFINITE

SOURCE FILE:  $DATA.HELP.RESEARCH
OWNER:  RADIO.CHIP     SECURITY:  AAAAA
ALWAYS SEND DESTINATION LIST:  TO INFA FOR DEBUGGING, TO PATIENT RECORD

SECTOR  1  SIGNIFICANT LESIONS IN THE RIGHT CORONARY ARTERY
SECTOR  2  INSIGNIFICANT LESIONS IN THE RIGHT CORONARY ARTERY
SECTOR  3  SIGNIFICANT LESIONS IN THE LEFT ANTERIOR DESCENDING CORONARY
           ARTERY
SECTOR  4  INSIGNIFICANT LESIONS IN THE LEFT ANTERIOR DESCENDING
           CORONARY ARTERY
SECTOR  5  SIGNIFICANT LESIONS IN THE LEFT CIRCUMFLEX CORONARY ARTERY
SECTOR  6  INSIGNIFICANT LESIONS IN THE LEFT CIRCUMFLEX CORONARY ARTERY
SECTOR  7  SIGNIFICANT LESIONS IN THE LEFT MAIN CORONARY ARTERY
SECTOR  8  INSIGNIFICANT LESIONS IN THE LEFT MAIN CORONARY ARTERY
SECTOR  9  NO SIGNIFICANT CORONARY ARTERY LESIONS
SECTOR 10  END DIASTOLIC VOLUME INDEX (ML/M**2) === *L
SECTOR 11  EJECTION FRACTION OF LEFT VENTRICULAR ANGIOGRAM IS ==
SECTOR 12  END DIASTOLIC VOLUME OF LEFT VENTRICULAR ANGIOGRAM IS === ML
SECTOR 13  END SYSTOLIC VOLUME OF LEFT VENTRICULAR ANGIOGRAM IS === ML
SECTOR 14  EJECTION FRACTION OF LEFT VENTRICULAR ANGIOGRAM POST-NITRO
           IS ==
SECTOR 15  END DIASTOLIC VOLUME OF LEFT VENTRICULAR ANGIOGRAM POST-
           NITRO IS === ML
SECTOR 16  END SYSTOLIC VOLUME OF LEFT VENTRICULAR ANGIOGRAM POST-
           NITRO IS === ML
SECTOR 17  ELEVATED LEFT VENTRICULAR END-DIASTOLIC PRESSURE AT =
SECTOR 18  ELEVATED RIGHT VENTRICULAR END-DIASTOLIC PRESSURE AT =
SECTOR 19  ABNORMAL CONTRACTIONS IN THE =
SECTOR 20  NO ABNORMAL CONTRACTIONS
SECTOR 21  PRESSURE GRADIENT ACROSS THE TRICUSPID VALVE (RESTING) ===
           MMHG
SECTOR 23  MITRAL VALVE AREA (MINIMUM VALUE) == == SQCM
SECTOR 24  PROLAPSE OF THE MITRAL VALVE
SECTOR 25  MITRAL REGURGITATION =
SECTOR 29  = MITRAL STENOSIS =
SECTOR 30  AORTIC VALVE AREA (MINIMUM VALUE) == == SQCM
SECTOR 31  AORTIC REGURGITATION =
SECTOR 32  SIGNIFICANT AORTIC REGURGITATION WITH ASSOCIATED STENOSIS
SECTOR 33  NO AORTIC OR MITRAL VALVE REGURGITATION
SECTOR 34  = AORTIC STENOSIS (GRADIENT)
```

SECTOR 35 = AORTIC STENOSIS =
SECTOR 36 NO MITRAL OR AORTIC REGURGITATION PRESENT (ANGIOGRAPHIC DATA)
SECTOR 37 NO MITRAL OR AORTIC STENOSIS WITH GRADE I or II REGURGITATION PRESENT
SECTOR 38 = RV OUTFLOW STENOSIS
SECTOR 39 = PULMONARY VALVULAR STENOSIS
SECTOR 40 = HYPERTROPHIC SUBAORTIC STENOSIS (HEMODYNAMIC DATA)
SECTOR 41 NO VALVULAR STENOSIS (HEMODYNAMIC DATA)
SECTOR 42 NO MITRAL OR AORTIC VALVE STENOSIS
SECTOR 43 CONSTRICTIVE PERICARDITIS OR RESTRICTIVE HEART DISEASE
SECTOR 44 PATIENTS PULMONARY ARTERIOLAR RESISTANCE INDEX AT REST IS == ==
SECTOR 45 PATIENTS PULMONARY ARTERIOLAR RESISTANCE INDEX WITH EXERCISE IS == ==
SECTOR 46 PATIENTS SYSTEMIC VASCULAR RESISTANCE INDEX AT REST IS == ==
SECTOR 47 PATIENTS SYSTEMIC VASCULAR RESISTANCE INDEX WITH EXERCISE IS == ==
SECTOR 48 PATIENT HAS ELEVATED PULMONARY VASCULAR RESISTANCE =
SECTOR 49 NO HIGHLY ABNORMAL VASCULAR RESISTANCE AT REST OR EXERCISE
SECTOR 50 HYPERTENSIVE HEART DISEASE
SECTOR 51 CONGESTIVE CARDIOMYOPATHY
SECTOR 52 RESTRICTIVE CARDIOMYOPATHY
SECTOR 53 NONSPECIFIED CARDIOMYOPATHY
SECTOR 54 NO CARDIOMYOPATHIES
SECTOR 55 NORMAL HEMODYNAMIC DATA
SECTOR 56 NO SIGNIFICANT CORONARY ARTERY DISEASE
SECTOR 57 NORMAL ANGIOGRAPHIC DATA

Abbreviations for HELP Sector Decisions from the Cardiac Catherization Laboratory

SECTOR 1 RCA DIS. -- significant lesions in the right coronary artery
SECTOR 3 LAD DIS. -- significant lesions in the left anterior descending coronary artery
SECTOR 5 LCX DIS. -- significant lesions in the left circumflex coronary artery
SECTOR 7 LMC DIS. -- significant lesions in the left main coronary artery
SECTOR 9 NO SIGNIF. COR. DIS. -- no significant coronary artery lesions
SECTOR 11 E.F. -- ejection fraction of left ventricular angiogram ==
SECTOR 12 LVEDV -- end diastolic volume of left ventricular angiogram is === ml
SECTOR 17 ELEVATED LVEDP -- elevated left ventricular end diastolic pressure at =
SECTOR 18 ELEVATED RVEDP -- elevated right ventricular end diastolic pressure at =
SECTOR 19 ABNORMAL CONTRACTIONS IN THE -- (no abbreviations)
SECTOR 20 NO ABNORMAL CONTRACTIONS -- (no abbreviations)
SECTOR 23 MVA -- mitral value area (minimum value) == == sqcm
SECTOR 25 MITRAL REGURG. -- mitral regurgitation =
SECTOR 29 MITRAL STENOSIS -- = mitral stenosis =
SECTOR 30 A.V.A. -- aortic value area (minimum value) == == sqcm
SECTOR 31 A. REGUG -- aortic regurgitation =
SECTOR 34 A.S. -- aortic stenosis (gradient)
SECTOR 40 I.H.S.S. -- hypertrophic subaortic stenosis (hemodynamic data)
SECTOR 43 CONST. PERICARD. OR RESTR. H. DIS. -- constrictive pericarditis or restrictive heart disease
SECTOR 48 ELEVATED PVR -- patient has elevated pulmonary vascular resistance
SECTOR 50 HTN H. DIS. -- hypertensive heart disease
SECTOR 51 CONG. MYOPATHY -- congestive cardiomyopathy
SECTOR 52 RESTR. MYOPATHY -- restrictive cardiomyopathy
SECTOR 53 NONSPEC. MYOPATHY -- nonspecific cardiomyopathy
SECTOR 55 NL HEMODYNAMICS -- normal hemodynamic data
SECTOR 57 NL ANGIOGRAPHY -- normal angiographic data

APPENDIX B

COMPUTER CODES FOR ECG DIAGNOSES

Tables 19, 20, 21, and 22 list computer codes for ECG diagnoses which are of interest in this study. These codes are separated into three categories, i.e., myocardial infarction, chamber enlargement, and repolarization abnormalities.

TABLE 19

MYOCARDIAL INFARCTION

Computer Codes	ECG Diagnoses
18.1	Anteroseptal Infarction
18.2	Anterior Infarction
18.3	Inferior Infarction
18.4	Posterior Infarction
18.5	Lateral Infarction
18.6	Anterolateral Infarction
19.7	Inferolateral Infarction
18.8	Posterolateral Infarction
18.9	Inferoposterior Infarction
18.10	Apical Infarction
18.11	Subendocardial Infarction

TABLE 20

CHAMBER ENLARGEMENT

Computer Codes	ECG Diagnoses
17.1	Left Ventricular Hypertrophy
17.2	Right Ventricular Hypertrophy
17.3	Combined Right and Left Ventricular Hypertrophy
17.4	Left Atrial Enlargement
17.5	P-Wave Variant--Consider Left Atrial Abnormality
17.6	Right Atrial Enlargement
17.7	Combined Right and Left Atrial Enlargement
17.8	LVH--Voltage Criteria Only

TABLE 21

REPOLARIZATION ABNORMALITIES

Computer Codes	ECG Diagnosis
ST Segment:	
13.1	Repolarization Abnormalities Secondary To Digitalis Effect
13.2	Suspected Digitalis Effect
13.3	Nonspecific ST-Segment Abnormalities
13.4	Nonspecific ST-T Wave Abnormalities
13.5	ST-Segment Abnormalities Consistent with Pericarditis/Myocarditis
13.6	ST Abnormalities Consistent with Injury
13.7	ST Abnormalities Consistent with Aneurysm
13.8	ST Abnormalities Consistent with Subendocardial Ischemia
13.9	ST Segment Has Returned To Baseline
13.10	ST Elevation
13.11	ST Depression
13.12	ST Abnormality--Plane Depression
U Waves:	
14.1	Prominent Upright U Waves
14.2	Inverted U Waves
QT Waves:	
15.1	Prolonged QT/QU Interval
15.2	Short QT Interval
15.3	Hyperkalemia

TABLE 21--Continued

Computer Codes	ECG Diagnosis
15.4	Hypokalemia
15.5	Hypercalcemia
15.6	Hypocalcemia
15.7	Electrolyte Imbalance or Drug Effect
15.8	Quinoidine Effect
T Wave:	
16.1	Primary T-Wave Abnormalities
16.2	Nonspecific T-Wave Abnormalities
16.3	T-Wave Abnormalities Associated with CNS Disease
16.4	T-Wave Abnormalities Consistent with Pericarditis/ Myocarditis
16.5	Peaked T Waves--Etiology Undetermined
16.6	T-Wave Inversion
16.7	Primary T-Wave Abnormalities--Symmetric T Waves

TABLE 22

MODIFIERS

Abbreviation	Representation
Group I Modifers:	
OL	Old
HY	Hyperacute
AC	Acute
AU	Age Undetermined
EL	Evolving
Group II Modifiers:	
CO	Consider
PO	Possible
PR	Probable
CE	Cannot Be Excluded
CW	Consistent With

APPENDIX C

DEFINITION OF CHANGES IN THE ECG DIAGNOSES

Myocardial Infarction

Equivalent groups are:

1. 18.1 = 18.2 = 18.6
2. 18.3 = 18.4 = 18.9
3. 18.7 = 18.8
4. 18.5 is unique.

Definition of a change: The change in computer codes between groups is a change.

Chamber Enlargement

Equivalent groups are:

1. 17.3 = 17.1 and 17.2
2. 17.7 = 17.4 and 17.6
3. 17.5 and 17.8 are unique.

Definition of a change: The change in computer codes between groups is a change.

Repolarizing Abnormalities

Equivalent groups are:

1. 13.6 = 13.10
2. 13.8 = 13.11
3. All other codes are unique.

Definition of a change: The change in computer codes between groups is a change.

TABLE 23

CHANGES IN THE SPECIFICITY OF ECG DIAGNOSES

Nonspecific Diagnoses	Specific Diagnoses
Chamber Enlargement:	
17.8	17.1
17.5	17.4
ST Segment:	
13.6 or 13.10	13.7
13.3, 13.4	13.1, 13.2, 13.5, 13.7, 13.8
QT Waves:	
15.1, 15.2	15.3, 15.3, 15.5, 15.6, 15.7, 15.8
T Waves:	
16.2, 16.6	16.1, 16.3, 16.4, 16.5

NOTE: The definition of change in specificity is the change in computer codes between the two columns is a change in the specificity of the diagnosis.

Group I modifiers are:

1. Equivalent modifiers are AC, HY, and EL.

2. Other unique modifiers are OL, and AU.

3. If a different modifier is used, it is a change except the ones defined as equivalent.

Group II modifiers are shown in Table 24.

TABLE 24

DEFINITION OF CHANGES IN MODIFIERS

Scale	Modifiers
0-25 Percent	CO = CW = CE
25-50 Percent	PO
50-75 Percent	PR
> 75 Percent	Definite

NOTE: Definition of a change is a difference of > 50 percent between two modifiers is a change.

APPENDIX D

CONCURRENT CHANGES OF BOTH CARDIOLOGISTS IN SEGMENTED CATEGORY OF ECG INTERPRETATION

Description of HELP Sector Decisions

Appendix D is comprised of three lists. The first and the second lists show all the possible HELP sector decisions from chest X-ray and cardiac catherization procedure, respectively. The last list is a list of abbreviations for the text in the HELP sector decisions from cardiac catherization procedure.

Only four HELP sector decisions in chest X-ray were pertinent to the study. They are sector numbers 8, 9, 10, and 27. In the case of cardiac catherization, there were twenty-six HELP sector decisions which were of interest in this study. They are listed as follows: 1, 3, 5, 7, 9, 11, 12, 17, 18, 20, 23, 25, 29, 30, 31, 34, 40, 43, 48, 50, 51, 52, 53, 55, and 57.

TABLE 25

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF ANTEROSEPTAL, ANTERIOR, OR ANTEROLATERAL INFARCTION

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	0
No -> Yes	No -> No	0
No -> Yes	No -> Yes	1
No -> Yes	Yes -> No	0
Yes -> No	Yes -> Yes	0
Yes -> No	No -> No	0
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	0
No -> No	No -> No	18
No -> No	No -> Yes	0
No -> No	Yes -> No	0
Yes -> Yes	Yes -> Yes	6
Yes -> Yes	No -> No	0
Yes -> Yes	No -> Yes	0
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No = ECG diagnosis does not have any of these computer codes; other codes for infarction at different locations may be present. Yes = ECG diagnosis has one of these computer codes; other codes for infarction at different locations may also be present. -> = the direction of changes in diagnoses from reading without clinical label to reading with the label.

NOTE: Computer codes are: 18.1, Anterospetal Infarction; 18.2, Anterior Infarction; and 18.6, Anterolateral Infarction.

TABLE 26

FREQUENCY OF CONVERGENT AND DIVERGENT DIAGNOSES

	Direction of Changes		
	Doctor 1	Doctor 2	Frequency Count
Divergent Diagnoses	No -> Yes	No -> No	0
Convergent Diagnoses	No -> Yes	No -> Yes	1

NOTE: Sample size = twenty-five. No and Yes have the same meaning as shown in Table 25.

NOTE: There was a total of seven patients who had one of these codes (18.1, 18.2, 18.6) in their diagnoses.

TABLE 27

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN DIAGNOSING INFERIOR, POSTERIOR, OR INFEROPOSTERIOR INFARCTION

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	0
No -> Yes	No -> No	1
No -> Yes	No -> Yes	1
No -> Yes	Yes -> No	0
Yes -> No	Yes -> Yes	0
Yes -> No	No -> No	1
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	1
No -> No	No -> No	16
No -> No	No -> Yes	0
No -> No	Yes -> No	2
Yes -> Yes	Yes -> Yes	3
Yes -> Yes	No -> No	0
Yes -> Yes	No -> Yes	0
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No means the ECG diagnosis does not have any of these codes; other codes for infarction at different sites may be present. Yes means the ECG diagnosis has one of these computer codes; other codes for infarction at different sites may also be present.

NOTE: Computer codes: 18.3, Inferior Infarction; 18.4, Posterior Infarction; and 18.9, Inferoposterior Infarction.

TABLE 28

FREQUENCY OF CONVERGENT AND DIVERGENT CHANGES

	Direction of Changes		
	Doctor 1	Doctor 2	Frequency Count
Divergent Diagnoses	No -> Yes	No -> No	1
Convergent Diagnoses	Yes -> No	No -> No	4
	No -> No	Yes -> No	
	No -> Yes	No -> Yes	

NOTE: Sample size = twenty-five.

NOTE: There was a total of nine patients who had one of these computer codes (18.3, 18.4, 18.9) in their diagnoses.

TABLE 29

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF LATERAL INFARCTION

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	0
No -> Yes	No -> No	1
No -> Yes	No -> Yes	0
No -> Yes	Yes -> No	1
Yes -> No	Yes -> Yes	0
Yes -> No	No -> No	0
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	1
No -> No	No -> No	20
No -> No	No -> Yes	0
No -> No	Yes -> No	1
Yes -> Yes	Yes -> Yes	0
Yes -> Yes	No -> No	0
Yes -> Yes	No -> Yes	1
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No means the ECG diagnosis does not have this code (18.5); other codes for infarction at different sites may be present. Yes means the ECG diagnosis has this computer code (18.5); other codes for infarction at different sites may also be present.

NOTE: Computer code: 18.5, Lateral Infarction.

TABLE 30

FREQUENCY OF CONVERGENT AND DIVERGENT CHANGES

	Direction of Changes		
	Doctor 1	Doctor 2	Frequency Count
Divergent Diagnoses	No -> Yes No -> Yes	No -> No Yes -> No	2
Convergent Diagnoses	Yes -> Yes No -> No	No -> Yes Yes -> No	2

NOTE: Sample size = twenty-five.

NOTE: There was a total of five patients who had a diagnosis of lateral infarction (18.5).

TABLE 31

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF INFEROLATERAL INFARCTION

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	0
No -> Yes	No -> No	1
No -> Yes	No -> Yes	0
No -> Yes	Yes -> No	0
Yes -> No	Yes -> Yes	1
Yes -> No	No -> No	1
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	0
No -> No	No -> No	22
No -> No	No -> Yes	0
No -> No	Yes -> No	0
Yes -> Yes	Yes -> Yes	0
Yes -> Yes	No -> No	0
Yes -> Yes	No -> Yes	0
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No means the ECG diagnosis does not have this computer code (18.7); other codes for infarction at different sites may be present. Yes means the ECG diagnosis has this computer code; other codes for infarction at different locations may be present.

NOTE: Computer code: 18.7, Inferolateral Infarction.

TABLE 32

FREQUENCY OF CONVERGENT AND DIVERGENT CHANGES

	Direction of Changes		
	Doctor 1	Doctor 2	Frequency Count
Divergent Diagnoses	No -> Yes Yes -> No	No -> No Yes -> Yes	2
Convergent Diagnoses	Yes -> No	No -> No	1

NOTE: Sample size = twenty-five.

NOTE: There was a total of three patients who had this code (18.7) in their diagnoses.

TABLE 33

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF APICAL INFARCTION

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	0
No -> Yes	No -> No	0
No -> Yes	No -> Yes	0
No -> Yes	Yes -> No	0
Yes -> No	Yes -> Yes	0
Yes -> No	No -> No	0
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	0
No -> No	No -> No	25
No -> No	No -> Yes	0
No -> No	Yes -> No	0
Yes -> Yes	Yes -> Yes	0
Yes -> Yes	No -> No	0
Yes -> Yes	No -> Yes	0
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No means the ECG diagnosis does not have this computer code (18.10); other codes for infarction at different sites may be present. Yes means the ECG diagnosis has this computer code; other codes for infarction at different locations may be present.

NOTE: Computer code: 18.10, Apical Infarction.

TABLE 34

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF ATRIAL ENLARGEMENT

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	2
No -> Yes	No -> No	1
No -> Yes	No -> Yes	0
No -> Yes	Yes -> No	1
Yes -> No	Yes -> Yes	0
Yes -> No	No -> No	1
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	0
No -> No	No -> No	13
No -> No	No -> Yes	0
No -> No	Yes -> No	1
Yes -> Yes	Yes -> Yes	4
Yes -> Yes	No -> No	1
Yes -> Yes	No -> Yes	1
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No means the ECG diagnosis does not have this computer code (17.4). Yes means the ECG diagnosis has this computer code.

NOTE: Computer code: 17.4, Left Atrial Enlargement.

TABLE 35

FREQUENCY OF CONVERGENT AND DIVERGENT DIAGNOSES

	Direction of Changes		
	Doctor 1	Doctor 2	Frequency Count
Divergent Diagnoses	No -> Yes	No -> No	2
	No -> Yes	Yes -> No	
Convergent Diagnoses	No -> Yes	Yes -> Yes	5
	Yes -> Yes	No -> Yes	
	No -> No	Yes -> No	

NOTE: Sample size = twenty-five.

NOTE: There was a total of twelve patients who had this code (17.4) in their ECG diagnoses.

TABLE 36

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF VENTRICULAR ENLARGEMENT

Doctor 1	Doctor 2	Frequency Count
No -> Yes	Yes -> Yes	0
No -> Yes	No -> No	1
No -> Yes	No -> Yes	2
No -> Yes	Yes -> No	0
Yes -> No	Yes -> Yes	0
Yes -> No	No -> No	1
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	0
No -> No	Yes -> Yes	0
No -> No	No -> No	16
No -> No	No -> Yes	0
No -> No	Yes -> No	1
Yes -> Yes	Yes -> Yes	2
Yes -> Yes	No -> No	0
Yes -> Yes	No -> Yes	3
Yes -> Yes	Yes -> No	0

NOTE: Sample size = twenty-five. No means the ECG diagnosis did not have one of these computer codes (17.1 or 17.2). Yes means the ECG diagnosis had one of these computer codes.

NOTE: 17.1, Left Ventricular Enlargement; 17.2, Right Ventricular Enlargement.

TABLE 37

CONCURRENT DIRECTION OF CHANGES IN THE DIAGNOSIS OF VENTRICULAR ENLARGEMENT BY DOCTOR 1 AND DOCTOR 2

	Direction of Changes		
	Doctor 1	Doctor 2	Frequency Count
Divergent Diagnoses	No -> Yes	No -> No	1
Convergent Diagnoses	Yes -> No	No -> No	7
	Yes -> Yes	No -> Yes	
	No -> Yes	No -> Yes	
	No -> No	Yes -> No	

NOTE: Sample size = twenty-five.

NOTE: There was a total of eight patients who had at least one of these codes (17.1 or 17.2) in their ECG diagnoses.

TABLE 38

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE DIAGNOSIS OF THE PRESENCE OR ABSENCE OF REPOLARIZING ABNORMALITIES

Doctor 1	Doctor 2	Frequency Count
No -> No	No -> No	2
No -> No	No -> Yes	3
No -> No	Yes -> No	2
No -> No	Yes -> Yes	3
Yes -> Yes	No -> No	1
Yes -> Yes	No -> Yes	0
Yes -> Yes	Yes -> No	1
Yes -> Yes	Yes -> Yes	2
Yes -> No	No -> No	6
Yes -> No	No -> Yes	0
Yes -> No	Yes -> No	1
Yes -> No	Yes -> Yes	0
No -> Yes	No -> No	3
No -> Yes	No -> Yes	1
No -> Yes	Yes -> No	1
No -> Yes	Yes -> Yes	1

NOTE: Sample size = twenty-five. No means there are no repolarizing abnormalities in the diagnosis. Yes means there are repolarizing abnormalities in the diagnosis.

TABLE 39

CONCURRENT BEHAVIOR OF DOCTOR 1 AND DOCTOR 2 IN THE CHANGES OF SPECIFICITY IN DIAGNOSING REPOLARIZING ABNORMALITIES

Doctor 1	Doctor 2	Frequency Count
NS -> S	NS -> S	6
NS -> S	NS <- S	0
NS -> S	No -> No	2
NS -> S	Yes -> Yes	0
NS -> S	No -> Yes	0
NS -> S	Yes -> No	0
No -> No	NS -> S	1
Yes -> Yes	NS -> S	0
No -> Yes	NS -> S	1
Yes -> No	NS -> S	0
NS <- S	NS -> S	0
NS <- S	NS <- S	0
NS <- S	Yes -> No	0

NOTE: Sample size = twenty-five. NS = nonspecific; S = specific; -> = direction of change after the label.

NOTE: No means there are no repolarizing abnormalities in the diagnosis. Yes means there are repolarizing abnormalities in the diagnosis.

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