PALPATION OF THE PULSE IN THE CARDIAC CARE UNIT

BY

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A THESIS

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CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM AND SURVEY OF LITERATURE

Cardio-vascular disease causes approximately 33 per cent of deaths per year in the United States. (17) The prevalence of disease in the community is reflected in the surveys which show that the greatest percentage of patient case-load has diagnoses of cardio-vascular disease. (13, 22) To reduce death rates from this cause, emergency care must be administered within hours of the occurrence of symptoms (17) and the problem remains a primary focus of concern, despite the fact that coronary care units have been successful in reducing death from heart attacks. The spectacular growth of such units in recent years has made them an integral and indispensable part of the hospital milieu.

This study was undertaken to increase the understanding of nursing techniques which contribute to the nursing care of the acute cardiac patient and to assess the validity and reliability of palpation of the pulse rate rhythm and magnitude in general nursing care when compared with standard measuring devices.

The introduction of technical equipment in the nursing care of the cardiac patients presents two questions: first, how far do technical devices replace the traditional activities of the nurse; second, can such devices serve as controls for nursing care procedures? Palpation of the pulse has been a nursing activity for many years, and has become imbued with the characteristics of tradition which has seldom been questioned. It is no longer enough to presume accuracy without research data to support claims of validity. Accordingly, this study was directed towards two frames of reference:

1. The accuracy of the traditional nursing activity of palpation of the pulse and

2. The use of technical equipment as objective measures of the palpation of the pulse.

The importance of challenging habitual, standardized, and traditionalized nursing actions will become of greater importance as new knowledge, new instrumentations and new techniques are introduced into medical and nursing care. To retain flexibility and adaptability in a rapidly advancing society, time-consuming and often futile actions must be discarded. Modes of practice which are retained unquestioned and unchallenged merely because they are rituals no longer acceptable when unsubstantiated by scientific investigation. Conversely, reliable procedures should be retained, and made more effective by potentiating their usefulness and applying them to practice, selectively and appropriately.

In comparison to the tradition of palpation of pulses, the cardiac monitor is relatively new and the increasing use of continuous monitoring has made this instrument irrevocably involved in the nursing care of the acutely ill patient. Peripheral blood flow is being measured by various electronic devices from photo sensitive cells to ultrasonic flow meters, and the scientific literature abounds in reports using such information in research activities. (2, 14, 21, 26) No studies could be found specifically investigating palpation as a diagnostic tool and comparing the accuracy of the procedure to electronic measuring devices.

HYPOTHESES

It was assumed, therefore, that a study examining these specific questions had not previously been undertaken. The following null hypotheses were formulated:

1. There is no significant difference between pulse rates palpated in the left side of the body and the right side of the body.

2. There is no significant difference between radial, temporal, pedal, and femoral palpations and apical pulse auscultation.

3. There is no significant difference between the rates of each artery recorded by the monitor and palpation rates of the same arteries.

4. There is no significant difference between the apical monitor rate and the radial pulse rate.

5. There is no significant difference between the monitor pulse rates on the right and left sides of the body.

6. There is no significant difference between the frequency of rhythm regularity on the monitor ($Q_1 - Q_2 > 3$ mm) and frequency of rhythm regularity by palpation (6 irregular beats/per minute). (25)

7. There is no significant difference between the regularity of rhythm on the left side of the body and on the right side of the body.

8. There is no significant difference of frequency of rhythm regularity between the monitor and palpation on the left side of the body and between monitor and palpation on the right side of the body.

9. There is no significant difference between the systolic blood pressure on the left side of the body and the right side of the body, recorded by sphygmomanometer.

10. There is no significance between the systolic blood pressure recorded by sphygmomanometer, the Doppler Ultrasonic unit and the plethysmograph.

11. There is no significant difference between the diastolic blood pressure recorded by sphygmomanometer on the right and on the left sides of the body.

12. There is no significant difference between the diastolic blood pressure recorded by sphygmomanometer or Doppler Ultrasonic Unit.

13. There is no significant difference between ranked magnitude

of the pulse (radial) when palpated and ranked systolic blood pressure recording.

REVIEW OF LITERATURE RELATED TO HYPOTHESES

To construct a research design to test these hypothese, further investigations of the literature were made and studies relevant to the present problems were reviewed.

In 1964 Victoria Canetto (6) reviewed the indiscriminate habitual gathering of four hourly T. P. R. recordings. From an accidental samples of 101 patients 4 percent were found to have received benefit from this practice. She concluded that routine measurements remained unchanged despite "revolutionary new discoveries," inferring that routines had become rituals. In 1968, Doyle and Jordon (9) compared serial to simultaneous measurement of the pulse deficit. They found no significant difference, but complained of operational problems in recording the apical pulse, particularly in patients with arrhythmias. They also experienced problems in accurate auscultation which was impaired through borborygmi and stertor. Neither of these studies had used any type of mechanical method of measuring pulse rates for comparison or control.

Pedal, brachial, axillary and carotid pulse had been measured by a photo-electric cell unit by Dr. C. Cope. (8) The purpose of his study was to decrease complications arising from arterial catheterization;

he placed the cell unit on the big toe in the case of femoral artery catheterization, and on the thumb in the case of axillary artery catheterization. When the catheter was misplaced, the blood flow around it impeded peripheral blood flow and the pulse was dampened or lost. He routed the pulse recording through the cardiac monitor to obtain an auditary and visual display. He preferred the use of the photoelectric cell to the plethysmograph as it provided a more reliable base line than the latter, for the plethysmograph was overly-sensitive to changes in position of the patient. Another study made by a team headed by Dr. S. H. Taylor (12) in Britain compared a "system engineered transducer computer linked" machine which measured six intravascular pressure channels, the cardiac output, and the electrocardiogram, to manual methods. Their results showed that the machine was just as accurate and considerably faster than manual methods. Most of the scientific literature which was reviewed, concentrated upon electric measurement of the pulse through recordings of pressures, peripheral blood flow, and simultaneous electric readings for diagnostic reasons.

Another point of view, however, was presented in a Public Health survey made in Tecumseth, Wisconsin. (14) It contained a plea for the retention of the use of a simple diagnostic tool and attempted to provide a quick easy method of diagnosing incipient heart disease. Its purpose was to try to establish that the presence or absence of the pedal pulses could predict groups at high risk of coronary occlusion.

The premise of the study was the relationship between arterio-sclerosis, arterial condition, and heart disease. The study illustrated the desirability of the simplicity of large-scale screening devices but data could not predict high risk.

Three studies concerning blood pressure readings are reported by Gunn, Sullivan, and Glor. The report was difficult to follow but the general ideas have merit. The compared sphygmomanometer readings to the Sauben polygraph, a device which transduced to sound waves and graphed them. The nurses recorded the blood pressures simultaneously, and no observer differences were found. They reported procedural difficulties with the mechanical devices and postulated the polygraph was inefficient.

CHAPTER II

MATERIALS AND METHOD

PILOT STUDY

Before commencing the research a pilot study was performed. (7) The purpose of this study was threefold:

1. To establish the advantages of recording data with the monitor, especially in regard to rate and rhythm of the pulse.

2. To establish advantages of palpation of the pulse rather than the monitor, particularly in regard to the pulse magnitude.

3. To compare auscultation of the apical beat with data collected by the monitor.

Data were collected from ten male patients ages 54-92, in the Cardiac Care Unit of the Veterans Administration Hospital, Portland, Oregon. All patients were on the Sanborn monitoring unit with floating electrodes placed in Lead II position. All patients were diagnosed for cardiac disease and were on full bed rest. Both temporal arteries, and both radial arteries were palpated and the apical pulses auscultated. Care was taken to collect the data one hour after meals to prevent contamination of the data from adreno-cortical stimulation. The data were then compared to the EKG tracings which had been recorded simultaneously. The apical beat was found by placing the stethoscope one inch to the left and one inch down from from the left nipple. The placement of intra-venous infusions was noted as were cardiac catheterization and angiograms. The latter were recorded in case either procedure had limited the integrity of the artery and so would influence the data. The EKG's were read according to the procedure recommended in the Nursing Manual for the Hackensack Hospital (25) to which an addition noting the T-wave was added by the author as it was felt that the notation would supply a more complete description of cardiac condition.

From the sample of ten subjects, two cases had no left radial nor left temporal pulses. Three cases had a discrepancy between pulse palpation and monitor tracing, two differing in rate and one in rhythm. Operational difficulties in ascertaining the apical beat were found in seven cases out of ten, and all cases differed in "tone" between temporal and radial pulses. If "tone" and apical beat operational differences were exlucded, then rate and rhythm were consistent with EKG tracings in seven patients.

It seemed, from these results, that a more detailed study was needed. Several important considerations were not included in the study. The specific diagnosis for each patient and date and place of birth constituted easily obtainable demographic data omitted from the pilot study. The relevance of controlling factors such as sudden stimulation of the adreno-cortical axis or the increased cardiac output after ingesting a meal was superfluous as the reflection of these factors upon the pulse would be recorded by the machines. More relevant is the factor of barometric pressure and environmental temperature. Changes in this nature may affect the machines as well as the patients in different and unpredictable ways. Another variable thought to be significant was the placement of the stethoscope for auscultation. In the pilot study no attempt was made to adjust the stethoscope to facilitate auscultation and this error may have unduly influenced the data concerning the apical beat.

The question of "tone" and "character" of the pulse presented the greatest challenge. One of the assumptions of the pilot study was that the machine was more accurate than the practitioner. Findings from the study supported a conclusion that the EKG machine registered greater diagnostic acumen in rate and rhythm than the nurse. Evidence of peripheral circulatory collapse, present or impending, was not provided by the monitor and alternate means of registering this phenomenon would have to be discovered.

PHYSIOLOGY AND TERMINOLOGY

When the pulse is palpated, the rate and rhythm are noted. The rate coincides almost exactly with contractions of the left ventricle. The mechanically induced wave traveling just below the speed of sound reaches the peripherial arteries almost immediately, quickly enough to reflect the heart as a simultaneous phenomenon. Rate is a time-ratio measurement, so it is reported as a means of measuring how many myocardial contractions occurs in one minute. Rhythm relates to the equality of intervals between beats. Both rate and rhythm are related to normal efficiency. The involuntary, striated cardiac muscle has an absolute refractory period (1) and therefore cannot be tetanized, but more importantly for the purpose of this study it must be repolarized before firing. This muscle has its own inherent rhythmicity (12) which is hastened by the atrial ventricular node and in turn is normally under the influence of the faster paced syno-auricular node. The heart is liberally supplied with nerves from the autonomic nervous system particularly the 10th cranial nurve (the Vagus). Interference in induction for whatever reason will reflect in a distrubance of rate and rhythm of contractions. The electro cardiographic tracing provides a remarkably accurate record of such deviations.

The way the pulse feels against the applied tips of the fingers is a much more subjective assessment than one in which equipment is used. The word "tone" was rejected as embodying far too indeterminate a rating scale; "volume" and "pressure" were also discarded as being descriptively inadequate. A basic physical law (Ohm's Law) states that pressure is equal to flow times resistance. (12). The relativity of these components is being assessed in the magnitude of the pulse. The stroke volume is the cardiac output for one ventricular contraction and is related to pulse pressure as Hamilton and Remington verify. (20)

Pressure exerted by the heart muscle forces the blood into the artery flowing at a rate which will be affected not only by the forward thrust of the ventricle, but also by the amount of resistance of the encircling arterial wall, and the area of the circumference of the vessels. This is consistent with the fact that any fluid exerts pressure equally in all directions, and so will meet resistance in all directions when enclosed. The practitioner, then, during pulse palpation, is making a qualitative estimate of the vigor of the stroke volume as related to the pressure with which the blood is forced into the arteries with each contraction but this pressure will always bear a direct relationship to the rate of flow and resistance of the vessels and periphery.

Estimation of stroke volume is not, strictly speaking, pulse volume. The blood which is ejected by the heart into the aorta during a specific time interval will not reach the palpable arterial pulses in the limbs until later, until the blood already present has flowed past the point of palpation. It was for these reasons, that magnitude was used to describe stroke volume and its relationship to peripheral resistance which is manifested by the digital palpation of the artery through the skin. As the monitor had not provided a reliable control against which to compare the magnitude of the pulse in the pilot study, technical devices were sought in the present study to measure such criteria.

MEASURING DEVICES

Blood pressure readings recorded through the sphygmomanometer are the traditional methods (5) of estimating the condition of the peripheral circulation in relationship to cardiac output. It was decided to include this procedure and compare the readings to those of the transcutaneous Doppler an ultrasonic blood velocity detector. (12) At the same time a plethysmograph, using a mercury strain gauge around the thumb to measure volume entering the area (12) was also used for comparison. In this way the traditional methods of measuring blood pressure could be contrasted to the Doppler Unit and the plethysmograph (19) and could be then used as criteria against which to compare magnitude of digital palpation.

The Parks Doppler Flowmeter (18) is a small, light weight easily transportable unit. Battery-driven, it transmits sounds from the artery to a set of earphones. Two crystals, one a transmitter and one a receiving crystal are embedded within a small transparent plastic container about the size of a postage stamp. The ultrasound energy (energy or small wavelength transmitted at the repetitious rate of about ten million times per second) rebounds from the blood particles and is picked up by the receiving crystal. This frequency can be measured if the blood is not in motion, but with blood movement the frequency is slightly different, and it is this difference which varies with velocity which is recorded by the Doppler. Higher velocity causes higher sounds and vice versa. As the blood flows past the designated point, the sound waves compress giving a higher tone; as the blood passes by this point, the sound waves elongate giving a lower tone. These sound are recorded by the Doppler and are distinctive, pronounced and characteristic. The sphygmomanometer cuff is placed on the limb and inflated until the sounds disappear. As the cuff pressure is gradually released the first sound heard corresponds with the systolic blood pressure and a slight change in sound with a coupling of the beat, though more difficult to ascertain, corresponds to the diastolic pressure. An acoustic coupling gel must be used between skin and crystal to preserve electrical contact through the skin. It is a non-abrasive, odorless, clear, non-irritating substance, easily removed with clear water and tissue. This causes no inconvenience to the patient, leaves no mark, and no complaint of subsequent itching, pain or skin variation of any kind was noted. The reliability of the Doppler recordings was measured by a team of investigators at University of Washington. They compared the readings of intra-arterial pressures in infants, measured by catheters in situ, to the Doppler recordings. They report a Pearson's $r = 0.90$ for systolic and $r = 0.87$ for diastolic.

For this study the Doppler was validated in the surgical Intensive Care Unit of Veteran's Hospital. The readings were taken simultaneously by Doppler and intra catheteral recording registered on a computer. The Pearson's r was found to be 0.87 for systolic pressure, which is significant at the 0.001 level. The diastolic pressure had a Pearson's r of 0.50, somewhat lower than the correlation found at University of Washington. (See Appendix C.) The Doppler then is a unit recording systolic pressure with great accuracy. As pressure is equal to flow times resistance, the relation of Doppler readings to cardiac sufficiency is intimate and comparable. The discrepancy between the researcher's correlation coefficient and that found in the University of Washington study will be subsequently discussed in further detail (Chapter III and also Appendix D).

The Parks plethysmograph records volume of blood entering a limb after occluding blood flowing out of the limb. It occludes venous flow so that changes in volume relate only to arterial blood input. Impedance plethysmography was rejected for this study even though this method is most accurate, but the placement of the necessary electrodes along the artery, constituted procedural complications deemed undesirable by the researcher. The mercury strain gauge method was used, even though in vasoconstriction and very low blood pressures the readings are almost impossible to obtain.. The mercury strain gauge is on a very narrow tubular elastic ring which is large enough to encircle the digit and is filled with mercury. To roll the pliable gauge onto the digit disturbs the electrical characteristics of the mercury and is an important technical point. (19) It is attached to a battery powered unit even smaller than the Doppler. Both these units could be connected to the electrocardiograph machine so that tracings of the pulse contours could be obtained. Although neither machine presented calibrated tracings it was intended to obtain evidence of change of area under the curve in an attempt to correlate higher pressures with changes graphically represented on the paper and then to compare them to the palpated estimations of magnitude. The vascular volumes increase with each cardiac pulse, which phenomenon could possibly be reflected in a variation of area under the contour curve. It was intended that if such evidence was manifested an attempt would be made to correlate higher pressures with the graphed changes and these representative to the pulse palpates of estimated magnitude. For operational difficulties experienced in setting up the equipment, please refer to Appendix B.

For this study three characteristics of pulse, namely rate, rhythm and magnitude have been measured by means of digital palpation plus the technical devices: monitor, sphymomanometer, Doppler, plethysmograph. Table I shows which characteristic was measured by which means and which hypotheses were tested by each.

Table I. Characteristics of Pulse, Method of Measurement and Hypotheses Tested.

Characteristics of Pulse	Method of Measurement					Hypotheses Tested
	Palpation	Monitor	Sphygomomanometer	Doppler	Plethysmograph	Number
Rate	X	X				1, 2, 3, 4, 5
Rhythm	X	X				6, 7, 8
Magnitude	X		X	X	X	9, 10, 11, 12, 13

SAMPLING AND PROCEDURE

Collection of Observations

Sampling. The sample was a purposive non-probability sample of 15 patients from the Veterans Administration Hospital Coronary Care Unit, Portland, Oregon. Data were collected during a three month period of summer. The average age of the patients was 65.2 years, range 51-75; place of birth was predominantly from the Northern states and Canada, but one patient had been born in Texas, and two were from the East Coast. Duration of cardiac disease varied from 31 years to two days, the mode being two years. Specific cardiac diagnoses were predominantly myocardial infarction but the sample included three congestive heart failures (with one complicated cirrhosis of the liver), one case of rheumatic heart disease, one heart block (3rd degree), one diagnosis of hypertensive heart disease, and one coronary artery disease. The sample, then, was adequate representation of the various cardiac conditions and was not restricted as to place of birth. The age grouping was truncated, no one above 75 years being included.

This sample was selected according to the following criteria: All patients were already utilizing the cardiac monitor systems; all patients were male in order to exclude the variable breast formation which could interfere with auscultation of the apical beat; all patients' charts were carefully examined for evidence of cardiovascular abnormalities of congenital origin, as their occurrence was seen as a serious contaminant of the data. Preference was given to severe arrhythmias where possible which would test the hypotheses more critically than other malfunctions.

The requirement for admission into the Veterans hospital is the fact of having been in military service. All servicemen have been subject to medical examination and subsequent medical supervision, creating a logical assumption that at least gross congenital abnormalities of the heart and blood vessels would have been identified and screened out. A brief inquiry from medical personnel substantiated the fact that congenital anomalies of the cardiac system had been an extremely rare occurrence.

To eliminate further any occurrence of congenital disfunction, the lower age range was limited to 45 years on the asumption that such problems would not only have been diagnosed before such time but the reduced longevity of such patients would further eliminate their probability of chance inclusion in the sample.

The Veterans Administration Hospital provided a population whose admissions were mostly of male sex; and the requirement of arrythmias as well as the presence of cardiac monitor was also adequately satisifed by the use of those patients admitted to their Coronary Care Unit.

Amputees were excluded as they eliminated the possibility of comparing right and left sides of the body for possible differences; and patients over 80 years of age were not included on the assumption that the compounding problems of age could unduly skew the data. As this research is essentially a comparison of variables this last fact later proved to be an erroneous conclusion.

Each patient was a volunteer and the permission of the patient was requested before the procedure began. If he appeared hesitant or looked concerned he was not included in the study. Only one patient declined on the basis that "machines frightened" him and he felt that his "heart couldn't stand it." No attempt was made to dissuade him, and he was reassured that his decision in no way disturbed either the experiment nor the experimenter. As soon as the patients realized that the procedure did not involve assault to skin or blood vessels, consent for participation was given without reserve.

The Cardiac Care Unit (C. C. U.) is air conditioned. Variability in findings were not due to changes in humidity, temperature and barometric pressure as they were controlled.

Administrative clearance for undertaking the study in the C. C. U. was sought. Initial contact was with Mrs. Margeurite Ingle, Associate Chief Nursing Service for Education. She received the plan of study, then telephoned to the Washington D. C. Central Office for specific approval. This was readily granted. The nature of the study was such that it was unnecessary for the proposals to be reviewed by a board. However, Dr. Paul E. Shick, Chief of Staff, was consulted and concurred with the approval to proceed. (See Appendix A. Correspondence.)

The plethysmograph and Doppler Unit were loaned by Mr. Loren Parks, manufacturer of these instruments in Beaverton, Oregon. Other equipment was available at the site of study.

Procedures

The procedure at the bedside was completed in thirty minutes time. Seriously ill patients usually slept throughout the collection of the data. The more alert patients cooperated very well and were a source of information concerning their own case history.

The blood pressure was recorded on both the right and left arms using the wall sphygomomanometer and cuff. The recording of the blood pressure was taken as recommended by the American Heart Association (15) as follows: The cuff was placed one inch above the anti cubital fossa, taking care that the cuff was greater in width than the diameter of the arm and that it was placed without wrinkles. The cuff was inflated, the stethoscope applied over the artery with part of the disc slightly under the cuff which was then inflated. The mercury column was allowed to descend at the rate of 10 mm per second. The systolic pressure was read at the first sound of the pulse beat, the diastolic pressure was read at the two levels, the first at the change in the Korotkoff sounds and also at their disappearance. Two readings were taken on each arm to provide an accuracy check upon the researcher's observations. The left cuff remained in place and the Doppler was used to record the blood pressure at the radial pulse. The radial artery was chosen rather than the brachial artery, as it was thought that the palpation of the radial artery is the most frequently used by nurses. Also, the magnitude of this pulse was to be directly compared to the Doppler contour tracing if possible. After applying gel to the crystal it was placed over the artery and the Doppler unit turned on. After adjusting the head phones on the researcher's head, the earphone volume was gradually raised to a comfortable level, usually between three and five on the dial. The crystal was gently manipulated to move with the patient's skin away from audible contact with the artery, leaving only irrelevant sounds; then the input level dial was slowly adjusted in an attempt to eliminate this background noise (usually this required a level of 5). This was not as effective as would have been desired, and some slight interference from this factor was experienced. The crystal was then gently replaced to make contact with the artery once more. These two dials were not adjusted again as they constituted a baseline from which to measure the blood pressure. The output level was the next adjustment to be made and governed the height (amplitude) depicted graphically on the tracing paper of the contour of the pulse. Although instructions for the use of the Doppler include the admonition to use 2 or 3 in the "artery" dial, "vein 1" gave the best readings with the least electrical interference upon the tracings. An adjustment level had to be made to obtain this reading between the Doppler dials governing arterial position and output level and the EKG sensitivity dial, the A. V. R. (unipolar) being the position of choice to record the Doppler tracing, usually. Each patient required an individualized balance of these three differentials to obtain the best response for pulse contour tracings. As the research became more facile these adjustments seldom took longer than a minute or two. The blood pressure was recorded by inflating the cuff and recording the first sound heard which was incumbent with the level of mercury on the sphygmomanometer. The diastolic pressure was difficult to locate until the researcher learned the Doppler instrument. It was registered at the point where the sound became "mushy" and doubled, somewhat (See Appendix D Validating the Doppler.) similar to the "lub-dub" of the heart beat but more specifically onomatopoiecally expressed by "swlush-lush." The pulse contour was traced precisely concomitant with the Doppler blood pressure reading which also were taken twice.

The Doppler unit was then exchanged for the plethysmograph. The patient's arm was positioned on a pillow so that it would be comfortable and raised from the bed. Slight movement registers on the tracings which tend to have a wandering baseline no matter how still the patient lies. One patient who was suffering from delirium tremens had extremely erratic tracings, despite sedative medication. The strain guage was placed by extending the elasticised ring around the thumb, rather than rolling it on--as one might a finger stall. The latter method would distort the electrical conductivity of the mercurial gauge. A tape, gently applied, helped to keep the gauge in place during the testing. The sphygmomanometer cuff was inflated and the column of mercury in the instrument was let down much more slowly than usual. This was done in an attempt to compensate for the following problem: The only way to locate the systolic blood pressure with the plethysmograph is to note the occurrence of the pulse contour on the tracing. As the cuff is inflated the tracing is obliterated and reoccurs at the point of systolic pressure. Thus, two visual operations have to be performed at the same time, one, noting the level of the mercury column and two, noting the occurrence of the contour on the paper. Despite lowering the pressure very slowly this was a difficult operation as the sphygmomanometer was upon the wall and the EKG machine used for this tracing was at waist level beside the patient's bed. This fact also required that the Doppler and the plethysmograph readings were taken on the left side of the patient. From this side of the patient the two observations could most easily be performed and perceived.

After completing two plethysmographic readings, the instrument was removed and the EKG machine used for the tracings was taken from the patient's room. The rest of the observations were made from the Sanborn 760B, already in use for patient monitoring. Before palpation of each pulse, the EKG tracing paper was marked to identify precisely, the tracing which would coordinate with the specific palpation.

The right and then the left radial arteries were palpated. If any difficulty was experienced it was noted. Palpation was conducted by using first, second, and third fingers of the right hand, applying moderate pressure along the path of the artery. Immediately after completing a 30 second count of each pulse rate, the EKG was stopped so that a measure for locating the exact point on the tracing which represented the exact time of cessation of palpation would be established. The apical pulse was taken immediately after the radial pulses to ascertain a point of reference for comparing auscultation of apical pulse to radial, as it was assumed that the tracing would serve as a guide if any notable change should occur between the radial palpation and auscultation. These readings were consecutive. It would have been more accurate to have had the radial artery palpated at the same time that the apical was being auscultated.

The chest was auscultated for rales immediately after auscultating and recording the apical pulse to ascertain if noise had interference with accuracy. In the pilot study the apical pulse had been recorded only at the Point of Maximum Input.(24) During this study, however, the apical beat was sounded in any place on the chest which would maximize auscultation, as this restriction in the pilot study had been felt to impede validity.

The temporal pulses (left then right) were then palpated followed by the femorals and the pedal pulses. Observations regarding the condition and color of the feet, and a notation regarding the relative temperature of the feet were recorded. A pulse which could not be located by the researcher was checked by C. C. U. nursing staff to verify the accuracy of the observation of this operator.

The data concerning palpation were invariably collected in this order and sequence. Other observations were not always taken in this order. This variability in sequence of actions was done to reduce the possibility of bias particularly (for example) from transferring the knowledge of one reading of the blood pressure by the Doppler to the reading of the plethysmograph.

All tracings for each patient were then removed from the mcahines and carefully filed for later interpretation together with pertinent information which was extracted from the charts. The data were then recorded on prepared schedules and examples of EKG tracings Doppler and plethysmograph pulse contour tracings were placed together in a separate sheet for any contrast and comparison. These constitute the raw data for this study and is reproduced in Appendix G. As in the pilot study the EKG readings were interpreted and according to the Hackensack method, with occasional reference to the Missoula Manual for analysis of tracings with complicated electrocardiographic patterns. These constitute the raw data for this study and is reproduced with appropriate individualized commentaries in Appendix G.

CHAPTER III

REPORT OF THE STUDY

This study was undertaken to increase the understanding of nursing techniques which contribute to the nursing of the acute cardiac patient and to assess the validity and reliability of palpation of the pulse rate, rhythm and magnitude in general nursing care using standard measuring devices for comparison. The procedural aspects, selection of sample, and the hypotheses as stated in Chapter I have been the defining propositions of this study.

Hypotheses Concerning Cardiac Rate

1. There is no significant difference between pulse rates palpated on the left side of the body and the right side of the body.

2. There is no significant difference between radial, temporal, pedal, femoral and apical pulse rates.

To test these hypotheses, 1 and 2, an Analysis of Variance (A. N. O. V. #1) a 2 x 5 factorial design, non-repeat measures was perperformed.

In this analysis the apical beat auscultation was included as it was necessary to compare this recording with the rest of the pulses. As it is neither right nor left, equality of the design was retained by including the apical data in each side; this was the same as adding a constant to the data and would leave the variance unchanged.

TABLE II

ANALYSIS OF VARIANCE #1 COMPARED ON RIGHT AND LEFT SIDES OF THE BODY

#1 ANOV for H_o 1) + 2)

Source of Variation	Sums of Squares	dF	Mean Square	F
A (Sides of Body)	580. 167	1	580. 167	< 1 NS
B (Pulse Rates)	13009. 360	4	3252. 340	3. 7*
AB	981. 867	4	217. 967	< 1 NS
Within Cell Error	120958. 800	140	863. 991	
Total ss = 135420. 194		149		

(Check ss total = (2)-(1) = 787369. 000-651948. 806 = 135420. 194 dF = 149)

As pulse rates were found to differ significantly (at $\alpha = 0.05$) it was necessary to do an individual comparison of the pulse rate means (Main Effect B) by the Newman-Keuls procedure.

Report on Newman-Keuls

Those means underlined by a common line do not differ from one another. All other means differ at the 0. 05 level of significance.

$\overline{B}_1 \overline{B}_2 \overline{B}_3 \overline{B}_4 \overline{B}_5$

B_1 = pedal pulse

B_2 = femoral pulse

B_3 = apical pulse

B_4 = radial pulse

B_5 = temporal pulse

The radial and temporal pulse rate had an almost identical mean rate. These differed significantly from the pedal pulse rates at the 95 percent level of confidence. No differences of statistical significance was found between all other pulse rates, nor between the pulses on either side of the body. Apart from the pedal pulse rates, all rates are equal representative of cardiac rate within 95 percent confidence limits.

Hypotheses 3, 4, 5 were next considered.

3. There is no significant difference between the pulse rates of each artery recorded by monitor and palpation rates of the same arteries.

4. There is no significant difference between the apical rate recorded by monitor and radial pulse palpation rate.

5. There is no significant differences between the pulse rates recorded by monitor on the right and left sides of the body.

To test hypotheses 3, 4, and 5 concerning cardiac rates an A. N. O. V. 2 x 2 x 5 factorial design repeat measured over the last two factors was done.

The apical pulse rate recordings were again included in both right sides and left side data as a constant, which would not effect the variance. This was necessary to allow comparison of the apical beat to other pulse rates and also to the monitor readings. As the pulses were assessed individually the left side palpations are treated as data which is independent of the right side palpations for the purposes of the analysis. Monitor tracings, taken at precisely the same moment as the pulse observations constitutes the repeat portion on this design.

TABLE III

ANALYSIS OF VARIANCE #2 COMPARING THE MONITOR RATES AND PULSE RATES ON SIDES OF THE BODY

	Sums of Squares	dF	Means of Squares	F
Between Subjects	28, 041. 300	29		
A	1. 766	1	1. 766	
s/w/gr	28, 039. 534	28	1, 001. 411	
Within Groups	[120, 494. 300]	270	16, 030. 833	
B	16, 030. 833	1	0. 027	
AB	0. 027	1		
Bx s/w/gr	8, 612. 440	28	307. 587	
C	10, 659. 283	4	2, 664. 820	
AC	11. 684	4	2. 921	
Cx s/w/gr	37, 355. 333	112	333. 529	
BC	14, 126. 685	4	3, 531. 671	11. 759*
ABC	60. 455	4	15. 113	< 1
BCx s/w/gr	33, 637. 560	112	300. 335	
	TOTAL	299		

Check 1, 631, 022. 000-1, 210, 527. 700 =
Total ss withing group = 120, 494. 300

* As the BC interaction was significant and the analysis for the main effects could not be accomplished as the data as they now exist, are contaminated. This concludes the statistical analyses of the data concerning pulse rates.

<u>Hypotheses Concerning Cardiac Rhythm</u>

Hypotheses 6, 7, 8 were tested.

6. There is no significant difference between the frequency of rhythm regularity by monitor and the frequency of rhythm regularity by palpation. (Regularity = $Q_1 - Q_3 \leq 3$ mm; monitor - 6 unevenly spaced beats per minute palpation.)

7. There is no significant difference of frequency of rhythm regularity on left and right sides of the body by palpation or by monitor.

8. There is no significant difference of frequency of rhythm regularity between monitor and palpation on the left side of the body and between monitor and palpation on the right side of the body.

To test hypotheses 6, 7 and 8 concerning cardiac regularity of rhythm a series of chi-squares was performed. Rhythm was dichotomized into the variables of regularity and irregularity and, as such, are mutually exclusive and independent. The observations of monitor and palpation were concurrent and so directly comparable. The monitor tracings provided an empirical referent where irregularity was visually displayed by a variance between R's of the QRS of more than three millimeters, and was therefore used as the expected frequency. The pulse palpation data were used as the observed phenomena. Irregularity was defined as more than three beats which were out of the sequence of even-spaced beats in thirty seconds. When the rhythm was not palpable it was denoted as irregular, as lack of ability to palpate is an undesirable deviation from the norm as is irregularity.

Hypothesis #6. There is no significant difference between the frequency of rhythm regularity by monitor and frequency of rhythm regularity palpation.

$X^2 = 13.46$. The hypotheses #6 was rejected at $p = 0.01$.

This calculation involved data for rhythm on all pulses. Consequently separate X^2 calculations comparing each pulse rhythm to the monitor rhythm were performed.

TABLE IV

COMPARISON OF PULSE RHYTHM TO MONITOR RHYTHM

Pulse to Monitor		Significance
For radial pulse	$X^2 = 1.015$	N. S.
apical pulse	$X^2 = 0.508$	N. S.
temporal pulse	$X^2 = 0.835$	N. S.
femoral pulse	$X^2 = 26.443$**	$p = 0.01$
pedal pulse	$X^2 = > 26.443$**	$p = 0.01$

**Both femoral and pedal pulses differed significantly at the 99 percent level of confidence from the monitor tracings regarding rhythm regularity.

Hypothesis #7. There is no sigificant difference between the frequency of rhythm regularity on the left and on the right sides of the body by palpation or by monitor.

A X^2 analysis was not done on this hypothesis as this procedure demands comparison to expected relationships which have been designated by this researcher as the monitor readings. This hypothesis would therefore demand comparison of expected to expected data and a comparison of observed to observed. However analysis by inspection of the raw results shows that the monitor readings for the left side and the right side are 48 and 47 respectively (regular rhythms). The palpation results for left and right sides are 40 and 38 respectively (regular rhythms). No statistical interpretations are attempted but common sense demands the consideration of the conclusion that little difference between left and right sides was found by either method of assessing rhythm regularity. If the researcher had any doubt of the relationship, a contingency X^2 could be applied, but it is not reasonable to expect a significant difference.

Hypothesis #8. There is no significant difference of rhythm regularity between the monitor and palpation on the left side of the body and on the right side of the body.

$X^2 = 6.695^{**}$ left side $p = 0.01$

$X^2 = 7.990^{**}$ right side $p = 0.01$

Hypothesis #8 was rejected at the 99 percent level of confidence. The monitor differed from palpation in denoting regularity of rhythm on the left side of the body. This difference was also present on the right side of the body, the level of confidence in both cases was 99 percent. This concludes statistical analysis of hypotheses concerning cardiac rhythm.

<u>Hypothesis Concerning Pulse Magnitude</u>

Hypotheses 9 and 10 were first considered.

9. There is no significant difference between systolic blood pressure on the left side of the body and the right side of the body recorded by sphygomomanometer.

10. There is no significant difference between the systolic blood pressure recorded by sphygmomanometer, the Doppler Ultrasonic unit and the plethysmograph.

To test hypotheses 9 and 10 concerning the magnitude of the pulse on sample A. N. O. V. (#3) over four factors was performed.

The blood pressures were taken by sphygmomanometer on both sides of the body. This was not the fact when taking pressure readings with the Doppler and the plethysmograph as the procedure would have taken almost twice as long and was deemed too tedious for the patient. Accordingly the systolic blood pressures were arranged as four variables for comparison. The first two consisting of the recordings by sphygmomanometer from the left and right sides of the body, the last two being systolic blood pressures from the Doppler and plethysmograph.

TABLE V

ANALYSIS OF VARIANCE #3 COMPARING SYSTOLIC BLOOD PRESSURES RECORDED BY SPHYGMOMANOMETER, DOPPLER AND PLETHYSMOGRAPH

Source of Variation	Sums of Squares	dF	Mean Square	F
Between treatments	77.00	3	25.33	F< 1 NS
Within treatments	4,286.93	56	76.05	
Total	4,363.93	59		

(Check 757452.00 - 753088.066 = 4363.934 dF 60-1)

The null hypotheses was supported as no significant difference was found between systolic blood pressure taken on the left and right sides of the body by sphygmomanometer and the Doppler Unit and the plethysmograph. All measuring devices for estimating systolic blood pressure were equally accurate.

Hypothesis 11. There is no significant difference between the diastolic blood pressure recorded by sphygmomanometer the Doppler Ultrasonic Unit, and the plethysmograph.

Hypothesis 12. There is no significant difference between the diastolic blood pressure recorded by sphygmomanometer or the right and on the left sides of the body.

To test Hypotheses (11) and (12) a simple analysis of variance over five factors was performed. According to the American Heart Association, diastolic readings should be taken at two levels, the first at the change of quality of Korotkoff sounds and the second at cessation of sound. Accordingly the data were divided into five factors. Upper and lower diastolic, left sphygmomanometer, upper and lower diastolic right sphygmomanometer and the Doppler diastolic pressure. No plethysmographic readings for diastolic pressure were possible with the strain gauge device.

TABLE VI

ANALYSIS OF VARIANCE #4 COMPARING UPPER AND LOWER DIASTOLIC BLOOD PRESSURES RECORDED BY SPHYGMOMANOMETER AND DOPPLER

Source of Variation	Sums of Squares	dF	Mean Square	F
Between treatments	1,868.609	4	467.15	4.509*
Within treatment	7,253.334	70	103.63	
	9,121.943	74		

(Check 489,442.000 - 480,320.057 = 9,121.943 dF 75-1 = 74)

A significant difference at $\alpha = 0.05$ was found between diastolic pressure readings. Accoringly a Newman-Keuls procedure to compare individual means was performed.

Results of Newman-Keuls A. N. O. V. #4. All means underlined with a common line do not differ significantly. All other means differ at the 95 percent level of confidence.

$$\underline{\bar{T}_1 \bar{T}_2 \bar{T}_3 \bar{T}_4}\,\bar{T}_5$$

The difference was found to be significant at the 95 percent level of confidence between the lower diastolic pressure (left side) recordings by sphygmomanometer and the Doppler recordings. The analysis shows the Doppler unit recorded consistently higher readings for diastolic pressure than the sphygmomanometer. There was no difference of significance between diastolic pressures on the left and right sides of the body.

Hypothesis 13. There is no significant difference between the ranked magnitude of the pulse (radial) when palpated and the ranked systolic blood pressure recording. RHO = 0.

It was acknowledged that magnitude was a subjective evaluation. In the pilot study it had been suggested by Dr. Friesen that this qualitative variable could be replaced by blood pressure measurement as this latter measure would also estimate cardiac insufficiency. To compare pulse palpation and blood pressure readings was the primary intent for introducing the Doppler and the plethysmograph. Both instruments can be adjusted to an EKG machine tracing an uncalibrated pulse contour. It was hoped that decrease in general area below the graphed pulsatile curve could vary with a ranked magnitude of the palpated pulse. Validation of the Doppler included a pulse contour.

tracing but correlation of the rise and fall of the curve was not obvious. While it is recognized that calibration has been impossible in previous studies and is notable from its absence, the ranking of the pulse data was postulated to present a broad if rough relationship between these variables. This did not prove to be the case; consequently relationship was confined to data between pulses and blood pressure measurements.

Ratings for magnitude of the pulse were:

1 = Absent

2 = Barely palpable

3 = Present and weak

4 = Present and firm

5 = Present and full

6 = Present and very full

7 = Present and bounding

8 = Corrigan pulse

The ratings for blood pressure were:

Systolic	Diastolic	Pulse Deficit
1=30	0	30
2=50	10	40
3=70	30	40
4=90	50	40
5=110	70	40
6=130	90	40
7=150	110	40
8=A difference greater than 60 mm of Hg.		

Statistical analysis demand that data are ranked for comparison from smallest to largest size. This was the justification for ranking the pressure thus. To have a difference of 10 mm between the ranking was too small, whereas a difference of 30 mm was too large to compare with pulses as described. A 20 mm Hg difference between ranking remained as the only reasonable alternative for the researcher. The difference between systolic and diastolic was established from a study of Lowenstein. (16) He had received the literature and had done a study on two tribes of Indians to try to establish any possible relationship between sex, age and blood pressures. He reported upon sevety-seven blood pressure readings. The mean difference of these blood pressures between the diastolic and systolic was 39.2 mm Hg. Therefore 40 mg differential is justified on the basis of these data.

Summary of Findings Regarding Magnitude

As a test case the right and left radial pulses were correlated to right and left systolic blood pressures recorded by sphygmomanometer.

For the left side

$$r^1 = -0.051$$

For the right side

$$r^1 = -0.080$$

Dichotomizing the variables into right and left, and agree or disagree for the paired ranked data $r\phi = 0$.

To the first place of decimal (without rounding off), the null hypothesis is supported. No correlation of any significance was found between the blood pressures (systolic) and the radial pulses in regard to magnitude when the data for both variables are ranked. This concludes statistical analyses concerning hypothese for pulse magnitude.

Validation of the Doppler

The hypothesis for validating the Doppler postulates that no relationship exists between the recordings by Doppler Unit and intra-arterial blood pressures recorded by in situ catheters containing transducers.

$$r = 0$$

The diastolic Doppler recordings were unfamiliar to the operator, particularly at the commencement of the study. They became more easily discernible as the characteristic sounds became recognizable. Analysis showed

Systolic pressure $r = +\ 0.87$

Diastolic pressure $r = +\ 0.50$

As mentioned in Chapter II, the correlation of systolic pressure was significant at 99.9 percent level of confidence. The diastolic pressure was not significant. This is possibly due to error of the researcher. The systolic pressure was easy to ascertain and the Pearson's r comparable to that of other studies reported in the literature: the diastolic correlation is much lower than is reported by other researchers. (12) This evidence when combined with the findings of A. N. O. V. #4 would seem to imply that the diastolic Doppler readings were recorded at too high a level for accurate assessment and should be interpreted from this frame of reference.

Summary of Statistical Findings

There is no significant difference between pulse rates on the left and pulse rates on the right sides of the body; however pulse rhythm recordings differs significantly at $p = 0.01$ between palpation and the monitor.

Between the different pulses the femoral and pedals were significantly different at $\alpha = 0.05$ for rate and at $p = 0.01$ for rhythm in these arteries. No differences were found in the temporal and radial arteries, nor in comparison to the apical pulse beat between each other in rate or rhythm.

There were no significant differences found between systolic recordings by any method, sphygmomanometer, Doppler or plethysmograph, all gave equally accurate results when tested at the 95 percent level of confidence. The diastolic pressure differed significantly at this level between the Doppler and the left lower recordings by sphygmomanometer medium.

The Doppler correlated with intracatheterial recordings of the blood pressure, systolic $r = 0.89$ and diastolic $r = .50$.

Pulse magnitude and ranked blood pressures had a very slightly negative and almost perfect zero relationship, virtually showing no relationship of direction or magnitude at all ($r^{1} = -0.05$ left side and $r = +0.08$ right side).

The data presented interesting factors. Serious arrhythmias occur in the older age group as illustrated in the pilot study data and the problems of advanced age, far from complicating the data in actual fact would have possibly provided situations which would test the hypotheses with greater accuracy.

The presence of ascites consistently interfered with palpation of the femoral pulses. When ascites was present three or four cases showed problems with femoral palpation; in the other patient angiograms using the femoral artery had been performed. The apical pulse, so consistently difficult to locate in the pilot study presented no problem in this research. The presence or absence of rales did not seem to affect the ease of auscultation for the apical pulse; it is interesting that the most difficult apical beat to locate (patient 9) was so consistently a problem for all members of the staff to hear, that the patient's skin had been gently marked over the precordial area where auscultation was easiest. Even the restless patient with emphysema and delirium tremens had an apical pulse which was easier to locate than patient #9. Obesity did not seem to be a relevant factor interfering with apical auscultation either, as one patient with notable cachexia manifested difficult auscultation.

There may be a relationship between the ability to palpate both femoral and pedal pulses on the same side on the same patient. When one artery is obscured, perhaps the other is also obscured to palpation, as the raw data show. There also appears to be some empirical correlation between the color, the temperature, and the presence of pedal pulses. This is not completely consistent but usually pink warm feet have palpable pedal pulses. These data are not unreasonable; good circulation in the periphery would produce these conditions.

On the whole the presence or absence of an intravenous infusion did not appear to impede radial pulse palpation as they correlate so closely with temporal rates. Medications did not seem to influence data collection. Individualized comments for each patient, interpretation of the EKG and other relevant data are found in Appendic G.

The statistical analysis indicated the unreliability of pedal pulses for nursing care designed to assess rate. It is notable that the temporal and radial arteries were very comparable as reliable indications of the pulse rates; even the apical beat did not differ significantly at 95 percent level of confidence from the pedal pulse rates. It is possible that the radial and temporal arteries may possibly be a more accurate assessment of cardiac rate than apical auscultation. The chi-square is a less exacting measure of probability of occurrence than A. N. O. V. However, the data in this study when analyzed by this statistical tool show significant differences between the monitor readings and the palpation when estimating arrhythmias between the sides of the body. If it is correct to assert that diagnoses of arrhythmias are the particular strengths of the monitor over other methods of observation (25), these data support the precariousness of palpation to estimate irregularity of cardiac rhythm. More specific examination reveals the gross error to be particularly in the femoral and pedal arteries, an error large enough to be reflected in the difference between left and right sides of the body.

It is to be regretted that the sensitivity of palpation of the magnitude of the pulse as measured by this study is open to question. The research supports the fact that a comparison between pulse and blood pressures on a ranked scale is a futile endeavor as described herein. To interpret the lack of correlation to mean lack of relationship between pressures and pulse would be gravely erroneous; the method of measurement is too precarious to draw such a conclusion and better ways to estimate this variable should be investigated.

What has been amply illustrated is that the different instuments, sphygmomanometer, Doppler and plethysmograph are, within probability limits, equally accurate measures for noting these physiological variables of the systolic blood pressure. Validation of the Doppler showed correlation with intra arterial pressures which supports the evidence found already in the literature.

The Doppler diastolic pressure was read consistently higher than the upper or lower diastolic pressures by sphygmomanometer, and validation of this tool showed a lower "r" than is reflected in other publications. This perhaps indicates the operator's initial difficulty in reading the Doppler diastolic levels. However, apart from this fact the study illustrates that nursing care can be conducted using either or all of these tools with accuracy and reliability of results for patient care.

Tool to Establish Variance Criteria for Pulse Rates

During collection of the data, the contingency that no significant difference existed between pulse rates by palpation was seriously considered as a possible outcome. Such a discovery would seem to support the conclusion that palpation by the nurse was a procedure which is reliable and basically accurate for rates particularly when using the radial and temporal arteries. The question arises, then, concerning the amount of variation from normal status of the pulse rate would be considered cause for patient concern, as the error is not likely to be because of poor nursing technique. Accordingly a measuring criterion to apply to this circumstance was calculated. The rationale for the calculation is to be found in Appendix E. The Variance Criteria for Pulse Rates is suggested as follows:

Pulse rates of 100 - range ± 5

Pulse rates of 90 - range ± 4.5

Pulse rates of 80 - range ± 4

Pulse rates of 70 - range ± 3.5

Pulse rates of 60 - range ± 3

This assessment criterion has been applied to each patient in the study on an individual basis, but has not been tested specifically. The range refers to that variation which will be acceptable as being within normal limits. Any pulse rate change beyond this range (over or below) would constitute a cause for a nursing diagnosis to initiate change. It is obvious that a fractionalized beat is not possible to assess. In applying it to the rates in this study, the larger whole number was used if the pulse was over the specified rate, the smaller if under. For example pulses of 70 or over have an acceptable variance of plus or minus 4, but 69 and under the variance is plus or minus 3. This measuring device is meant to be a guide and must be interpreted in regard to total patient care. It has the advantage that it is simple to remember, easy to apply, and is based on empirical scientific analysis. It is seen as a tool to be used particularly in the community where nursing decisions are independent and important. It is also possibly a means of assisting in the education process, providing a baseline for student performance of precision when teaching fundamental nursing care procedures regarding pulse palpation.

The results of this investigation do not supply enough evidence to call for a change in nursing action to include palpation of pulses on both sides of the body for each patient in regard to rate. The grave discrepancy in the pilot study regarding accurate assessment of the apical beat was generally not indicated in this sample; nor was there as much arterial occlusion, with the exception of the femoral arteries, to interfere with nursing care.

It is notable that accuracy of nurse action is evident in regard to rate. This is supported by the agreement in pulse rates between the radial and temporal arteries, even though they are palpated consecutively. It is possible that inference be drawn comparing the accuracy of the monitor to palpation which is also quite evident. It should be remembered that these patients have cardiac conditions. The monitor assumes precedence over palpation in the coronary care unit specifically in regard to rhythm and operationally in regard to rates, rendering palpation of rates unnecessary. Note that rate calculated by counting Q. R. S. complexes is equally as accurate as calculating the rate of measuring $R\text{-}R_1$.

Problems of peripheral circulatory collapse remained undefined. The presence or absence of palpable pulses in the cardiac unit still appears to have merit as a procedure denoting presence or absence of pulsation due to this research supporting that the lower extremities show inconsistency in regard to this factor.

CHAPTER IV

SUMMARY

The general purpose of this study was to establish the importance and reliability of palpation of the pulse in patients on monitoring systems.

A purposive sample of fifteen male patients age 45-75 were included in this study made in the Cardiac Care Unit of the Veteran's Administration Hospital, Portland, Oregon. Each patient was on a cardiac monitor Sanborn 780. The radial, temporal, femoral, and pedal pulses were palpated and compared for rate and rhythm to the monitor tracings, and the apical beat was auscultated for the same factors. Pulse magnitude was ranked and compared to ranked blood pressures which were recorded by sphygmomanometer, Doppler Ultrasonic Unit and a plethysmograph. Pulse contour tracings were made through the Doppler Ultrasonic Unit, and the strain gauge plethysmograph.

The results were used to compare palpation of each artery to the rest and to compare the rates and rhythm to the right and left sides of the body. Blood pressures recorded by the sphygmomanometer from the right and left sides of the body were contrasted, as were blood pressures recorded by the Doppler and plethysmograph.

The monitor results were used as a control against which to compare the accuracy of the observations.

RESULTS

Significant differences at the 95 percent level of confidence were found between the pedal arterial rate, and radial and temporal rates. Femoral and pedal pulses differed significantly in rhythm to the monitor findings, at $p = 0.001$ as did the left and right sides of the body regarding palpated rhythm when compared to the tracings. No significant difference in blood pressure readings were found either right or left, or between the different measuring tools. The pulse contour did not show any relevance to pulse magnitude; nor did any correlation result between pulse magnitude and blood pressure readings.

The Doppler was validated by correlation with intra-arterial pressures. This resulted in a Pearson $r = 0.89$ for systolic pressure and Pearson $r = 0.50$ for diastolic. A measuring tool for nursing assessment of a pathological variance of pulse rates based on EKG tracing procedures was submitted for consideration. It was concluded that nursing palpation of radial temporal and apical pulses was in fact reliable and accurate. The monitor made rate and rhythm calculation by palpation redundant, but palpation of the lower extremities remained useful to identify absence or presence of palpable pulses when administering nursing care in the cardiac care unit. Palpation for pulse rates on the left or right sides of the body did not differ significantly, nor did systolic blood pressure recordings. The study illustrates that systolic blood pressure readings were equally reliable when taken by sphygmomanometer, Doppler or plethysmograph but a significant difference at the 95 percent level of confidence occurred between the Doppler diastolic pressure readings and the lowest diastolic recording by the sphygmomanometer. It is suggested that this is due to the relative difficulty of locating diastolic levels upon initiating the use of the Doppler unit. In general, nursing care using these instruments is appropriate and accurate.

IMPLICATIONS FOR FURTHER STUDY

A study with comparable hypothesis would benefit from being confined to the grossly arrhythmic cardiac patient with a repeat measures design to reduce error sources. This study has not statistically indicated that the monitor is more accurate than palpation for assessing rates. Such a study design would perhaps establish this as a fact. The magnitude of the pulse and its possible correlation with blood pressure recordings remains unanswered and presents an interesting challenge for further studies. It is of interest to postulate a pulse contour which may be characteristic of each patient. If this were true, what implication for nursing care would variation from this contour imply?

Pedal pulses and femoral pulses may have some consistent relationship regarding presence and absence. The appearance of the skin of the feet both in color and turgor should be correlated with palpable pedal pulses to establish any significance for nursing observations. Could the Doppler be used to locate pedals with greater accuracy than the sphygmomanometer? Is the Doppler a more useful tool in the community for care of the atherosclerotic patient? Can it indicate the gradual or precipitate occlusion of peripheral arteries in time to take action for tertiary prevention? The Doppler is a highly accurate measuring tool for the systolic blood pressure and may be more versatile than a sphygmomanometer for nursing care. Due to the fact that one patient in this study was hemoplegic, the postulation of difference in pulses due to stroke in the affected and inaffected side was formulated and would bear further investigation.

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APPENDICES

APPENDIX A

CORRESPONDENCE

6/1/70 c/c J.Boyle
L.Gregerson
E. Schindler

VETERANS ADMINISTRATION
HOSPITAL
SAM JACKSON PARK
PORTLAND, OREGON 97207
May 28, 1970

YOUR FILE REFERENCE:

IN REPLY REFER TO: 648/118
MI:hr

Mrs. Maxine Patrick
University of Oregon School of Nursing
3181 S.W. Sam Jackson Park Road
Portland, Oregon 97201

Dear Mrs. Patrick:

After my conversation with you the other day, I thought it would eliminate any further delay on Mrs. Chavign's study if I sent you the requirements as specified by Dr. Paul E. Shick, Chief of Staff.

Quoting a memorandum from Doctor Shick:

"Subject: Research Projects

1. Nursing students desiring to perform research using patients in this hospital should describe their projects in writing and detail what is to be done to the patient.

2. There should be written approval by their instructor, VA Nursing Service, the Section Chief, and the verbal consent of the patient.

3. If there is possibility of adverse effect or accident, there should be written consent by the patient.

4. The Station Research Committee does not desire to review these proposals."

Mrs. Chavigny just stopped in and gave me the thesis proposal. All we need now is a statement of her instructor's approval.

I am enclosing a copy of the above requirements for you to give to Mrs. Chavigny.

Sincerely

[redacted]

Associate Chief, Nursing Service
for Education

Encs.

UNIVERSITY OF OREGON SCHOOL OF NURSING

INTER-SCHOOL MEMORANDUM

TO: Mrs. Marguerite Ingle

Date June 1, 1970

FROM: Lucile Gregerson

This is to express approval of the study tentatively titled "Palpation of the Pulses on Monitored Patients" to be carried out at the Portland Veterans Administration Hospital by Mrs. Katherine Chavigny. We very much appreciate your interest and cooperation.

VETERANS ADMINISTRATION
HOSPITAL
SAM JACKSON PARK
PORTLAND, OREGON 97207

June 12, 1970

YOUR FILE REFERENCE:

IN REPLY REFER TO: 648/118
MI:hr

Mrs. Maxine Patrick
Professor, Medical-Surgical Nursing
University of Oregon School of Nursing
3181 S. W. Sam Jackson Park Road
Portland, Oregon 97201

Dear Mrs. Patrick:

We have approval for Mrs. Chavingny to gather data for the research project at the Portland Veterans Administration Hospital.

Will you please inform her approval has been granted?

Sincerely,

[redacted]

Associate Chief, Nursing
Service for Education

6/22/70 c/c to Mrs. Chavigny

APPENDIX B

USE OF THE ELECTROCARDIOGRAPH MACHINE

APPENDIX B

USE OF THE EKG MACHINE

It had first been planned to use the 760B Sanborn EKG machine to record the pulse contour tracings from both the Doppler and the plethysmograph. The connector wire from the Doppler is constructed with a phalange plug which is placed in the D. C. outlet of the appropriate EKG machine. The plethysmograph connecting wire has a five-pronged plug and the outlet is labelled on the back of the machine. The 760B Sanborn was unable to transduce the electrical input from the Doppler, but could possibly have been adjusted by the placement of a jack after the pre-amplifier. This would have necessitated an adjustment for all the machines in the C. C. U. causing considerable inconvenience to staff and to patient care.

Four patients were examined and data compiled using the Doppler unit which was plugged into the DC outlet of the 100 EKG machine. The plethysmograph tracings were taken on the 780B Sanborn. Unfortunately the tracings procured were mirror images of the contours and all data had to be discarded.

Of these four patients one was readmitted later and one remained in the Care Unit long enough for the data to be taken again with his permission. During the second instance, it became obvious that enough difference existed between the first and second readings in both these patients that it is questionable whether the researcher's insistence on using different patients for each set of observations was necessary. In fact, five patients carefully chosen for the diagnosis of severe arrhythmias and repeat measures for two days, could in fact, have been the design of choice.

APPENDIX C

EXTRA OBSERVATIONS REGARDING PROCEDURES

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EXTRA OBSERVATIONS REGARDING PROCEDURES

The blood pressure by sphygomomanometer was taken on Patient #1 upon his first day admission into the unit. These data had to be discarded due to operational difficulties involved. It was, however, noticed that the left arm registered a systolic pressure of 50 mm hg higher than the right arm. The experimenter repeated the measures three times in each arm, the last readings being taken after removal of the cuff and replacement of same, in case some inadvertent factor had interfered with the placement of the apparatus. The readings retained the 50 mm disparity. However, on returning two days later with the equipment in good working order, and again having received permission from the patient to repeat the readings, this phenomenon had disappeared. Perhaps pertinent to these observations is the fact that there was some renal failure and emboli formation which may have prevailed in the first readings, but had been resolved by the time of the second reading.

APPENDIX D

VALIDATION OF THE DOPPLER

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VALIDATION OF THE DOPPLER

Permission was obtained from Doctor Vian to take Doppler readings in the Surgical Unit at the Veterans Administration Hospital, as no patients in the C. C. U. had evidenced the need for intra-arterial catheters. Accordingly Dr. T. L. Anderson, surgeon in residence, was consulted about the practicality of obtaining some readings in the Surgical Intensive Care Unit on one of his post-surgical patients. With his approval, ten readings were procured from a patient with repair of mitral stenosis who had an intra-arterial catheter inserted in the left radial artery halfway between the anti-cubital fossa and the wrist. With the help of the head nurse in the unit, who read the diastolic and systolic pressure registered on the computer, ten observations were made between the Doppler readings and the intra-arterial catheter readings.

The results were:

	Intracatheter Recording of Blood Pressure Systolic over Diastolic	Doppler Recording of Blood Pressure Systolic over Diastolic
Trial 1.	174/90	170/90
2.	175/84	174/85
3.	164/87	160/80
4.	177/90	178/80
5.	183/90	180/88
6.	162/92	168/88
7.	174/86	178/84
8.	160/96	170/90
9.	158/88	160/88
10.	155/88	160/80

It is generally conceded that the blood-pressure as recorded within the artery itself is the desired criterion for accurate measurement of this physilogical manifestation. It suffers, however, from the disadvantage that assault to the patient must be performed to place the instrument in the lumen of the artery. Even from these raw data, a degree of accuracy of recording between the Doppler and the intra-arterial readings is obvious, though a greater discrepancy occurs in the diastolic recordings rather than the systolic. Doppler pulse contours were taken at the same time; it was apparent, however, that the Doppler contour did not fluctuate up or down in accordance with the rise or fall in blood pressure so that a comparison between the area below the Doppler curve and pulse magnitude was impractical.

These readings represent a validation of the Doppler's accuracy even without statistical interpretation, fact which has been illustrated competently in the literature. The readings also provided an opportunity to compare the diastolic observations of the operator with documented evidence of the intra-arterial pressure. The systolic pressure, being a presence or absence of sound is objective; the diastolic pressure requires practice and experience before competence in interpretation can be acquired.

> Pearson's $r = 0.87$ (significant at 0.001 level) for systolic pressure and $r = 0.50$ for the diastolic. (See Appendix F for statistical calculation.)

This is consistent with the raw data observations and seems to consolidate previous data obtained regarding the accuracy of Doppler recordings. The lower correlation of the diastolic readings perhaps reflects the greater inaccuracy of the researcher when collecting these data, and should be assessed in combination with the possibility of this error.

APPENDIX E

MEASURING TOOL TO ESTABLISH VARIANCE CRITERIA FOR ASSESSING PATHOLOGICAL CHANGE IN PATIENT PULSE RATES

APPENDIX E

MEASURING TOOL TO ESTABLISH VARIANCE CRITERIA FOR ASSESSING PATHOLOGICAL CHANGE IN PATIENT PULSE RATES

Irregularity of rhythm is denoted by a difference of 3 mms measured between the R peaks of the Q. R. S. complexes. This principle of denoting abnormality by variation of the differences between the $R_1 R_2 R_x$ can be applied to pulse rates also in the following way.

The range of mm of differences between the R's in this study was approximately 15-30 mm between $R_1 - R_2 - R_x$; by calculation this is equal to 100 pulse rate per minute and 50 pulse rate per minute as it takes one minute for 1, 500 mms of the EKG tracing paper to run through the machine. $[\frac{1500}{15}$ and $\frac{1500}{30}]$ This also illustrates that the smaller the $R - R_1$ the faster the pulse. If one estimates a range which is a plus or minus one mm on each side of any R of the QRS for a pulse rate when the rhythm is regular, a graded measuring tool will result as follows:

When the pulse rate is 100 the range will be 10 ($\pm$ 5)

When the pulse rate is 90 the range will be 9 ($\pm$ 4. 5)

When the pulse rate is 80 the range will be 8 ($\pm$ 4)

When the pulse rate is 70 the range will be 7 ($\pm$ 3. 5)

When the pulse rate is 60 the range will be 6 ($\pm$ 3)

When the pulse rate is 50 the range will be 5 ($\pm$ 2. 5)

The range in this case is that variation which will be acceptable as possible error or by chance variance. Any pulse rate change beyond this range (over or below) would constitute a cause for nursing diagnosis and consideration for action for patient comfort. Thus, it constitutes a quick measuring device for accuracy of pulse palpation of rate. For example the slight changes of 2-3 beats below a pulse rate of 60 in a digitalized patient, would be ample cause for concern; a change from 100 to 105 would be necessary to cause concern in the higher levels of rate. As is usual, measuring devices are guidelines and must be interpreted in the frame of reference of total patient needs for total patient care. This tool is easy to remember and simple to apply. It forms a baseline for acceptance or lack of acceptance of accuracy of palpation for data collected by student nurses. Though empirical evidence points to slight differences between pulses left and right, the difference is not significant. The question arises concerning what difference would be significant. This tool represents a possible measure which is easy and logical.

Tachycardia is defined as rates above 100 and bradycardia as rates below 60 (inclusive). Accordingly this tool is designed to exclude both these extremes and is intended to cover the range usually denoted as normal status. Calculations by logarithm to six places result in this variance criteria as follows:

Calculation for Variance Criterion for Pulse Rates

mm $R_1 - R_2 = x$	$\frac{1500}{x}$	Pulse Rate	Ranking
15	Log 3.176091 1.176091 2.000000	100 (100)	0
15	Log 3.176091 1.204120 1.971971	93.7497(94)	1
17	Log 3.176091 1.230449 1.945642	88.24349(88)	2
18	Log 3.176091 1.255273 1.920818	83.3335(83)	3
19	Log 3.176091 1.278754 1.897337	78.9478(79)	4
20	Log 3.176091 1.301030 1.875061	74.9998(75)	5
21	Log 3.176091 1.322219 1.854872	71.4282(72)	6
22	Log 3.176091 1.342423 1.834668	68.3392(68)	7

When the variance is set at $\pm$ 1mm the calculations are as follows:

$x=R_1-R_2$	Range $\pm$1mm	Ranking	Calculation of Range $\pm$ 1	Pulse Rate Range
16	15-17	0-2	100.000 -88.2449	11.7631
17	16-18	1-3	93.7497-83.3335	10.4161
18	17-19	2-4	88.2349-79.9478	9.2991
19	18-20	3-5	83.3335-74.9998	8.3337
20	19-21	4-6	78.9478-71.4282	7.5196
21	20-22	5-7	74.9998-68.3392	6.6606

Using whole numbers

Pulse Rates		Approximate Range Values
94	100-88	Range 11.8
88	93-83	Range 10
83	88-79	Range 9
79	83-74	Range 8
75	79-72	Range 7
68	74-68	Range 6

For ease of computation and ease of recall the following assessment criteria for pulse rate change is suggested.

Pulse Rate of	$\overline{X}$	
95-105	100	10 $\pm$ 5
85-95	90	9 $\pm$ 4.5(over 90+5 under 90+4)
75-85	80	8 $\pm$ 4
65-75	70	7 $\pm$ 3.5(over 70+4 under 70+3)
55-65	60	6 $\pm$ 3

In actual practice it is suggested that if the pulse rate is over the mean of the range for those values including a decimal that the higher value be considered for those pulses below and including the mean the lower value be considered as the range. Rates over 100 is defined as tachycardia - below 60 as bradycardia and is not included in this measuring tool.

APPENDIX F

CALCULATIONS OF STATISTICS

APPENDIX F

ANALYSIS OF VARIANCE #1

Hypothesis

Arterial pulse rates in the left side of the body are equal to arterial pulse rates on the right side of the body.

All pulse rates are equally representative of each other and do NOT differ significantly.

Generalized Hypothesis

$H_o = \mu_{11} = \mu_{12} = \mu_{25}$

$H_1 = \text{Not } H_o$

Let a = left and right sides of body
Let b = diferent pulses
So That b_1 = radial pulses
b_2 = temporal pulses
b_3 = femoral pulses
b_4 = pedal pulses
b_5 = apical pulse (included for each side a_1 or a_2)

Decision Rules

$p = 2 \quad q = 5 \quad n = 15$

1) For interaction AB Reject H_1

$F \text{ obs} > F_{1-\alpha}\left[(p-1)(q-1)pq(n-1)\right]$

$F \text{ obs} > F_{.95}\ (4,\ 140)$

$F \text{ obs} > 2.44$

2) For main effect B Reject H_1

$F \text{ obs} > F_{1-\alpha}\left[(q-1)pq(n-1)\right]$

$F \text{ obs} > F_{.95}\ (4,\ 140)$

$F \text{ obs} > 2.44$

3) For main effect A Reject H_1

$F \text{ obs} > F_{1-\alpha}\left[(p-1)pq(n-1)\right]$

$F \text{ obs} > F_{.95}\ (1,\ 140)$

$F \text{ obs} > 3.91$

a_1 = left side a_2 = right side b_1 = radial rates b_2 = temporal rates b_3 = femoral rates b_4 = pedal rates b_5 = apical rates

	b_1					b_2					b_3					b_4					b_5				
Left a_1	72	68	68	94	96	70	66	68	92	96	68	68	92	0	0	68	64	92	0	80	74	72	70	56	94
	60	72	74	68	74	56	76	74	70	78	60	80	70	80	0	0	72	76	0	82	58	72	78	74	0
	78	94	70	72	84	74	82	70	66	84	60	0	88	62	68	0	0	72	33	78	72	76	68	66	82
Right a_2	70	72	66	100	94	72	72	70	100	94	68	64	100	62	78	66	66	94	0	0	74	72	70	56	94
	58	74	78	64	72	62	74	72	70	80	66	76	68	64	100	78	72	66	66	0	58	72	78	74	0
	80	88	70	66	84	68	82	66	68	84	0	0	78	62	84	94	0	82	68	68	72	76	68	66	82

AB Summary Table $n = 15$

	b_1	b_2	b_3	b_4	b_5	A's
a_1	1144	1122	802	717	1012	4797
a_2	1136	1134	970	840	1012	5092
B's	2280	2256	1772	1557	2024	9889 = N(G)

Computational Formulae for the A. N. O. V.

1) $$\frac{G^2}{nqp} = \frac{9889^2}{15 \times 2 \times 5} = \frac{97792321}{150} = 651948.806$$

2) $$x^2 = 787369$$

3) $$\frac{(A)^2}{nq} = \frac{23011209 + 25928464}{nq = 75} = 652528.973$$

4) $$\frac{(B)^2}{np} = \frac{19948745}{np = 30} = 664958.166$$

5) $$\frac{(AB)^2}{n} = \frac{9996153}{15} = 666410.200$$

Computing the Sums of Squares

			Sums of Squares	dF
SS_A =(3)-(1) =	652528.973 651948.806	=	580.167	($\overset{p-1}{q}$-1) = 1
SS_B =(4)-(1) =	664958.166 651948.806	=	13009.360	(q-1) = 4
SS_{AB}=(5)-(4)-(3)+(1) =	1318359.006(5+1) 1317487.139(4+3)	=	871.867	(p-1)(q-1) = 4
Within Cell Error = (2)-(5) =	787369.000 666410.200 120958.800	=	120958.800	pq(n-1) = 140
Check SS Total = (2)-(1) =	787369.000 651948.806	=	135420.194	npq-1 = 149

A. N. O. V. #1 Summary Table

Source of Variation	Sums of Squares	dF	Means of Squares	F
A (Sides of Body)	580.167	1	580.167	< 1
B (Pulse Rates)	13009.360	4	3252.340	3.7*
AB	871.867	4	217.967	F < 1
Within Cell Error	120958.800	140	863.991	
Total		149	4914.465	

Inspection of Summary Table indicates the need for an individual comparison of the means of the rates of the different pulses, (B), by Newman-Keuls procedure.

Table $\overline{AB}$

	b_1	b_2	b_3	b_4	b_5
a_1	74.27	74.80	53.47	47.80	67.47
a_2	75.73	75.60	64.67	56.00	67.47
$\overline{B}$	75.00	75.20	59.07	51.90	67.47

$\overline{B}_1 = b_4 =$ pedals
$\overline{B}_2 = b_3 =$ femoral
$\overline{B}_3 = b_5 =$ apicals
$\overline{B}_4 = b_1 =$ radial
$\overline{B}_5 = b_2 =$ temporal

Ordered Means	$\overline{B}_4$	$\overline{B}_3$	$\overline{B}_5$	$\overline{B}_1$	$\overline{B}_2$
	51.9	59.07	67.47	75.00	75.20

<u>Newman-Keul</u>

dF of within cell error=140

	$\overline{B}_1$ 51.90	$\overline{B}_2$ 59.07	$\overline{B}_3$ 67.47	$\overline{B}_4$ 75.00	$\overline{B}_5$ 75.20
$\overline{B}_1$		7.17	15.57	23.10*	23.30*
$\overline{B}_2$			8.40	15.93	16.30
$\overline{B}_3$				7.53	7.73
$\overline{B}_4$					0.20
$\overline{B}_5$					

(r, 140)		2	3	4	5
	q·95	2.27	3.31	3.63	3.86
$S_{\overline{X}}$	q·95	13.10	17.76	19.48	20.61
	q·99	3.64	4.12	4.40	4.60
$S_{\overline{X}}$	q·99	19.53	22.11	23.61	24.69

$$S_{\overline{X}} = S_{\overline{B}} = \sqrt{\frac{S^2}{Np}}$$

$$= \frac{\text{MS WC error}}{n \times p}$$

$$= \sqrt{\frac{863.991}{30}}$$

$$= \sqrt{28.80}$$

Log =

$= 0.729686$

Anti-log $= \underline{5.36636}$

Log of 5.36636

= 0.729686 + 0.442480 = 1.172166 = 2.77

= 13.0981

0.729686 + 0.519828 = 1.249514 = 3.31

17.7627

0.729686 + 0.559907 = 1.289593 = 3.63

19.480

0.729686 + 0.584331 = 1.314017 = 3.86

20.6072

0.729686 + 0.561101 = 1.290787 = 3.64

19.530

0.729686 + 0.614897 = 1.344583 = 4.12

22.1096

0.729686 + 0.643453 = 1.373129 = 4.40

23.6113

0.729686 + 0.662758 = 1.392444 = 4.60

24.6854

<u>Summary of Newman-Keuls</u>

Those means underlined by a common line do NOT differ from one another. All other means differ at the 0.05 level of significance.

$\bar{B}_1 \quad \bar{B}_2 \quad \bar{B}_3 \quad \bar{B}_4 \quad \bar{B}_5$

$\bar{B}_1$ = pedal pulse = b_4

$\bar{B}_2$ = femoral pulse = b_3

$\bar{B}_3$ = apical pulse = b_5

$\bar{B}_4$ = radial pulse = b_1

$\bar{B}_5$ = temporal pulse = b_2

Analysis of Data

AB There is no interaction and thus no contamination of the data comparing the sides of the body and the rates of the radial, temporal, femoral, pedal pulses and apical pulse and data can be analysed accordingly.

A No significant differences in pulse rates were found between taking pulses in the left side of the body versus the right side. It therefore indicates no particular difference more than chance error would operate when taking pulse rates on the left or right sides of this population of patients.

B There is no significant difference at the 95 percent level of confidence in recording rates of the pulses at different places in the body. This difference occurs between the temporal arteries and pedal arteries and also the radial arteries and pedal arteries. Though the data show a large deviation between the mean of the apical pulse rate and that of the pedal rates, no significance was calculated in this study. For these cardiac patients, the reliability of the pedal pulses for recording rates is highly questionable, if one assumes that the correct reading is given by radial and temporal pulse rate recording.

ANALYSIS OF VARIANCE #2

#1 There is no significant difference between monitor rates on left or right sides of the body. (A's)

#2 There is no significant difference between the pulse rates of each artery recorded by the monitor and the palpation of the rates of the same artery. (B's)

#3 There is no significant difference between the different pulse rates (C's) (particularly the apical monitor rate and the radial pulse rate.). (C's)

Generalized H_o

$H_o = \mu_{111} = \mu_{112} \cdots\cdots = \mu_{225}$

H_1 = NOT H_o

<u>Decision Rules</u>

1) For interaction ABC Reject H_o	$F\ obs > F_{1-\alpha}[(p-1)(q-1)(r-1); (q-1)(r-1)p(n-1)]$ $F\ obs > F_{.95}\ (4, 112)$ $F\ obs > 2.45$
2) For interaction BC Reject H_o	$F\ obs > F_{1-\alpha}[(q-1)(r-1); (p-1)(q-1)p(n-1)]$ $F\ obs > F_{.95}\ (4, 112)$ $F\ obs > 2.45$
3) For interaction AC Reject H_o	$F\ obs > F_{1-\alpha}[(p-1)(r-1); (p-1)p(n-1)]$ $F\ obs > F_{.95}\ (4, 112)$ $F\ obs > 2.45$
4) For interaction AB Reject H_o	$F\ obs > F_{1-\alpha}[(p-1)(q-1); p(n-1)(q-1)]$ $F\ obs > F_{.95}\ (1, 28)$ $F\ obs > 4.20$

5) For main effect C
Reject H_o

$F_{obs} > F_{1-\alpha}[(r-1); (r-1)p(n-1)]$

$F_{obs} > F_{.95}\ (4, 112)$

$F_{obs} > 2.45$

6) For main effect B
Reject H_o

$F_{obs} > F_{1-\alpha}[(q-1); p(n-1)(q-1)]$

$F_{obs} > F_{.95}\ (1, 28)$

$F_{obs} > 4.20$

7) For main effect A
Reject H_o

$F_{obs} > F_{1-\alpha}[(p-1); p(n-1)]$

$F_{obs} > F_{.95}\ (1, 28)$

$F_{obs} > 4.20$

Raw Data

	p	b_1 c_1	b_1 c_2	b_1 c_3	b_1 c_4	b_1 c_5	b_2 c_1	b_2 c_2	b_2 c_3	b_2 c_4	b_2 c_5	p's
a_1	1	72	70	0	0	74	71	71	71	69	72	570
	2	68	66	68	68	72	69	69	69	70	70	680
	3	68	68	68	64	70	72	67	65	70	70	682
	4	94	92	92	0	56	95	96	94	94	93	806
	5	96	96	0	92	94	93	93	93	93	92	842
	6	60	56	60	0	58	56	61	63	65	62	541
	7	72	76	0	0	72	76	75	77	76	74	598
	8	74	74	80	80	78	77	76	85	84	80	778
	9	68	70	70	72	0	71	72	74	76	70	643
	10	74	79	80	76	74	78	81	78	79	76	774
	11	78	74	66	82	72	81	85	85	91	80	794
	12	94	82	68	0	76	90	88	89	92	80	759
	13	90	70	62	72	68	73	82	82	84	74	757
	14	72	66	0	33	66	65	64	64	65	64	559
	15	84	84	0	78	82	85	82	88	89	82	754
a_2	1	70	72	0	0	74	69	71	71	70	72	569
	2	72	72	68	66	72	71	70	67	69	70	697
	3	66	70	64	66	70	70	68	69	70	70	683
	4	100	100	100	0	56	95	94	94	94	93	826
	5	94	94	0	94	94	93	92	93	92	92	838
	6	58	62	62	0	58	58	59	56	63	62	538
	7	74	74	0	0	72	76	74	76	77	74	597
	8	78	72	78	78	78	78	77	80	84	80	783
	9	64	70	66	72	0	71	71	75	77	70	686
	10	72	80	76	0	74	80	80	78	82	76	698
	11	80	68	78	82	72	83	85	86	90	80	804
	12	88	82	0	0	76	93	84	86	94	80	683
	13	70	66	62	68	68	76	82	84	83	74	733
	14	66	68	0	85	66	65	64	64	64	64	606
	15	84	84	84	88	82	85	83	84	86	82	842
Σ C's		2300	2256	1452	1416	2024	2315	2316	2340	2392	2278	G=21089

$\Sigma\ p^2 = 7,537,615$

Summary ABC

	b_1 c_1	b_1 c_2	b_1 c_3	b_1 c_4	b_1 c_5	b_2 c_1	b_2 c_2	b_2 c_3	b_2 c_4	b_2 c_5	A's
a_1	1164	1122	714	717	1012	1152	1162	1177	1197	1139	10556
a_2	1136	1134	738	699	1012	1163	1154	1163	1195	1139	10533
Σ BC	2300	2256	1452	1416	2024	2315	2316	2340	2392	2278	G=21089

$\Sigma\ BC^2$ 45,699,101.00

$\Sigma\ A^2 = 222,373,225$

$\Sigma\ x^2 = 1,631,022$

$G^2 = 444,745,921$

Calculations for degree of Freedom.

a_1 = left side of body	b_1 = palpation	c_1 = radial
a_2 = right side of body	b_2 = monitor	c_2 = temporal
		c_3 = femoral
		c_4 = pedal
		c_5 = apical

N = 15 a = 2 = p b = 2 = q c = 5 = r

Between Subjects	np-1 =	29
A's	p-1 =	1
S/W/gr	p(n-1) =	28
With Subjects	np(qr-1) =	270
B's	(q-1) =	1
AB	(p-1)(q-1) =	1
Bx s/w/gr	p(n-1)(q-1) =	28
C's	(r-1) =	4
AC	(p-1)(r-1) =	4
Cx s/w/gr	(r-1)p(n-1) =	112
BC	(q-1)(r-1) =	4
ABC	(p-1)(q-1)(r-1) =	4
BCx s/w/gr	(q-1)(r-1)(n-1) =	112

[Between = 29 [check]
A + S/W/gr = 29]

Total dF npqr-1 300-1 = 299 [Between + Within = Total]
29 + 270 = 299

AC Table

	c_1	c_2	c_3	c_4	c_5	
a_1	1164 1152	1122 1162	714 1177	717 1197	1012 1139	
a_2	1136 1163	1134 1154	738 1163	699 1195	1139 1012	
ΣC	4615	4572	3792	3808	4302	21089

$$\Sigma c^2 = 45,699,101$$

	c_1	c_2	c_3	c_4	c_5
a_1	2316	2284	1891	1914	2151
a_2	2299	2288	1901	1894	2151
	4615	4572	3792	3808	4302

$$AC^2 = 44,794,733 \div 30$$

$$= 1,493,159.133$$

AB Table

	b_1	b_2	
a_1	4729	5827	10, 556
a_2	4719	5814	10, 533
	9448	11641	21, 089

$$B^2 = 89,264,704 + 135,512,881 = 224,777,585$$

$$AB^2 = 4729^2 + 5827^2 + 4719^2 + 5814^2 = 112,388,927 \div 75$$

$$= 1,498,519.026$$

Computational Formulae

1) $\frac{G^2}{npqr} = \frac{21089^2}{15 \times 2 \times 2 \times 5} = \frac{444,745,921}{300} = 1,482,486.400$

2) $\Sigma x^2 = 1,631,022.000$

3) $\Sigma A^2 = \frac{10556^2 + 10533^2}{15 \times 2 \times 5} = \frac{222,373,275}{150} = 1,482,488.166$

4) $\Sigma B^2 = \frac{9448^2 + 11641^2}{15 \times 2 \times 5} = 1,498,517.233 = [224,777,585 \div 150]$

5) $\Sigma C^2 = \frac{4615^2 + 4572^2 + \cdots 4302^2}{15 \times 2 \times 2} = \frac{89,588,741}{60} = 1,493,145.683$

6) $\Sigma AB^2 = \frac{4729^2 + 5827^2 + 4719^2 + 5814^2}{15 \times 5} = 1,498,519.026 = \frac{112,388,927}{75}$

7) $\Sigma AC^2 = \frac{2316^2 + 2284^2 + \cdots 2151^2}{15 \times 2} = \frac{44,794,773}{30} = 1,493,159.133$

8) $\frac{\Sigma BC^2}{np} = \frac{2300^2 + 2256^2 + 1452^2}{30} = 1,523,303.201$

9) $\frac{\Sigma ABC^2}{n} = \frac{1164^2 + 1122^2 \cdots 1139^2}{15} = \frac{22,850,657}{15} = 1,523,377.133$

10) $\frac{\Sigma p^2}{qr} = \frac{15,105,277}{2 \times 5} = 1,510,527.700$

11) $\frac{\Sigma Bp^2}{r} = \frac{216^2 + 342^2 + 338^2 \cdots 422^2}{5} = \frac{7,675,855}{5} = 1,535,171.000$

12) $\frac{\Sigma Cp^2}{q} = \frac{143^2 + 141^2 + 71^2 \cdots 164^2}{2} = \frac{3,117,108}{2} = 1,558,554.000$

Between Subjects	(10)-(1)
A	(3)-(1)
S/w/gr	(10)-(3)
Within Subjects	(2)-(10) = 1, 631, 022. 000 - 1, 510, 527 = 120, 494. 300
B	(4)-(1)
AB	(6)-(3)-(4)+(1)
B x s/w/gr	(11)-(6)-(10)+(3)
C	(5)-(1)
AC	(7)-(3)-(5)+(1)
Cx s/w/gr	(12)-(7)-(10)+(3)

BC	(8)-(4)-(5)+(1)
ABC	(9)-(6)-(7)-(8)+(3)+(4)+(5)-(1)
BC/s/gr	(2)-(9)-(11)-(12)+(6)+(7)+(10)-(3)

Calculations of Computational Formulae

BC x s/w/q

(2) +1, 631, 022. 000
(9) -1, 523, 377. 133
(11) -1, 535, 171. 000
(12) -1, 558, 554. 000
(6) +1, 498, 519. 026
(7) +1, 493, 159. 133
(10) +1, 510, 527. 700 = 33, 637. 560
(3) -1, 482, 488. 166

AB

(6) +1, 498, 519. 026
(3) -1, 482, 488. 166
(4) -1, 498, 517. 233 = 0. 027

B

+1, 498, 517. 233
(4)(1) -1, 482, 486. 400 = 16. 030. 833
16, 030. 833

B x s/w/q

(11) +1, 535, 171. 000
(6) -1, 498, 519. 026 = 8. 612. 440
(10) -1, 510, 527. 700
(3) +1, 482, 488. 166

C

(5) +1, 493, 145. 683
(1) -1, 482, 486. 400

AC

(7) +1, 493, 159. 133
(3) -1, 482, 488. 166 = 11. 684
(5) -1, 493, 145. 683
(1) +1, 482, 486. 400

C x s/w/q

(12) +1, 558, 554. 000
(7) -1, 493, 159. 133
(10) -1, 510, 527. 700 = 37, 355. 333
(3) +1, 482, 488. 166

BC

(8) +1, 523, 303. 201
(4) -1, 498, 517. 233
(5) -1, 493, 145. 683 = 14, 126. 685
(1) +1, 482, 486. 400

ABC

(9) +1, 523, 377. 133
(6) -1, 498, 519. 026
(7) -1, 493, 159. 133
(8) -1, 523, 303. 201 = 60. 455
(3) +1, 482, 488. 166
(4) +1, 498, 517. 233
(5) +1, 493, 145. 683
(1) -1, 482, 486. 400

Summary Table

Between Subjects	28, 041. 300	29		
A	1. 766	1		
s/w/gr	28, 039. 534	28	1, 001. 411	
Within Groups	120, 494. 300	270	16, 030. 833	
B	16, 030. 833	1	0. 027	
AB	0. 027	1		
Bx s/w/gr	8, 612. 440	28	307. 587	
C	10, 659. 283	4	2, 664. 820	
AC	11. 684	4	2. 921	
Cx s/w/gr	37, 355. 333	112	333. 529	
BC	14, 126. 685	4	3, 531. 671	11. 759*
ABC	60. 455	4	15. 113	1
BCx s/w/gr	33, 637. 560	112	300. 335	
		229		

[Check 1, 631, 022. 000 - 1, 510, 527. 700 =
Total ss within groups = 120, 494. 300]

Interaction between sides of the body on pulse was not significant.

* But interaction between monitor and palpation rates is significant and data is contaminated.

H_o Concerning Cardiac Rhythm

6) There is no significant difference between the frequency of regular rhythm and the number and the frequency of regular rhythm by palpation. Regularity = $R\text{-}R_1 \leq 3$ mm or monitor tracing. Regularity = 6 irregular (not evenly spaced) beats per minute upon palpation.

7) There is no significant difference between rhythm regularity on the left and right side rates by palpation or by monitor.

8) There is no significant difference of rhythm regularity between monitor and palpation on the left side and between monitor and palpation on the right side of the body.

Rhythm is a dichotomy between regularity and irregularity, conditions which are mutally exclusive - that is, the observations are independent. The monitor readings were taken at precisely the same time as the pulse was being palpated and so these factors are also independent. The monitor readings are used on the expected frequency.

dF = 1

Generalized Hypothesis

$H_o = 0 = E$

$H_1 = 0 \neq E$

Decision Rules

Reject H_o | $x^2 \leq 6.635$ when $p = 0.01$ or
$x^2 \leq 3.841$ when $p = 0.05$

Irregular rhythm is defined as more than three mm difference R_1-R_2 on the monitor tracing. Irregularity is defined as six or more extra beats occurring in a 60 second interval out of context with even-spaced beats upon palpation.

Raw Data

	Palpation		Monitor	
	Regular	Irregular	Regular	Irregular
Radial	24	6	25	5
Apical	12	3	13	2
Temporal	22	8	24	6
Femoral	16	14	22	8
Pedal	16	14	24	6

Total Observations

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	90	108	-18	320	2.96
Irregular	45	27	+16	256	9.50
					13.46*

As the data show significance at $p = 0.01$ separate X^2's were performed to establish exact location of significance.

Temporal

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$	
Irregular	22	24	-2	4	0.169	
Regular	8	6	+2	4	0.666	
					0.835	NS

Raw Data for Comparing Left and Right Sides of the Body

Left Side (Palpation) = 40 regular, 20 irregular

Left Side (Monitor) = 48 regular, 12 irregular

Right Side (Palpation = 38 regular, 22 irregular

Right Side (Monitor = 47 regular, 13 irregular

dF = (r-1)(-1) = 1 x 1 = 1

	O		E	
Left	40	20	48	12
Right	38	22	47	13

$$X^2 = \frac{(40-48)^2}{48} + \frac{(20-12)^2}{12} + \frac{(38-47)^2}{47} + \frac{(22-13)^2}{13}$$

$$= \frac{(\bar{8})^2}{48} + \frac{(8)^2}{12} + \frac{(-9)^2}{47} + \frac{(9)^2}{13}$$

$$= \frac{64}{48} + \frac{64}{12} + \frac{81}{47} + \frac{81}{13} = \begin{array}{r} 1.36^{*} \\ 5.33 \\ 1.75^{*} \\ 6.25^{**} \\ \hline 14.69 \end{array}$$

6.695** see later

7.99** see later

Apical

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	12	13	-1	1	$\frac{1}{13} = 0.0077$
Irregular	3	2	+1	1	$\frac{1}{2} = \frac{0.5}{0.508}$

No significance

Radial

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	24	26	-2	4	$\frac{4}{26} = 0.0156$
Irregular	6	4	+2	4	$\frac{4}{4} = \frac{1.0000}{1.015}$

No significance

Femoral

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	16	22	-6	36	$\frac{36}{12} = 1.666$
Irregular	14	8	+6	36	$\frac{36}{8} = \frac{4.500}{6.166}$ *

Pedal

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	16	24	-8	64	2.666
Irregular	14	6	+8	64	$\frac{64}{8} = \frac{8.000}{10.666}$ **

The discrepancy is even greater between E and O and significance will be found at $P \geq 0.01$. **

[When NO palpation was possible the rhythm was counted as irregular as it is a deviation for the desirable norm.]

OR

Left Side Between Palpation Monitor

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	40	48	-8	64	$\frac{64}{48} = 1.362$
Irregular	20	12	+8	64	$\frac{64}{12} = \frac{5.333}{6.695}$ **

Right Side Between Palpation and Monitor

	O	E	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Regular	38	47	-9	81	$\frac{81}{47} = 1.74$
Irregular	22	13	+9	81	$\frac{81}{13} = 6.25$**
					7.99

[The apical beat was neither left nor right and so was not included in the data for this calculation.]

Analysis of Data - x^2 for Pulse Rhythm

No significant difference between left and right side of the body in depicting irregularity of rhythm or palpation, or by monitor was found.

But level of significance is $p < 0.01$ for comparison of monitor (the control) versus palpation for detecting differences between left and right, i. e. between monitor and between palpation of right sides and between monitor and palpation of left sides.

This finding possibly reflects the difference between femoral and pedal rhythm as this difference occurs in the raw data mainly between these right and left pulses.

The femoral and pedal pulses were found to differ significantly at $p < 0.02$ and $p < 0.01$ and so are unreliable pulses for detecting arrhythmias. This is possibly due in some cases to the femoral artery being used for angiograms and this also could interfere with pedal palpations. Peripheral collapse and cardiac insufficiency are other possible causes for this phenomenon.

ANALYSIS OF VARIANCE #3

A simple A. N. O. V. to compare left sphygmomanometer and right sphygmomanometer to Doppler and plethysmograph (using systolic pressure readings only) is justified if these interval data are treated as independent observations of these variable homogeneity is present but patient sampling is purposive.

Left Sphygmomanometer = T_1

Right Sphygmomanometer = T_2

Doppler = T_3

Plethysmograph = T_4

Generalized Hypothesis

$H_o = \mu_1 = \mu_2 = \mu_3 = \mu_4$

1) There is no significant difference between the systolic blood pressure on the left side of the body and on the right side as recorded by sphygmomanometer.

2) There is no significant difference between systolic blood pressure recorded by sphygmomanometer, Doppler Unit and plethysmograph.

Decision Rules

Reject H_o

$F > 1 - [(k-1)k(n-1)]$

$F > 0.95\ [3.56]$

$F > 2.76$

T_1		T_2		T_3		T_4	
x	x^2	x	x^2	x	x^2	x	x^2
126	15876	129	16641	121	14641	124	15376
113	12769	113	12769	105	11025	107	11449
117	13698	118	13924	112	12544	107	11449
86	7396	91	8281	78	6084	90	8100
90	8100	85	7225	90	8100	86	7396
114	12996	115	13225	110	12100	106	11236
107	11449	108	11664	119	14161	109	11881
108	11664	113	12769	119	14161	112	12544
114	12996	111	12321	109	11881	116	13456
98	9604	98	9604	97	9409	93	8649
104	11664	100	1000	98	9604	105	11025
123	15129	130	16900	150	22500	118	13924
129	16641	129	16641	126	15876	125	15625
128	16384	130	16900	127	16129	127	16129
126	15876	131	17141	124	15376	128	16384
1683	192233	1701	187005	1685	193591	1653	184623

$\Sigma x = 6722$

$Ga^2 = (6722)^2 = 45,185,284$

$\Sigma T^2 = (1683)^2 + (1701)^2 + (1685)^2 + (1653)^2 = 11,297.24$

Computational Formulae $(G=N) = \Sigma x$

1) $\frac{G^2}{nK} = 753088.066$

2) $x^2 = 757452$

3) $\frac{T^2}{n} = 753165.066$

Summary of A. N. O. V. #3

Source	Sums of Squares	dF	Means of Squares	F
Between treatments	77.00 (k-1)	3	25.33	F < 1 N.S.
Within treatments	4286.93 k(n-1)	56	76.05	
Total	4363.93 (nk-1)	59		

Check (2) 757452
-(1) 753088.066
4363.934

There is no significant difference at the 5 percent level of confidence between systolic blood pressure taken on the left side or right side by sphygmomanometer or plethysmograph or by Doppler.

Analysis of the Data

No significant difference at $\alpha = 0.05$ is found; thus there is nothing but chance error operating in this sample of cardiac patients between the left and right blood pressure recordings by sphygmomanometer. No difference other than chance is found between the Doppler Unit, the plethysmograph and the sphygmomanometer either, all recording equally reliably at the 95 percent level of confidence. Despite the sensitivity of the plethysmograph, to body movement, and also, in spite of technical problems requiring visual correlation of mercury level and pulse contour tracing, no difference of significance was found.

ANALYSIS OF VARIANCE #4

Diastolic Blood Pressure

T_1 = Upper Diastolic Left sphygmomanometer

T_2 = Lower Diastolic Right sphygmomanometer

T_3 = Upper Diastolic Right sphygmomanometer

T_4 = Lower Diastolic Right sphygmomanometer

T_5 = Doppler Diastolic

Generalized H_o

$H_o = \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$

1) There is no significant difference between the diastolic blood pressure recorded by sphygmomanometer on the right and left sides of the body.

2) There is no significant difference between the diastolic blood pressure recordings of sphygmomanometer and Doppler Unit.

Decision Rules

Reject H_o

$F > 1\text{-}\alpha\ [(k-1)k(n-1)]$ $\quad k = 5$

$F > .95\ [4,\ 70]$ $\quad n = 15$

$F > 2.53$

T_1	T_2	T_3	T_4	T_5
x^1	x^2			
90	74	91	75	89
85	61	85	65	75
81	70	81	70	81
63	55	70	62	60
70	67	70	70	73
85	63	90	70	85
81	75	90	90	88
75	73	75	73	94
88	80	90	85	80
80	73	78	76	84
79	75	78	75	80
87	84	70	70	115
80	78	92	82	101
78	75	95	80	85
103	93	103	88	102
$\Sigma x=1225$	$\Sigma x=1096$	$\Sigma x=1258$	$\Sigma x=1131$	$\Sigma x=1292$
$\Sigma x^2=101,213$	$\Sigma x^2=81,302$	$\Sigma x^2=106,958$	$\Sigma x^2=86,217$	$\Sigma x^2=113,752$

$\Sigma(\Sigma x^2) = 489,442$ $\quad$ $\Sigma x = 6002$ $\quad$ $(\Sigma x)^2 = 36,024,004$

Computational Formulae

1) $\frac{\Sigma G^2}{nk} = \frac{36,024,004}{15 \times 5} = 480,320,057$

2) $\Sigma x^2 = 489,442.00$

3) $\frac{\Sigma T^1}{N} = \frac{1225^2 \times 1096^2 + 1258^2 + 1131^2 + 1292^2}{15} = \frac{7,232,830.00}{15}$

$= 482,188.666$

Summary A. N. O. V. #4

Source	Sums of Squares	dF	Means of Squares	F
Between treatment	1, 868. 609	4	467. 15	4. 509**
Within treatment	7, 253. 334	70	103. 63	
Total	9, 121. 943			

[Check (2)-(1) 489, 442-480, 320. 057 = 9, 121. 943 - correct]

The null H_o is rejected and a Newman-Keul is required to compare individual means of the different diastolic pressures.

T_1 = 1225/15 = 81. 67 = 3

T_2 = 1096/15 = 73. 67 = 1

T_3 = 1258/15 = 83. 87 = 4

T_4 = 1131/15 = 75. 40 = 2

T_5 = 1292/15 = 85. 13 = 5

$T_2 = \overline{T}_1$ = 73. 67 = Lower Diastolic Left Sphygmomanometer

$T_4 = \overline{T}_2$ = 75. 40 = Lower Diastolic Right Sphygmomanometer

$T_1 = \overline{T}_3$ = 81. 67 = Upper Diastolic Left Sphygmomanometer

$T_3 = \overline{T}_4$ = 83. 87 = Upper Diastolic Right Sphymomanometer

$T_5 = \overline{T}_5$ = 85. 13 = Doppler Diastolic

	$\bar{T}_1$	$\bar{T}_2$	$\bar{T}_3$	$\bar{T}_4$	$\bar{T}_5$
	(1)	(2)	(3)	(4)	(5)
	73.67	75.40	81.67	83.87	85.13
$\bar{T}_1$		1.73	8.00	10.20	11.46*
T_2			6.27	8.47	9.73
T_3				2.20	3.46
T_4					1.26
T_5					

$$S_{\bar{X}} = \sqrt{\frac{ms/wc}{n}}$$

$$= \sqrt{\frac{103.63}{15}}$$

$$= 2.62845$$

R = 70	2	3	4	5
$S_{\bar{X}}$ q.95(r, 70)	2.83	3.80	3.74	3.98
$S_{\bar{X}}$ q.99(r, 70)	7.415	8.938	9.831	12.621

All those means underlined do NOT differ significantly at the 95 percent level of confidence.

$$\underline{\bar{T}_1\bar{T}_2\bar{T}_3\bar{T}_4}\,\bar{T}_5$$

T_1 differs from T_5

The lower diastolic by sphygmomanometer differs from Doppler diastolic.

Analysis

The Doppler readings are consistently higher than all diastolic sphygmomanometer readings: (From the lowest sphygmomanometer readings from the Doppler differ greater by chance, the Doppler readings running consistently higher.) The sphygmomanometer gives consistent readings with no difference between the sides of the body.

r^1 = RHO Correlation Coefficient

$H_o = R^1 = 0$

Left Pulse	Left Blood Pressure	D	D^2	Right Radial Pulse	Right Blood Pressure	D	D^2
4	6	-2	4	4	6	-2	4
3	5	-2	4	3	5	-2	4
4	5	-1	1	3	5	-2	4
5	4	1	1	5	4	+1	1
3	4	-1	1	3	4	+1	1
3	5	-2	4	3	5	-2	4
4	5	-1	1	4	5	-1	1
4	5	-1	1	3	5	-2	4
4	5	-1	1	3	5	-2	4
4	4	0	0	4	4	0	0
4	5	-1	1	4	5	1	1
5	6	-1	1	4	6	-2	4
4	6	-2	4	3	6	-3	9
5	6	-1	1	5	6	-1	1
4	6	-2	4	4	6	-2	4
		ΣD^2 29				$\Sigma D^2 = 46$	

dF = 10 - 2 = 8 n = 10 pairs

$$r^1 = \frac{1-6\Sigma D^2}{n^3-n} = \frac{1-6(29)}{1000-10} \qquad r^1 = \frac{1-6\Sigma D^2}{n^3-n} = \frac{1-6(46)}{1000-10}$$

Log 173 = 2.238046
Log 3375 = 3.528274
$\overline{2}.709772$

Log 269 = 2.429752
Log 3375 = 3.528274
$\overline{2}.901478$

Antilog = - 0.051 = r^1

Antilog = -0.080 = r^1

There is a very slight negative relationship between the magnitude (ranked) and the blood pressure (ranked) on the left side. This is even smaller for the data on the right side of the body. For all practical purposes this relationship is zero in both cases. Examination of the raw data for the other pulses appeared to be much the same and the researcher accepted the results as void.

Calculations for Pulse Magnitude

As there is no significant difference between sphygmomanometer, Doppler and plethysmograph comparison it is only necessary to compare onte instrument. The sphygmomanometer and radial pulse palpation for correlation.

Though they are NOT simultaneous it is hoped to relate them in some way.

Raw data inciate great discrepancy in rating between all arteries so only radials are compared.

Radial		Blooc Pressure Systolic		Rating	
L	R	L	R	L	R
4	4	126	129	6	6
3	3	113	113	5	5
4	3	117	118	5	5
5	5	86	91	4	4
3	3	90	85	4	4
3	3	114	115	5	5
4	4	107	108	5	5
4	3	108	113	5	5
4	3	114	111	5	5
4	4	98	98	4	4
4	4	104	100	5	5
5	4	123	130	6	6
4	3	129	129	6	6
5	5	128	130	6	6
4	4	126	131	6	6

$$R\phi = 0$$

	Agree	Disagree	
Left	1	14	15
Right	1	14	15
	2	28	30

Correlation is positive.

$$\phi = \frac{ad-bc}{jklm} \quad \frac{14-14}{jklm}$$

It is obvious that the enumerator is 0 and $\phi = 0$

No correlation.

$H_o = R_\phi = 0$ between the right and left ranked radial pulse magnitude and the right and left ranked blood pressures (sphygmomanometer). The Null hypothesis is accepted.

Validation of the Doppler Unit

Systolic Pressures

No.	X	Y	X^2	Y^2	XY
1	174	170	30, 276	28, 900	29, 580
2	175	174	30, 625	30, 276	30, 450
3	164	160	26, 896	25, 600	26, 240
4	177	178	31, 329	31, 684	31, 506
5	183	180	33, 489	32, 400	32, 940
6	162	168	26, 244	28, 224	27, 216
7	174	178	30, 276	31, 684	30, 972
8	160	170	25, 600	28, 900	27, 200
9	168	160	24, 964	25, 600	25, 280
10	155	160	24, 025	25, 600	24, 800
Total	1, 682	1, 698	283, 724	288, 868	286, 184
	(ΣX)	(ΣY)	(ΣX^2)	(ΣY^2)	(ΣXY)

X = Intra-arterial pressure

Y = Doppler Ultrasonic pressure recording

N = (total paired observations of X, Y) = 10

r = Pearson's product-moment correlation coefficient

Formula: $r = \dfrac{N(\Sigma XY)-(\Sigma X)(\Sigma Y)}{\sqrt{[N(\Sigma X^2)-(\Sigma X)^2][N(\Sigma Y^2)-(\Sigma Y)^2]}}$

Therefore: $r = \dfrac{10(286,184)-(1682)(1698)}{\sqrt{[10(283,724)-(1682)^2][10(288,868)-(1698)^2]}}$

$= 0.8706$

Validation of the Doppler Unit

Diastolic Pressures

No.	X	Y	X^2	Y^2	XY
1	90	90	8, 100	8, 100	8, 100
2	84	85	7, 056	7, 225	7, 140
3	87	80	7, 569	6, 400	6, 960
4	90	80	8, 100	6, 400	7, 200
5	90	88	8, 100	7, 744	7, 920
6	92	88	8, 464	7, 744	8, 096
7	86	84	7, 396	7, 056	7, 224
8	96	90	9, 216	8, 100	8, 640
9	88	88	7, 744	7, 744	7, 744
10	88	80	7, 744	6, 400	7, 040
Total	891	853	79, 489	72, 913	76, 064

X = Intra-arterial pressure

Y = Doppler Ultrasonic pressure recording

$N_1 r_1$ formula = see above

Therefore: $r = \dfrac{10(7604)-(891)(853)}{\sqrt{[10(79,849)-(891)^2][10(72,913)-(853)^2]}}$

$= 0.498$

Calculation for Variance Criterion for Pulse Rates

$R_1 - R_2 = x$ (mm)	$\frac{1500}{x}$	Pulse Rate	Ranking
15	Log 3.176091 1.176091 2.000000	100 (100)	0
16	Log 3.176091 1.204120 1.971971	93.7497(94)	1
17	Log 3.176091 1.230449 1.945642	88.24349(88)	2
18	Log 3.176091 1.255273 1.920818	83.3335(83)	3
19	Log 3.176091 1.278754 1.897337	78.9478(79)	4
20	Log 3.176091 1.301030 1.875061	74.9998(75)	5
21	Log 3.176091 1.322219 1.854872	71.4282(72)	6
22	Log 3.176091 1.342423 1.834668	68.3392(68)	7

When the variance is set at ± 1mm the calculations are as follows:

$x=R_1-R_2$	Range $\pm$ 1mm	Ranking	Calculation of Range $\pm$ 1	Pulse Rate Range $\pm$ 1mm
16	15-17	0-2	100.0000-88.2449	11.7631
17	16-18	1-3	93.7497-83.3335	10.4161
18	17-19	2-4	88.2349-79.9478	9.2991
19	18-20	3-5	83.3335-74.9998	8.3337
20	19-21	4-6	78.9478-71.4282	7.5196
21	20-22	5-7	74.9998-68.3392	6.6606

Using whole numbers

Pulse Rates		Approximate Range Values
94	100-88	Range 11.7
88	93-83	Range 10
83	88-79	Range 9
79	83-74	Range 8
75	79-72	Range 7
68	74-68	Range 6

For ease of computation and ease of recall the following assessment criteria for pulse rate change is suggested.

Pulse Rate of	$\bar{X}$	
95-105	100	10 $\pm$ 5
85-95	90	9 $\pm$ 4.5 (over 90+5 under 90+4)
75-85	80	8 $\pm$ 4
65-75	70	7 $\pm$ 3.5 (over 70+4 under 70+3)
55-65	60	6 $\pm$ 3

In actual practice it is suggested that if the pulse rate is over the mean of the range for those values including a decimal that the higher value be considered for those values below and including the mean the lower value be considered as the range. Over 100 is defined as tachycardia - below 60 as bradycardia and so is not included in this measuring tool.

APPENDIX G

RAW DATA

RAW DATA

Dialogue

A/C	Alternating Current
M. T.	Muscle Tremor
W. B.	Wandering Baseline

For Palpation

E. L.	Easy to locate
D. L.	Difficult to locate

For EKG Readings

R_1 — # of Q. R. S. complex in 60 second tracing

R_2 — Range between largest and smallest $R\text{-}R_1$ interval

$$\text{Rate} = \frac{1500}{\#\text{mm } R\text{-}R_1}$$

PATIENT NO. 1

Age 51	Diagnosis	Date of Admittance
Wt. 199 lbs.	M. I.	July 24
Ht. 5'6"	Duration of	
Obese	cardiac disease	Place of Birth
Comments	2 yrs.	Oklahoma
Ascites		
Some evidence of emboli		

BLOOD PRESSURE READINGS

Sphymomanometer				Doppler				Plethysmograph		
Left	127:125=126			120:122=121	Sens.	1		125:123=124	Sens.	1
	90	90	90	90 88 89	Out	2			EKG	A.V.R.
	75	72	74		In	3.5			Sens.	1
					Art.	2				
					EKG	3		(Only AVR(the unipolar		
Right	130:128=129			(AVR and standard leads				lead)will record)		
	90	92	91	will record tracing)						
	75	75	75							

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	72	70	74	70	72	Nil	Nil	Nil	Nil
Rhythm	Reg	Reg	Reg	Reg	Reg	-	-	-	-
Magnitude	4	4	No rales	3	3	2	1	1	2

Comments: Feet cold, skin dry, color white

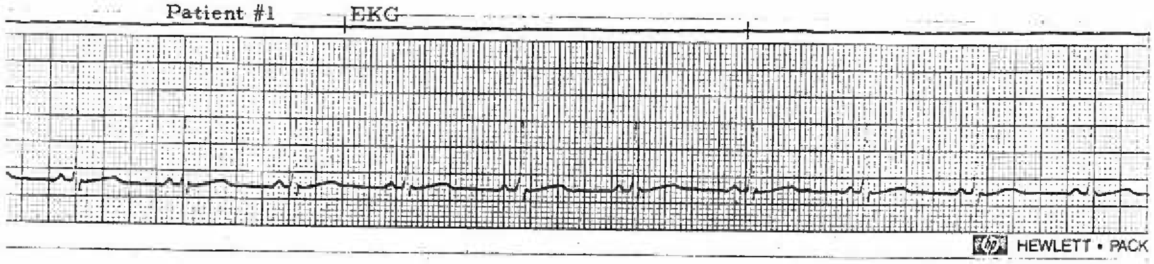
EKG SAMPLE Tracing good Only occasional W. B. No A/C artifact or N. T.

$Rate_1$	72	68	72		70	70	72	70	68		69	
$Rate_2$	(68-72)	(68-72)	(68-76)	(68-76)	(68-76)	(68-72)	(68-76)	(68-72)	(68-72)			
	70	70	72		72	72	70	72	70		70	
Rhythm	Reg	Reg	Reg		Reg	Reg	Reg	Reg	Reg		Reg	
	One P. V. C.											

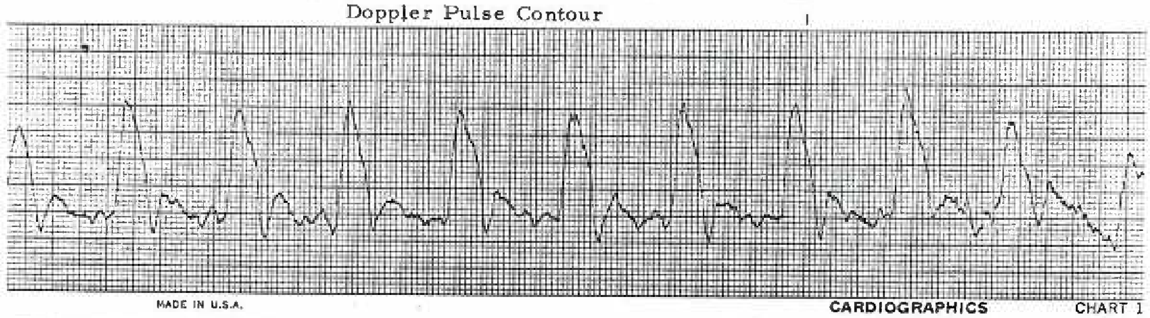
EKG INTERPRETATION

Rate - Apical 72	P-Wave	Positive 0. 12 sec.	Drugs	Digoxin KCI Heparin
Rhythm + Conduction Singular Sinus except for occasional P. V. C.	Q. R. S.	Preceded by P 0. 06 secs.	I/V	Right Arm
	T-Wave	Present, Positive S-T depressed	Other	Pacemaker on demand No angio No cardio

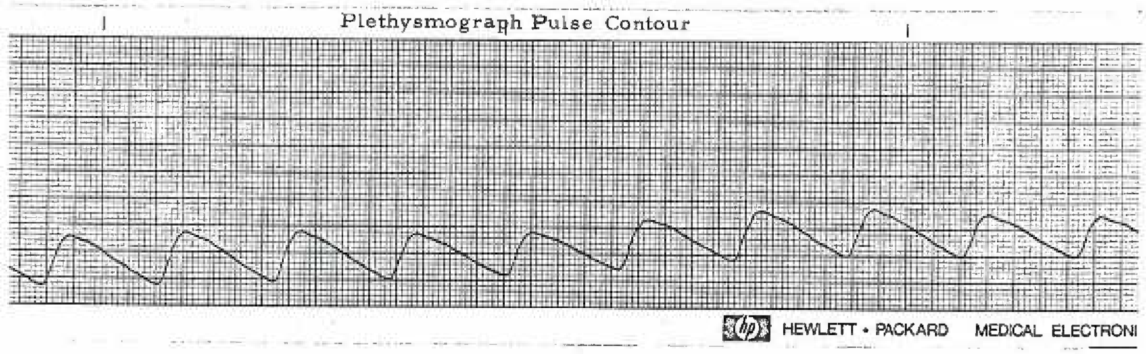
Patient #1 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #1

Ascites possibly interfered with femoral palpation and should be correlated with other patients suffering the same phenomenon.

Pedal pulses are absent and the feet are cold to touch.

PATIENT NO. 2

Age 73	Diagnosis	Date of Admittance
Wt. 132 lbs.	Acute M. I.	July 30
Ht. 5'6"	Duration of	
Thin	cardiac disease	Place of Birth
Comments	8 yrs.	Pennsylvania

BLOOD PRESSURE READINGS

Sphymomanometer				Doppler					Plethysmograph		
Left	110:115=113			105:105=105			Sens.	1	105:108=107	Sens.	1
	85	85	85	75	75	75	Out	3		EKG	AVR
	60	62	61				In	5.5		Sens.	1/2
							Art.	1			
							EKG	1/2			
Right	115:110 = 113										
	90	80	85								
	65	65	65								

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	68	72	72	66	72	68	68	68	66
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg
Magnitude	3	3	No rales	3	3	2	3	4	4

Comments: Feet warm, color Sl. Pink, skin moist

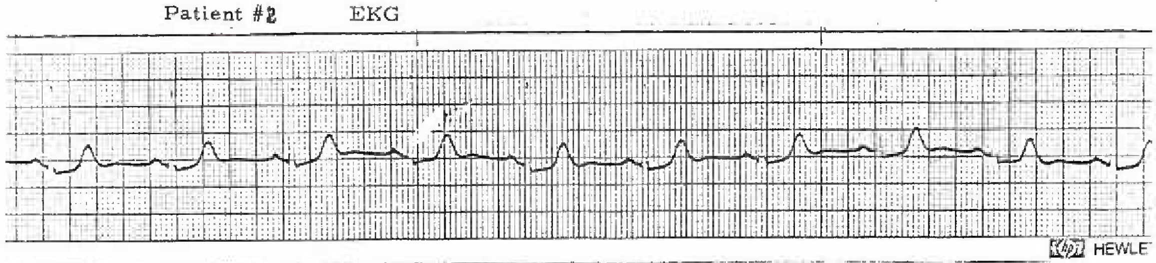
EKG SAMPLE Tracing good. Some M. T. and W. B. Q. R. S. complexes very light

$Rate_1$	68	70	70	70	70	70	68	68	70
$Rate_2$	(68-72)	(68-76)	(68-72)	(64-70)	(68-72)	(62-68)	(68-74)	(64-72)	
	70	72	70	67	70	68	65	71	68
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg

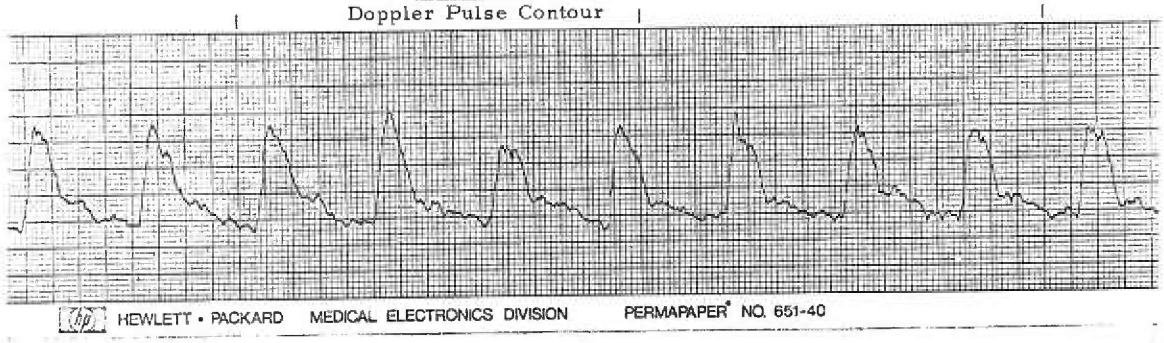
EKG INTERPRETATION

Rate - Apical 70	P-Wave 0. 12 secs.	Drugs Digoxin KCl Heparin
Rhythm + Conduction Regular: Sinus Premature beats with	Q. R. S. Occur after each P. 0. 06 secs.	I/V Right Arm
compensation occasionally Comments	T-Wave Positive	Other Pacemaker, internal, on demand No Angio No Cardio

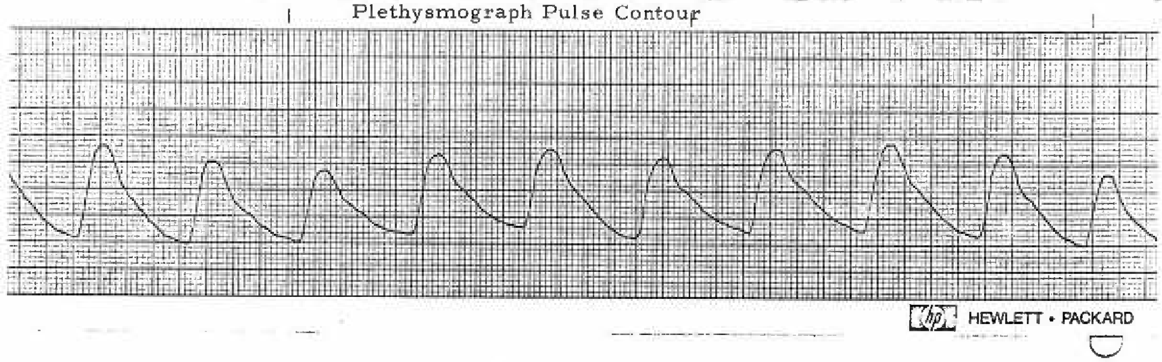
Patient #2 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #2

Compensatory pauses were not included in the measurement of $R_1 - R$ unless three or more occurred in 30 seconds tracings; thus premature beats which were occasional and did not essentially disturb the method of conduction would not then be erroneously named as an arrhythmia.

Even the barely palpable femoral pulse compares favorably to the tracings.

PATIENT NO. 3

Age 59	Diagnosis	Date of Admittance
Wt. 175 lbs.	Rheumatic Heart	July 23
Ht. 5'9"	Dis. Duration of	
Thin	cardiac disease	Place of Birth
Comments: Smokes	27 hrs.	Arkansas

BLOOD PRESSURE READINGS

	Sphymomanometer			Doppler					Plethysmograph		
Left	118:115=117			114:110=112			Sens.	3.5	105:108=107	Sens.	0.5
	82	80	81	80	82	81	Out	3		EKG	AVR
	70	70	70				In	4		Sens.	1/2
							Art.	1			
							EKG	1/2			
Right	120:115=118										
	80	82	81								
	70	70	70								

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	68	66	70	68	70	68	64	64	66
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg
Magnitude	4	3	No rales	3	3	4	2	4	4

Comments: Feet warm, skin dry, color sl. pink

EKG SAMPLE Tracing good Q. R. S. Faint Slight A/C artifact WB+MT

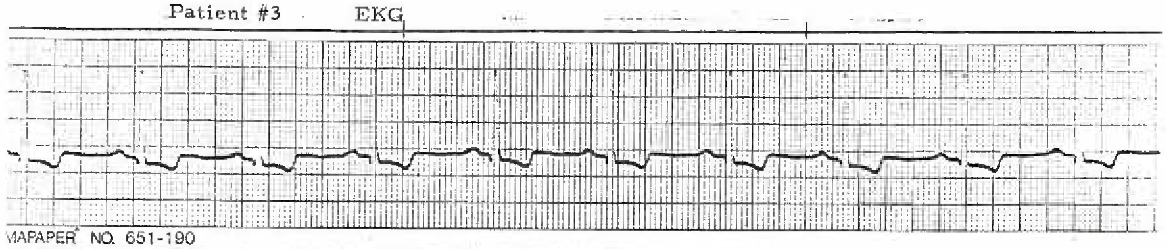
$Rate_1$	70	70	70	68	70	65	68	70	70
$Rate_2$	(72-76)	(68-72)		(64-68)	(64-68)	(68-72)	(68-72)	(68-72)	
	70	70	68	66	66	65	70	70	70
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg

EKG INTERPRETATION

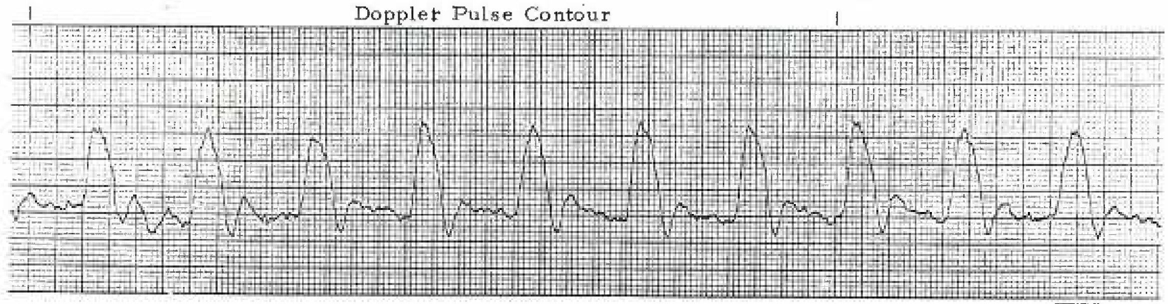
Rate - Apical 70	P-Wave 0.12 secs Proceeds each complex	Drugs	Digoxin K+
Rhythm+Conduction Regular Sinus	Q.R.S. Normal shape 0.06 sec.	I/V	Right Arm
	T-Wave Inverted	Other	Angiogram in Right Femoral

Comments

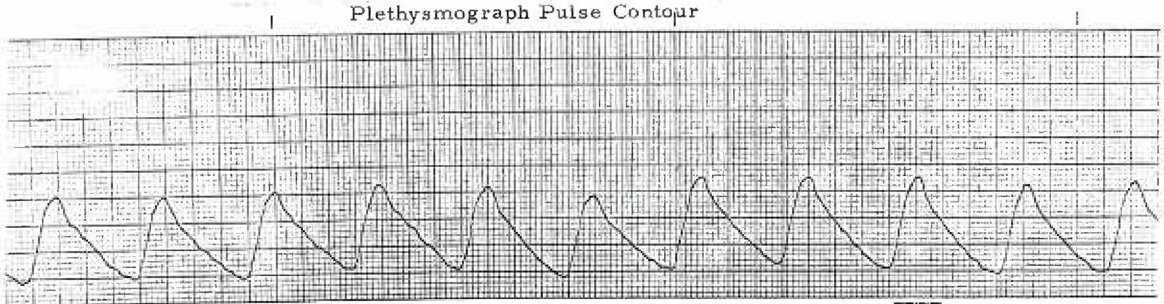
Patient #3 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #3

The accuracy criteria establishes a range within which this data falls. The only questionable palpation that of the right femoral, is still accurate enough not to deviate markedly from the EKG tracings. However, it is interesting to note that this artery had been used for an angiogram.

PATIENT NO. 4

Age 74	Diagnosis	Date of Admittance
Wt. 100 lbs. (approx.)	C. H. F. Alcoholism	Aug. 2, 1970
Ht. 5'6" (approx.)	Cirrhosis. Duration	
Cachexic	of cardiac disease	Place of Birth
Comments	unknown	Not known

Emphysema with typical barrel-shaped
Fixed thoracic cage
? D. T.'s. very restless and incoherent

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler		Plethysmograph	
Left 86:86=86	75:80=78	Sens. 3.5	90?	Sens. .5
60 65 63	60 60 60	Out 2.5	Very rest-	EKG AVR
55 55 55		In 3.5	less patient	Sens. 1
		Art. 2	which inter-	
		EKG 1/2	fered with	
			recording	
Right 90:92=91				
70 70 70				
60 64 62				

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	V. D. L.	L	R	L	R	L	R
Rate	94	100	56?	92	? 100	92	100	Nil	Nil
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	-	-
Magnitude	5	5	Rales	3	2	5	5	2	1

Comments: Feet cold, skin dry, color white

EKG SAMPLE Tracing adequate. No A/C artifact. Some M. T. + W. B.

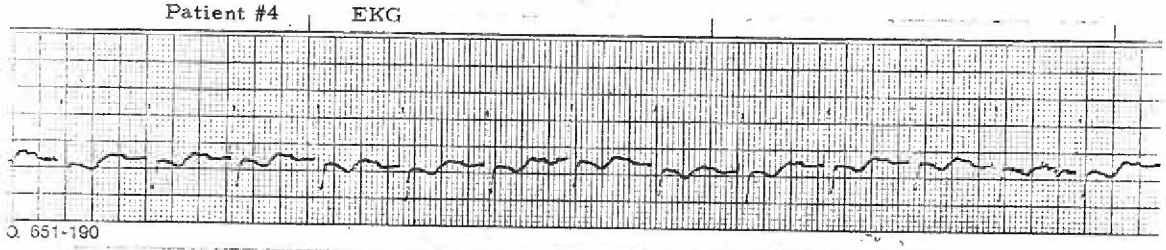
$Rate_1$	96	96	92	94	94	94	94	94	94
$Rate_2$	(88-100)	(88-100)	(88-100)	(94-100)	(88-100)	(88-100)	(88-100)	(88-100)	(88-100)
	94	94	94	97	94	94	94	94	94
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg
			One P. V. C.		One P. V. C.				

EKG INTERPRETATION

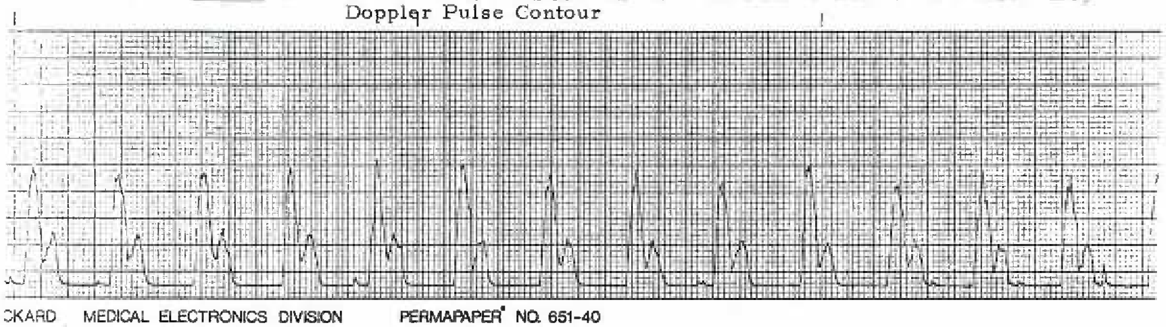
Rate - Apical 92	P-Wave Abnormal and extended 0. 24 secs.	Drugs	Digoxin Phenobarbitol I/M K+
Rhythm+Conduction Regular Supra-ventricular	Q. R. S. Biphasic after each p-0. 08 secs.	I/V	Right arm
	T-Wave Inverted	Other	No Angio)not No Cardio)known

Comments

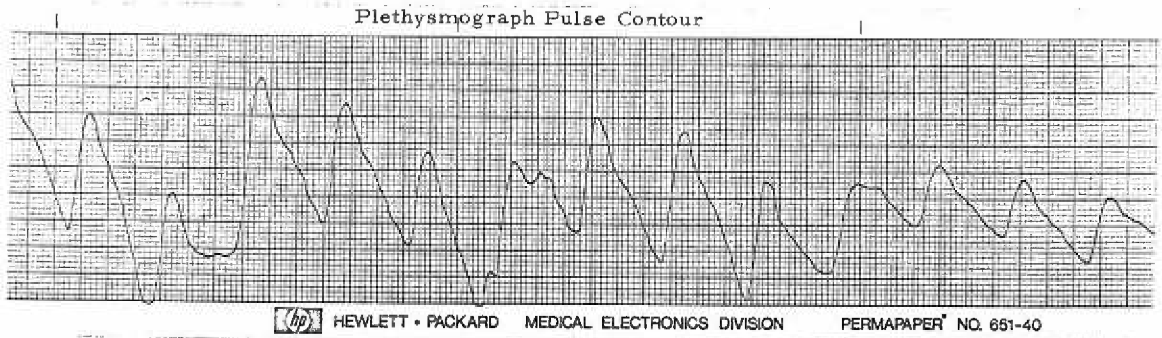
Patient #4 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #4

This very ill and restless patient exhibits remarkable accuracy of rate and rhythm in the data presented.

The apical pulse is recorded as 56. This was checked and it really was such a low figure. It presents the only gross inaccuracy, but the rales and pulmonary condition were so pathological that this discrepancy is not surprising.

The lack of pedal pulses is possibly due to cardiogenic shock. (Note the low BP recordings). The feet were cold.

The plethysmograph reading in this restless patient was taken repeatedly, but was very inaccurate due to muscle tremor. Even with quiet and constant reassurance, the patient was unable to lie still without the sensitive plethysmograph responding to his condition.

PATIENT NO. 5

Age 74
Wt. 150 lbs.
Ht. 5'4 1/2"
Thin
Comments
Some Ascites

Diagnosis
M. I.
Duration of
cardiac disease
3 months

Date of Admittance
August 1, 1970

Place of Birth
Nebraska

BLOOD PRESSURE READINGS

Sphymomanometer		Doppler			Plethysmograph	
Left	90:90=90	90:90=91	Sens.	3	85:86=86	Sens. 2
	70 70 70	75 70 73	Out	4		EKG AVR
	65 68 67		In	4.5		Sens. 1/2
			Art.	1		
			EKG	1/2		
Right	85 84					
	70 70					
	70 70					

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(D. L.)	L	R	L	R	L	R
Rate	96	94	94	96	94	Nil	Nil	92	94
Rhythm	Irreg	Irreg	Irreg	Irreg	Irreg	-	-	Reg	Reg
Magnitude	3	3	Rales	2	3	1	1	3	3

Comments: Feet warm, dry, white

EKG SAMPLE Tracing good. Amplitude low. Occasional WB and M. T.

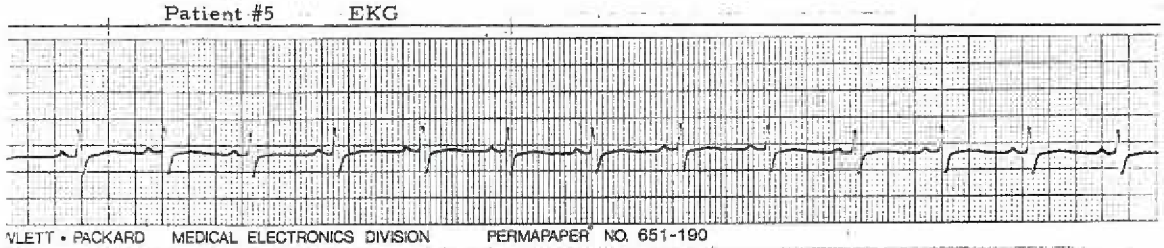
$Rate_1$	94	94	93	94	92	94	94	94	92
$Rate_2$	(88-94) 91	(88-94) 91	(88-94) 91	(88-94) 91	(88-94) 91	(88-94) 91	(88-94) 91	(88-94) 91	(88-94) 91
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg

EKG INTERPRETATION

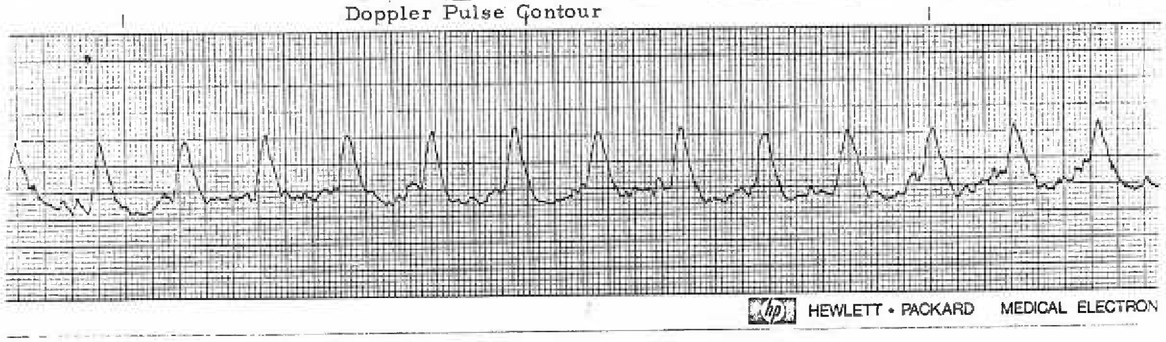
Rate - Apical 93	P-Wave Present Position 0. 12 sec	Drugs	Digoxin
Rhythm+Conduction	Q. R. S. Biphastic following every P-	I/V	None
	T-Wave S-T depressed	Other	No Angio No Cardio

Comments

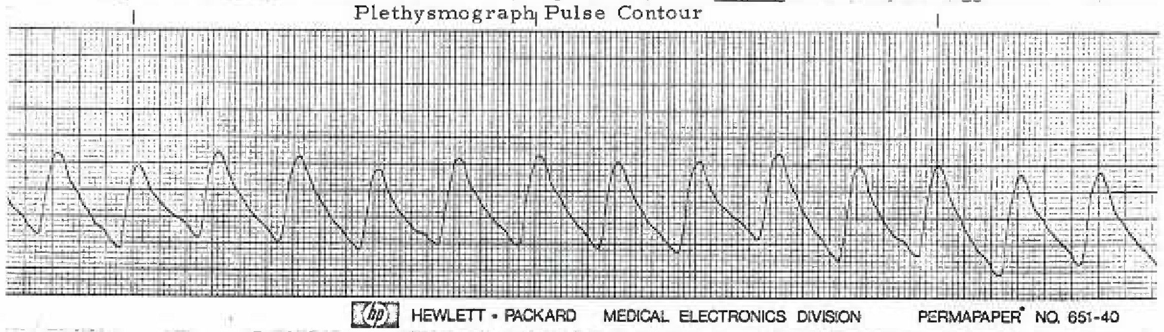
Patient #5 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #5

The presence of the ascites may have interfered with femoral palpation.

The rest of the data are amazingly similar, the difference by the accuracy criterion in this range would be 9. Even between all arterial notation, this range is not exceeded, the rhythm remaining constantly regular.

PATIENT NO. 6

Age 75	Diagnosis C. H. F.	Date of Admittance
Wt. 125 lbs.	Heart Block	August 1, 1970
Ht. 5'8"	Duration of	
Cachexic	cardiac disease	Place of Birth
Comments	2 yrs.	Idaho

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler		Plethysmograph
Left 118:110=114	110:110=110	Sens. 3	105 106 Sens. 1
80 90 85	90 80 85	Out 2	EKG AVR
60 65 63		In 3	Sens. 1/2
		Art. 1	
		EKG 1/2	
Right 120:110=115			
90 90 90			
70 70 70			

PULSE PALPATIONS in beats per minute

	Radial L	Radial R	Apical	Temporal L	Temporal R	Femoral L	Femoral R	Pedal L	Pedal R
Rate	60	58	58	56	62	60	62	Nil	Nil
Rhythm	Irreg	Irreg	Irreg	Irreg	Irreg	Irreg	Irreg	-	-
Magnitude	3	3	No rales	3	3	4	4	2	1

Comments: Feet cold, skin dry, color white

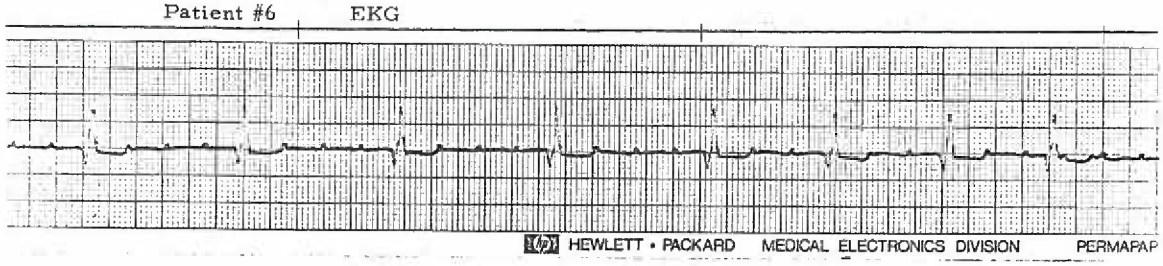
EKG SAMPLE Tracing adequate. Some A/C artifact. M. T. and W. B.

$Rate_1$	60	58	62	62	60	62	58	64	62
$Rate_2$	(36-48) 52	(42-68) 57	(45-72) 59	(45-72) 59	(42-68) 57	(34-94) 64	(37-75) 56	(44-78) 66	(50-78) 64
Rhythm	Irreg	Irreg	Irreg 1 P. V. C.	Irreg	Irreg	Irreg	Irreg	Irreg	

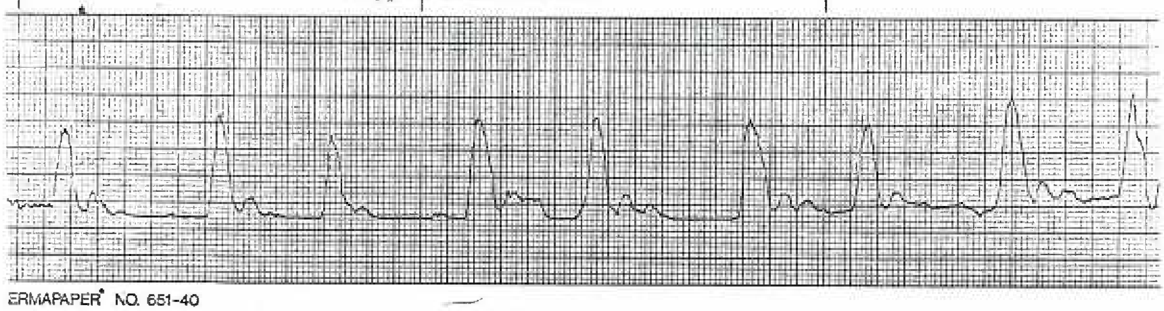
EKG INTERPRETATION

Rate - Apical ventricular = 62 atrial = 140	P-Wave Abnormal Shape 0.24 sec.	Drugs	Digitoxin Darvon K+
Rhythm+Conduction Irregular. Heart Block 3d degree	Q.R.S. Slurred 0.08 sec.	I/V	
Occasional atrial fibrillation	T-Wave often hidden inverted when present	Other	Pacemaker- external No angio No cardio

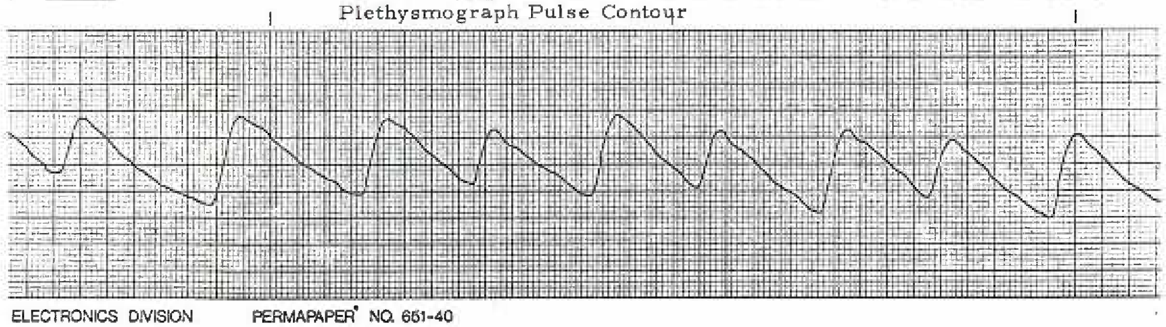
Patient #6 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #6

This exceptionally interesting tracing shows amazing accuracy in both palpation and in the EKG pulse ratings. The wide deviation in R-R is illustrated, but the accuracy of taking the largest and smallest interval as a measure holds true except for one case--the left radial EKG reading. The distance of 8 beats between rate, and rate is, by the accuracy criterion, too broad to be reliable which, in bradycardia of this nature should not be greater than 6. Though the left pedal was palpable, the pulses were not obvious enough to be recorded--this accounts for the difference in magnitude (left and right pedals) as one was palpable but fleeting--the other was not.

Notice the age of this patient.

PATIENT NO. 7

Age 63	Diagnosis	Date of Admittancd
Wt. 165 lbs.	Hypertensive heart	July 4, 1970
Ht. 5'7 1/2"	disease. Duration	
Well nourished.	of cardiac disease	Place of Birth
Comments	11 yrs.	Wisconsin
Right arm scarred and		
oedematous from old		
3-4 degree burn.		
Ascites		

BLOOD PRESSURE READINGS

Sphymomanometer				Doppler					Plethysmograph
Left	108:106=107			118:120=119			Sens.	2.5	Sens. 2
	80	82	81	90	85	88	Out	3	EKG AVR
	75	75	75				In	4	Sens. 1/2
							Art.	1	
							EKG	1/2	
Right	110:106=108								
	90	90	90						
	90	90	90						

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	72	74	72	76	74	Nil	Nil		palpable
Rhythm	Reg	Reg	Reg	Reg	Reg	-	-	Reg	-
Magnitude	4	4	Rales++	3	3	1	1	3	2

Comments: Feet both cold, skin dry, color sl. pink

EKG SAMPLE Tracing generally good. High amplitude. Some A/C artifact

$Rate_1$	76	78	74	76	76	78	76	76	78
$Rate_2$	(74-78) 76	(70-78) 74	(74-70) 72	(70-78) 74	(70-74) 72	(74-78) 76	75	(74-80) 76	(74-80) 76

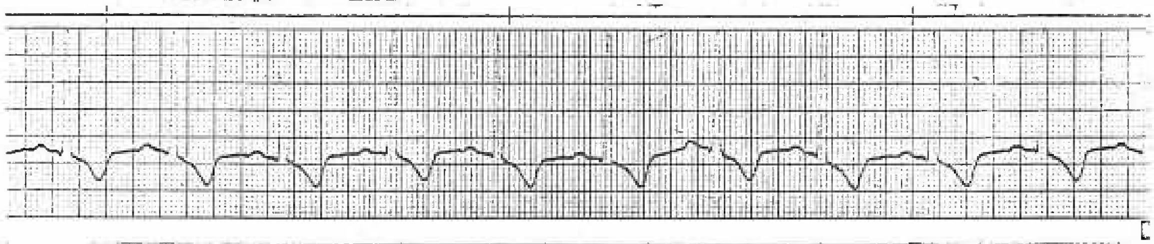
Rhythm

EKG INTERPRETATION

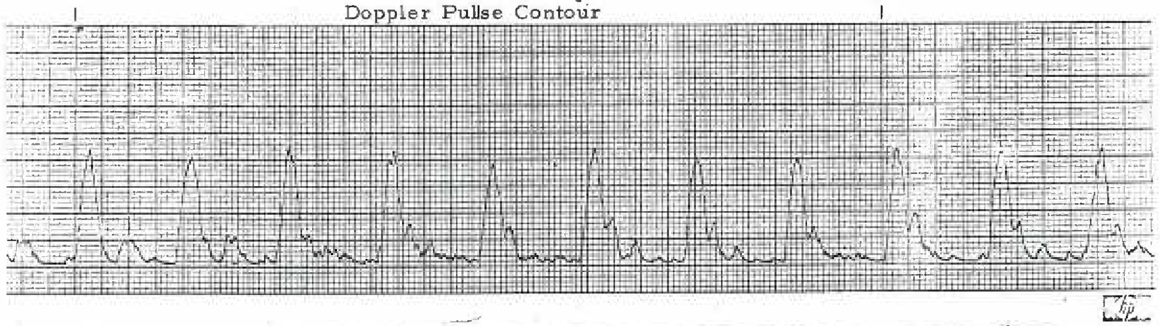
Rate - Apical 74	P-Wave 0.14 sec. present and positive pepre each complex	Drugs	Atropine
Rhythm+Conduction Regular and Sinus	Q.R.S. 0.08 sec	I/V	Left wrist
	T-wave Inverted	Other	No Angio No Cardio

Comments

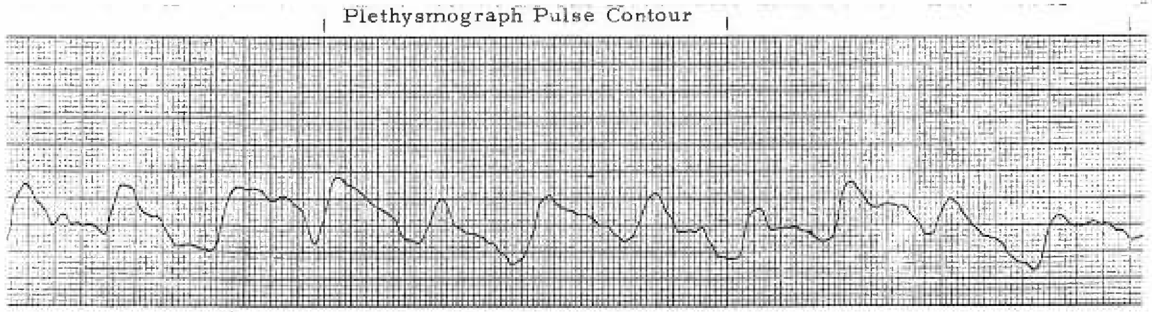
Patient #7 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



NO. 651-40

Patient #7

Notice here that the ascites may have impeded the palpation of the femoral pulses.

Both feet were cold but the pedal pulse (left) was palpable and accurate, whereas the right pedal pulse was not sufficiently palpable to count.

PATIENT NO. 8

Age 74	Diagnosis	Date of Admittance
Wt. 147 lbs.	Acute M. I.	August 5, 1970
Ht. 5'9"	Duration of	
Slightly obese	cardiac disease	Place of Birth
Comments	13 yrs.	Canada

BLOOD PRESSURE READINGS

Sphymomanometer		Doppler			Plethysmograph
Left	105:110=108	118:120=119	Sens.	4	112:112=112 Sens. 1
	80 70 75	95 92 94	Out	3.5	EKG AVR
	75 70 73		In	5	Sens. 0.5
			Art.	1	
			EKG	1/2	
Right	115:110=113				
	75 75 75				
	70 75 73				

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	74	78	78	74	72	80	78	80	78
Rhythm	Reg 1 missed beat	Reg	Reg	Reg	Reg one missed beat on inspir.	Reg	Reg	Reg	Reg
Magnitude	4	3	No rales	3	3	4	4	3	3

EKG SAMPLE

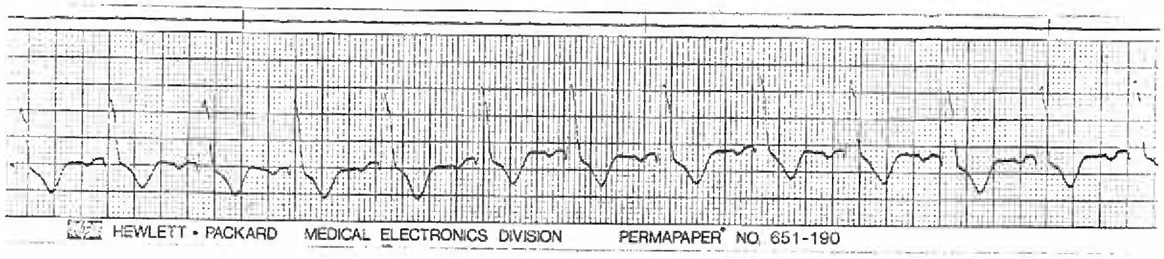
Tracing good. Slight A/C artifact. M. T. T W B

$Rate_1$	78	80	80	76	78	84	78	82	84
$Rate_2$	(74-78) 76	(74-78) 76	(74-78) 76	(74-78) 76	(74-78) 76	(84-88) 86	(78-84) 81	(84-88) 86	(78-88) 83
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg

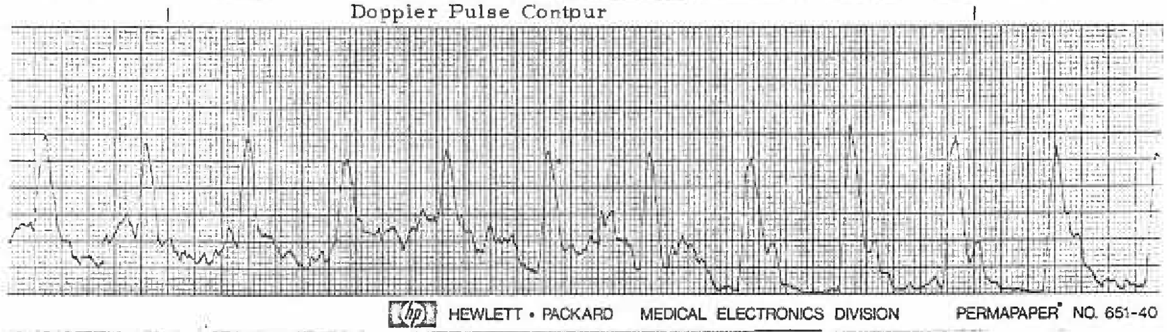
EKG INTERPRETATION

Rate - Apical 80	P-Wave 0.12 sec. P.A.C. inverted	Drugs	Pronestyl
Rhythm+Conduction Regular. Nodal premature contractions [supraventricular conduction comments]	Q.R.S. sluured and notched -.10 sec. - 0.12 sec.	I/V	Right arm
	T-wave Inverted	Other	No angio No cardio

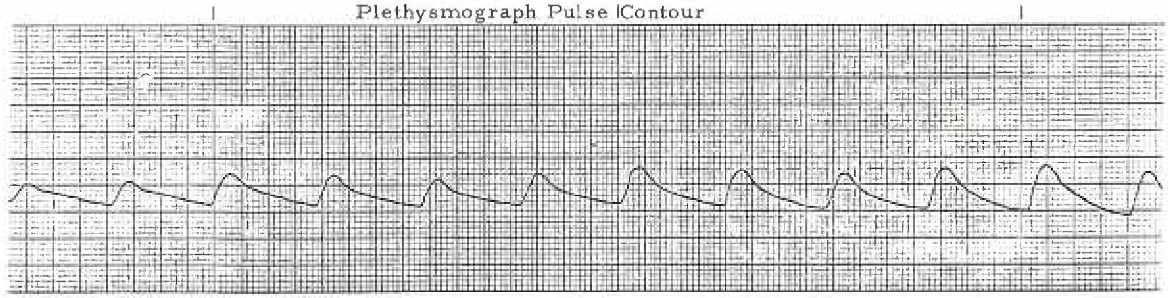
Patient #8 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #8

The Doppler readings are higher than the sphygmomanometer reading. This is not usual.

PATIENT NO. 9

Age 60	Diagnosis	Date of Admittance
Wt. 174 lb.	Acute M. I.	August 10, 1970
Ht. 5'9"	Duration of	
Very slightly obese	cardiac disease	Place of Birth
Comments	2 days	Texas

BLOOD PRESSURE READINGS

Sphymomanometer				Doppler					Plethysmograph	
Left	118:110=114			110:108=109			Sens.	3	116:114=115	Sens. 2
	90	85	88	80	80	80	Out	5		EKG AVR
	80	80	80				In	4		Sens. 1
							Art.	1		
							EKG	1/2		
Right	112	110								
	90	90								
	85	85								

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(V. D. L.)	L	R	L	R	L	R
Rate	68	64	-	70	(D. L.) 70	70	66	72	72
Rhythm	Reg 1 missed beat	Reg	-	Reg	Reg	Reg	Reg	Reg	Reg
Magnitude	4	3	- No rales	3	3	3	5	3	3

Comments: Feet warm, skin dry, color white

EKG Sample Tracing faint but adequate. No M. T. No AC artifact. Base mostly steady

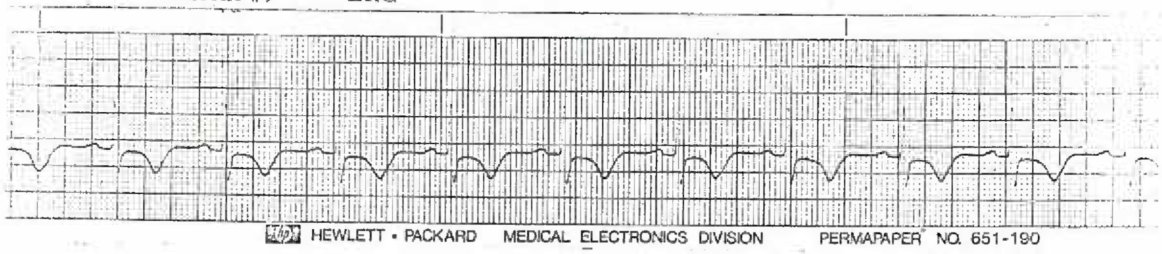
$Rate_1$	72	70	70	72	70	72	74	76	78
$Rate_2$	(68-72)	(68-76)	(68-76)	(68-76)	(68-76)	(72-78)	(72-78)	(72-78)	(72-78)
Rhythm	Fluctuant Amplitude Reg	Reg	Reg	Reg	Reg	Reg	Reg	one P.V. C. Reg	one P.V.C. Reg

EKG INTERPRETATION

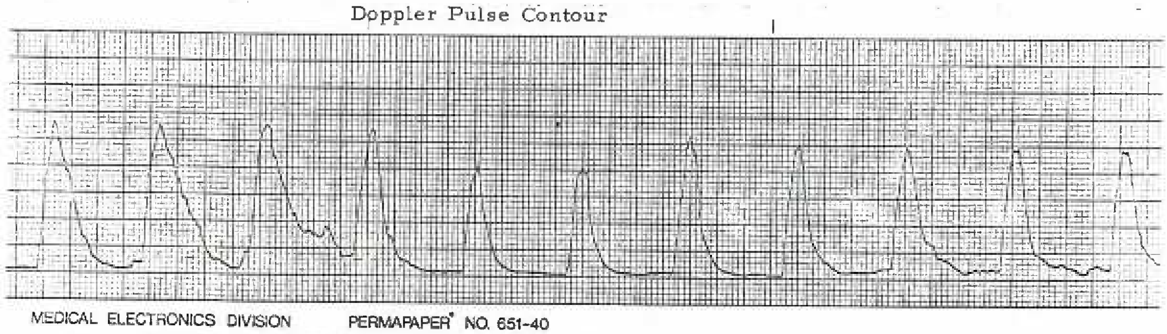
Rate - apical 70	P-Wave 0.14 sec Present and positive	Drugs	Heparin Pronestyl
Rhythm+Conduction Reg. Sinus with occasional P.V.C.	Q.R.S. follows eahc P. Biphasic 0.04 sec.	I/V	Left wrist
	T-Wave Inverted	Other	No angio No cardio

Comments

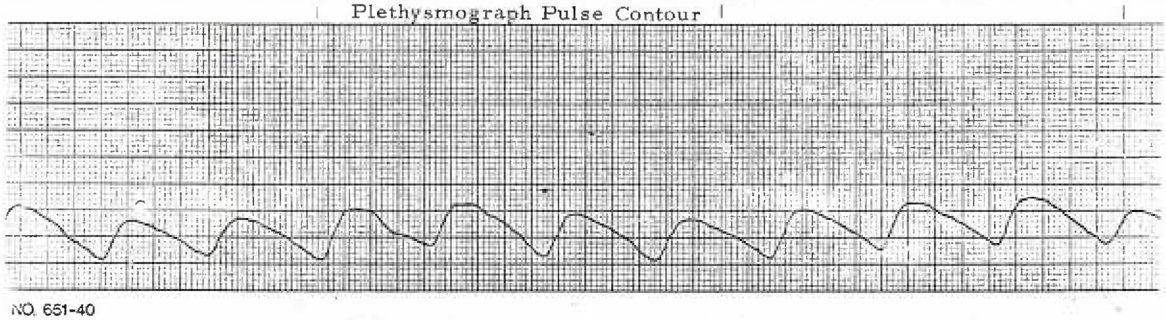
Patient #9 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #9

The apical beat was so difficult that the point of maximum auscultation had been marked on the skin with a small "x". It could occasionally be heard but not enough to count. Several places in the precordium were also auscultated without result. No rales, nor extreme age, nor abesity, nor edema could explain this degree of difficulty.

The right femoral palpation is beyond the range of the accuracy criterion (7) as this difference is 8. Femoral palpation was consistently the most difficult operation and it would be logical to presume that the palpation was inaccurate as the Rate one and Rate two are almost identical.

Despite a reported difficulty of palpation of the radial artery, the range is within the accuracy criterion.

PATIENT NO. 10

Age 58	Diagnosis M. I.	Date of Admittance
Wt. 143 lbs.	C. H. F. Poss.	August 12, 1970
Ht. 5'8 1/2"	Digitalis Toxicity	
Thin	Duration of	Place of Birth
Comments	cardiac disease	Montana
	4 months	

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler			Plethysmograph	
Left 100:96=98	98:96=97	Sens.	4	92:94=93	Sens. 1 + 0.5
80 80 80	85 82 84	Out	4.5		EKG AVR
72 72 73		In	6.5		Sens. 2
		Art.	1		
		EKG	1/2		
Right 98:98=98					
78 78 78					
74 78 76					

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	74	72	74	78	80	80	76	76	Nil
Rhythm	Reg	Reg	Reg	Reg	Reg	?	Reg	Reg	-
Magnitude	4	4	No rales	3	3	2	3	3	1

Comments: Feet R cold, dry, white, L warm, dry, white

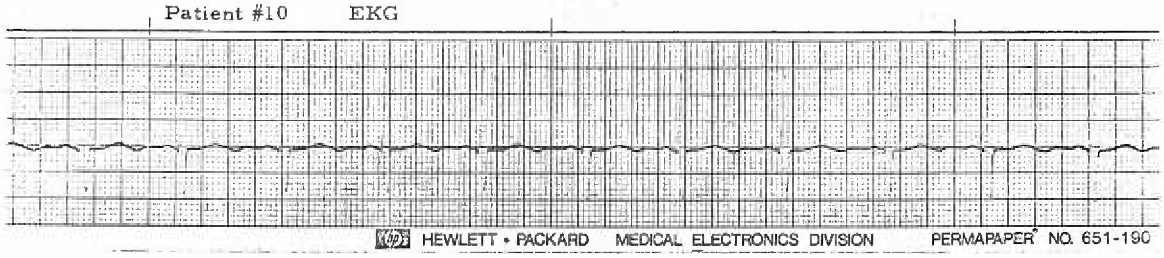
EKG SAMPLE Good tracing. No A/C artifact. Steady baseline
Some M. T.

$Rate_1$	76	78	76	80	78	78	78	80	82
$Rate_2$	(75-83)	(75-88)	(75-83)	(78-83)	(78-83)	(75-83)	(75-83)	(75-83)	(78-88)
	79	82	78	81	81	78	78	78	82
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg

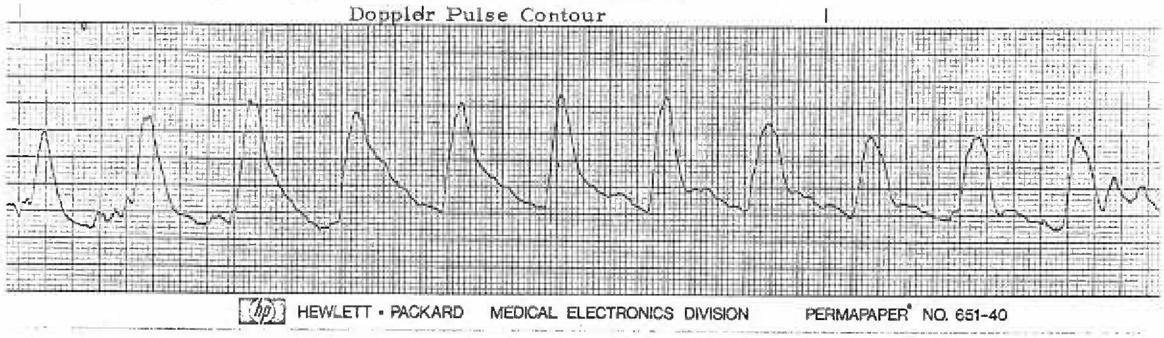
EKG INTERPRETATION

Rate - Apical 76 (Ventricular) 100 (Atrial)	P-Wave 2 present or intimated to each Q. R. S. complex 0. 12 sec. approx.	Drugs	Quinidine Digoxin Heparin
Rhythm+Conduction Generally regular possible 1:2 heart block	Q. R. S. Biphasic 0. 06 sec.	I/V	Right radial vein
	T-Wave Depressed S-T segment	Other	No angio No cardio
Comments			

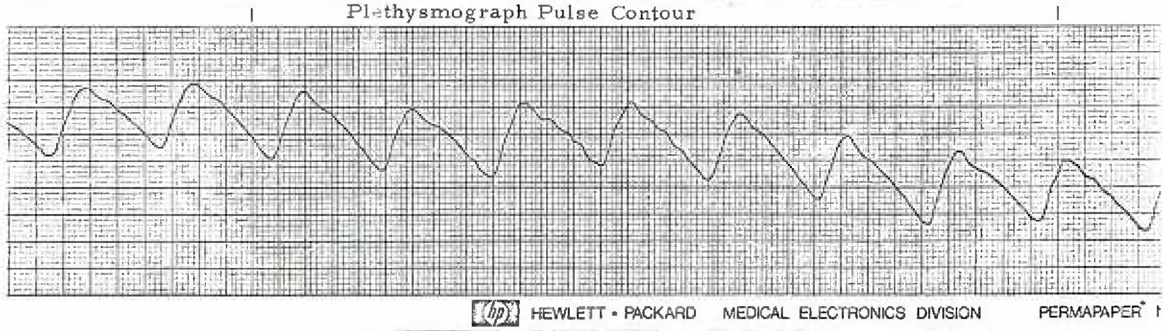
Patient #10 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #10

The readings between palpation and counting of QRS complexes is very accurate here but the greatest discrepancy lies with the radial (right) readings. Note this is also where the I/V is running. According to the accuracy criterion this is within bounds however, but according to the EKG it is irregular, but only just irregular as the variance was one of 4 mm, never greater.

PATIENT NO. 11

Age 52
Wt. 212 lbs.
Ht. 6'1"
Comments
well nourished

Diagnosis Acute
Ant. M. I.
Duration of
cardiac disease
2 yrs.

Date of Admittance
August 20, 1970

Place of Birth
Canada
Saskatchewan

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler			Plethysmograph	
Left 105:103=104	98:98=98	Sens.	3.5	104:106=105	Sens. 1 and 0.5
80 78 79	80 80 80	Out	2.5		EKG AVR
75 75 75		In	4		Sens. 1
		Art.	1		
		EKG	1/2		
Right 100:100=100					
78 78 78					
75 75 75					

PULSE PALPATIONS in beats per minute

	Radial L	Radial R	Apical (E. L.)	Temporal L	Temporal R	Femoral L	Femoral R	Pedal L	Pedal R
Rate	78	80	72	74	78	66	78	82	82
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg
Magnitude	4	4	No rales	3	3	3	3	4	4
Comments									

EKG SAMPLE Tracing good. Some M. T. No A/C artifact. Baseline steady

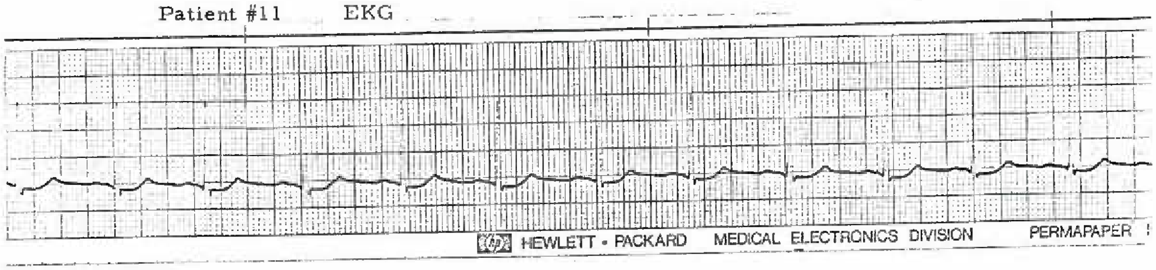
$Rate_1$	80	84	80	84	84	84	86	92	90
$Rate_2$	(78-88) 82	(78-88) 82	(74-84) 79	(78-94) 86	(78-94) 86	(78-94) 86	(78-94) 86	(84-94) 89	(84-94) 89
Rhythm	Reg	Reg	Reg	Irreg	Irreg	Irreg	Irreg	Reg	Reg

EKG INTERPRETATION

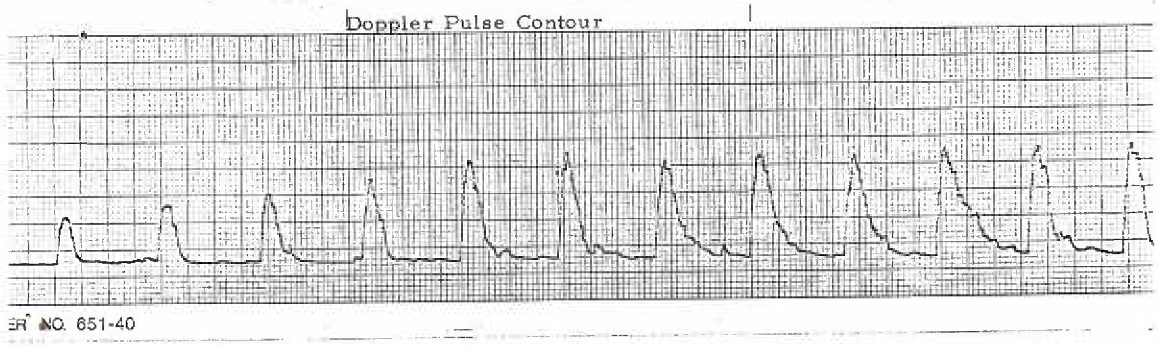
Rate - Apical 80	P-Wave 0.12-0.16 sec. Occasional ADC with inversion or distortion	Drugs	M. S. p. r. n.
Rhythm+Conduction Variant. Some premature beats with compensatory pauses	Q. R. S. Present after each P. 0.06 sec.	I/V	Right arm
Possible supravention conduction	T-Wave Positive S-T depressed	Other	No Angio No Cardio

Comments

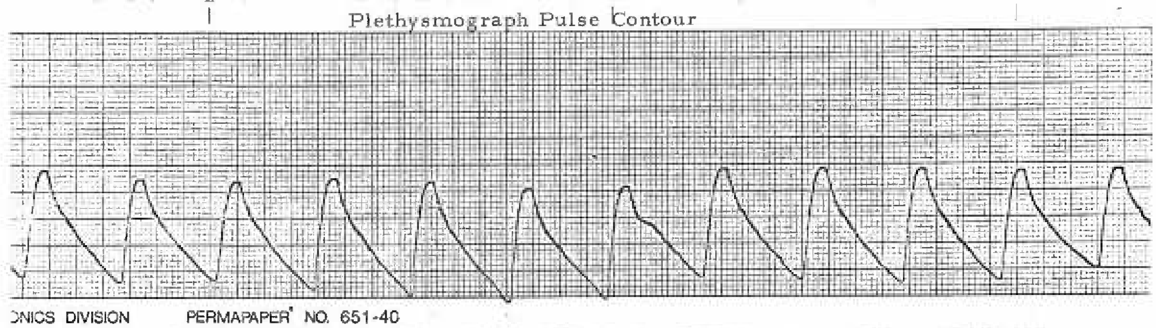
Patient #11 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #11

Compensatory pauses followed premature beats. When this occurs less than three times in a 30 second strip the interval was not counted as it was felt that this would unduly bias the data. One or two quick beats in a minute is not usually thought of as an arrhythmia, but 6 A. P. C. s or 6 P. V. Cs are considered pathological. Three compensatory pauses in thirty seconds were arbitrarily counted as arrhythmia and the R_1R interval was registered in the R_2 column and irregularity noted.

Both temporals and left femoral do not meet the accuracy criterion. Irregularity is shown in the temporals but the femoral may be an inaccurate palpation. The apical beat is being counted here as NOT meeting criterion standards 80-72 = 8. Being the range required from 75-85 and is just not quite accurate enough.

PATIENT NO. 12

Age 58	Diagnosis M. I.	Date of Admittance
Wt. 138 lbs.	C. H. F. (C. V. A Ad)	August 17, 1970
Ht. 5'7"	Duratio of cardiac	
Thin	disease	Place of Birth
Comments	20 yrs.	Canada
Left Hemiplegia		(Saskatchewan)

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler		Plethysmograph
Left 120:126=123	150:150=150	Sens. 4	115:120 Sens. 2 + 0.5
84 90 87	110 120 115	Out 4	EKG AVR
78 90 84		In 5	Sens. 2
		Art. 1	
		EKG 1/2	
Right			

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R		L	R	L	R	L	R
Rate	94	88	76	82	82	88	Nil	Nil	Nil
Rhythm	Irreg	Irreg	Reg	Irreg	Reg	Reg	-	-	-
Magnitude	5	4	No rales	4	4	4	1	1	1

Comments: Feet cold, very dry, sl. pink

EKG SAMPLE

Tracing excellent. Very little W. B. or A/C artifact

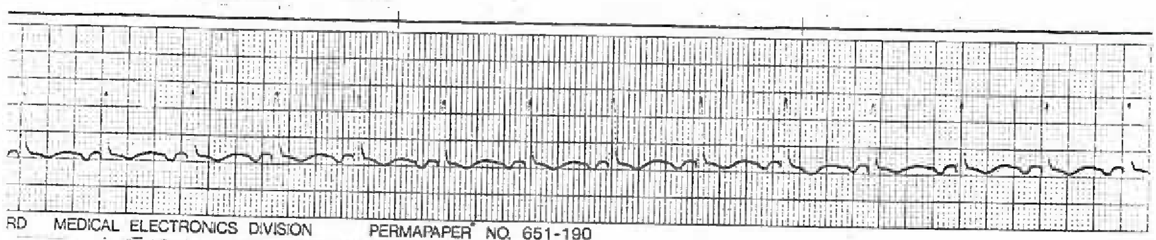
$Rate_1$	88	90	80	82	86	89	90	92	91
$Rate_2$	(84-100)	(84-108)	(65-100)	(76-88)	(75-88)	(84-94)	(68-94)	(84-100)	(84-100)
	91	96	83	82	81	89	81	91	96
Rhythm	Irreg	Irreg	Very Irreg	Irreg	Irreg				

EKG INTERPRETATION

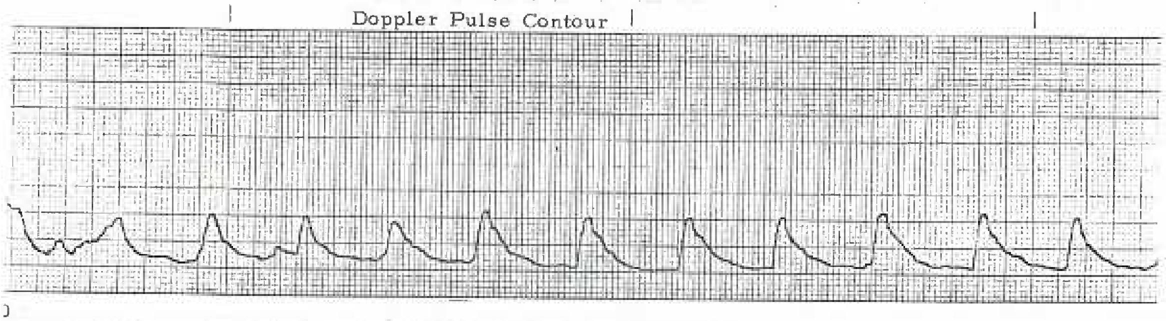
Rate - Apical 80	P-Wave 0.16-0.21 secs. inverted. Present before each Q.R.S.	Drugs	Digoxin KCP
Rhythm+Conduction Irreg. Supraventricular with nodal premature contraction	Q.R.S. Occasionally notched 0.06-0.08 secs.	I/V	Right arm
	T-Wave Inverted	Other	Angiogram

Comments

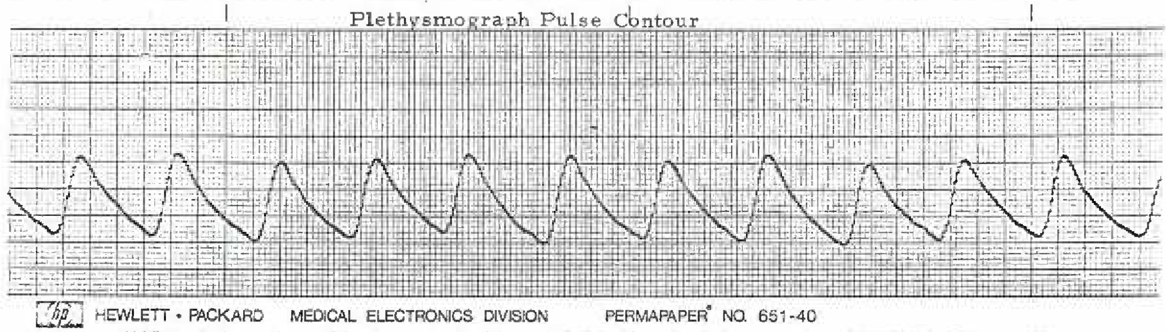
Patient #12 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #12

In this grave disturbance of conduction in an injured heart, note that the measurement of the longest and shortest interval between R's is remarkably accurate.

The really surprising inconsistency lies between the apical recordings. The rate is within accurate limits as estimated by the accuracy criterion but the rhythm upon auscultation was not recorded as irregular. The EKG is grossly arrhythmic; as estimated by Hackensack an irregularity of more than 3 mms is irregular. The variance here is 23-15 = 8 mms and is grossly variant showing an irregular rhythm. (This variance was not progressive but haphazard.)

The Doppler readings had been consistently taken on the left side of the patient, mainly because the wall plug was placed on the left of the bed and the sphygmomanometer was also on the left wall. This blood pressure is therefore recorded on the side suffering from hemiplegia. It is not unlikely that the neuro-muscular mechanism governing the dilation and contraction of the arterial walls had been injured in the medulla from the cerebro vascular accident, influencing this widely deviant reading. It also give rise to speculation about the difference between blood pressure readings on the left and right, and how the pressure is affected in the limbs of the stroke victum.

The feet were cold with no pedal pulses.

PATIENT NO. 13

Age 62 Wt. 207 lbs. Ht. 5'10" Well nourished Comments Excellent physical condition Very athletic	Diagnosis Acute M. I. Duration of cardiac disease 2 days	Date of Admittance August 23, 1970 Place of Birth

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler		Plethysmograph	
Left 130:128=129	126:126=126	Sens. 5	124:126=125	Sens. 2+0.5
80 80 80	100 102=101	Out 3	easily	EKG AVR
80 75 78	Very obvious	In 5	amotated	Sens. 1/2
	diastolic	Art. 1		
	readings	EKG 1		
Right 130:128=129				
90 94 92				
80 84 82				

PULSE PALPATIONS in beats per minute

	Radial L	Radial R	Apical (E. L.)	Temporal L	Temporal R	Femoral L	Femoral R	Pedal L	Pedal R
Rate	70	70	68	70	66	62	62	72	68
Rhythm	Reg 1 extra beat	Reg	Reg	Reg	Irreg	Irreg	Irreg	Irreg	Irreg
Magnitude	4	3	No rales Borborygmi	3	4	3	3	4	4

Comments: Feet warm, moist, sl. pink

EKG SAMPLE Tracing good. Some A/C artifact and some W. B.

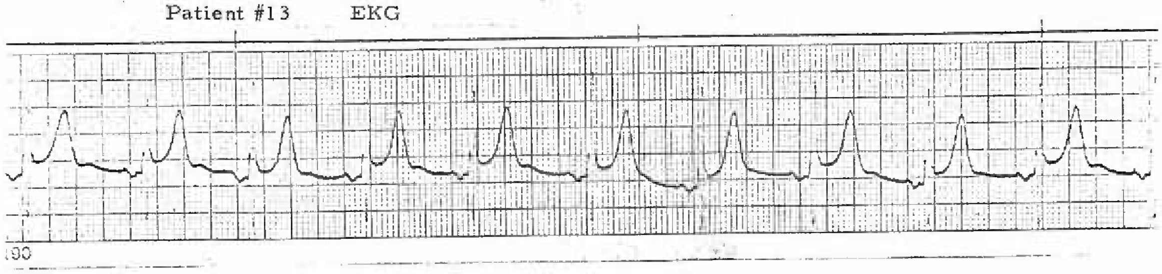
$Rate_1$	74	76	74	74	74	74	78	76	75
$Rate_2$	(68-76)	(72-78)	(72-78)	(68-72)	(62-115)	(62-115)	(62-115)	(62-115)	(62-115)
Rhythm	Reg	Reg	Reg	Reg	Reg	Irreg 4 nodal tachycardial beats	Irreg	Irreg	Irreg

<u>EKG INTERPRETATION</u>

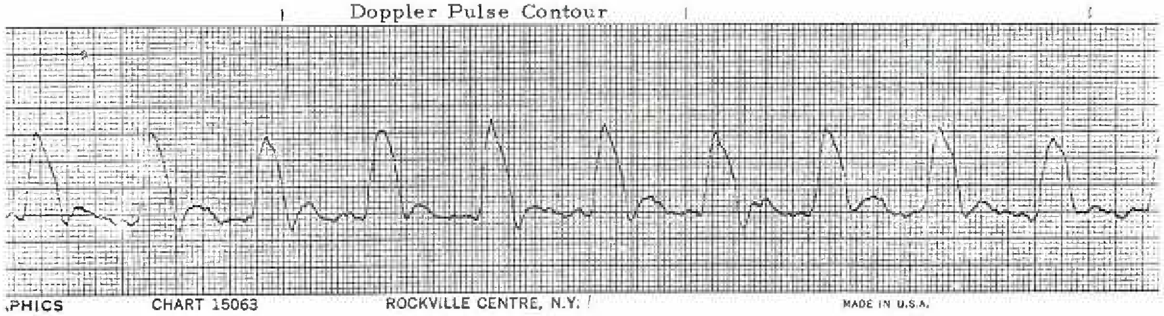
Rate - Apical 74	P-Wave 0.14-0.16 sec. Positive	Drugs	Digitalization in Progress
Rhythm+Conduction Varies. Supraventricular conduction-Nodal. Premature contractions	Q.R.S. Biphasic but follows the P.	I/V	Left Hand
	T-Wave Very high but positive	Other	No Angio No Cardio

Comments

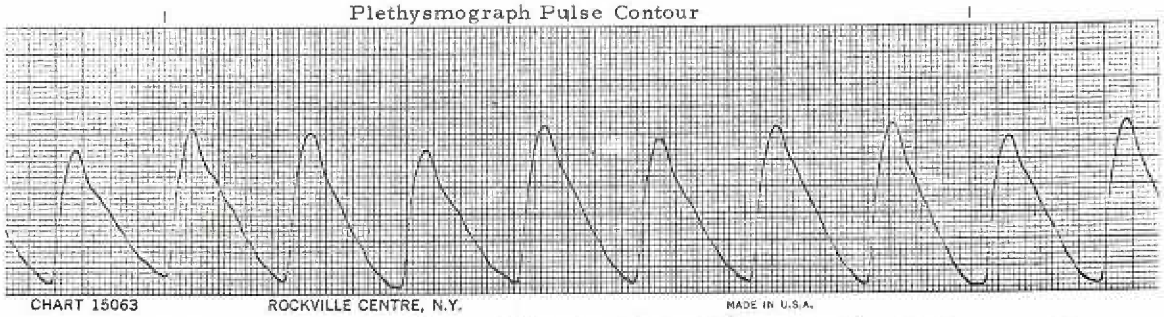
Patient #13 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #13

Left femoral palpating is too deviant from the tracing record to be accepted without question, but the rhythm in this case was irregular. The accuracy criterion however should have been within a range of 7. This difference is 12 in case of the L. femoral, and accuracy of the palpation questionable.

There is no reason to accept gradations of degrees of irregularity and where the pulse is irregular whether slight or gross, it is so stated to comply with the frequency denotation for chi-square.

It is interesting that measuring the largest R-R interval and the smallest gives an accurate estimation of the rate, when comparing it to counting the complexes and when applying the accuracy criterion.

Note that the P-wave conduction is too slow and that the T-wave is so high that the athletic heart could possibly be inferred.

The Doppler diastolic readings were so obvious in this patient that a special notation was made. It also became patently obvious to the author that further experience with Doppler diastolic readings was necessary.

PATIENT NO. 14

Age 75	Diagnosis M. I.	Date of Admittance
Wt. 166 lbs.	Glaucoma. C. V. A.	August 22, 1970
Ht. 5'9"	(old) Duration of	
Slight obese	cardiac disease	Place of Birth
Comments	2 yrs.	Wisconsin

BLOOD PRESSURE READINGS

Sphygmomanometer	Doppler		Plethysmograph
Left 128:128=128	126:128=127	Sens. 3.5	128:126=127 Sens. 2+0.5
80 76 78	90 80 85	Out 2.5	EKG AVR
80 70 75		In 5	Sens. 1
		Art. 1	
		EKG 1	
Right 128:132=130			
100 90 95			
80 80 80			

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	72	66	66	66	68	68	Nil	33	Nil
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	-	Reg	-
Magnitude	5	5	No rales	3	3	5	1	3	1

Comments: Feet L warm, pink, moist, Feet R cold, pink, moist

EKG SAMPLE Tracing good. Low amplitude. Some W. B. No A/C or W. B.

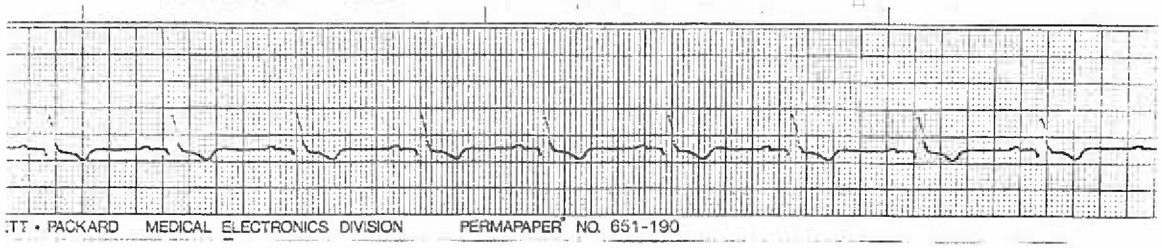
Rate_1	66	66	64	64	64	64	63	66	64
Rate_2	(62-66)	(62-66)	(62-66)	(62-66)	(62-66)	(62-66)	(62-66)	(62-66)	(62-66)
Rhythm	64 Reg	64 Reg	64 Reg	64 Reg 1 PVC	64 Reg 2 PVCs	64 Reg	64 Reg	64 Reg	64 Reg

EKG INTERPRETATION

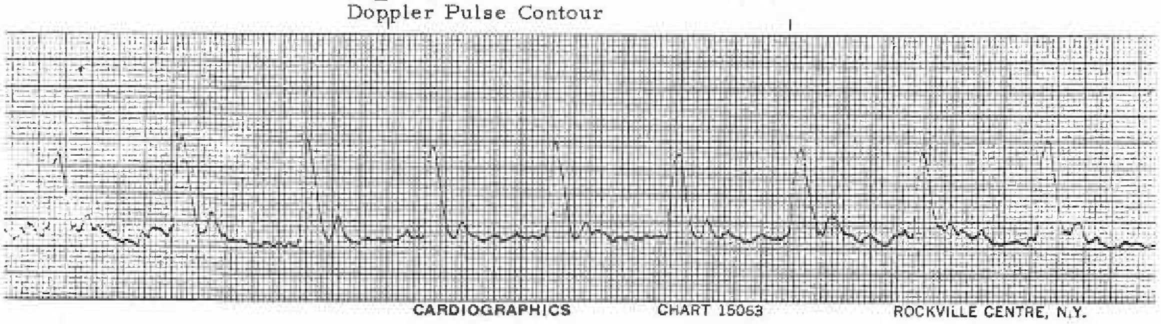
Rate - Apical 64	P-Wave 0.20 sec. positive followed by complexes	Drugs	Dicoumarol
Rhythm+Conduction Reg. Generally sinus but abnormality of Q. R. S. implies dis-turbance in ventricular conduction	Q. R. S. slightly slowed and notched 0.08 secs.	I/V	Left Hand
	T-Wave Inverted	Other	No Cardio Angiogram

Comments

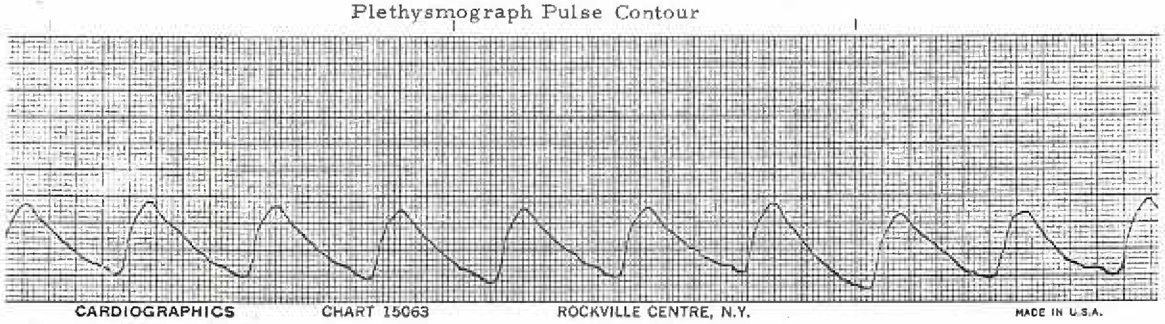
Patient #14 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #14

The left and right radial palpations are only just within acceptable limits when measured by the accuracy criterion (7). Perhaps the I/V interfered with palpation.

It is obvious that the angiogram (this patient had had two) had obliterated the femoral artery and also the pedal artery on the right side.

Notice that the obliterated pedal artery was also in the foot that was cold although there was no obvious change in skin condition or color--temperature was a differentiating factor.

PATIENT NO. 15

Age 70 Wt. 196 lbs. Ht. 5'9" slightly obese Comments Left forearm 3-4" shorter than right due to accident in childhood	Diagnosis Coronary artery disease Duration of cardiac disease 31 yrs.	Date of Admittance August 27, 1970 Place of Birth Chicago

BLOOD PRESSURE READINGS

Sphymomanometer	Doppler		Plethysmograph
Left 126:126=126 105 100 103 95 90 93	122:126=124 100 104=102	Sens. 4 Out 4.5 In 5 Art. 1 EKG	130:126=128 Sens. 2+0.5 EKG AVR Sens. 1/2
Right 130:132=131 105 100 103 90 85 88			

PULSE PALPATIONS in beats per minute

	Radial		Apical	Temporal		Femoral		Pedal	
	L	R	(E. L.)	L	R	L	R	L	R
Rate	84	74	88	84	84	Nil	84	78	88
Rhythm	Reg	Reg	Reg	Reg one missed beat	Reg	-	Reg	Irreg	Reg
Magnitude	4	4	Rales r base	3	3	1	4	3	3

Comments: Feet warm, moist, sl. pink

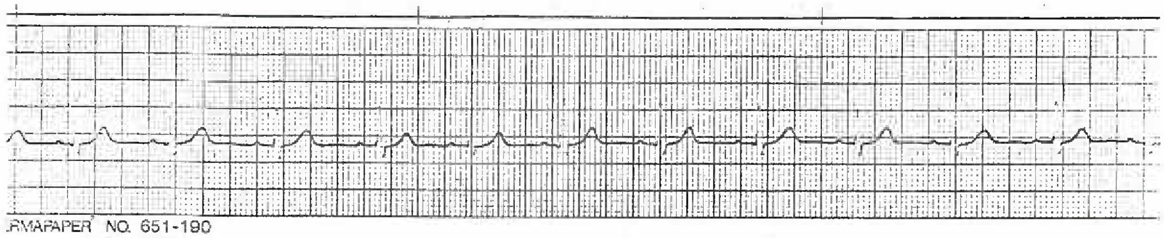
EKG SAMPLE Tracing good. No A/C artifact. No M. T. Occasional W. B.

$Rate_1$	84	84	82	82	84	88	84	88	86
$Rate_2$	(84-88) 86	(84-88) 86	(78-88) 84	(78-84) 81	(78-84) 81	(94-94) 88	(78-88) 83	(84-94) 89	(84-88) 86
Rhythm	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg

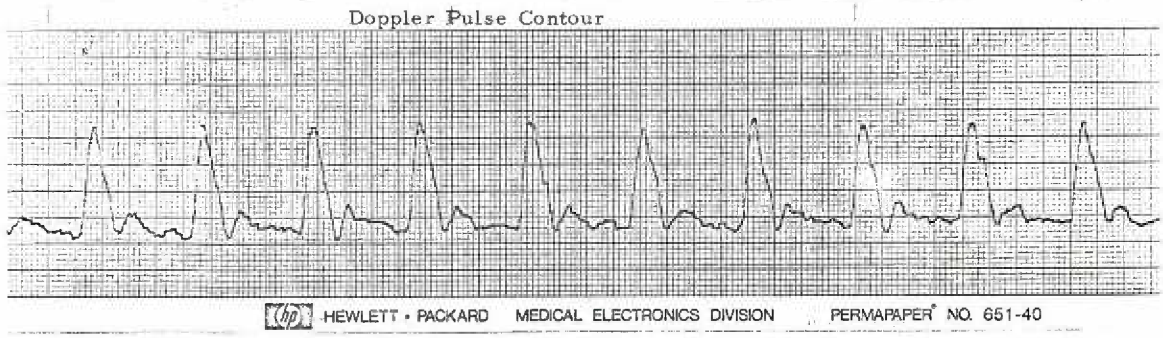
EKG INTERPRETATION

Rate - Apical 82	P-Wave positive 0.12 secs. followed by Q.R.S. each time	Drugs	Digoxin
Rhythm+Conduction regular and sinus	Q.R.S. Normal 0.06 secs.	I/V	Right radial vein
	T-Wave Positive	Other	No angio No cardio

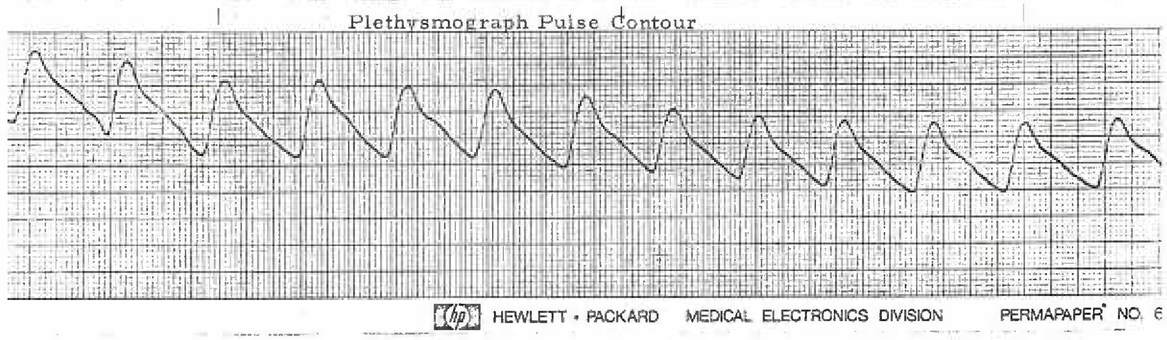
Patient #15 EKG



Doppler Pulse Contour



Plethysmograph Pulse Contour



Patient #15

Notice that in the left pedal pulse the rate goes down and the rhythm appears irregular, perhaps due to the fact that not all the pulsatile fluctuations were palpable.

This EKG is remarkable from the viewpoint of exhibiting sinus rhythm with such precision. It is the most nearly non-pathological tracing in the sample.

The present episode had been precipitated by an emotional upset with his new wife, who had come home drunk. On interview it was evident that he was very angry and had used his long term cardiac problem in an effort to control the situation.

The difference in rate between left and right radial palpations is open to discussion. If the accuracy criterion for pulse rate is applied here, the range difference should not be more than 8. Unless the rhythm is irregular, the palpation is in error. It is suggested that the palpation was in fact, erroneous, the magnitude was similar; no record is noted as being difficult. The pedal pulse were both palpable; the patient was not dyspnoeic, though the rales indicated some possible pulmonary edema--in fact, only insipient decompensation could be assumed to interfere. The palpation was most likely in error, but notice the error was in the hand with the I/V infusion.

THESIS SUMMARY

The purpose of the study was to compare palpation of the pulse to instrumental controls. Palpation is a traditional activity in nursing care; modern technology in the form of monitoring systems provide measures to which this activity was compared. The study checked the accuracy of this nursing activity on acutely ill cardiac patients, so that the variables of rate, rhythm and magnitude of the pulse were researched under conditions of cardiac misfunction. The purpose of the study was also to disclose the usefulness of pulse palpation in the cardiac care unit where instruments were already effectively providing information regarding the status of the patient. It was also planned to compare the results of data collected on the left and right sides of the body, in case this finding assumed significance for nursing care.

A pilot study upon ten patients in the Cardiac Intensive Care Unit at the Veterans Hospital, Portland, Oregon was performed using ten male patients aged 42-91 years who were admitted for acute care. All patients were on Sanborn monitoring systems with floating electrodes placed at Lead II position. Right and left radials, then temporals were palpated. Then the apical pulse was auscultated and the results compared for rate and rhythm to the EKG tracings which had been recorded simultaneously. Placement of the stethoscope for the apical pulse was at point of maximum input and no deviation from this proceeding occurred. The magnitude of the pulse nor, indeed, its presence at the periphery was recorded by the machine, and this

qualitative assessment was not comparable to the instrumental tracings.

The results of the pilot study showed that three out of ten patients had an appreciable difference in results from the monitor, two regarding rate and one in rhythm. Differences in "tone" or magnitude occurred constantly between temporal and radial pulses and one patient had no temporal pulse on the left side at all, another had no palpable right radial pulse. The apical beat was difficult to locate in seven out of ten patients. No statistical analyses were performed, but the raw data presented such unusual features that a more carefully controlled study was planned and executed.

A purposive sample of fifteen male veterans were included in the main study. Female patients were not used to exclude the variable of breast formation which could interfere with results. Congenital anomalies were considered a serious data contaniment and veterans were the patients of choice, as screening for military service eliminated gross problems of this kind. The patients were representative of many cardiac illnesses, including congestive heart failure, rheumatic heart disease, myocardial infarction and heart block. Age was limited to 45-75 years to exclude the compounding problems of increased age, a factor which proved detrimental to the study later.

All patients were on cardiac monitors and the palpation of rate and rhythm was compared to the EKG tracings. Magnitude was ranked by nursing assessment. A Doppler Ultrasonic Unit and a strain gauge plethysmograph were used to obtain pulse contour tracings against which it was planned to compare the magnitude of the pulse. As the blood pressure is related to the peripheral circulatory condition as is the magnitude of the peripheral pulse, the blood pressures were also taken by Doppler and plethysmograph and by sphygomomanometer. Technical problems caused the researcher to record blood pressures on the left and right sides of the body only by sphygmomanometer, as to use all measuring devices would extend the time for patient participation beyond the point of comfort for the sick person. Radial and temporal pulses were recorded in the same way as in the pilot study, and femoral and pedal palpations were added. The apical pulse was auscultated but this time any point on the frontal thorax was used where the heart beat could be heard most effectively. Notations regarding demographic information, presence or absence of intravenous infusions, previous angiography or cardiograms, type of drugs in use for each patient, and also appearance and palpable warmth of the feet were carefully documented.

Results. An analysis of variance showed significant difference at the 95 percent level of confidence between the palpation rate of the temporal and pedal pulses and the radial and pedal pulses. The radial and temporal pulses gave almost exactly the same readings and this accounts for the fact that both differ significantly from the pedal palpations. It is obvious that nursing situations involving pedal palpation for rate are, according to this study, open to question. No difference was found between all palpations for rate on the right side of the body when compared to the left side, and palpation can be performed on this population of patient with equal reliability regardless of which side of the body is chosen to palpate rates.

Total observations for palpated rhythm regularity were compared to the monitor tracings using chi-squares and significance was found at $p = 0.01$. Further analyses located this difference as occurring primarily with the femoral and pedal arteries. However further analysis, comparing monitor to palpation on the right sides and then on the monitor to palpation on the left side of the body (not between the sides of the body) also showed a significant difference at the 99 percent level of confidence. Ascites had interfered with femoral palpation, but this fact alone does not sufficiently account for the statistical results for rhythm notations. It would evoke a conclusion that palpation for rhythm irregularity must be interpreted with care, as the monitor provides a more tangible and reliable evidence of cardiac arrhythmias.

Prior to analysis of the data regarding magnitude of the pulse, the instruments were compared for validity by Analysis of Variance over systolic pressures recorded by the sphygmomanometer, Doppler Unit and plethysmograph. No significant difference was found. The

Doppler unit registered the diastolic pressures with a change in sound which was unfamiliar to the researcher and this unit was validated in the Surgical Intensive Care Unit at the Veterans Hospital ($r = 0.87$ systolic, $r = 0.50$ diastolic). When the diastolic pressures were compared by analysis of variance, a significant difference was found at $\alpha = 0.05$ between the lowest diastolic pressure reading of the sphygmomanometer and the Doppler diastolic pressure. It can be seen, then, that all instruments demonstrate reliability in this study for recording systolic blood pressure. The low Pearson's r, and the statistical significance are interpreted to indicate the difficulty of the operator in locating diastolic pressures by Doppler as the Doppler readings appear to have been recorded consistently higher than is accurate.

The pulse contours varied from patient to patient and were not comparable to the ranked pulse magnitude. Blood pressure recordings were scaled and ranked but no correlation could be demonstrated by the RHO correlation coefficient. No control measures were established in the study for comparing pulse magnitude by palpation. The apical pulse in this study was not significantly variant from the monitor or other pulse rates. Operational difficulties in locating the apical beat were minimized by adjusting the stethoscope to facilitate hearing. The more variant finding of the pilot study are postulated to be due to the extreme age of the patients used in the sample, as more extreme cardiac problems are experienced with advanced age and the elimination of this group in the major study was felt to be an error.

As nursing palpation for rates particularly the radial and temporal pulse, was so accurately demonstrated, a tool to measure an acceptable range of variance from established normal patterns of the individual patient was included in the study as follows: Pulse rate of range 10 [$\pm$ 5], pulse rate range 9 [$\pm$ 4.5], pulse rate range 8 [$\pm$ 4], pulse rate range 7 [$\pm$ 3.5], pulse rate range 6 [$\pm$ 3]. This tool was calculated on the basis of plus or minus one millimeter between R-R_1 on the EKG tracings.