The Effect of Lateral Body Positions Upon Pulmonary Artery and Pulmonary Wedge Pressures in Critically Ill Patients

Sharon Greer Millard

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ABSTRACT

THE EFFECT OF LATERAL BODY POSITIONS UPON PULMONARY ARTERY AND PULMONARY CAPILLARY WEDGE PRESSURES IN CRITICALLY ILL PATIENTS

by Sharon Greer Millard

The effect of lateral body positions on pulmonary artery pressures and pulmonary capillary wedge pressure was studied in a clinical comparative study using eight critically ill patients. Pulmonary artery pressures (systolic, diastolic, and mean) and pulmonary capillary wedge pressure measurements were taken with the patients in three different positions, i.e., supine flat, right lateral, left lateral. Comparison was made between the control data (pressure measurements in the supine flat position) and the pressure measurements in each lateral body position. Mean pressures were lower in the lateral body positions than those in the supine flat position, ranging from 0.1 mm Hg to 3.3 mm Hg lower. F-ratios for all pressure differences in relation to position were not significant at the 0.05 level. It was concluded that for the eight critically ill patients in the study, taking the pulmonary artery pressures and pulmonary capillary wedge pressure measurements in the lateral body positions, utilizing the external reference points as described, resulted in insignificant differences in pressure measurements. No generalization of the findings can be made to other critically ill patients.
THE EFFECT OF LATERAL BODY POSITIONS UPON PULMONARY
ARTERY AND PULMONARY WEDGE PRESSURES
IN CRITICALLY ILL PATIENTS

by
Sharon Greer Millard

A Thesis in Partial Fulfillment
of the Requirements for the Degree Master of Science
in the Field of Nursing

May 1979
The persons whose signatures appear below certify that this thesis in their opinion is excellent, in scope and quality, as a thesis for the degree Master of Science.

Evelyn L. Elwell, Assistant Professor of Nursing

Lavaun W. Sutton, Associate Professor of Nursing

Burton A. Briggs, Assistant Professor of Anesthesiology
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Chapter 1

INTRODUCTION

The nursing care of critically ill patients often includes the frequent monitoring of pulmonary artery pressures. Traditionally, this type of monitoring has involved placing the patient supine and flat before taking the pressure readings.

From personal experience and from talking with critical care nurses, several problems have been identified in conjunction with this type of monitoring: (a) because these pressures are monitored frequently, this may involve disturbing a sleeping patient to reposition him flat and supine; (b) some patients, e.g., those in respiratory distress or cardiac decompensation, cannot tolerate lying flat; (c) frequent turnings are exhausting to a very ill patient and are cumbersome and very time consuming for the nurse because of the many tubes and monitoring lines and therefore, although the nurse recognizes the need for and the importance of position changes, the patient may go for long periods of time lying on his back without being repositioned in the side-lying positions; (d) undesirable time intervals between pressure readings may occur because the patient is positioned on his side and the nurse does not want to disturb him to reposition him supine.

NEED FOR THE STUDY

If pulmonary artery pressure readings can be taken with the patient lying on his side some of the problems identified in the preceding section
may be alleviated. The rest periods of the patient will not be disturbed. Nursing care, which includes preventive measures against the complications of immobility, can be improved. Therefore, it was decided that a study of the effect of lateral body positions upon pulmonary artery pressures might yield important information that would contribute to patient well-being and would also expand the body of nursing knowledge by broadening and strengthening its scientific basis.

PURPOSE OF THE STUDY

The purpose of this study was to investigate whether nurses can take pulmonary artery pressure and pulmonary capillary wedge pressure readings with the critically ill patient in lateral positions and have the assurance that the pressure readings are reliable. If this is possible, then nursing care of these patients can be greatly enhanced.

RESEARCH QUESTION

One specific problem was identified for this study: In the critically ill patient, is there a difference between pulmonary artery pressures and pulmonary capillary wedge pressure in the supine flat position compared to the right and left lateral positions?

HYPOTHESIS

The study problem can also be stated as a null hypothesis. This hypothesis stated that there would be no significant difference ($\alpha=0.05$) between pulmonary artery pressures and pulmonary capillary wedge pressure
in the supine flat position compared to the right and left lateral positions in critically ill patients.

DEFINITIONS

It is important in the research process that the terms, concepts, and variables of a study be clearly defined within the context of this specific study. It may be that the reader is not familiar with some of the terms and concepts used in this study. Some terms may be subject to several meanings or different interpretations. Therefore, the following section will be devoted to explicit clarification and definition of terms, concepts, and variables used in this study.

Pulmonary Artery Catheter

The pulmonary artery catheter is a balloon flotation catheter used to measure pulmonary artery pressures. It can be inserted percutaneously through the internal jugular or subclavian veins or through a cutdown into an antecubital vein and then it is advanced until the tip is near the right atrium. The balloon on the catheter is properly inflated with air and blood flow carries the catheter through the tricuspid valve into the right ventricle and out the pulmonary valve into the pulmonary artery. The catheter continues to advance into the pulmonary artery until it becomes "wedged" into position because the diameter of the balloon occludes a pulmonary vessel.

When the balloon is deflated pulmonary artery pressures can be monitored. When the balloon is inflated pulmonary capillary wedge pressure (PCWP) is recorded.

The basic design of the catheter is a soft, flexible double-lumen
catheter made of polyvinylchloride. The larger, or major lumen terminates at the catheter tip and is used to measure pulmonary pressures. The small lumen terminates in a latex balloon which can be inflated to surround, but not occlude, the tip of the catheter.

Other types of catheters are now available. These include a triple-lumen catheter which allows simultaneous measurements of right atrial and pulmonary artery pressures (Swan and Ganz, 1975, pp. 502-504). Another catheter facilitates measurement of cardiac output by thermal dilution because there is a thermister at the tip of the catheter. Other catheters are designed to facilitate cardiac pacing (Swan, 1975b, p. 85).

Pressure Transducer

The pulmonary artery catheter is connected to a pressure transducer. A pressure-sensitive diaphragm inside the transducer converts the pressure which is transmitted through the pulmonary artery catheter into an electronic signal. This signal is displayed on the oscilloscope of the pressure monitor as a wave form. It can also be recorded on graph paper for permanent records and for precise measurement of pressure.

Pulmonary Artery Pressures

Pulmonary artery pressures (PAP), along with PCWP, are the dependent variables in this study. These pressures can be obtained when the tip of the pulmonary artery catheter is in the pulmonary artery (with the balloon on the catheter deflated). The following pressures are included:

1. Pulmonary artery systolic pressure (PASP) which has a normal mean of 25 mm. Hg.
2. Pulmonary artery diastolic pressure (PADP) which has a normal mean of 10 mm. Hg.

3. Pulmonary artery mean pressure (PAMP) which has a normal mean of 15 mm. Hg.

Pulmonary Capillary Wedge Pressure

The pulmonary capillary wedge pressure (PCWP) is one of the dependent variables for this study. It is obtained when the balloon of the pulmonary artery catheter is inflated which causes the catheter to be "wedged" into the pulmonary artery. In the "wedge" position the tip of the catheter senses the pressures which are transmitted in a retrograde fashion from the left atrium. The normal mean for PCWP is 12 mm. Hg.

Lateral Body Positions

The right and left side-lying positions were considered to be the independent variables here. The patient was turned approximately 90° in the lateral position and was propped with a 75° angular sponge bolster. A pillow was used under the head and another between the legs with the anterior leg flexed over the dependent leg.

External Reference Points

The external reference points are the points on the body which are used to accurately position the pressure transducer which is used in measuring the PAP and PCWP. The following reference points were used:

1. For the supine position the anterior axillary line in the second intercostal space was used.

2. For the lateral positions the second intercostal space at the left sternal border was used.
Extraneous Variables

Extraneous variables were identified as those variables which could not be measured or controlled in the present study. These include organismic, antecedent, confounding, and intervening variables (Treece and Treece, 1977, pp. 121-123).

Organismic variables. Sex, age.

Antecedent variables. Diagnosis, duration of illness, smoking history, cardiac status, non-cardiopulmonary dysfunctions which might affect the cardiopulmonary system.

Confounding variables. Effects of cardiopulmonary bypass, pharmacologic agents, transient changes in circulating volume and/or left ventricular pressure.

Intervening variables. Stress, anxiety, sleep and sensory deprivation, sensory overload.

CONCEPTUAL BASIS

Knowledge of cardiac function is very important in guiding physicians and nurses in the treatment of patients with acute critical illnesses (Ellertson, and Others, 1974; Swan, 1975a; Swan, 1975b). Cardiac failure is the most critical determinant of the outcome of most acute critical illnesses. If cardiac output is inadequate for even very short periods of time, then the function of other systems of the body will deteriorate as a direct consequence (Swan, 1975b, p. 83). Therefore, it is imperative to have an accurate means of assessing cardiovascular
function so that decisions concerning treatment can be made and therapy can be evaluated.

Need for Hemodynamic Monitoring

Assessment of cardiovascular function involves the monitoring of a variety of parameters. Some are considered relatively imprecise methods of assessing cardiac function. These may include cuff arterial blood pressure, heart rate, cardiac rhythm, central venous pressure, and urinary output. Although these parameters are important in the overall assessment of cardiac function more precise methods of monitoring have been developed in the past eight years and are now being used frequently. In addition to the above-mentioned methods of hemodynamic monitoring physicians and nurses are relying on direct intra-arterial pressure measurements, measurements of the filling pressure of the left ventricle, and evaluation of cardiac output for precise and rapid assessment of cardiac status (Swan, 1975b, pp. 83, 84).

Left ventricular function is important to know because it determines the perfusion of body organs. Left ventricular end-diastolic pressure (LVEDP) is a major determinant of left ventricular function (Braunwald and Ross, 1963, p. 147; Braunwald, 1965, p. 10). In 1961 Braunwald and associates found that left atrial pressure (LAP) closely approximates and reflects LVEDP (p. 268). In the absence of mitral valve disease, e.g., mitral stenosis which has resulted in left atrial hypertension, the LAP is closely related to the filling pressure of the left ventricle and is therefore an indicator of left ventricular function (Swan, 1975a, p. 866; 1975b, p. 86).
Direct monitoring of left atrial and left ventricular pressures can be accomplished by retrograde catheterization or by transseptal catheterization of the left heart. These are involved procedures which require skilled physicians, sophisticated equipment, and which present a considerable risk to patients. Alternate methods of monitoring these pressures are needed.

As early as 1954 Connolly and his associates demonstrated that "... the pulmonary artery wedge pressure pulse is a reasonably accurate reflection both in magnitude and in contour of the left atrial pressure pulse in man during normal respiration and also during assisted respiration at operation." (Connolly, and Others, 1954, p. 434) Since then other studies have shown that the PCWP closely correlates with LAP (Luch-singer, and Others, 1962; Lappas, and Others, 1973; Walston, II, and Kendall, 1973). Sapru and his colleagues (1968) found striking similarity between LVEDP and PCWP both in direction and in magnitude of changes.

Since it is not feasible or desirable to monitor PCWP on a continuous basis the pulmonary artery diastolic pressure (PADP) has been used in assessing LAP and therefore left ventricular function (Rapaport and Scheinman, 1969, p. 57; Kaltman, and Others, 1966; Jenkins, and Others, 1970). Good correlation between PADP and LVEDP has been observed (Scheinman, and Others, 1973) which demonstrates the usefulness of PADP in the assessment of cardiac function and thus a useful tool in guiding therapy. The physiologic basis for this correlation between the two pressures is explained by Falicov and Resnekov:

At the end of diastole ... [the] left atrium, and left ventricle form a functionally single chamber with a minute pressure
gradient in the direction of flow. During this phase of the cardiac cycle, pulmonary arterial pressure is determined predominantly by the resistance encountered by the blood as it circulates across the pulmonary vascular bed. Since this is usually a low resistance circuit and flow is least at this time, end-diastolic pulmonary arterial pressure should approximate closely the left atrial and left ventricular pressures at a point just prior to atrial and ventricular contractions. (Falicov and Resnekov, 1970, p. 70)

High pulmonary vascular resistance which is seen in such conditions as cor pulmonale, pulmonary embolus and pulmonary fibrosis does alter the close correlation between PADP and the left heart pressures (Kaltman, and Others, 1966; Jenkins, and Others, 1970; Falicov and Resnekov, 1970; Swan, 1975b). When this occurs it precludes the use of PADP for the accurate assessment of left heart functions. In view of the above information it seems then that PADP and PCWP can give reliable information concerning the function of the left ventricle which can aid health care personnel in the treatment of very ill patients.

In 1970 Swan and Ganz (Swan, and Others, 1970) introduced the balloon flotation catheter which can be used to monitor pulmonary artery and pulmonary capillary wedge pressures. This catheter is now used frequently in a variety of critically ill patients for hemodynamic monitoring of PAP and PCWP (Swan and Ganz, 1975). It has provided essential information which has greatly facilitated the management of acute burn patients who require rapid infusion of large amounts of fluids (German, and Others, 1973). Acutely ill surgical patients benefit from this type of monitoring (Sharefkin and MacArthur, 1972; Ellertson, and Others, 1974; Sorensen, 1975). Advantages in the effective treatment of patients with multiple system trauma have been reported (Civetta, and Others, 1971; Rosenbaum, and Others, 1973). In the observation and treatment of patients with acute
myocardial infarctions the use of a pulmonary artery catheter is highly recommended (Forrester, and Others, 1971; Forrester and Swan, 1974; Rutherford, and Others, 1971).

Use of Hemodynamic Monitoring by Nurses

The value of monitoring PAP and PCWP has been presented in the preceding paragraphs. Nurses are now having to become familiar with the rationale for use of this type of monitoring; they must be able to assist with the insertions of the monitoring catheters; they must be able to use and maintain them. Numerous articles have been published in nursing journals concerning the nursing care of patients with pulmonary artery catheters in place (Adams, 1976; Bolognini, 1974; Ethling, and Others, 1976; Gernert and Schwartz, 1974; Lalli, 1978; Woods, 1976).

Traditionally, readings for PAP and PCWP have been taken with the patient supine and flat (Gernert and Schwartz, 1973, p. 1184; Etling, 1976, p. 203). Many critically ill patients cannot tolerate the flat position, e.g., patients who are in respiratory distress. Also, since these pressures are monitored frequently in the critical patient, it may mean that the resting patient has to be disturbed in order to take the pressure readings.

Woods and Mansfield (1976) questioned whether it was really necessary to place the patient flat in order to obtain reliable PAP and PCWP readings. On non-critically ill cardiac patients, they showed that elevation of the backrest from the horizontal supine position to 20 degrees and 45 degrees did not result in any clinically significant differences in PADP and PCWP. Studies are being done now to determine the effect of backrest positioning on these pressures in critically ill patients (Woods,
The data from Woods' and Mansfield's study seemed to indicate that nurses may not have to position their patients flat and supine in order to obtain reliable PAP and PCWP. This would certainly promote the care and comfort of the patient.

It is even more disturbing to patients to be repositioned from side-lying to supine positions for pressure readings. Since these hemodynamic parameters are monitored frequently, the patient may have just had time to get comfortable on his side and begin to rest when it is time to turn him over in order to take the PAP and PCWP. Precious patient energy is used in repositioning. Some patients, e.g., those experiencing surgery or trauma, find it quite painful to turn from side to supine and back again. When they must do this very frequently their energy is depleted.

The primary goal of nursing is to help the patient make the maximum use of his adaptive processes in order for him to function as effectively and efficiently as possible. Energy is used by the patient to adapt to changes in his internal and/or external environment and thus maintain his system in a steady state (Menninger, 1963, pp. 92, 93) or dynamic equilibrium. Hans Selye (1956, pp. 65, 66) has used the term "adaptation energy" for this energy. When one area of the patient's system is not functioning well, energy must be reallocated from other areas in order to regain balance in the malfunctioning area (Byrne and Thompson, 1972, p. 21; Selye, 1956, p. 66). Man does not have an unlimited supply of this energy (Selye, 1950, p. 1383; 1956, pp. 66, 68), so when depletion occurs he will have to function on a reduced level of available energy.

Nurses can apply this concept of adaptation, e.g., maintenance
of a steady state through the utilization of adaptation energy, to nursing care. Much of the energy of the acutely ill person is focused on maintaining his current level of function, and on trying to restore his function to the pre-illness level. The goal of the nurse is to enhance the amount of energy available for restoration by reducing energy utilization not aimed at restoring the function of the system.

Besides the aspect of unnecessary energy expenditure which has been discussed above in relation to frequent repositioning of patients for PAP and PCWP readings, problems in administering basic nursing care seem to arise. First of all, if the patient must be placed on his back in order to take the PAP and PCWP, he may not be turned for long periods of time. Or, the patient may be maintained in side-lying positions for only very short periods of time. Another problem that may arise is that the pressure readings may not be taken as frequently as is necessary in order to allow the patient to remain on his side for longer periods of time.

Nurses are well aware of the problems that can arise as a result of bedrest and immobility. Basic nursing care includes repositioning to prevent complications of immobility, e.g., pressure sores, respiratory problems related to pooling of secretions and atelectasis, and stasis of blood with the attendant clotting phenomenon resulting in thrombus formation (Martin, 1976, pp. 381, 382; Olson, 1967). With the advent of new procedures and techniques of monitoring and treating patients nurses must not forget these basic concepts of nursing care.

In order to promote the comfort of the critically ill patient and conserve his energy for restoration, and to prevent complications
that occur due to prolonged periods of immobility, it would be of great help to the nurse to be able to take the PAP and PCWP with the patient in the lateral positions. If this is to be done, assurance of reliable pressure readings is very important.

In order to assure that reliable pressure readings are being obtained for both supine and lateral positions it is important to establish appropriate external reference points from which to measure the pressure readings. As it is with other types of hemodynamic monitoring, although it is of importance to have accurate PAP and PCWP readings, the trend of the readings is more important than the absolute values. If pressure readings are consistently taken from one external reference point, even if that reference point does not accurately reflect the internal anatomical location indicated, the trend of the values will be reliable. But if readings are to be taken from two different reference points these points must accurately reflect the same internal anatomical area.

For the purposes of this study it was decided that the trunk of the pulmonary artery as it comes from the right ventricle would be the common anatomical location for establishing external reference points, both for the supine and the lateral positions. The external reference points used in this study for the measurement of PAP and PCWP were based upon the following information.

The pulmonary artery is contained within the pericardium which is attached firmly to the sternum by the sterno-pericardial ligaments (Gray, 1974, p. 458). Because of this there may be very little, if any, shift of position of the pulmonary artery with a change of body position.
The position of the pulmonary artery in the chest cavity is such that the pulmonary trunk lies behind the sternal end of the left second interspace and the second costal cartilage (Brash, 1951, p. 1489). After the procedures described in Chapter 3, it was determined that with the body in lateral positions the second intercostal space at the left sternal border is an appropriate external reference point for the pulmonary artery. With the body in the supine position the external reference point would need to be at the anterior axillary line in the second intercostal space.

Theoretical Assumptions

Some basic assumptions can be drawn from the concepts discussed in the above theoretical approach to this study.

First, knowledge of left ventricular function as reflected by PAP and PCWP is important in the diagnosis and treatment of critically ill patients. Because this method of hemodynamic monitoring has been found to be valuable in guiding patient management physicians are utilizing this method very frequently.

Secondly, in the critically ill patient PAP and PCWP readings are taken frequently so that appropriate therapy can be given. These pressures have usually been taken with the patient supine. Patient comfort, patient energy utilization, and patient risk for complications of immobility are all involved if the PAP and PCWP are taken consistently with the patient in the supine position.

The third assumption is that if these pressures (PAP and PCWP) can be taken with the patient in the side-lying position, with the assurance of accuracy of the readings, then patient comfort and energy utilization
will be promoted and measures to prevent immobility problems can be maximally utilized.

The last assumption involves the external reference points for taking PAP and PCWP measurements. It is of utmost importance that external points of reference accurately reflect the same internal anatomical structure; otherwise the pressure readings taken from the different points of reference will not be reliable. Appropriate reference points for the study have been chosen as follows:

1. For the supine position the anterior axillary line in the second intercostal space was selected.

2. For the lateral body positions the second intercostal space at the left sternal border was identified.

ORGANIZATION OF THE REMAINDER OF THE STUDY

Chapter 1 has been a general introduction of the study with emphasis placed upon the theoretical basis. In Chapter 2 the literature and related studies will be reviewed. The research method and the data collection procedures used in the study will be described in Chapter 3. The findings of the study which include the analysis of the data and the statistical analysis is reported in Chapter 4. Finally, a brief summary and the conclusions and nursing implications, and recommendations that have arisen from this study will be discussed.
The purpose of the literature review is to determine what has already been discovered about the difference between pulmonary artery pressure (PAP) and pulmonary capillary wedge pressure (PCWP) in the supine flat position compared to the right and left lateral body positions. It was undertaken to give insight into the relationship of the variables in the study. Selected literature was reviewed to expand the knowledge and broaden the background regarding pulmonary artery and pulmonary capillary wedge pressures, regarding those things which affect these pressures and the importance of these pressures in nursing. The writer then could achieve a better understanding of the results obtained in the present study. Therefore, appropriate conclusions and recommendations could be made regarding patient positioning for pressure monitoring and for further study of PAP and PCWP.

The purpose of this study was to determine whether nurses can take PAP and PCWP readings with the critically ill patient in lateral positions with the assurance that the pressure readings are reliable.

RELATIONSHIP OF RIGHT AND LEFT HEART PRESSURES AND PULMONARY PRESSURES

It is important to understand what kind of information the pressures in the right and left heart and in the pulmonary vasculature can give. These pressures reflect function of the heart and the status of
the venous return which are important to the physician and the nurse in assessing a patient's clinical condition and in guiding appropriate treatment. It is also important to understand the relationship of these pressures, how they affect each other and what things affect them. Studies concerning central venous pressure, left atrial pressure, pulmonary artery pressure, and pulmonary capillary wedge pressure will be reviewed in the following section.

Central Venous Pressure (CVP)

In 1969 Rapaport and Scheinman (p. 57) reported the results of their work with CVP and PAP. Their experience with 24 patients with severe left ventricular failure showed that one-third of these patients had normal CVP values (<10 cm H₂O) when they were showing very obvious signs of pulmonary edema with elevated PAP.

In comparing CVP with PADP there was very poor correlation between the two pressures. Furthermore, there was poor correlation between changes in CVP compared to changes in PADP over a period of hours (r=0.36). Rapaport and Scheinman (1969, pp. 56, 57) concluded that CVP reflects the state of the intravascular volume and the competence of the right ventricle, but that it does not accurately reflect left ventricular filling pressures especially in the presence of damage and impairment in function of the left ventricle. Monitoring of PADP should be carried out in patients with acute myocardial infarction, shock or persistent heart failure.

Forrester and co-workers (1970, p. 306) compared CVP and left ventricular filling pressure in five patients with the diagnosis of acute
myocardial infarction. Their data revealed that CVP bore no consistent relationship to left ventricular filling pressure.

Another study reported in 1971 by Forrester and associates measured the CVP and PCWP simultaneously on patients who had been admitted to a coronary care unit with acute myocardial infarction. Data were collected on these pressures during volume expansion and during diuretic therapy.

The findings showed that the level of the PCWP correlated closely with the presence or absence of pulmonary congestion as seen on x-ray while CVP was of no value in assessing the presence of congestive heart failure as established by radiologic criteria. It also had no consistent relationship to the PCWP. Another finding was that the CVP was not an accurate indicator of directional changes in PCWP during fluid therapy. From these data the investigators concluded that the monitoring of CVP in acute myocardial infarction is of very limited value and could even be seriously misleading (Forrester, and Others, 1971, p. 190).

Surgical patients with a diversity of diagnoses were studied by Civetta and others (1971). The diagnoses included coronary artery disease, decompensated cirrhosis, injury to multiple systems, and advanced peritonitis. Pulmonary artery catheters were placed in these patients for PCWP monitoring. CVP was also monitored. It was found that CVP and PCWP were not related in these patients with surgical intervention for serious illnesses.

Mond, Hunt, and Sloman (1973) studied thirteen patients in the coronary care unit. Eight of these patients had left ventricular failure as evidenced by pulmonary crepitations which did not clear with coughing and by a ventricular gallop. The remaining five patients were considered
to be in cardiogenic shock. The criteria for this classification included the presence of a systolic blood pressure below 90 mm Hg along with evidence of reduced peripheral flow and central blood flow, i.e., cold, clammy extremities; low urinary output; impairment of cerebral function.

A pulmonary artery catheter was used to monitor the pressures being studied. Right atrial pressure, PADP, and PCWP were monitored and recorded on at least three consecutive days. The data obtained showed that there was a correlation between right atrial pressure (which is CVP) and PCWP over the whole group of patients (r=0.064, p<0.001). If the patients with mild left ventricular failure are considered separately from those with severe failure and cardiogenic shock, the correlation between right atrial pressure and PCWP is very good (r=0.68, p<0.001). Thus in those patients with severe left ventricular failure and cardiogenic shock, the correlation fails to reach significance (r=0.53, p>0.05) (Mond, and Others, 1973, pp. 636, 637).

Left Atrial Pressure (LAP)

Braunwald and associates (1961) studied the pressures on the left side of the heart in subjects with no cardiovascular disease while in a basal physiologic state. Eighteen subjects were studied during right and left (transseptal) heart catheterization. The following results were obtained:

1. The mean LAP ranged from -2 to 12 mm Hg, with an average of 7.9 mm Hg. The mean LAP exceeded the mean right atrial pressure in every instance.

2. LAP at the onset of atrial contraction was almost identical to mean LAP with a range of 1-2 mm Hg and an average of 7.1 mm Hg.

3. LAP at the onset of left ventricular contraction was in the range of 1 to 13 mm Hg with an average of 7.6 mm Hg.
4. Left ventricular end-diastolic pressure differed very little from mean LAP and LAP at the onset of left ventricular contraction, i.e., range of 5-12 mm Hg, average of 8.7 mm Hg (Braunwald, and Others, 1961, pp. 267, 268).

Forsberg (1971, p. 495) studied the relation between LAP and left ventricular pressure in eight patients without mitral valve obstruction. Seven patients had normal sinus rhythm and one patient was in atrial fibrillation. He found that there was diastolic congruence in all of these patients.

Pulmonary Artery Pressures (PAP)

Since direct monitoring of left heart pressures to determine left ventricular function is fraught with problems such as hazards to the patient and the skill and time needed to cannulate the left side of the heart, much study has been done regarding the relationship of PAP to left heart pressures. It was thought that PAP might be a useful estimate of LVEDP.

In 1966 Kaltman and associates conducted a study on 70 patients. They studied the relationship of the PADP to left ventricular diastolic pressure and to left atrial mean pressure. In 56 of the 70 patients no gradient in the diastolic pressure between the pulmonary artery and the left ventricle was noted. Several variables changed these pressures, but the change was in the same direction and magnitude. These variables included premature ventricular contractions, performing the Valsalva maneuver, and prolonged straining (Kaltman, and Others, 1966, p. 377).

There were 14 patients with congenital heart disease. It was
found that in these patients there was a definite diastolic gradient between the pulmonary artery and the left ventricle. The PADP was greater than 15 mm Hg. in all of these cases. It was felt that these patients had some degree of pulmonary vascular disease to account for the gradient noted (Kaltman, and Others, 1966, p. 378).

The LVEDP was obtained in 45 patients who had normal or near normal PADP. When these pressures were under 17 mm Hg. there was close correlation between them. In 46 instances the left atrial mean pressure was compared to the PADP. Here correlation was found to be highly significant (r=0.874; p<0.001) (Kaltman, and Others, 1966, pp. 378, 381).

From these data the investigators concluded that when the left atrium and the mitral valve are normal the pressure in the pulmonary veins must be close to the LVEDP. When there is difference between PADP and LVDP it must be due to pulmonary vascular resistance (Kaltman, and Others, 1966, p. 382).

Bouchard and co-workers (1970) investigated the relationship of pulmonary artery end-diastolic pressure (PAEDP) to LVEDP in patients with normal left ventricular function and in patients with myocardial disease and elevated LVEDP. Eleven patients with normal left ventricular function and 12 patients with cardiac disease and elevated LVEDP (average of 23 mm Hg.) were studied. Their results revealed that in those patients with normal left ventricular function the PAEDP and LVEDP were equal while the LVEDP was consistently higher than PAEDP (by an average of 10 mm Hg.) in the patients with impaired left ventricular function (Bouchard, and Others, 1970, p. 86).
In four patients the LVEDP was increased (by an average of 10 mm Hg.) with the use of drugs. Three of these patients initially had normal LVEDP. The PAEDP remained unchanged or increased only slightly with this drug-induced increase of LVEDP (Bouchard, and Others, 1970, p. 86).

From the data from this study it was concluded that in patients with chronic left ventricular failure the PAEDP does not provide an accurate estimate of LVEDP. Furthermore, PAEDP often fails to reflect an acute increase in LVEDP (Bouchard, and Others, 1970, p. 86).

Using a flow-directed balloon tip catheter, pulmonary artery catheterization was performed on 23 critically ill patients, twelve of whom had acute myocardial infarction. In five of these patients (with myocardial infarction) a left ventricular catheter was also placed. It was found that PADP exceeded left ventricular filling pressure by at least 5 mm Hg. or more in 30 per cent of the measurements which were taken (Forrester, and Others, 1970, p. 306).

Twenty-eight patients with acute or chronic heart disease were studied to determine under what circumstances the PAEDP can be safely assumed to reflect left atrial mean pressure. Twenty-two patients with congenital or valvular disease were studied post cardiac surgery. Of the remaining six patients with acute disease, two had acute myocardial infarction and four had a diagnosis of pulmonary embolism. The independent variables included alterations in blood volume (eight patients), use of isoproterenol or epinephrine (five patients), and changes in blood volume and the simultaneous use of inotropic drugs (thirteen patients). All these measures are known to affect pulmonary vascular resistance (Jenkins, and Others, 1970, pp. 75, 77).
It was found that when pulmonary vascular resistance is elevated left atrial mean pressure cannot be accurately estimated from the PAEDP. Although changes in PAEDP are associated with changes in left atrial mean pressure in the same direction the magnitude of the change differs. Therefore, the investigators concluded that only when the pulmonary vascular resistance is normal can PAEDP be considered to accurately reflect left atrial mean pressure (Jenkins, and Others, 1970, pp. 77, 78).

Falicov and Resnekov (1970) examined the relationship of the PAEDP to LVEDP and to pulmonary artery wedge pressure. The patients were divided into two groups, those with normal left ventricular function (LVEDP of 4-12 mm Hg.) and those with left ventricular dysfunction (LVEDP of 12-55 mm Hg.). They found that PAEDP was within 3 mm Hg. of LVEDP and PCWP in the patients with normal left ventricular function. As was noted in other studies, these investigators found that in those patients with high LVEDP the PAEDP did not correlate well. In 42 cases the PAEDP was lower than LVEDP; in six instances the two pressures were the same; the PAEDP was higher in eight patients. Although the PAEDP and LVEDP correlated poorly in patients with left ventricular dysfunction, the PAEDP did correlate closely with PCWP.

In another study right and left heart catheterizations were done on 13 patients with acute myocardial infarction. The diastolic pressures in the left ventricle and the pulmonary artery were measured and compared before, during, and after atrial contraction. It was noted that just before atrial contraction the pulmonary artery pressure closely reflected mean left ventricular diastolic pressure (r=0.98). During maximum atrial contraction the pulmonary artery pressure correlated well with LVEDP.
(r=0.92). After atrial contraction the pressures in the left ventricle were higher than those in the pulmonary artery. LVEDP in the thirteen patients averaged 5.2 mm Hg. higher than the mean left ventricular diastolic pressure (Schoenfeld, and Others, 1970).

Forsberg (1971) gathered data on 158 patients who had undergone right and left heart catheterization. He studied the relationship between the PADP and LAP. In 17 patients with normal hearts the difference between PADP and mean LAP was 1.4±2.0 mm Hg. Fifteen patients with heart disease who had mean LAP at rest of 12 mm Hg. or less and a pulmonary vascular resistance of less than 2.0 units had similar relationships of PADP to mean LAP. In these patients PADP minus mean LAP was 1.0±2.0 mm Hg. which is very close to the results of the normal patients (Forsberg, 1971, p. 495).

The difference between PADP and mean LAP in relation to pulmonary vascular resistance was calculated for 155 patients with normal sinus rhythm or atrial fibrillation. It was found that as pulmonary vascular resistance increased the average pressure difference did increase. The pressure difference though was not greater than 4 mm Hg. with pulmonary vascular resistance as high as 4.0 units (Forsberg, 1971, pp. 495, 496).

Bouchard and associates (1971) evaluated the PAEDP as an estimate of LVEDP in patients with normal and abnormal left ventricular function. The sample included 50 patients, 24 with normal left ventricular function and 26 with left ventricular disease with elevated LVEDP (average of 22 mm Hg.). In the normal patients the PAEDP and LVEDP were very close (average of 8 mm Hg. with a maximum difference of ±4 mm Hg.). In 20 of the 26 patients with left ventricular disease the LVEDP was higher than the PAEDP.
by an average of eight mm Hg. Of further note is the fact that in 12 of these 20 patients the PAEDP was 12 mm Hg. or less. Twelve mm Hg. is in the upper limits of normal for LVEDP. Therefore, in the 12 patients the PAEDP gave no indication of elevated LVEDP. It was noted that the left ventricular diastolic pressure, the pressure just prior to atrial contraction, correlated more closely with PAEDP (Bouchard, and Others, 1971, p. 1072).

Pulmonary artery end-diastolic pressure and LVEDP were then studied after elevation of systemic blood pressure. Six patients received methoxamine to induce the elevated blood pressure. Two patients had spontaneous blood pressure elevations. The LVEDP increased by 2-11 mm Hg. (average of six) while the PAEDP remained unchanged or increased only slightly (Bouchard, and Others, 1971, p. 1072).

Atrial pacing was initiated in 14 patients. At heart rates of 124 beats per minute or more the LVEDP decreased while PAEDP increased in 12 of the 14 patients which resulted in a consistent disparity in these pressures (by an average of 11 mm Hg.). Actually this disparity was seen at heart rates as low as 115/minute. An explanation for this disparity in pressures could be that at fast heart rates diastolic filling time is shortened which results in a lower filling pressure for the left ventricle. Also, during fast rates the left atrium may contract against a closed or partially closed mitral valve which could cause a disparity in pressures (Bouchard, and Others, 1971, pp. 1072, 1077).

As with the study they conducted in 1970, Bouchard and others (1971, p. 1072) concluded that the PAEDP does not give an accurate reflection of LVEDP in patients with chronic left ventricular failure. Pulmonary
artery end-diastolic pressure may also fail to reflect acute alterations in LVEDP.

Because various workers had been unable to show a positive correlation between PAEDP and LVEDP (Bouchard, and Others, 1970; Falicov and Resnekov, 1970), Balcon, Bennet, and Sowton (1972) elected to re-study these pressures under more controlled conditions. They felt that the previous studies had involved patients who could be divided into a number of different etiological groups. They further felt that the point taken for pressure measurement was not consistent. Therefore, they proposed to compare PADP and LVEDP just before atrial contraction in a group of patients with the diagnosis of ischemic heart disease (Balcon, and Others, 1972, p. 172).

Fifteen patients were studied. Just before atrial contraction there is a point on the pressure curve that is designated as the pre 'a' point. When pressures were measured at this point the correlation between PADP and LVEDP was good with a correlation coefficient of 0.942 for 300 pressure comparisons. Five mm Hg. was the greatest pressure difference and this occurred in only 2.5 per cent of the comparisons. In 80 per cent of the pressure measurements the difference was 2 mm Hg. or less (Balcon, and Others, 1972, pp. 172, 174).

The reliability of using PAEDP as an index of LVEDP and thus of left ventricular function in patients in shock was examined by Scheinman and co-workers (1973). Their study "was designed to analyze the effects of change in arterial oxygen tension (PO2), heart rate, stroke volume, and
systemic pressure, induced by various therapeutic agents, on the relationship between PAEDP and LVEDP in these patients." (Scheinman, and Others, 1973, p. 317)

The sample included 26 patients who were in shock due to a variety of causes. Twelve patients were in shock because of acute myocardial infarction; three patients were postcardiac arrest; five were in sepsis; three were hypovolemic; cerebrovascular accident was the cause in two patients; drug overdose was the cause of shock in one. The independent variables included high-oxygen administration to 16 patients, inotropic drug therapy with norepinephrine or isoproterenol or glucagon in seven patients, diuretic therapy with ethacrynic acid for two patients, and one patient received a volume challenge of 250 ml. (Scheinman, and Others, 1973, pp. 317, 319).

The results from this study revealed that there was no statistically significant difference between mean PAEDP and mean LVEDP for the group as a whole. The correlation coefficient was \( r = +0.85 \) (\( p < 0.01 \)). In 27 studies after various types of interventions the changes in PAEDP correlated significantly (\( p < 0.01 \)) with changes in LVEDP. It was found that when PAEDP was above 15 mm Hg. the LVEDP was above 12 mm Hg. while a PAEDP of 10 mm Hg. or less was associated with an LVEDP of less than 12 mm Hg. (Scheinman, and Others, 1973, pp. 318-320).

Further findings in relation to heart rate showed that there was good correlation between PAEDP and LVEDP (\( r = +0.91 \)) at heart rates less than 100 beats per minute. With heart rates above 100 beats per minute the correlation was not as close (\( r = +0.80 \)). As opposed to Bouchard's study (1971), in this study the PAEDP was not consistently
higher than LVEDP at fast heart rates (Scheinman, and Others, 1973, p. 320).

The administration of high oxygen flows to 16 patients produced no significant difference between mean PAEDP and mean LVEDP. With the use of inotropic drug therapy the changes in LVEDP were accompanied by comparable changes in PAEDP. In the three patients who received either diuretic therapy or a fluid challenge the changes that occurred in PAEDP and LVEDP were in the same direction, but the investigators felt that a valid statistical conclusion could not be made from so little data (Scheinman, and Others, 1973, pp. 320, 321).

From the data in this study the conclusion was made that PAEDP can accurately reflect LVEDP in patients in shock. Under a variety of conditions such as changes in systemic blood pressure, heart rate, arterial oxygen tension, and the use of various therapeutic measures the PAEDP correlated well with LVEDP (Scheinman, and Others, 1973, p. 317).

Pulmonary Capillary Wedge Pressure (PCWP)

In 1954 Connolly and workers examined the relationship between pulmonary artery wedge pressure and left atrial pressure. The sample consisted of 33 patients. Seventeen patients were studied during cardiac catheterization and 16 were studied during surgery.

The 17 patients studied at heart catheterization had atrial septal defect. It was found that there was close correlation between PCWP and LAP in these patients. The average mean of the PCWP was 8 mm Hg. and for the LAP, 7 mm Hg. (Connolly, and Others, 1954, p. 439).
The surgical patients included 12 patients with mitral stenosis who were having a commissurotomy and four patients who had lung tumors. In the 12 mitral commissurotomy patients there was a close similarity both in contour and in magnitude of the pulmonary artery wedge and the left atrial pulse pressures. It was noted that this similarity was not affected either by respiration or arrhythmias. The similarity between the two pressures was not as striking in the patients with the lung tumors, but it still was present (Connolly, and Others, 1954, p. 439).

Luchsinger and associates (1962) also studied the relationship of PCWP to LAP. In their work patients were studied in the control state, during epinephrine infusion which raised the brachial blood pressure by 20 to 40 per cent, and with positive and negative intra-alveolar pressures. These pressures were created by having the patients either blow against or suck on a "U" tube water manometer (Luchsinger, and Others, 1962, p. 315).

The results indicated that there was a linear relationship (regression coefficient $b=0.86\pm0.04$) between PCWP and LAP during control, epinephrine infusion, and positive and negative intra-alveolar pressures. This relationship was maintained over a pressure range of LAP up to 30 mm Hg. and of PCWP up to 50 mm Hg. (Luchsinger, and Others, 1962, p. 316).

In 1968 the PCWP was compared with the LVEDP in man (Sapru, and Others). At rest and during exercise PCWP and LVEDP were measured. There was close agreement between these two pressures. They showed a similarity in both the direction and in the magnitude of the changes in
pressures observed. The investigators concluded that in the absence of mitral valve obstruction the PCWP accurately reflects LVEDP (Sapru, and Others, 1968, pp. 129, 138).

The relationship of PCWP to LVEDP and to left ventricular mean diastolic pressure in critically ill patients was investigated by Forrester and co-workers (1970). They found that there were significant differences between LVEDP and PCWP. The PCWP correlated best with left ventricular mean diastolic pressure (Forrester, and Others, 1970, p. 306).

Evaluation of PADP versus PCWP as an indirect method of measuring LAP was done (Lappas, and Others, 1973). Eighteen cardiac surgical patients were studied. One hundred sixty-one sets of pressure measurements were taken. The investigators found that although overall correlation was good, the PCWP was a more sensitive indicator of LAP than was the PADP (Lappas, and Others, 1973, pp. 395, 396).

Walston and Kendall (1973) compared PCWP with left atrial pressure in man. Since PCWP is used to evaluate the filling pressure of the left ventricle it was felt that the precise correlation of PCWP and left atrial pressure over a wide range of pressures was indicated.

The records of 700 patients who had had cardiac catheterization between the years of 1959 and 1972 were reviewed. The patients included those with normal hearts and those with a variety of cardiac diseases including coronary artery disease, mitral stenosis or insufficiency, aortic stenosis or insufficiency, or a combination of valvular lesions (Walston and Kendall, 1973, p. 159).
Comparison of mean values for PCWP and LAP in all patients showed that despite a wide variation in range of pressures, linear regression analysis gave a correlation coefficient of r=0.93 with a standard deviation of ±3.0 mm Hg. The degree of scatter did increase as the PCWP and LAP rose. At PCWP below 25 mm Hg, there was no significant difference between mean PCWP and mean LAP. With a mean PCWP of 10 mm Hg or less, the error in predicting LAP was only ±2 mm Hg. Error increases considerably as PCWP rises. This data indicated that great care should be taken in using the PCWP as a reflection of filling pressures of the left ventricle when the PCWP is higher than 10 mm Hg. (Walston and Kendall, 1973, pp. 160, 161).

Positive end-expiratory pressure (PEEP) can affect the relationship of PCWP to LAP. As PEEP is increased, there is an increase in the gradient between PCWP and LAP. In order for PCWP to accurately reflect LAP there must be a continuous column of fluid from the pulmonary artery catheter tip to the left atrium. This continuity of fluid can be disrupted by increased alveolar pressure which may collapse the capillaries. This can occur with PEEP. In such cases the PCWP may be reflecting alveolar pressure rather than LAP (Hobelmann, and Others, 1974; Lozman, and Others, 1974; Kane, and Others, 1978).

In addition to the effects of PEEP on the fluid column between the left atrium and the tip of the pulmonary artery catheter, the effect of position of the catheter in the lung and the effect of hydrostatic pressure have been studied. If the catheter tip was placed above the left atrium PEEP caused a gradient between PCWP and LAP. If the
catheter tip was below the left atrium no effects of PEEP were noted. A pressure gradient between PCWP and LAP which was accentuated with the addition of PEEP was noted during hypovolemia (Kane, and Others, 1978).

THE USE OF PAP AND PCWP MONITORING

Since the advent of coronary care units and cardiac rhythm monitoring, deaths due to arrhythmias in myocardial infarction patients have been greatly reduced. More myocardial infarction patients now die from pump failure. Rutherford and associates studied the usefulness of PAP monitoring in assessing the initial severity of myocardial impairment, subsequent prognosis, detection of complications, and as a basis of therapy in myocardial infarction patients (Rutherford, and Others, 1971).

It was found that a normal PAP on admission was a good indication of an uncomplicated course of recovery. If the PAP is elevated on admission but drops to about normal within 38 hours a prognosis for recovery without major complications can be expected, whereas, if the PAP is elevated on admission and subsequently continues to rise, or if it does not begin to drop within the first 48 hours, a complicated course can be expected. The PAP appears to be a good indicator of heart failure. In a group of 12 patients who had elevated PAP (>20 mm Hg.) on admission only one patient had clinical signs of left ventricular failure. The other 11 patients did not show signs of failure until the third day of monitoring. The PAP appeared to be the only objective
indicator of a deteriorating cardiovascular state. An elevated PAP preceded other clinical signs of heart failure, such as a fourth heart sound and pulmonary venous constriction, by six to 24 hours. This study related PAP to other parameters which have been used to indicate left ventricular deterioration. These parameters included pulmonary artery oxygen saturation, stroke volume index, and arterial oxygen saturation. It was found that there was a linear fall in each of these parameters with a rising PAP (Rutherford, and Others, 1971, pp. 662, 664, 666).

The clinical application of PAP and PCWP monitoring in evaluation of rapidly changing clinical situations and of response to therapy, and in the diagnosis of specific cardiac lesions has been reported by Forrester and coworkers (1972). They found PCWP valuable in diagnosing and treating iatrogenic hypovolemia (resulting from vigorous diuretic and digitalis therapy). Shock due to hypovolemia was diagnosed in the face of a CVP of 12 mm Hg. The PCWP was found to be 1 mm of Hg, while the CVP was 12 mm Hg. The PCWP was helpful in the early detection and treatment of congestive heart failure and in the differentiation of pulmonary embolism from cardiogenic shock. Diagnosis of ventricular septal defect following myocardial infarction was made with the aid of PCWP. In another case acute mitral insufficiency was found in a patient in cardiogenic shock from myocardial infarction. The patient had no murmur to indicate involvement of the mitral valve. It was felt that due to a low cardiac output state no murmur occurred (Forrester, and Others, 1972, pp. 60–62).

Sharefkin and MacArthur (1972) evaluated the usefulness of monitoring PAP as a guide in assessing the hemodynamic status of surgical patients. They monitored both CVP and PAP in these patients. They found
that in patients with prior evidence of heart disease and who had large volume losses during operation the PAEDP was a more sensitive indicator of fluid overload during volume replacement than was CVP. In some patients despite a normal CVP the levels of PAEDP were compatible with pulmonary edema. It was also found that patients with heart disease had higher mean PAEDP with a wider variation for any given CVP. The investigators felt that this data indicated that in those patients with evidence of heart disease who are going to need large volume replacements at surgery the PAEDP or the PCWP should be monitored.

Scott and associates (1972) reported their experience in 123 patients with the use of pulmonary artery catheters for PAP and PCWP monitoring. They found this type of monitoring very helpful to the clinician when there is a changing clinical situation. A pulmonary artery catheter was used in a variety of situations. In cardiac surgical patients the PAP proved to be similar to LAP in a series of 30 simultaneous measurements. It was also helpful in recognizing cardiac tamponade, pending left ventricular failure, and pulmonary edema in these patients. Another situation were PAP monitoring was useful was in posttraumatic pulmonary insufficiency such as is seen in post-cardio-pulmonary bypass, massive blood transfusions, fat embolization, crushing injuries, and in burns. In the acute myocardial infarction patient the monitoring of pulmonary artery pressures can help in the early detection of cardiogenic shock and this can help to reduce the mortality by 10 per cent. The usefulness of monitoring with pulmonary artery catheters has been seen in other situations such as pulmonary embolism, renal failure, and drug overdoses (Scott, and Others, 1972, pp. 690, 692).
The case report of a 59-year-old male who fell 35 feet sustaining a depressed skull fracture, a left flail chest with rib fractures, and pulmonary contusions of the left lung illustrates the usefulness of a pulmonary artery catheter in managing fluid therapy. In this patient the PAP was high but the PCWP was normal. Therefore, the PCWP was used as a guide to fluid management. It was felt that this type of monitoring greatly enhanced the care of this patient (Rosenbaum, and Others, 1973, pp. 261-264).

Pulmonary artery pressure monitoring has been found to be of great help in the management of acute burns. It has been found that PAP is much more sensitive than is CVP during fluid resuscitation in the acute burn patient. The CVP lagged hours behind the PAP in response to fluid infusion. Experience has shown that in relation to CVP the PAP is a much better indicator of blood volume, cardiac function, and smoke-induced pulmonary edema (German, and Others, 1973, pp. 788-791).

Forrester and Swan (1974) have written a comprehensive article on the assessment of cardiac function in the myocardial infarction patient. They first discuss the assessment of heart function by physical examination and by direct invasive methods. The interrelationships between the findings by these methods and the physiology involved is outlined. Helpful tables are included for clarification and ease of understanding. The authors then discuss the physiologic basis for treatment and the means of assessing therapy. Priorities for treatment are outlined. The use of pulmonary artery catheters for monitoring PAP and PCWP is emphasized.

A pulmonary artery catheter can be used to provide valuable
information regarding left ventricular performance, pulmonary venocapillary hydrostatic pressure, pulmonary vascular resistance, and peripheral tissue oxygenation in critically ill surgical patients. Ellertson and others (1974) reviewed the underlying physiologic principles of pulmonary artery monitoring in relation to the parameters noted above.

Three case studies are reported which help to illustrate the physiologic principles discussed by the authors. The management of seriously ill surgical patients can be enhanced by the use of the information obtained from pulmonary artery monitoring.

In 1975 Sørensen reported his experience with pulmonary artery pressure monitoring in surgical patients. A sudden marked rise in PAP preceded all other signs of deterioration in the patient's condition by seven hours in one case. It was also found that occult bleeding was more rapidly reflected by a fall in PAP than a fall in CVP. Blood loss and adequate replacement could be followed more closely with PAP monitoring.

Invasive techniques for hemodynamic monitoring, and specifically PAP and PCWP monitoring by the use of balloon flotation catheters, is described by Buchbinder and Ganz (1976). The technique for pulmonary artery catheterization is explained and the relevance of the pressure readings obtained is discussed. The PAP and PCWP can be very helpful in the diagnosis and treatment of commonly occurring clinical situations such as hypovolemia, pulmonary congestion, heart failure, pulmonary embolism, chronic obstructive pulmonary disease, acute mitral regurgitation, and cardiac tamponade.
Swan published two articles in 1975 (1975a; 1975b) in which he discussed the importance of having hemodynamic information concerning the function of the left heart in the management of critically ill patients. Pulmonary artery catheterization can give the physician and nurses this needed information. Besides the information obtained from pressure measurements, the pulmonary artery catheter can also be used for cardiac output determination. As with most invasive monitoring methods there are certain complications that can occur. Reported complications include pulmonary infarction, arrhythmias, thromboembolism, balloon rupture, electrical hazards, and knotting of the catheter. The design of the catheter which includes flexibility and the protective qualities of the balloon around the tip has helped to reduce the potential for complications. In the hands of skilled and careful users the incidence of complications is very low. Most complications occur because either precautions are disregarded or the users are not skilled in the use of the catheter.

Swan and Ganz (1975) combined their efforts in a comprehensive article on the use of balloon flotation catheters in critically ill patients. First they gave an historical overview of the use of pulmonary artery catheters. They then described the construction of the catheter and outlined the principles and techniques of balloon flotation catheterization. The kinds of data which can be obtained with this type of monitoring include pressure measurements, cardiac output, and measurement of the left ventricular contractile state. This kind of information can be obtained during diagnostic cardiac catheterization. It is necessary for the accurate assessment of cardiac function in critically ill patients.
It is also useful in establishing a precise diagnosis in the face of several complex circulatory syndromes. Some of these syndromes may include mitral regurgitation, ventricular septal defect, significant pulmonary hypertension, and cardiac tamponade. Complex arrhythmias may also be identified with the use of the newer multipurpose catheter which has sensing electrodes in both the atrium and the ventricle. Finally, the authors discuss the most frequent complications that can arise from the use of the catheter. They offer guidelines for preventing and/or dealing with the various complications that can occur.

Katz and others (1977) studied the indications for the use of pulmonary artery catheters in the operating room. These indications include: 1) marginal cardiovascular reserve, 2) anticipated large fluid or blood loss, 3) hypotensive anesthesia. The study which was both retrospective and prospective examined the complications which occurred with the use of pulmonary artery monitoring in 392 critically ill surgical patients. Early complications were arrhythmias, carotid artery puncture at time of insertion, and pneumothorax. Later complications were positive bacterial cultures, pulmonary infarction, and neuropathology which was caused by a technical error in exposing the basilic vein. No deaths due to complications occurred.

A comprehensive article by Pace (1977) discusses flow-directed pulmonary arterial catheterization. Limitations in the use of pulmonary artery monitoring are reviewed. The pulmonary capillary pressure, how it is obtained, its relationship to other heart pressures, and aspects of its reliability are discussed. The use of the pulmonary artery catheter in determining left ventricular function either by thermo-
dilution or by analysis of mixed venous blood is examined. Mention is made of the complications which have been reported with the use of pulmonary artery catheters. The article also discusses the use of this type of monitoring in clinical anesthesia. There is an extensive reference section of 168 entries.

EFFECT OF BODY POSITION ON PULMONARY ARTERY AND PULMONARY CAPILLARY WEDGE PRESSURES

In 1953 Donald and associates studied the effect on cardiac output of sitting in bed at 70° with the back supported and the feet extended. The investigators felt that this position is commonly used for nursing patients.

Data were collected on 36 patients. In addition to cardiac output measurements, PAP were also recorded. In ten patients with normal hearts and who had mean PAP below 25 mm Hg., sitting up to 70° caused no significant change in mean PAP (except in one patient with pulmonary emphysema who had a drop of mean PAP from 23 mm Hg. to 9 mm Hg.). Eight patients had definite pulmonary hypertension. In these patients there was a marked fall in mean PAP in the sitting position (mean fall of 17 mm Hg.). The supine mean PAP ranged from 29 to 69 mm Hg. The degree of fall of mean PAP upon sitting was not related to the degree of pulmonary hypertension. These changes in PAP with posture change were accompanied by little or no change in the cardiac output (Donald, and Others, 1953, pp. 199-215).

The hemodynamic effects of postural changes in myocardial infarction patients were studied by Prakash and associates (1973). Twenty-one
patients with the diagnosis of myocardial infarction were studied both in the supine and in the semierect position at 70°. A wide range of hemodynamic data was collected. This data included physical examination for rales or S3 heart sound; heart rate; right atrial pressure; PASP; PCWP; cardiac output; stroke volume; aortic systolic, diastolic and mean pressures; pulmonary vascular and systemic vascular resistance. The external reference point used for zeroing the pressure transducers for both body positions was a point five centimeters vertically below the sternal angle in the fourth intercostal space. After position change at least five minutes time was allowed to elapse before pressure measurements were taken.

With the change of position from supine to semierect the right atrial pressure had a mean rise of 2.9 mm Hg (p < 0.001). The PASP rose from 27.2 to 29.5 mm Hg upon sitting up (p<0.01). A mean rise of 3.4 mm Hg. (p<0.01) occurred in the PCWP with the change of body position to upright. The variable changes occurring in the other parameters monitored were not significant. There was no change associated with the change in body position in the clinical status of any of the 21 patients. Neither were there any patient preferences for either one of the positions (Prakash, and Others, 1973).

No study has been found in the literature on the effect of lateral positions upon PAP and PCWP. The study which first interested this investigator in the effect of body position upon PAP and PCWP is the study reported by Woods and Mansfield (1976, pp. 83-90).

Their study included data on 10 non-critically ill cardiac patients. The effect of position upon PAP and PCWP was studied in
conjunction with an ongoing study of hemodynamic measurements during exercise tolerance testing. Four pressures (PASP, PADP, PAMP, PCWP) were measured with the patient in five different positions. These positions included: 1) flat and supine, 2) backrest at 20°, 3) backrest at 45°, 4) backrest at 90°, and 5) sitting on edge of bed, back unsupported, feet dangling (Woods and Mansfield, 1976, pp. 83-90).

The results of this study revealed that PADP, PAMP and PCWP showed no significant differences in relation to position. Pulmonary artery systolic pressures had a wider range and greater mean differences than the other pressures. This variation was statistically significant (p=0.05) for the 90° and dangle positions (Woods and Mansfield, 1976, p. 87).

Based on these findings the investigators included that in non-critically ill cardiac patients with normal pulmonary artery pressures these pressure measurements can be taken without having to lower the patient to the flat supine position (Woods and Mansfield, 1976, p. 89).

From flat to the 45° angle is the most common range for patient positioning in the hospital. Application of the results of this study in specific situations in the care of cardiac patients is warranted.

Jereos (1971) studied the effect of lateral positioning on CVP. She found that the difference in CVP between the supine flat position and the lateral positions was statistically significant at the p=0.001 level. In the lateral positions the CVP was lower. The question was asked whether the reference point for taking the CVP in the supine position (the mid-axillary line at the fifth intercostal space) might not be several centimeters posterior to the mid-right atrium. If this were
true it could have accounted then for the differences in pressure readings.

Based on the findings of Jereos' study Wright (1974) studied post-mortem subjects in an attempt to identify accurate external reference points for taking CVP readings both in the supine position and in the lateral positions. Wright found that in the supine position the mid-axillary point at the fifth intercostal space was two to nine centimeters posterior to the mid-right atrium. She suggested that the anterior axillary line might represent a more accurate reference point. With the sternal reference point (used for lateral positions) at the fourth intercostal space within the right sternal border, Wright found no significant difference (p=0.05) between the sternal reference point and the right atrium. But there was a high degree of variability (SD 2.55 cm) which suggests that this test is not conclusive.

The two studies mentioned in the previous paragraph were concerned with CVP. There are several differences in CVP and PAP and PCWP. Some factors which affect them differ. The hemodynamic information is different also. The CVP reflects the status of the filling pressures in the right heart whereas PAP and PCWP can give important information regarding left heart function. But these studies do show the importance of accurate external reference points so that information gained from these pressure readings is valid and reliable.

**SUMMARY**

This chapter has reviewed the literature which is related to the present study. The relationship of the various pressures in the heart
and pulmonary vascular system was reviewed. Studies and reports relating to the use of pulmonary artery pressure monitoring in clinical situations were examined. Finally, the effect of body positions upon PAP and PCWP was presented. Although no study closely related to the present research was found in the literature review, the studies done by Prakash and associates (1973), and Woods and Mansfield (1976) which dealt with elevations from the supine position were discussed. The following chapter will include research methodology, data collection procedures, design, and methods of statistical analysis which were used in the study.
Chapter 3

METHODOLOGY

The research approach and design will be described in this chapter. Discussion of the pilot study is included. Factors involved in the selection of the sample are examined. The data collection, recording, and analysis methods are described. Finally, the methodological assumptions and the weaknesses are discussed.

RESEARCH METHOD AND DESIGN

This was a clinical study using the comparative approach to determine the effect of patient position on PAP and PCWP in critically ill patients. The dependent variables were the PAP and PCWP. The lateral body positions were the independent variables. Each patient served as his own control; the PAP and PCWP readings in the supine flat position were the control data. Definition and clarification of the variables are described in Chapter 1.

STUDY SAMPLE

The sample included eight patients, of either sex, who were admitted to one of two selected medical centers in Southern California and who met the selection criteria. No attempt was made to randomly select the sample because of the selective nature of the sample and the limitations of the investigator's time and funds. The sample was selected purposively at the convenience of the investigator as patients meeting
the criteria for selection were admitted to the medical centers (Treece and Treece, 1977, pp. 104-105).

Selection Criteria

The selection criteria attempted, as much as possible, to limit some of the extraneous variables which were identified for this study. The following criteria were used to select patients for the sample:

1. Age 18 through 75.
2. Pulmonary artery catheter in place.
3. Ability to wedge the pulmonary artery catheter.
4. Less than 24 hours since insertion of pulmonary artery catheter.
5. On one of the hospital units—not in cardiac catheterization laboratory.
6. Pulmonary artery systolic pressure of 60 mm. Hg. or less.
7. Not grossly obese (by 70%)—no intestinal bypass surgery.
8. No severe deformity of thorax or spinal column.
9. No impairment to brainstem function.
10. No cerebrospinal injury.
11. Not totally dependent upon ventilator for respirations due to cerebral impairment.

Rationale for Selection Criteria

The following section will explain the rationale for the criteria used in selecting the sample. Some of the items were chosen to control the effect of some of the extraneous variables. Other items were included in the selection criteria to facilitate the data-gathering process.
Age. An arbitrary decision was made not to include minors in the study; therefore, the lower limit of eighteen years was chosen. Ideally, a narrow age range is desirable for investigations such as the present study. This could effect some control over the influence of the aging process upon body structures and functions. But, because of the selective nature of the sample and the limitations of time and funds of the investigator, the upper age limit was extended to 74 years.

Ability to wedge pulmonary artery catheter. The ability to wedge the pulmonary catheter was crucial to the study. The following factors could affect patient selection for inclusion in the study.

It is possible to have the catheter in the pulmonary artery but not be able to achieve the wedge position. This can occur when the balloon on the catheter has ruptured due to a defective balloon, when the balloon has been damaged during insertion of the catheter, or during the inflation of the balloon for monitoring purposes. Sometimes the catheter can displace back into a larger pulmonary artery and the inflated balloon cannot occlude that vessel resulting in the inability to obtain a wedged position. There is a third factor which can cause difficulty in wedging the catheter. When patients (usually young patients) who have distensible pulmonary vessels go into heart failure the pulmonary vessels become distended and the lumen of the vessel where the pulmonary artery catheter was placed becomes larger than the inflated balloon.

In order to avoid some of the complications which can occur with PA monitoring, some physicians prefer that nurses do not inflate the
balloon to wedge the catheter because of the possibility of over-inflating it and causing balloon rupture. Another potential problem is damage to pulmonary parenchyma because the catheter is left in the wedged position (Archer and Cobb, 1974, pp. 748-749; Swan, 1975b, pp. 88-89).

Less than 24 hours since insertion of pulmonary artery catheter. An intact balloon is necessary for wedge pressure monitoring. The balloon, which is made out of latex, absorbs body lipoproteins which cause the balloon to lose its elastic properties. This increases the potential for balloon rupture (Woods, 1976, p. 1770). Repeated inflations also increase the possibility of balloon rupture (Archer and Cobb, 1974, p. 748). It was felt that if the data were collected within 24 hours of insertion of the pulmonary catheter the assurance of balloon integrity was improved.

On one of the hospital units versus in cardiac catheterization laboratory. If the results of this study were to be applied to other critically ill patients in patient care situations, it was felt that the study should be conducted on nursing care units. Introduction of variables which would arise in a diagnostic situation such as the cardiac catheterization laboratory would only weaken the control of the study.

Pulmonary systolic pressure of 60 mm Hg. or less. Studies have shown that as pulmonary vascular resistance increases correlation between PADP and PCWP and the LVEDP decreases (Kaltman, and Others, 1966; Jenkins, and Others, 1970; Falicov and Resnekov, 1970; Rao and Sissman, 1971). The present study, however, did not examine the relationship between PA pressures, PCWP and LVEDP. The findings of the above-mentioned
studies are significant when utilizing the pressures for determining patient care.

The upper limit of 60 mm Hg. pulmonary artery systolic pressure was chosen for reasons of accuracy in data analysis. In order to precisely read the pressures on the recorder paper each millimeter division on the paper should equal not more than 2 mm Hg. pressure. It was preferred that each millimeter division on the paper should equal 1 mm Hg. pressure.

Not grossly obese—no intestinal bypass surgery. There were several reasons for this selection criterion. The effects of obesity upon body functions can be significant. It was felt that for a critically ill patient, the added stress of obesity would be a significant variable which should be controlled. Another reason was that there could also be problems with positioning of the obese patient in the lateral positions which would affect the control of the independent variable.

Many times weights are not taken on critically ill patients. In these cases the patient's weight was either estimated or a family member was asked for the information. The patient's weight was then compared to a chart of ideal weights (Christakis, 1973, p. 22) and determination was made if the weight was 70 per cent over the ideal weight for the patient.

No deformity of thorax or spinal column. Deformities of either the thorax or the spine could cause problems in adequately positioning the patient for data collection. Another potential problem was the
possibility of using incorrect external reference points on patients with such deformities.

**No impairment of brainstem function.** The pons and the medulla are responsible for the regulation of some of the vital functions of the body, i.e., respiration and cardiac. Impairment to these vital functions could influence the results of the study; therefore, these types of patients were excluded from the study.

**No cerebrospinal injury.** Injury to the spinal cord can affect the cardiovascular system by affecting vascular tone. It was felt that this variable should be controlled in the study.

Positioning of a patient with spinal cord injury also presents a problem. Many of these patients are not turned to the lateral positions. This then would automatically exclude the patient from the study.

**Not totally dependent upon ventilator for respirations due to cerebral impairment.** This criterion was eliminated due to similarity to criterion number 9 (no impairment of brainstem function).

**EXTERNAL REFERENCE POINTS**

Numerous external reference points for zero have been cited in the literature. All are for the supine position. Zero level at five centimeters below the sternal angle has been chosen for several studies (Forrester, and Others, 1972, p. 59; Sharefkin and MacArthur, 1972, p. 699; Prakash, and Others, 1973, p. 8; Lozman, and Others, 1974, p. 270). Two studies give the zero reference point as ten centimeters above the
top of the table (Donald, and Others, 1953, p. 206; Sapru, and Others, 1968, p. 129). Sapru (1968) feels that at this level the likely error in pressure readings is 2 per cent. Buggs (1973) and Jenkins and associates (1970) make reference to the sternal angle in a rather non-specific manner. Mond (1973) cites the manubrio-sternal junction as the zero point. Swan (1975a, p. 866) has specified that the zero point should be at one-half the distance from the sternum to the back at the fourth interspace. In addition to the point five centimeters below the sternal angle, Prakash and associates (1973, p. 8) have also identified the fourth intercostal space as the junction for the reference zero point. Rutherford (1971) cites the mid-chest level as the appropriate point. Etling and others (1976) and Scott (1972) have given the mid-axillary level as the reference point. Connolley and others (1954) used the mid-antero-posterior chest at the junction of the third intercostal space as the zero reference level.

In her study Woods (1976, pp. 84-85) used the phlebostatis level for the reference point. As the patients were elevated from the supine flat position to the various degrees of backrest positions the transducer was recalibrated at the phlebostatic level. Winsor and Burch (1945) introduced the phlebostatic axis and level as an appropriate reference point to use on all patients for taking central venous pressure measurements. The phlebostatic axis can be defined as "the junction between a transverse plane of the body passing through the fourth intercostal space at the lateral margin of the sternum and a frontal plane of the body passing through the midpoint of a line from the outermost point of the sternum to the outermost point of the posterior chest."
(Eckstein, 1972, p. 1223) The phlebostatic level rotates about the axis as the patient changes position from the flat supine to erect postures. It is the plane which passes through the axis and is parallel to the horizon (Eckstein, 1972, p. 1223; Woods, 1976, pp. 84-85).

**Pilot Test**

As was discussed in Chapter 1, when monitoring hemodynamic pressures such as PAP and PCWP utilizing only one external reference point the trend of the pressure values is more significant than the absolute pressure readings. In this case, a slight error in determining the appropriate external reference point for an internal anatomical location is not crucial. But, when the same pressure is being monitored from two external reference points, these two points must both reflect the same internal anatomical location.

For purposes of this study the trunk of the main pulmonary artery was chosen as the internal structure for selecting external reference points. A cadaver dissection was done with the chairman of the Department of Anatomy, Loma Linda University School of Medicine, to determine the position of the trunk of the pulmonary artery and to identify appropriate external reference points.

It was verified (Brash, 1951, p. 1489) that the trunk of the pulmonary artery exits from the right ventricle and lies at the second intercostal space at the left sternal border. It was also found that the pulmonary artery lies four to five centimeters dorsal to the sternum. The anterior axillary line corresponded to a location four or five centimeters below the sternum. This was chosen as the external reference
point for the supine position. The second intercostal space at the left sternal border was chosen as the external reference point for the lateral body positions.

PILOT STUDY

A pilot study was conducted on one patient to carefully check the procedure of data collection and to detect any flaws in methodology. The patient was a 70-year-old male who was two weeks post ventral hernia repair. A gastrointestinal bleed and aspiration pneumonia complicated his recovery and placed him in critical condition.

As a result of this study one change was made in the data collection procedure. Originally the plan was to record PAP and PCWP measurements one, two, three, four, and five minutes after each change of body position. It was found that it took at least five minutes to reposition the transducer and recalibrate after a position change. Therefore, it was usually not possible to record data prior to the five minutes.

All other tools and steps in the data-gathering process were quite functional during the pilot test. It was not felt that any changes were needed other than what has already been discussed.

DATA COLLECTION

Methods and Tools

The method for collecting the data was by taking PAP and PCWP measurements by the use of a pulmonary artery catheter. The patient was placed in the three positions described in Chapter 1 for pressure
measurements, e.g., supine and flat, and right and left lateral positions. The specific pressures which were measured are PAS, PAD, PAM, and PCW.

Positioning of patient and reference points. For the supine flat position the patient was placed on his back with the head of the hospital bed flat. The patient's head was placed on one pillow. The reference points were then marked. The second intercostal space at the left sternal border was found and marked with a water soluble felt pen. The anterior axillary line was also marked with the felt pen. The pressure transducer was placed at the anterior axillary line level in line with the second intercostal space. A small bubble level taped to a firm yardstick (Appendix Z) was used to place the transducer at the correct level.

For the right and left lateral positions the patient was positioned as follows. The hospital bed was flat and the patient's head was placed on one pillow. The patient was turned approximately 90° in the lateral position. A 75° angular sponge bolster (Appendix AA) was placed at the patient's back as a prop. A pillow was placed between the legs with the superior leg flexed over the dependent leg to help maintain the body angle of as close to 90° as possible. A carpenter's angle finder (Appendix BB) was used to check the body angle. The angle finder was placed just below the scapula for measurement of the angle. The transducer was positioned using the sternal reference point as the level for position. The bubble level was used to correctly position the transducer.
**Instrumentation.** The function of the pressure transducer has been described in Chapter 1. The specific transducers used in this study were Gould Statham P231D, Hewlett-Packard 1280C, and Bentley 800. With each position change of the patient the pressure transducer was re-calibrated to atmospheric pressure.

Several pressure amplifiers (monitors) were utilized for data collection. These included Gould Statham Model SM 7067, Tektronix Model 412, and Hewlett-Packard Models 78205A and 78205C.

The pressure waveforms were recorded on grid paper by a strip chart recorder run at 25 millimeters per second speed. For any given transducer, establishment of the reference offset on the strip chart recorder was accomplished by using the internal reference values in the pressure amplifier instead of using a standard mercury manometer as the reference source. The clinical error using this method is not greater than 3 per cent.

Three strip chart recorder systems were used in the data collection. These were Gould Statham, Hewlett-Packard, and an ECG recorder which was modified for the purpose.

In order to record pressure signals with a conventional ECG recorder, two items have to be accomplished. An input to the ECG recorder must be available which responds to very low frequency signals, ideally as low as zero cycles per second. This is often referred to as "DC response." In the study a Hewlett-Packard recorder model 1511 was utilized. It conveniently has such an input which can be activated by simply selecting an appropriate slider switch on the side of the machine. The second item is an "attenuator cable" which serves two functions. It
carries the electrical signal from the source monitor amplifier to the recorder input jack. It also provides a means of adjusting the amplitude of the electrical signal presented to the recorder in such a way as to cause the mechanical motion of the recorder pen to move a standard number of physical units for each unit of pressure sensed by the transducer. Such adjustment was necessary since the output of different monitors used in the study varied for a specific pressure input. Mechanically the adjustment control (known as a trimpot) was mounted inside the connector on the monitor end of the cable. A small screwdriver was used to adjust this control.

The calibration for the Gould Statham system was 1.2 mm Hg. per each millimeter division on the grid paper. The Hewlett-Packard calibration was 1 mm Hg. per millimeter division on the grid paper. Except for patient 7, the calibration for the modified ECG recorder was 1 mm Hg. per millimeter division on the grid paper. In this one case the calibration was changed to 2 mm Hg. per millimeter division on the grid paper because of pressures over 50 millimeters of mercury when the patient was on his left side.

Procedure and Ethical Considerations

Physician consent was obtained before any data was collected on patients who met the selection criteria. The required informed consent from the patient was waived for the patients' well-being. Since the patients in the study were critically ill it was felt that it might be detrimental to their physiologic status to have to read and then sign a consent form. In addition, their physiologic status might have prevented
them from signing a consent form, e.g., the patient who is on a respirator. Since the variables which were studied were already part of the patients' routine care it was felt that there was no hazard to the patient associated with the investigation.

The patient was then positioned and the external reference points marked as was described earlier in the chapter. The sequence of body positions varied from patient to patient depending on the initial position of the patient. Because the patients were critically ill the investigator attempted to disturb them as little as possible. At least five minutes of elapsed time was allowed between position changes before pressure readings were taken (Prakash, and Others, 1973, p. 8).

For each patient position the pressures were recorded on paper by the strip chart recorder. The PAS and PAD pressures were recorded first. The balloon on the catheter was then inflated and the PCWP was obtained. The time and the patient position (including the degree of the body angle for the lateral positions) were recorded on the graph paper. The respiratory cycle of the patient was observed and the beginning of inspiration was marked on the graph paper. Pressures were recorded during several consecutive respiratory cycles.

### Data Recording

The form used for data collection can be seen in Appendix Y. Each patient was given an identification code number. Information was taken from the patient's medical record which would be of value for data interpretation and evaluation.

As a precautionary measure to avoid any bias on the part of the
investigator, the pressure readings were not read from the write-out paper until data had been collected on all patients. The pressure readings were transcribed onto the Data Collection Record (Appendix Y). The readings were read by the investigator and confirmed by the physician member of the research committee.

When the pressures were read, they were read at the end of expiration (just before the mark on the paper denoting the beginning of inspiration). Reading the pressures at end-expiration reduces the effect of respiration and thus reduces the artifact caused on the pressure trace by respiration (Lozman, and 0 hers, 1974, p. 270). Scheinman and associates (1973, p. 323) found that patients being treated with respirators had higher pulmonary artery pressures than left ventricular pressures at peak inspiration. It was recommended that in these patients pressures should be read at end-expiration.

The PASP, PADP, and PCWP were read from the recorder paper. The PAMP was then computed by using the following formula:

\[ \text{Mean pressure} = \frac{\text{Systolic} + 2 \times \text{diastolic}}{3} \]

(Burton, 1972, p. 88).

STATISTICAL ANALYSIS

The statistical test chosen for data analysis was the two-way analysis of variance procedure. The 0.05 level of significance was selected.
METHODOLOGICAL ASSUMPTIONS

Since the location of the tip of the pulmonary artery catheter in the lungs does vary (Benumof, and Others, 1977), it was assumed that the trunk of the pulmonary artery would be an appropriate structure to use in choosing the external reference points for zeroing the pressure transducer for both the supine and lateral patient positions. Furthermore, it was assumed that the external reference points used in this study did represent the location of the trunk of the pulmonary artery in each of the patients included in the study.

Support is given to the above assumptions by the fact that the position of the pulmonary artery catheter in the pulmonary artery does not affect the pressure "as long as the pressure is measured with a fixed position transducer, properly zeroed." (Stein, and Others, 1973, p. 452) This, of course, does not hold true if a catheter-tipped transducer is used.

Although the sample size was small, patients with a variety of critical diagnoses were included in the study. This would then seem to be a representative sample of patients who are critically ill and have PAP and PCWP monitoring in their management.

LIMITATIONS

Several different types of monitoring systems and strip chart recorders were used in the data collection. This was an unavoidable variable due to uncontrollable circumstances. Each system had some differences in operation from the other systems. This situation can
increase the chance of human error thus bringing a question to the reliability of the collected data. The use of the same equipment in the same location would contribute to reliability in data collection.

In the calibration of the pressure transducers with the pressure amplifiers the internal reference in the amplifiers, which is an electrical input, was utilized instead of an actual external pressure reference by pressure input with a manometer. Sometimes there is a discrepancy between the internal reference of a pressure amplifier and the sensitivity of the transducer being used. There are variations in transducer sensitivity due to such things as temperature or damage. However, the actual clinical error due to this discrepancy is not more than 3 per cent.

There were problems with malfunction of equipment which prevented some data collection. No data were used in the data analysis which were obtained with questionably faulty instrumentation.

It is known that PEEP can cause artifact in PCWP readings. There may be a possibility that the effect of PEEP on the pulmonary vasculature may vary as body position changes. This then could affect the differences in PCWP that are seen with a body position change.

Another limitation seen in the study is that the time it takes to stabilize pressures after a change of body position is unknown. Factors involved in this include the efficiency of the cardiac pump, the vascular tone, and the effect of pharmacologic agents, to name a few. Any of these or a combination of these factors can affect pressure stabilization from patient to patient.
The small sample size poses another limitation. The results of such a study with a small sample size cannot be generalized to other critically ill patients.

It was originally planned to exclude from the study patients with mitral valve stenosis. Other studies (Sharefkin and MacArthur, 1972, p. 700; Fisher, and Others, 1975, p. 542) have included this in the selection criteria. These studies were concerned with comparing PAP and PCWP with LAP and LVEDP. In the presence of mitral valve stenosis the PAP and PCWP do not correlate well with LAP and LVEDP (Herbert, 1972, pp. 229-230). In the present study no attempt was made to correlate these pressures. Therefore, it was decided that patients with mitral valve disease would be included in the sample. Data was collected on two patients with mitral stenosis, but the pulmonary pathology that occurs with this condition produced unreliable PCWP wave forms. It was not possible to read the PCWP with certainty in these cases; therefore, the data was not included in the study. Because of this difficulty it is recommended that patients with mitral valve stenosis be excluded from investigations such as the present study.

SUMMARY

The present study was a clinical study comparing the PAP and PCWP taken with the patient in the supine flat position with these same pressures taken with the patient in the two lateral positions. Eight critically ill patients comprised the sample. Eleven selection criteria were chosen in order to control the effect of as many extraneous variables as possible and to control data collection procedures.
The PAP and PCWP were measured with each patient in the three specified positions: supine and flat; left lateral; right lateral. No specific sequence of patient position change was followed. The external reference points used for positioning the transducer are the second left intercostal space at the anterior axillary line for the flat supine position and the left second intercostal space for both lateral body positions.

The PAP and PCWP waveforms were recorded on graph paper by a strip chart recorder. The pressures were later read and recorded on the data collection record.

The data were subjects to two-way analysis of variance. The level of significance of 0.05 was used.

It was assumed that the trunk of the pulmonary artery was an appropriate internal structure to use in choosing external reference points for zeroing the pressure transducer. It was then assumed that the external reference points used in the study represented the location of the trunk of the pulmonary artery in each of the patients in the sample. The above assumptions were taken because it was accepted that the position of the catheter in the pulmonary artery does not affect the pressure readings as long as a fixed position transducer which is properly zeroed is used. The variety of illnesses which the sample brought to the study seems to represent an adequate cross-section of the types of critical illnesses seen in patients who have PAP and PCWP monitoring as part of their medical management.

Several weaknesses were identified in the study. The fact that
several monitoring systems and strip chart recorders with differences in calibration and operation were used decreases the reliability of the collected data due to possibilities of human error in the operation of the instrumentation. Some discrepancy in calibration may have occurred (not more than 3 per cent) between the internal reference of the pressure amplifiers and the actual sensitivity of the transducers. Breakdown of data collection equipment presented some limitation to the study. The effect of PEEP on the data collected is not known. Another limitation which was seen is that it is unknown how long it takes to stabilize pressures after a change in body position. This may be a factor which is so variable from patient to patient that it cannot be controlled. The small sample size prevents the results of the study from being generalized to other critically ill patients. Patients with mitral valve stenosis should be excluded from studies such as the present one. The pulmonary pathology which occurs with mitral stenosis precludes reliable PCWP waveforms.
Chapter 4

ANALYSIS OF DATA

Eight critically ill patients were studied to investigate the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. This chapter will include a report of the individual patient data, the pressure findings, the data analysis, and a discussion of the findings.

SUMMARY OF INDIVIDUAL PATIENT DATA

Table 1 reports categorized data for each patient studied. This data includes information regarding age, sex, diagnosis, respiratory status, the patient's heart rate and rhythm, medications in use at the time of data collection, and the number of hours between the insertion of the pulmonary artery catheter and the time of data collection.

The ages of the eight patients ranged from 38 to 75 years. Five patients were male and three were female. Three of the patients were hospitalized in the shock unit of the Surgical Intensive Care Unit, three patients were in the Coronary Care Unit, one patient was on the Cardiac Surgery Unit, and one patient was in the Respiratory Intensive Care Unit.

Three subjects, patients 1, 3, and 5, were post-operative patients. The pulmonary artery pressures were being monitored in patients 1 and 3 as a result of complications either during surgery or post-operatively. Patient 5 had open-heart surgery and her pulmonary artery
<table>
<thead>
<tr>
<th>Patient Code No.</th>
<th>Age</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>Respiratory Status</th>
<th>Heart Rate &amp; Rhythm</th>
<th>Drugs</th>
<th>Hrs Since PA Cath Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64</td>
<td>M</td>
<td>Whipple Procedure with Adult Resp. Distress Syndrome</td>
<td>Entubated Volume Respirator with PEEP of 12</td>
<td>140 Sinus</td>
<td>Dopamine, Digoxin, Pavulon, Valium, Morphine</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>F</td>
<td>Tuberculosis of the Spine &amp; Aspiration Pneumonia</td>
<td>Entubated Volume Respirator with PEEP of 12</td>
<td>115 Sinus</td>
<td>Dopamine</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>F</td>
<td>Post-op release of adhesions with hypotensive episode</td>
<td>Entubated Volume Respirator</td>
<td>115 Sinus</td>
<td>Dopamine</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>44</td>
<td>M</td>
<td>Bronchogenic carcinoma</td>
<td>Spontaneous</td>
<td>107 Sinus</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>M</td>
<td>Aortic Valve Replacement</td>
<td>Entubated Volume Respirator</td>
<td>100 Sinus</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>52</td>
<td>F</td>
<td>Old M.I. Unstable Angina For three vessel bypass next day</td>
<td>Spontaneous</td>
<td>60 Sinus</td>
<td>Nitroglycerine</td>
<td>3½</td>
</tr>
<tr>
<td>7</td>
<td>38</td>
<td>M</td>
<td>Anteroseptal M.I.</td>
<td>Spontaneous</td>
<td>80 Sinus</td>
<td>Lidocaine</td>
<td>18½</td>
</tr>
<tr>
<td>8</td>
<td>59</td>
<td>M</td>
<td>M.I.</td>
<td>Spontaneous</td>
<td>100 Sinus</td>
<td></td>
<td>18</td>
</tr>
</tbody>
</table>
pressures were monitored as a matter of routine to detect complications post-operatively.

Patients 6, 7, and 8 were in the Coronary Care Unit. Pulmonary artery pressures were being monitored in these patients to assess myocardial function after damage had occurred to the heart muscle due to infarction or severe ischemia.

Patients 2 and 4 had respiratory problems, i.e., aspiration pneumonia and bronchogenic carcinoma, respectively. Pulmonary artery pressures in such cases assist the health team in following the pulmonary pathology as well as the resultant effect on the heart.

PRESSURE CHANGES

Individual pressure measurements were tabulated and may be seen in Table 2. The position sequence and the degree of the body angle to the bed in the lateral positions were also tabulated.

Four patients were receiving vasoactive drugs which may have affected blood pressure. Patients 1, 2, and 3 were receiving dopamine. As shown on Table 2, no consistent pattern of change in pressure with position change was apparent.

Patient 6 received a tablet of nitroglycerine before the left lateral pressures were recorded. It can be noted that the left lateral pressures were consistently lower than either the right lateral pressures or the control data, i.e., supine flat pressures.

When taking the lateral pressure measurements the patients were positioned as close to a 90° angle with the bed as was possible. The
Table 2

Individual Pressure Measurements: Pulmonary Artery Systolic, Diastolic, Mean, and Pulmonary Wedge Pressures Measured in Three Different Positions

<table>
<thead>
<tr>
<th>Patient Code Number</th>
<th>Position Sequence and Body Angle Lateral</th>
<th>PAS</th>
<th>PAD</th>
<th>PAM</th>
<th>PCW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Supine Flat</td>
<td>23</td>
<td>16</td>
<td>18.3</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—90°</td>
<td>20</td>
<td>15</td>
<td>16.7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Left Lateral—80°</td>
<td>21</td>
<td>16</td>
<td>17.7</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Left Lateral—80°</td>
<td>26</td>
<td>16</td>
<td>19.3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Supine Flat</td>
<td>24</td>
<td>16</td>
<td>18.7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—75°</td>
<td>27</td>
<td>16</td>
<td>19.7</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Left Lateral—65°</td>
<td>32</td>
<td>15</td>
<td>20.7</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Supine Flat</td>
<td>31</td>
<td>17</td>
<td>21.7</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—85°</td>
<td>38</td>
<td>14</td>
<td>22</td>
<td>16.5</td>
</tr>
<tr>
<td>4</td>
<td>Supine Flat</td>
<td>22</td>
<td>12</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—85°</td>
<td>20</td>
<td>13</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Left Lateral—70°</td>
<td>15</td>
<td>9</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Supine Flat</td>
<td>15</td>
<td>11</td>
<td>12.3</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—70°</td>
<td>9</td>
<td>1</td>
<td>3.7</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Left Lateral—75°</td>
<td>14</td>
<td>3</td>
<td>6.7</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>Supine Flat</td>
<td>24</td>
<td>12</td>
<td>16</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—85°</td>
<td>26</td>
<td>12</td>
<td>18.7</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>Left Lateral—90°</td>
<td>20</td>
<td>8</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Supine Flat</td>
<td>50</td>
<td>20</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—90°</td>
<td>49</td>
<td>25</td>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Left Lateral—85°</td>
<td>58</td>
<td>30</td>
<td>39</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>Supine Flat</td>
<td>26</td>
<td>11</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Right Lateral—80°</td>
<td>25</td>
<td>15</td>
<td>18</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Left Lateral—85°</td>
<td>20</td>
<td>11</td>
<td>14</td>
<td>4</td>
</tr>
</tbody>
</table>
data were too few for reliable comparisons, but there did not appear to be a pattern of pressure change in relation to the degree of body angle.

The mean pressure in each lateral position was lower than that in the supine flat position. The greatest variations were observed between the supine flat and the lateral positions for the mean PCWP. It was further noted that for the PAS, PAD, and PAM pressures the means were the lowest in the left lateral position as shown in Table 3. For these pressures the greatest variance from supine to left was seen for the PAS, with a drop of 1.1 mm Hg.

Table 3

Differences in Mean Pressure Between the Supine Flat Position and the Right and Left Lateral Positions for Pulmonary Artery Systolic (PAS), Diastolic (PAD), and Mean (PAM) Pressures in Eight Critically Ill Patients

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Lateral Position</th>
<th>Difference from Supine Flat Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAS</td>
<td>Right</td>
<td>drop of .1 mm Hg.</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>drop of 1.1 mm Hg.</td>
</tr>
<tr>
<td>PAD</td>
<td>Right</td>
<td>drop of .5 mm Hg.</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>drop of .9 mm Hg.</td>
</tr>
<tr>
<td>PAM</td>
<td>Right</td>
<td>drop of .1 mm Hg.</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>drop of .9 mm Hg.</td>
</tr>
</tbody>
</table>
As noted previously, the greatest variance in mean pressures was observed for the PCWP. The changes in means did not follow the same pattern as was seen in the PAP. The greatest drop in mean pressures occurred between the supine flat and right lateral pressures. There was a drop from 14.1 mm Hg. to 10.8 mm Hg., a difference of 3.3 mm Hg. A 2.5 mm Hg. difference was observed between supine flat and left lateral mean pressures.

The means and ranges of the PAP and PCWP of the 10 patients studied may be seen in Table 4. Figure 1 was constructed to also show the means of the pressures studied in relation to position. The mean pressure dropped from 14.1 mm Hg. to 11.6 mm Hg.

Relationship of PADP and PCWP

There are times when PADP is used as an index of LVEDP instead of PCWP. This occurs most often when the initial PADP and PCWP measurements are congruent. Comparison was made of the PADP and PCWP. The mean PADP and PCWP for the eight patients studied may be seen in Table 5. The mean PCWP's were consistently lower than mean PADP with the greatest drop in mean PCWP being in the right lateral position.

Individual pressure measurements showed a much greater range of differences than the differences in mean pressure showed. Differences in individual PADP and PCWP measurements ranged from 1 to 13 mm Hg. Furthermore, there was no consistent pattern of differences between PADP and PCWP in relation to position. In patients 1, 2, 4, and 8 the PCWP was lower than the PADP in each of the three patient positions. But patients 3, 5, 6, and 7 had higher PCWP than PADP in one or more of the positions.
Table 4
Means and Ranges for Pulmonary Artery Systolic (PAS), Diastolic (PAD), Mean (PAM), and Pulmonary Capillary Wedge (PCW) pressures in Eight Critically Ill Patients Measured in Three Different Positions

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Position</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAS</td>
<td>Supine Flat</td>
<td>26.9</td>
<td>15.0-50.0</td>
</tr>
<tr>
<td></td>
<td>Right Lateral</td>
<td>26.8</td>
<td>9.0-49.0</td>
</tr>
<tr>
<td></td>
<td>Left Lateral</td>
<td>25.8</td>
<td>14.0-58.0</td>
</tr>
<tr>
<td>PAD</td>
<td>Supine Flat</td>
<td>14.4</td>
<td>11.0-20.0</td>
</tr>
<tr>
<td></td>
<td>Right Lateral</td>
<td>13.9</td>
<td>1.0-25.0</td>
</tr>
<tr>
<td></td>
<td>Left Lateral</td>
<td>13.5</td>
<td>3.0-30.0</td>
</tr>
<tr>
<td>PAM</td>
<td>Supine Flat</td>
<td>18.5</td>
<td>12.3-30.0</td>
</tr>
<tr>
<td></td>
<td>Right Lateral</td>
<td>18.4</td>
<td>3.7-33.0</td>
</tr>
<tr>
<td></td>
<td>Left Lateral</td>
<td>17.6</td>
<td>6.7-39.0</td>
</tr>
<tr>
<td>PCW</td>
<td>Supine Flat</td>
<td>14.1</td>
<td>5.0-32.0</td>
</tr>
<tr>
<td></td>
<td>Right Lateral</td>
<td>10.8</td>
<td>4.5-30.0</td>
</tr>
<tr>
<td></td>
<td>Left Lateral</td>
<td>11.6</td>
<td>3.0-33.0</td>
</tr>
</tbody>
</table>
Figure 1

Mean Pulmonary Artery Systolic (PAS), Diastolic (PAD), Mean (PAM), and Pulmonary Capillary Wedge (PCW) Pressures in Eight Critically Ill Patients Measured in Three Different Positions.
Table 5

Differences in Mean Pulmonary Artery Diastolic Pressures (PADP) and Pulmonary Capillary Wedge Pressure (PCWP) in Eight Critically Ill Patients Measured in Three Different Positions

<table>
<thead>
<tr>
<th>Position</th>
<th>Mean PADP</th>
<th>Mean PCWP</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine Flat</td>
<td>14.4</td>
<td>14.1</td>
<td>.3 drop</td>
</tr>
<tr>
<td>Right Lateral</td>
<td>13.9</td>
<td>10.8</td>
<td>3.1 drop</td>
</tr>
<tr>
<td>Left Lateral</td>
<td>13.5</td>
<td>11.6</td>
<td>1.9 drop</td>
</tr>
</tbody>
</table>
STATISTICAL ANALYSIS

The data were subjected to two-way analysis of variance to test whether there was a significant difference between PAP and PCWP in the supine flat position compared to these same pressures in the two lateral positions. The degrees of freedom, sum of squares, mean squares, and F-ratio are presented in Table 6.

No statistically significant differences were found in any of the pressures in relation to patient position. Therefore, the null hypothesis, which stated that there would be no significant difference (alpha=0.05) between PAP and PCWP in the supine flat position compared to the right and left lateral positions, was retained for all pressures examined in this study of eight critically ill patients. The changes in the PADP had the lowest F-ratio of .16 (p>.75). The PCWP showed wider ranges in pressure and the greatest variance in mean pressures. The F-ratio for the PCWP was 3.05 (p>.05). This was still below the F-ratio of 3.74 at which the null hypothesis would have been rejected for this pressure.

DISCUSSION

Any discussion of the results of this investigation must, of course, begin with the observation that more data must be obtained before definite conclusions regarding the relationship of the findings to the statement of the research problem or any real comparisons to other research findings can be made. However, with this limitation in mind, the
<table>
<thead>
<tr>
<th>Pressures</th>
<th>Between Positions</th>
<th>Between Patients</th>
<th>Within Positions &amp; Patients</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAS</td>
<td>6.08</td>
<td>3035.30</td>
<td>166.58</td>
<td>3207.96</td>
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<td>3.04</td>
<td>433.61</td>
<td>11.90</td>
<td>.26</td>
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<td>(p&gt;.75)</td>
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<tr>
<td>PAD</td>
<td>3.08</td>
<td>694.50</td>
<td>138.25</td>
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<td>1.54</td>
<td>99.21</td>
<td>9.88</td>
<td>.16</td>
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<td></td>
<td>(p&gt;.75)</td>
<td>(p&gt;.75)</td>
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<td>4.17</td>
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<td>(p&gt;.75)</td>
<td>(p&gt;.75)</td>
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<td>1629.53</td>
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<td>(p&gt;.05)</td>
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Not significant -- $F_{.05}$ (df 2,14) = 3.74 (critical value)
following paragraphs will tie together the findings with the study question and the theoretical framework, and with the results of other investigations related to the present study. Weaknesses in the data and possible problems in methods of data collection will be evaluated.

The research question asked if there would be a significant difference between PAP and PCWP taken in the supine flat position and those taken in the right and left side-lying positions. Differences in the means for these pressures showed very little clinical significance in relation to position. The biggest differences with position change were observed for the mean PCWP, i.e., differences of 3.3 mm Hg. for the right lateral position and 2.5 mm Hg. for the left lateral position. These differences are not that clinically significant either. Statistical analysis with the F test also showed no significance in pressure differences at an alpha is equal to or less than 0.05.

These findings tended to support the null hypothesis. One of the major weaknesses of the study due to the small amount of data was that the pressure differences between patients are so large that the differences in pressures in any one individual patient are masked. This weakness might have been corrected with a larger sample size or if more sets of pressures for each patient studied could have been made.

There is a possibility that certain patients may react more to one position change than to another. Interactions such as this may be different for each patient. This information was not available because of too little data. Again, more sets of pressures for each patient would facilitate further study into this possibility.
It is interesting to compare the results of the present study with those of Woods and Mansfield (1976) (Glenn-Woods, 1975), although the position changes studied are dissimilar. Glenn-Woods found a significant difference in PASP with the five position changes and therefore rejected the null hypothesis for the study (Glenn-Woods, 1975, p. 27). This variation was significant for the 90° and dangle positions. It was not significant at the 20 and 45 backrest positions (Woods and Mansfield, 1976, pp. 87, 88). In the present study it was found that the pressure changes for the PASP were not significant. Glenn-Woods found that the PCWP was very stable (Woods and Mansfield, 1976, p. 88). The PCWP showed the most variation in the present investigation.

In this study the question arises as to the reason the PCWP was most affected by position. Since the PCWP is an indication of left ventricular function, except in cases of mitral valve stenosis and significant pulmonary vasoconstriction, changes in PCWP with position change may indicate hemodynamic changes occurring in the left ventricle when a patient changes position. It may be that if there are changes which occur in left ventricular hemodynamics with position changes these are more pronounced in a critically ill patient. Perhaps in a healthy person position change does not cause changes in left ventricular hemodynamics which are reflected by changes in PCWP.

The mean pressures for the lateral positions were lower than the mean pressures for the supine flat position (control data). The means for the three PAP (PAS, PAD, PAM) were the lowest in the left lateral position. It may be that the external reference point used for data
collection in the lateral positions did not reflect the same internal anatomical location as the external reference point used for data collection in the supine flat position.

SUMMARY

The findings of the investigation were reported and evaluated in Chapter 4. Individual patient data was shown in Table 1. The pressure changes in relation to position demonstrated that mean pressures for all pressures studied (PAS, PAD, PAM, PCW) were lower in the lateral positions than in the supine position (difference of .1 mm Hg. to 3.3 mm Hg.). Statistical analysis found no significant differences (alpha=.05) in any of the pressures in relation to patient position. The null hypothesis was retained.

The limitations of the study must be considered in the interpretation of the data. A larger sample size or multiple pressure readings on the patients studied would have enhanced the investigation. Comparison of findings with previous research of Glenn-Woods (1975) (Woods and Mansfield, 1976) showed that whereas Glenn-Woods found a significant difference in PASP with position change and a stable PCWP, the present study found the PCWP to be the most unstable and the PASP the most stable. The question arises as to the possible hemodynamic effects occurring in the left ventricle with lateral position change. Since all mean pressures were lower in the lateral positions it may be that the external reference points used for data collection do not reflect the trunk of the pulmonary artery.
Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A brief summary of the study will be presented in this chapter. Conclusions and recommendations arising from the investigation will be discussed.

SUMMARY

This summary will briefly describe the information presented in the first three chapters and in the results portion of chapter 4. The problem, the methodology, and the findings will be discussed.

Problem

Knowledge of cardiac function is very important to health team members in the care of critically ill patients. The increasing use of PAP monitoring has enhanced the management of many critically ill patients. When this type of pressure monitoring is used in patient management, it has been the custom to place the patient supine and flat when pressure measurements are done. This frequently causes problems in giving nursing care. For example, a resting patient may be disturbed; some patients cannot tolerate lying flat; frequent turnings of a critically ill patient are exhausting to the patient; it is difficult and time-consuming for the nurse to frequently turn a patient who has many monitoring and intravenous lines in place; if the patient is in the side-lying position the
nurse may not take the pressure readings as frequently as is ordered/desired so that the patient can remain on his side for a longer period of time, especially if the patient appears extremely fatigued.

It was felt that some of the above-mentioned problems might be eliminated if PAP and PCWP could be taken with the patient lying on his side. The purpose of this study was to investigate whether there was a significant difference in PAP and PCWP measurements taken with the patient in side-lying positions compared to those in the supine flat position. If the nurse could be sure that pressure measurements taken with the patient in a side-lying position were accurate then patient care could be enhanced by using preventive measures against complications of immobility and by allowing for longer rest periods for the patient.

Methodology

Eight critically ill patients with a variety of diagnoses were studied. A pulmonary artery catheter was in place in each patient. Comparison of the PAP and PCWP measurements taken in the supine flat and the two side-lying positions was made. Each patient was placed in three different positions (supine flat, right lateral, left lateral) and the PAP and PCWP measurements were recorded in each position.

The instrumentation used in pressure measurement included a pressure transducer, a pressure amplifier, and a strip chart recorder. The recorder was used to record the pressure waveforms on grid paper.

Before pressure measurements were taken the transducer was placed at the level of the external reference points used in the study and then
calibrated. The external references used were the anterior axillary level in line with the second intercostal space for data collection in the supine flat position and the second interspace at the left sternal border for data collection in the right and left lateral positions.

Findings

Tables and figures were constructed to report pertinent patient information and pressure measurements in relation to patient position. Of the four patients receiving vasoactive drugs, the three who were receiving dopamine infusions showed no consistent pattern of change of pressure with position change. The one patient who received a nitroglycerine tablet just prior to pressure measurements in the left lateral position had lower pressures in that position than in either of the two other patient positions.

Mean pressures for the three PAP and the PCWP were calculated. Mean pressures were lower in the lateral body positions than in the supine flat position. Except for the mean PCWP, the mean pressures in the left lateral position were lower than those in the right lateral position. Mean PCWP was lowest in the right lateral position. The influence of drugs on the results of the data must be weighed along with the other limitations of the study.

The data were subjected to two-way analysis of variance. No statistical differences (alpha=.05) were noted in any of the pressures in relation to patient position. The null hypothesis was accepted; there was no statistical difference between the PAP and PCWP in the supine flat position compared to the right and left lateral positions.
CONCLUSIONS AND NURSING IMPLICATIONS

The findings of this small preliminary investigation of the effects of lateral body positions compared to the supine flat position on PAP and PCWP in critically ill patients seemed to indicate that there was no significant difference. Although the data base is not large, it can be concluded that for the eight critically ill patients involved in the investigation, taking PAP and PCWP measurements while the patients were lying on their sides, using the external reference points as described for transducer leveling, resulted in insignificant differences in pressure readings.

Although it would greatly enhance the ability of nurses in giving patient care by accurately assessing the patient's condition, promoting patient energy conservation, and preventing complications of immobility, great care must be taken in generalizing the results of this study beyond the patients involved in the investigation. Until more research is conducted which replicates the present findings no recommendation should be made regarding utilization by nurses of the two lateral body positions in addition to the flat supine position for PAP and PCWP measurements in critically ill patients.

RECOMMENDATIONS FOR FURTHER RESEARCH

Further investigation of the effects of body position on PAP and PCWP should be undertaken. The findings of this study suggest the worth of conducting a similar study with a larger sample size. Since the sample
size in the present study was so small, reliability of the data is not assured. Other studies would assist in establishing the reliability of such data.

Studies using the same basic design of the present research but with some changes in selection criteria and/or data collection methods are recommended. Suggested changes include:

1. Sample should be restricted to patients having a common diagnosis, i.e., myocardial infarction, coronary artery-bypass heart surgery, respiratory failure.

2. Exclude patients with PASP of over 50 mm Hg.

3. Collect data using the same data collection instrumentation.

4. Collect several sets of pressure readings on the same patient at different times, i.e., 12, 18, 24 hours or 12, 24, 36 hours.

These changes would improve the control and/or reliability and validity of the study, but they would also make it very difficult to obtain a large enough sample size unless data collection occurred over a very long period of time.

Correlation between the degree of body angle with the bed when the patient is placed in lateral positions and the PAP and PCWP needs to be examined. Perhaps only two angles need to be studied, i.e., 75° and 90°. The hypothesis for such a study could be that there will be no significant change in the PAP and the PCWP taken with the patient in a 90° lateral position and the same pressures with the patient in a 75° lateral position. Data from a study such as this would certainly help nurses to know at what angle patients can be positioned laterally for
pressure measurements. It may be that this kind of study need not be done on critically ill patients who are on a nursing unit. Perhaps a body angle study could be done in the cardiac catheterization laboratory. Comparison of the PAP and PCWP in the supine position and the prone position could be made. A Circo-Lectric bed would be needed for placing the patient prone.

Several other questions have arisen during the course of the present study which could be topics for further investigation. These questions include:

1. Many critically ill patients are treated with the drug dopamine. What effect, if any, does dopamine have on the pressure changes which occur with position change?

2. What effect does the drug nitroglycerine have on PAP and PCWP? The one patient in the present study who had a tablet of nitroglycerine prior to pressure measurements in the left lateral position had lower pressures in that position than in either the right lateral or supine flat positions. Is this just a coincidence or does it occur in other patients as well?

3. What is the stabilization time for PAP and PCWP after a lateral body position change? Pressure readings at 5, 10, 15, and 20 minute intervals after a position change could be measured. A problem seen in the workability of such a study is that a large enough sample might be very hard to obtain because many critically ill patients cannot tolerate lying flat and in lateral positions for longer than just a few minutes. It may be that such a study could be done with changes in body position from supine flat to specific elevated backrest positions, i.e., 20° and 45°.
4. Were the external reference points used in the present investigation accurate with reference to the internal location of the trunk of the pulmonary artery? A possible method for study of this problem is the method used by Wright (1974) in the study done on external reference points for central venous pressure measurement.

5. What, if any hemodynamic changes occur in the left ventricle with lateral body positions? Are these reflected by changes in PCWP? Is there a difference in the changes which occur in a healthy person and those that occur in a critically ill patient? Perhaps some answers to these questions could be found by studying LAP's in relation to lateral body positions. If both LAP and PCWP are being monitored comparison between these two pressures in lateral body positions could be made.
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY


Lalli, Susan M. The complete Swan-Ganz. Why it's used, how it works, the complexities of caring for catheterized patients. RN 41(9):64-77, September 1978.


APPENDIX A

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY AT
LOMA LINDA UNIVERSITY MEDICAL CENTER

--ASSISTANT ADMINISTRATOR,

NURSING SERVICE (1977)
Dear Miss Haussler:

As a graduate student in nursing, I am investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. The research study is entitled "The Effect of Lateral Body Positions upon Pulmonary Artery and Pulmonary Capillary Wedge Pressures in Critically Ill Patients." It will meet part of the requirements for a master's degree in nursing at Loma Linda University. I am hereby requesting permission to involve patients at the Loma Linda University Medical Center in my study. My thesis committee chairman, Evelyn L. Elwell has approved this thesis and I have obtained approval from the University Committee on Human Studies.

The proposed research will be quasi-experimental in nature. The method for collecting data will be by taking the pulmonary artery pressure and pulmonary capillary wedge pressure measurements, by the use of a pulmonary artery catheter, with the patient lying in the following three positions: 1) supine and flat, 2) right lateral, 3) left lateral. Patients, age 18 through 75, who have pulmonary artery catheters in place for continuous pressure monitoring and who are on the nursing service units will be included in the study. Patients in the cardiac catheterization laboratory will not be included in the study.

I have received permission from the University Committee on Human Studies to waive the required informed consent form from the patients I propose to use in my study. Since these patients will be critically ill it might be detrimental to their physiologic status to read and sign a consent form. Also, their physiologic status may prevent them from signing a consent form, e.g., when the patient is on the respirator. The procedures used to collect data will not involve any maneuver or treatment in addition to that which is already being done for the patient. The change in patient position is done on a routine basis and the hemodynamic measurements are also used for routine care. There is no known physical, emotional, or social hazard associated with the study. All data will be strictly confidential and will never be associated with the patient's name. Consent will be obtained from the
physicians involved in the care of the critically ill patients. The physician will be free to withdraw permission for the patient's participation in the study at any time.

I will be conducting the study under the supervision of Dr. Burton A. Briggs, Lavaun Sutton, Evelyn Elwell, and Ann Ekroth.

With your permission, I would like to begin data collection in June. I expect to collect data on at least ten patients over a period of two to three months. I will be happy to make an appointment with you to discuss this research further if you desire. I will also be happy to share the findings of the study after its completion. Space has been provided on the attached letter from the graduate program for your reply. Thank you so much for your assistance.

Sincerely yours,

Sharon Millard

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosure
APPENDIX B

PERMISSION TO CONDUCT THE STUDY FROM THE ASSISTANT ADMINISTRATOR,
NURSING SERVICE, LOMA LINDA UNIVERSITY MEDICAL CENTER (1977)
Loma Linda University Medical Center

Date: 6-1-77

Dear Ms. Millard:

Your request for permission to collect data for your research project at Loma Linda University Medical Center has been received and reviewed. The following action has been taken:

- You have my permission to conduct your study in our facility.
- Your request has been temporarily denied pending provision of additional information.
- Your request cannot be granted at this time.

Also, it will be necessary for you to:

- Obtain permission from the attending physician since your study involves patients and/or their records.
- Obtain additional permission from Phyllis McElmurry.
- Notify and/or advise the following persons of your study:

Make an appointment with __________________________ for additional discussion and information provision.

Other

If I can be of further help, please let me know.

Sincerely,

Gertrude L. Haussler, R.N., M.S.
Assistant Administrator
Nursing
APPENDIX C

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY ON THE CRITICAL CARE UNITS AT LLUMC—ASSISTANT DIRECTOR OF NURSING SERVICE, CRITICAL CARE (1977)
May 26, 1977

Ms. Phyllis McElmurry, R.N., M.S.
Assistant Director of Critical Care Nursing Service
Loma Linda University Medical Center
Loma Linda, CA 92354

Dear Miss McElmurry:

As a graduate student in nursing, I am investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. The research study is entitled "The Effect of Lateral Body Positions upon Pulmonary Artery and Pulmonary Capillary Wedge Pressures in Critically Ill Patients." It will meet part of the requirements for a master's degree in nursing at Loma Linda University. I am hereby requesting permission to involve patients at the Loma Linda University Medical Center in my study. My thesis committee chairman, Evelyn L. Elwell, has approved this thesis and I have obtained approval from the University Committee on Human Studies.

The proposed research will be quasi-experimental in nature. The method for collecting data will be by taking the pulmonary artery pressure and pulmonary capillary wedge pressure measurements, by the use of a pulmonary artery catheter, with the patient lying in the following three positions: 1) supine and flat, 2) right lateral, 3) left lateral. Patients, age 18 through 75, who have pulmonary artery catheters in place for continuous pressure monitoring and who are on the nursing service units will be included in the study. Patients in the cardiac catheterization laboratory will not be included in the study.

I have received permission from the University Committee on Human Studies to waive the required informed consent form from the patients I propose to use in my study. Since these patients will be critically ill it might be detrimental to their physiologic status to read and sign a consent form. Also, their physiologic status may prevent them from signing a consent form, e.g., when the patient is on the respirator. The procedures used to collect data will not involve any maneuver or treatment in addition to that which is already being done for the patient. The change in patient position is done on a routine basis and the hemodynamic measurements are also used for routine care. There is no known physical, emotional, or social hazard associated with the study. All data will be strictly confidential and will never be associated with the patient's name. Consent will be obtained from the
physicians involved in the care of the critically ill patients. The physician will be free to withdraw permission for the patient's participation in the study at any time.

I will be conducting the study under the supervision of Dr. Burton A. Briggs, Lavaun Sutton, Evelyn Elwell, and Ann Ekroth.

I have sent a letter to Miss Haussler requesting permission to collect data at the Loma Linda University Medical Center. I am also requesting your permission. I would like to begin data collection in June. I expect to collect data on at least ten patients over a period of two to three months. I will be happy to make an appointment with you to discuss this research further if you desire. I will also be happy to share the findings of the study after its completion. Space has been provided on the attached letter from the graduate program for you reply. Thank you so much for your assistance.

Sincerely yours,

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosure
APPENDIX D

PERMISSION TO CONDUCT THE STUDY FROM THE ASSISTANT DIRECTOR
OF NURSING SERVICE, CRITICAL CARE, LLUMC (1977)
Dear Ms. Millard:

Your request for permission to collect data for your research project at Loma Linda University Medical Center has been received and reviewed. The following action has been taken:

- [✓] You have my permission to conduct your study in our facility.
- ___ Your request has been temporarily denied pending provision of additional information.
- ___ Your request cannot be granted at this time.

Also, it will be necessary for you to:

- ___ Obtain permission from the attending physician since your study involves patients and/or their records.
- [✓] Obtain additional permission from UNIT CHARGE NURSE FOR EACH PH.
- ___ Notify and/or advise the following persons of your study.

- ___ Make an appointment with __________________________ for additional discussion and information provision.
- ___ Other

If I can be of further help, please let me know.

Sincerely,

Phyllis McElmurry, R.N., M.S.
Assistant Director
Critical Care Nursing Service
APPENDIX E

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY AT
LLUMC—ASSISTANT ADMINISTRATOR
NURSING SERVICE (1978)
May 30, 1978

Ms. Gertrude Haussler, R.N., M.S.
Assistant Administrator of Nursing Service
Loma Linda University Medical Center
Loma Linda, CA  92354

Dear Miss Haussler:

I am a graduate student in nursing. During the summer of 1977 I was involved in the data collection for my research study. I was investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. My data collection was done on the critical care units of the Loma Linda University Medical Center.

I was not able to complete my data collection last summer before I moved to Northern California. Therefore, I am going to have to continue with my study at Loma Linda this coming summer. I am again requesting your permission to involve patients on the critical care units at Loma Linda University Medical Center in my study. I have sent a similar request to Phyllis McElmurry and am awaiting her reply.

I have included a copy of my original request to you so that you may refresh your memory regarding my study. There will be no change in the method of data collection.

I would like to begin data collection after June 15, 1978. The plan is to stay at Loma Linda until I am finished. I need to collect data on four patients.

Thank you so much for your assistance.

Sincerely yours,

Sharon Millard

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosure
APPENDIX F

PERMISSION TO CONDUCT THE STUDY FROM THE ASSISTANT ADMINISTRATOR, NURSING SERVICE, LLUMC (1978)
June 8, 1978

Ms. Sharon Millard, RN, BS
Graduate Program in Nursing
Loma Linda University
School of Nursing

Dear Sharon:

I received your letter of May 30, 1978 requesting permission to begin data collection for your research study.

I have reviewed your study and see no reason why you can't begin collecting your data June 15, 1978. My only suggestion would be for you to contact Phyllis McElmurry and clear with her for you to begin.

Good luck with your data collection.

Sincerely,

Gertrude Haussler, RN
Assistant Administrator, Nursing

GH:kap
APPENDIX G

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY ON
THE CRITICAL CARE UNITS AT LLUMC--ASSISTANT
DIRECTOR OF NURSING SERVICE,
CRITICAL CARE (1978)
May 30, 1978

Ms. Phyllis McElmurry, R.N., M.S.
Assistant Director of Critical Care Nursing Service
Loma Linda University Medical Center
Loma Linda, CA 92354

Dear Miss McElmurry:

During the summer of 1977 I was involved in the data collection for my research study. I was investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. My data collection last summer was done on the intensive care units of the Loma Linda University Medical Center.

I was not able to complete my data collection last summer before I moved to Northern California. Therefore, I am going to have to continue with my study at Loma Linda this coming summer. I am again requesting your permission to involve patients on the critical care units at Loma Linda University Medical Center in my study.

I have included a copy of my original request to you so that you may refresh your memory regarding my study. There will be no change in the method of data collection.

I would like to begin data collection after June 15, 1978. The plan is to stay at Loma Linda until I am finished. I need to collect data on four patients.

Thank you so much for your assistance.

Sincerely yours,

Sharon Millard

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosure
APPENDIX H

PERMISSION TO CONDUCT THE STUDY FROM THE
ASSISTANT DIRECTOR OF NURSING SERVICE,
CRITICAL CARE, LLUMC (1978)
Loma Linda University Medical Center

Date: 6/5/78

Dear Ms. Millard:

Your request for permission to collect data for your research project at Loma Linda University Medical Center has been received and reviewed. The following action has been taken:

✓ You have my permission to conduct your study in our facility.

☐ Your request has been temporarily denied pending provision of additional information.

☐ Your request cannot be granted at this time.

Also, it will be necessary for you to:

☐ Obtain permission from the attending physician since your study involves patients and/or their records.

☐ Obtain additional permission from ____________________________.

☐ Notify and/or advise the following persons of your study.

☐ Make an appointment with ____________________________ for additional discussion and information provision.

☐ Other

If I can be of further help, please let me know.

Sincerely,

Phyllis McElmurry, R.N., M.S.
Assistant Director
Critical Care Nursing Service
APPENDIX I

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY

AT ST. BERNARDINE'S HOSPITAL—SUPERVISOR

OF ICU AND CCU (1977)
August 8, 1977

Ms. Anne E. Koran, R.N., B.S.
Supervisor of ICU and CCU
St. Bernardine's Hospital
2101 N. Waterman
San Bernardino, CA 92404

Dear Ms. Koran:

As a graduate student in nursing, I am investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. The research study is entitled "The Effect of Lateral Body Positions Upon Pulmonary Artery and Pulmonary Capillary Wedge Pressures in Critically Ill Patients." It will meet part of the requirements for a master's degree in nursing at Loma Linda University. My thesis committee chairman, Evelyn L. Elwell, has approved this thesis and I have obtained approval from the University Committee on Human Studies.

I am at present collecting data at the Loma Linda University Medical Center. My sample size is ten patients and up to now I have only been able to collect data on two patients. It is important to note that I have all my data collected by the first week of September because I will be moving out of the area at that time. Because of this I would like to ask permission to involve patients at St. Bernardine's Hospital in my study.

In the following paragraphs I will describe my study briefly for you. I will be happy to make an appointment with you to discuss this research further if you desire. I will also be happy to share the findings of the study after its completion.

The proposed research will be quasi-experimental in nature. The method for collecting data will be by taking the pulmonary artery pressure and pulmonary capillary wedge pressure measurements, by the use of a pulmonary artery catheter, with the patient lying in the following three positions: 1) supine and flat, 2) right lateral, 3) left lateral. Patients, age 18 through 75, who have pulmonary artery catheters in place for continuous pressure monitoring and who are on the nursing service units will be included in the study.

I have received permission from the Loma Linda University Committee on Human Studies to waive the required informed consent form from the patients I propose to use in my study. Since these patients will be critically ill it might be detrimental to their physiologic status to read and sign a consent form. Also, their physiologic status may prevent them from signing a consent form, e.g., when the patient is on the respirator.
The procedures used to collect data will not involve any maneuver or treatment in addition to that which is already being done for the patient. The change in patient position is done on a routine basis and the hemodynamic measurements are also used for routine care. There is no known physical, emotional, or social hazard associated with the study. All data will be strictly confidential and will never be associated with the patient's name. Consent will be obtained from the physicians involved in the care of the critically ill patients. The physician will be free to withdraw permission for the patient's participation in the study at any time.

I will be conducting the study under the supervision of Dr. Burton A. Briggs, Lavaun Sutton, Evelyn Elwell, and Ann Ekroth of Loma Linda University.

I am enclosing a copy of my abbreviated research proposal to give you further information regarding my study. In addition, space has been provided on the attached letter from the graduate program for your reply. Thank you so much for your assistance.

Sincerely yours,

[Signature]

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosures

SM:pc
APPENDIX J

PERMISSION TO CONDUCT THE STUDY FROM THE SUPERVISOR
OF ICU AND CCU, ST. BERNARDINE'S HOSPITAL (1977)
St. Bernardine Hospital

Date: August 10, 1977

Dear Ms. Millard:

Your request for permission to collect data for your research project at St. Bernardine Hospital has been received and reviewed. The following action has been taken:

- You have my permission to conduct your study in our facility.
- Your request has been temporarily denied pending provision of additional information.
- Your request cannot be granted at this time.

Also, it will be necessary for you to:

- Obtain permission from the attending physician since your study involves patients and/or their records.
- Obtain additional permission from ________________________.
- Notify and/or advise the following persons of your study:

Make an appointment with ________________________ for additional discussion and information provision.

Other

If I can be of further help, please let me know.

Sincerely,

[Signature]
APPENDIX K

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY AT
ST. BERNARDINE'S HOSPITAL—SUPERVISOR
OF ICU AND CCU (1978)
May 30, 1978

Ms. Anne E. Koran, R.N., B.S.
Supervisor of ICU and CCU
St. Bernardine Hospital
2101 N. Waterman Avenue
San Bernardino, CA 92404

Dear Ms. Koran:

During the summer of 1977 I was involved in the data collection for my research study. I was investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. My data collection last summer was done, in part, in the critical care units at St. Bernardine Hospital.

I was not able to complete my data collection last summer before I moved to Northern California. Therefore, I am going to have to continue with my study this coming summer. I am again requesting your permission to involve patients in the critical care units at St. Bernardine Hospital.

I have included a copy of my original request to you so that you may refresh your memory regarding my study. There will be no change in the method of data collection.

I would like to begin data collection after June 15, 1978. I need to collect data on four patients.

Thank you so much for your assistance.

Sincerely yours,

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosure
APPENDIX L

PERMISSION TO CONDUCT THE STUDY FROM THE SUPERVISOR
OF ICU AND CCU, ST. BERNARDINE'S HOSPITAL (1978)
St. Bernardine Hospital

Date: June 15, 1978

Dear Ms. Millard:

Your request for permission to collect data for your research project at St. Bernardine Hospital has been received and reviewed. The following action has been taken:

X You have my permission to conduct your study in our facility.

— Your request has been temporarily denied pending provision of additional information.

— Your request cannot be granted at this time.

Also, it will be necessary for you to:

— Obtain permission from the attending physician since your study involves patients and/or their records.

— Obtain additional permission from ____________________________.

— Notify and/or advise the following persons of your study.

— Make an appointment with ____________________________ for additional discussion and information provision.

— Other

If I can be of further help, please let me know.

Sincerely,

[Signature]
APPENDIX M

LETTER REQUESTING PERMISSION TO CONDUCT THE STUDY AT
ST. BERNARDINE'S HOSPITAL--DIRECTOR OF
NURSING SERVICE (1978)
June 26, 1978

Ms. Barbara VanDusen, R.N.
Director of Nursing Service
St. Bernardine Hospital
2101 N. Waterman
San Bernardino, CA 92404

Dear Ms. VanDusen:

As a graduate student in nursing, I am investigating the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures. The research study is entitled "The Effect of Lateral Body Positions Upon Pulmonary Artery and Pulmonary Capillary Wedge Pressures in Critically Ill Patients." It will meet part of the requirements for a master's degree in nursing at Loma Linda University. My thesis committee chairman, Evelyn L. Elwell, has approved this thesis and I have obtained approval from the University Committee on Human Studies.

I am at present collecting data at the Loma Linda University Medical Center. My sample size is ten patients and to date I have collected data on six patients. I need to have all my data collected by the end of July because I will be leaving the area. Therefore, I would like to ask permission to involve patients at St. Bernardine Hospital in my study. I have already discussed this matter with Anne Koran, supervisor of ICU and CCU, and she is most willing to work with me in this regard.

In the following paragraphs I will describe my study briefly for you. I will be happy to make an appointment with you to discuss this research further if you desire. I will also be happy to share the findings of the study after its completion.

The proposed research will be quasi-experimental in nature. The method for collecting data will be by taking the pulmonary artery pressure and pulmonary capillary wedge pressure measurements, by the use of a pulmonary artery catheter, with the patient lying in the following three positions: 1) supine and flat, 2) right lateral, 3) left lateral. Patients, age 18 through 75, who have pulmonary artery catheters in place for continuous pressure monitoring and who are on the nursing service units will be included in the study.

I have received permission from the Loma Linda University Committee on Human Studies to waive the required informed consent form from the patients I propose to use in my study. Since these patients will be critically ill it might be detrimental to their physiologic status to read and sign a consent form. Also, their physiologic status may pre-
vent them from signing a consent form, e.g., when the patient is on the respirator.

The procedures used to collect data will not involve any maneuver or treatment in addition to that which is already being done for the patient. The change in patient position is done on a routine basis and the hemodynamic measurements are also used for routine care. There is no known physical, emotional, or social hazard associated with the study. All data will be strictly confidential and will never be associated with the patient's name. Consent will be obtained from the physicians involved in the care of the critically ill patients. The physician will be free to withdraw permission for the patient's participation in the study at any time.

I will be conducting the study under the supervision of Dr. Burton A. Briggs, Lavaun Sutton, Evelyn Elwell, and Ann Ekroth of Loma Linda University.

I am enclosing a copy of my abbreviated research proposal to give you further information regarding my study. In addition, space has been provided on the attached letter from the graduate program for your reply.

Sincerely yours,

Sharon Millard

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosures
APPENDIX N

PERMISSION TO CONDUCT THE STUDY FROM THE DIRECTOR OF
NURSING SERVICE, ST. BERNARDINE'S HOSPITAL (1978)
St. Bernardine Hospital

Date: 6/29/78

Dear Ms. Millard:

Your request for permission to collect data for your research project at St. Bernardine Hospital has been received and reviewed. The following action has been taken:

X You have my permission to conduct your study in our facility.

□ Your request has been temporarily denied pending provision of additional information.

□ Your request cannot be granted at this time.

Also, it will be necessary for you to:

X Obtain permission from the attending physician since your study involves patients and/or their records.

□ Obtain additional permission from ____________________________.

□ Notify and/or advise the following persons of your study.

   MS. ANNE KORAN R.N., R.S.
   ICU - CCU SUPERVISOR

□ Make an appointment with MS. KORAN for additional discussion and information provision.

□ Other

If I can be of further help, please let me know.

Sincerely,

[Signature]

Barbara J. Vanderveen R.N., B.A.
DIRECTOR OF NURSING SERVICE
APPENDIX O

STATEMENT OF APPROVAL OF THE RESEARCH PROPOSAL

SUBMITTED TO THE UNIVERSITY COMMITTEE ON

HUMAN STUDIES
STATEMENT OF APPROVAL OF THE RESEARCH PROPOSAL SUBMITTED TO THE UNIVERSITY COMMITTEE ON HUMAN STUDIES

TO: Dr. Jack Provonsa, Chairman of the University Committee on Human Studies
FROM: E. L. Elwell, Advisor, Chairman of the Research Committee, School of Nursing
DATE: May 5, 1977

SUBJECT: Research Proposal approval for submission to the University Committee on Human Studies

GRADUATE STUDENT'S/INVESTIGATOR'S NAME: Sharon Millard
DATE: May 5, 1977 OPTION: THESIS x NON-THESIS x PUB. PAPER x

The proposed research of this graduate student has my approval for submission to the UNIVERSITY COMMITTEE ON HUMAN STUDIES as it is outlined in the attached form of the research proposal. The proposed research of this student is of ____ sufficient _____ more than sufficient x excellent scientific merit for fulfillment of the requirements for graduate study. In my opinion, the extent of the emotional, social, or physical risk to the patients in the proposed sample is _____non-existent, x minimal, _____moderate, x Other (please explain below).

The proposed research will contribute to increased patient welfare and is within the capability of the student. It is feasible to carry out within a reasonable time. I feel that it would be very difficult to obtain informed consent from the proposed sample and might even add to their physiologic distress. I concur with Sharon's request for waiver of a signed consent form from patients, especially in view of the fact that the variables that will be measured or manipulated are already a part of the critically-ill patient's routine care. Thank you.

Signature of Research Committee Chairman,
School of Nursing
APPENDIX P

LETTER FROM B. A. BRIGGS TO J. PROVONSHA, CHAIRMAN

COMMITTEE ON HUMAN STUDIES, LLU
May 4, 1977

Jack Provonsha, M.D.
Chairman
Committee on Human Studies
Loma Linda University
Loma Linda, CA 92354

Re: The Research Proposal of Sharon Millard

Dear Dr. Provonsha,

I have reviewed the research proposal of Sharon Millard in detail with her. She is requesting information for her thesis which we are currently obtaining or can obtain with no added risk or inconvenience to these patients. Her objective is that of correlating certain currently measured parameters with the patient's position. The change in patient position is currently done on a routine basis and the hemodynamic parameters which she wishes to record are also used for routine care.

I personally see no objection to her obtaining this information without informed consent of the patient.

If there is any additional information or help which I can provide, please feel free to request such.

I remain,

Sincerely yours,

Burton A. Briggs, M.D.
Medical Director, Surgical Intensive Care Unit
Loma Linda University Medical Center

BAB/dy
APPENDIX Q

LETTER FROM E. L. ELWELL TO J. PROVONSHA, CHAIRMAN

COMMITTEE ON HUMAN STUDIES, LLU
Jack W. Provonsha, M.D., Chairman
University Committee on Human Studies
Loma Linda University
Loma Linda, California 92354

Dear Doctor Provonsha:

As chairman of the Ethics in Nursing Research Committee, I have deferred the approval of the proposed research by Sharon Millard entitled "The Effect of Body Position Upon Pulmonary Artery and Pulmonary Capillary Wedge Pressures in Critically Ill Patients" to the University Committee on Human Studies. Sharon is requesting waiver of the required informed consent form from the patients she proposes to include in her sample. Since these patients will be critically ill it might be detrimental to their physiologic status to read and sign a consent form. Also, their physiologic status may prevent them from signing a consent form, e.g. when the patient is on the respirator.

There is no question about the value of Sharon's proposed study or its potential for contribution to increased patient welfare. The variables Sharon proposes to study are already part of the routine care of the proposed sample and should not add to the patient's discomfort. Deferral was made on the basis of absence of the informed consent form only. Consent will be obtained from the physicians involved in the care of the critically ill patients as indicated in the attached proposal. No physical, emotional, or social hazards are known to be associated with this study. Thank you.

Sincerely,

Evelyn L. Elwell, Chairman
Ethics in Nursing Research Committee

ELE:lw

Enclosure
APPENDIX R

PERMISSION TO CONDUCT THE STUDY FROM THE

COMMITTEE ON HUMAN STUDIES, LLU
24 May 1977

Sharon Millard, R.N.
c/o Evelyn Elwell, R.N.
Loma Linda University School of Nursing
Loma Linda, California 92354

Dear Ms. Millard:

Your proposed study on the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures in critically ill patients was reviewed by the Committee on Human Studies of Loma Linda University by mail ballot. A consensus of the members has been received as of this date and the results are as follows.

Committee members agree that:

The subjects are deemed not at risk.

The application shall be approved.

If there are modifications to the proposed protocol, please notify the committee in writing of these changes or problems. If you have any questions, please feel free to contact me at ext. 2026 or the committee chairman, Dr. Jack Provonsha, ext. 2041.

Sincerely yours,

Linda H. Baldwin
Linda H. Baldwin
Secretary
Committee on Human Studies

lhb
cc: Evelyn Elwell, R.N.
APPENDIX S

LETTER TO THE ETHICS IN NURSING RESEARCH COMMITTEE
REQUESTING PERMISSION TO CONDUCT STUDY AT
RIVERSIDE GENERAL HOSPITAL AND
ST. BERNARDINE'S HOSPITAL
August 9, 1977

Evelyn L. Elwell, Chairman
Ethics in Nursing Research Committee
Loma Linda University School of Nursing
Loma Linda, CA 92354

Dear Ms. Elwell:

I received permission from the University Committee on Human Studies to conduct my research study entitled "The Effect of Lateral Body Positions upon Pulmonary Artery and Pulmonary Capillary Wedge Pressures in Critically Ill Patients" with patients at the Loma Linda University Medical Center. I have now been collecting data for six weeks. My sample size is ten patients and to date I have only been able to collect data on three patients.

It is important that I have all my data collected by the first week of September because I will be moving out of the area at that time. Because of this I have requested permission from Riverside General Hospital and St. Bernardine Hospital to involve their patients in my study. I have received tentative permission from St. Bernardine Hospital and am waiting reply from Riverside General Hospital.

I would like to request permission from the Ethics in Nursing Research Committee to utilize patients at the above mentioned facilities in my research study.

Sincerely,

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing
APPENDIX T

PERMISSION TO CONDUCT THE STUDY FROM THE
ETHICS IN NURSING RESEARCH COMMITTEE
Sharon Millard  
24414 University, #169  
Loma Linda, CA 92354

Dear Sharon:

The Ethics in Nursing Research Committee has reviewed the proposal you submitted for a research study to partially fulfill the School of Nursing requirements for a Master of Science degree from Loma Linda University.

The committee has voted that your study is:

- Approved as submitted.
- Approved after the attached recommended changes have been made and a memo from your committee chairman to this effect has been received by the committee chairman.
- Not approved as submitted to the committee. See the attached comments for recommended changes. Must be resubmitted prior to any data collection.

Deferred to: _URACHE _ Major Advisor _ Research Chairman  
__Other _ Advisor

Please see attached comments regarding this action.

Please contact the Chairman of the Ethics in Nursing Research Committee if you have questions related to the decision of the Committee. If any changes are made in the hypothesis, tool, consent form, or the procedure for data collection, this proposal must be resubmitted to this Committee.

We pray that the Lord will continue to bless your endeavors.

Sincerely,

Evelyn L. Elwell, Chairman  
Ethics in Nursing Research Committee

ELE:lw

cc: Research Committee Chairman
RECOMMENDATIONS AND COMMENTS
OF THE
ETHICS IN NURSING RESEARCH COMMITTEE

Approve request for additional institutions to collect research data pending written confirmation of coverage from insurance carrier.

1. St. Bernardine's Hospital
2. Riverside General Hospital
3. St. Helena Hospital
APPENDIX U

LETTER REQUESTING ANNUAL REVIEW OF STUDY BY THE
COMMITTEE ON HUMAN STUDIES

138
June 9, 1978

Linda Halstead, Secretary
Committee on Human Studies
Grants Resources Service
Loma Linda University
Loma Linda, CA  92354

Dear Ms. Halstead:

In May of 1977 my research was approved by the University Committee on Human Studies. I have not yet completed the data collection for this study. Therefore, I am submitting my study for the required annual review by the Committee on Human Studies.

Enclosed please find a copy of my request for research approval which was submitted last year. I have also included copies of two letters, one from Evelyn Elwell and one from Dr. Burton A. Briggs, which I feel are important to my research proposal.

There have been no changes or modifications in the data collection method. All protocol remains the same.

Thank you for your attention to my study.

Sincerely yours,

Sharon Millard, R.N., B.S.
Graduate Program in Nursing
Loma Linda University
School of Nursing

Enclosures
APPENDIX V

APPROVAL FOR CONTINUATION OF STUDY FROM THE
COMMITTEE ON HUMAN STUDIES
Miss Evelyn Elwell, R.N.
Loma Linda University
School of Nursing
Loma Linda, California 92350

Dear Miss Elwell:

The proposal entitled "The effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures in critically ill patients" which was submitted by Sharon Millard, graduate student in the School of Nursing, was reviewed by Loma Linda University's Committee on Human Studies at its regular meeting on June 14, 1978.

It was noted that this request involves the annual review by the committee and that there have been no changes or modifications in the protocol. Continuation of this project was approved; the subjects are not at risk.

If there are any changes involved in this protocol or the consent form in the future, please notify either the committee chairman or myself in writing.

Best wishes for continued success in this study.

Sincerely yours,

Linda G. Halstead
Linda G. Halstead
Secretary
Committee on Human Studies

lgh

xc.: Sharon Millard
APPENDIX W

PHYSICIAN CONSENT FORM--LLUMC
As a graduate student in nursing and as part of the requirements for a masters degree in nursing, I am investigating the effects of lateral body positions upon pulmonary artery pressures and pulmonary capillary wedge pressures. If these pressure readings are accurate with the patient in side-lying positions then nurses will be able to record pulmonary artery pressures and pulmonary capillary wedge pressures with the patient lying in lateral positions in addition to the flat supine position.

Permission to conduct this study has been obtained from the University Committee on Human Studies; Ms. Gertrude Hausalar, Assistant Administrator of Nursing Service; Ms. Phyllis McElmurry, Assistant Director of Critical Care Nursing Service; and the members of my thesis committee, Evelyn Elwell, Dr. Burton Briggs, and Lavaun Sutton. I am hereby requesting permission to include your patients in this study, which is explained in more detail below.

CRITERIA FOR SAMPLE SELECTION

1. Age 18 through 75
2. Pulmonary artery catheter in place
3. Patient is on one of the hospital units. Patients in cardiac catheterization laboratory will not be included.
4. Patient does not have pulmonary hypertension.
5. Patient does not have mitral valve stenosis.
6. Patient is not grossly obese. No intestinal bypass surgery patients.
7. Patient does not have severe deformities of thorax or spinal column.
8. Patient is not comatose related to cerebral impairment and therefore is not totally dependent upon a ventilator for respirations.
9. No cerebrospinal injury patients will be included.
10. Patients with impairment to brainstem function will not be included.

PROCEDURE

The method for collecting data will be by taking the pulmonary artery and pulmonary capillary wedge pressure measurements, by the use of a pulmonary artery catheter, with the patient lying in the following three positions: 1) supine and flat, 2) right lateral, 3) left lateral.

The procedures used to collect data will not involve any maneuver or treatment in addition to that which is already being done for the patient. The change in patient position is done on a routine basis and the hemodynamic measurements are also used for routine care.

I have considered the above statements and hereby give my consent to permit Sharon Millard, R.N., under the supervision of Dr. Burton A. Briggs and Lavaun Sutton, R.N. of the Loma Linda University Medical Center and Evelyn Elwell of Loma Linda University, to include my patient(s) in the research study of the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures in critically ill patients. I understand that I am free to withdraw permission for my patient’s participation in this study at any time.

Signed

Date

Witness
APPENDIX X

PHYSICIAN CONSENT FORM—ST. BERNARDINE'S HOSPITAL
As a graduate student in nursing and as part of the requirements for a masters degree in nursing, I am investigating the effects of lateral body positions upon pulmonary artery pressures and pulmonary capillary wedge pressures. If these pressure readings are accurate with the patient in side-lying positions then nurses will be able to record pulmonary artery pressures and pulmonary capillary wedge pressure with the patient lying in lateral positions in addition to the flat supine position.

Permission to conduct this study has been obtained from the Loma Linda University Committee on Human Studies; Ms. Anne Koran, Supervisor of ICU and CCU, St. Bernardine Hospital; and the members of my thesis committee, Evelyn Elwell, Dr. Burton Briggs, and Lavaun Sutton of Loma Linda University. I am hereby requesting permission to include your patients in this study, which is explained in more detail below.

CRITERIA FOR SAMPLE SELECTION

1. Age 18 through 75
2. Pulmonary artery catheter in place
3. Patient is on one of the hospital units. Patients in cardiac catheterization laboratory will not be included.
4. Patient does not have pulmonary hypertension.
5. Patient does not have mitral valve stenosis.
6. Patient is not grossly obese. No intestinal bypass surgery patients.
7. Patient does not have severe deformities of thorax or spinal column.
8. Patient is not comatose related to cerebral impairment and therefore is not totally dependent upon a ventilator for respirations.
9. No cerebrospinal injury patients will be included.
10. Patients with impairment to brainstem function will not be included.

PROCEDURE

The method for collecting data will be by taking the pulmonary artery and pulmonary capillary wedge pressure measurements, by the use of a pulmonary artery catheter, with the patient lying in the following three positions: 1) supine and flat, 2) right lateral, 3) left lateral.

The procedures used to collect data will not involve any maneuver or treatment in addition to that which is already being done for the patient. The change in patient position is done on a routine basis and the hemodynamic measurements are also used for routine care.

I have considered the above statements and hereby give my consent to permit Sharon Millard, R.N., under the supervision of Dr. Burton A. Briggs and Lavaun Sutton, R.N., of the Loma Linda University Medical Center and Evelyn Elwell of Loma Linda University, to include my patient(s) in the research study of the effect of lateral body positions upon pulmonary artery and pulmonary capillary wedge pressures in critically ill patients. I understand that I am free to withdraw permission for my patient’s participation in this study at any time.

Signed

Data

Witness
APPENDIX Y

DATA COLLECTION RECORD
DATA COLLECTION RECORD

<table>
<thead>
<tr>
<th>Subject Code #</th>
<th>Hospital Unit</th>
<th>Date</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Positions</th>
<th>Pulmonary artery pressures</th>
<th>Pulmonary Wedge Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PAS</td>
<td>PAD</td>
</tr>
<tr>
<td>Supine flat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left lateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right lateral</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Birth Date (age):

Sex:

Diagnosis:

Pertinent Medical History:

Medications:

Management:

Heart Rate and Rhythm:

Date and Time of Pulmonary Artery Catheter Insertion:

Other:
Figure 2

Bubble Level on Yardstick
Figure 3

Angular Sponge Bolster
APPENDIX BB

FIGURE 4
Figure 4

Carpenter's Angle Finder