ECHOCARDIOGRAPHIC DETERMINATION OF ATRIAL LEVELS IN SUPINE AND LATERAL POSITIONS

by

LAURA-ANN L. KEE

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

NURSING

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA

San Francisco

[redacted]

Date University Librarian

Degree Conferred: . . . January 4, 1987 . . . .

ABSTRACT

Pulmonary artery pressure measurements are an integral part of nursing care of the critically ill. Accuracy of measurement depends on use of a valid reference point which reflects right or left atrial location. To date, question exists whether there is a valid external reference point for the right and left atrium.

The purpose of this study was to evaluate the validity of the midaxillary line (MAL) and midanterior-posterior diameter (midAP) as reference points for the supine position (supine) and to assess changes in the position of the right atrium (RA) and left atrium (LA) with lateral body positions.

A repeated measures design was used. The convenience sample consisted of 25 adults, 18 female and 7 male, aged 23 to 44 years (mean 31). Instruments included two dimensional echocardiographic imager, digitizing light pen, protractor, and carpenter level.

After informed consent was obtained, the level of the subject's MAL and midAP while supine were measured relative to a fixed location (bed surface). The transducer (Tx) position on the chest in each body position was also measured relative to this fixed location. Two dimensional echocardiograms in the parasternal short axis view of the aorta were recorded with subjects positioned supine, 30 degrees right, 30 degrees left, and 90 degrees left lateral.

The vertical distances from the Tx to the RA and LA at end-expiration were measured on videotaped images with a digitizing light pen, and adjusted geometrically for the protractor measured Tx angle to the chest wall in each position. Using a geometric model, the level of the RA and LA in each position was calculated to determine the change of the level of the RA and LA with thorax rotation.

Repeated measures ANOVA indicated significant differences in the reference points for RA and LA location ($p<.001$). Posthoc Scheffe' test identified significant differences between the RA supine and the lateral positions ($p<.001$) and between RA supine and midAP ($p<.01$), but none between RA supine and MAL (p=NS). Significant differences between LA supine and the lateral positions were also found ($p<.001$). However, there were no significant differences between LA supine, MAL and midAP.

The results indicate that the MAL is a valid reference point for RA, and MAL and midAP are valid reference points for LA in the supine position. However, neither MAL nor midAP of the supine patient are valid reference points in the lateral positions. Pressure measurements obtained when patients are in the lateral positions cannot be considered accurate. There remains a need to develop valid methods of accurate pressure measurement in various body positions.

ACKNOWLEDGEMENTS

This study would not have become a reality without the assistance of some very special people.

I owe much gratitude to Dr. Nancy A. Stotts who provided me with continuous guidance, time, and patience throughout the duration of the project, to Dr. Nelson B. Schiller who provided great support, allowing me to conduct the study in his echocardiography department and offering me the support of his staff and equipment, and to Ms. Phylita Skov who was always nearby for advise, encouragement, and support, irregardless of the time of day.

I am particularly grateful to Dr. Jay S. Simonson who so generously gave his precious time to help me to conduct the study. The project would have been impossible to complete without his assistance and efforts.

Special thanks go to Dr. Kan Gill who gave me the opportunity to test my budding ideas in his lab, to Dr. Gordon Gamsu who encouraged me to continue the pursuit of my ideas and opened doors along the way, and to my father, Norman Lau Kee, who helped me to develop the geometric model, the key to this study.

I am very appreciative of the warmth, patience, and assistance of the staff in the Echocardiography Department at UCSF. In addition, I am thankful for the assistance of the staff in the Computer Resource Lab who has all too often made the dash down to the wire with me.

I will never forget the encouragement, support, and understanding of family and friends who were patient with me through the long process, who shared my excitement and struggles, and who kept me on the path towards completion.

Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

INTRODUCTION

Problem

Monitoring pulmonary artery pressures is common practice in the care of critically ill patients, and accurate pressure measurements are essential in management of patients. Central venous and pulmonary artery pressures reflect right and left atrial pressure respectively. Elevation of these pressures may indicate significant physiological changes such as pulmonary congestion and pulmonary edema (Forrester, Diamond, & Swan, 1971). Because the pressures provide a basis for diagnostic and clinical decisions, clinicians must use reliable and valid techniques for hemodynamic monitoring.

One factor which influences the accuracy of the pulmonary artery pressure measurement is the relationship of the pressure transducer to the heart. To reflect accurate intracardiac pressures, pressure transducers must be placed at the same level as the chamber of the heart which is being monitored. This level is called the zero reference level. Use of the zero reference level eliminates the effects of hydrostatic pressure, pressure at one end of a column of fluid induced by the difference in the vertical height of the opposite end.

Various methods of determining this level using external reference points have been devised. Winsor and Burch (1945) identified the intersection of the fourth intercostal space and midchest lines as an external reference point for the right atrium and called it the phlebostatic axis. This level is commonly used by nurses monitoring patients' intracardiac pressures (Laulive, 1982; Woods, 1976.) It has been assumed that the patient must be positioned supine for accurate pressure measurements using this zero reference point (Woods, 1976).

Critically ill patients may require frequent hemodynamic measurements, from every five minutes to every hour. At the same time, nursing care traditionally includes turning immobile patients at least every two hours for respiratory and skin care (Steinberg, 1980). Thus, patients are frequently repositioned between supine and lateral positions and are often disturbed from essential sleep.

Methods are needed to decrease patients' disturbances due to frequent repositioning for both hemodynamic monitoring and patient care. However, reliability of pressure measurements in various positions must be determined before such practice can be instituted. Before the reliability of pressures can be tested, validity of zero reference levels must be established.

Purpose

The purpose of the study is to determine the validity of the phlebostatic axis, the right atrial reference level as identified by Winsor and Burch (1945), in supine patients using echocardiography. The phlebostatic axis was originally identified by measuring venous pressures of the hand and has not been validated by methods comparing the level to the right atrium. In addition, the validity of using this reference level in the 30 degree right and left lateral positions and the 90 degree left lateral position will be determined.

Significance

Determining the validity of the reference point in the supine position will benefit both patients and clinicians. If the reference point presently used is valid, patients can receive care based upon reliable techniques, and clinicians can be confident that their clinical decisions are based on accurate pressure measurements. If the reference point is not validated, the need for developing one will have been established.

Determining the validity of the phlebostatic axis in lateral positions would lead towards development of a valid reference level for lateral positions. This would allow nurses to monitor intracardiac pressures with patients in lateral positions and to provide adequate rest for patients by minimizing the interruptions of sleep cycles without sacrificing essential aspects of care.

Patients need to be positioned laterally for various aspects of care, such as respiratory and skin care, yet need to be supine during hemodynamic pressure measurments. If the nurse is able to obtain reliable pressure measurements with the patient in side lying positions, she would not need to reposition the patient onto his back for pressure measurements. Leaving patients in one position for longer periods of time would minimize the disturbance of patients, and thus, potentially reduce the occurrence of sleep deprivation in patients.

Less frequent turning of patients will conserve nurses' time allowing nurses to utilize their time for other aspects of patient care. In addition, knowing they will not have to frequently reposition patients onto their backs for accurate hemodynamic pressures, nurses will not hesitate to position critically ill patients on their side for respiratory and skin care, a simple procedure which can reduce the complications of immobility, and lead to shorter hospitalizations (Chulay, Brown, & Summer, 1982) and greater financial savings by the patient, family, hospital and community.

Chapter Two

REVIEW OF LITERATURE

Immobility

Turning and repositioning of immobile patients is essential to their recovery and well being. Bedrest and immobility affect all systems of the body. During immobility, the response of the nervous system is slowed, and the patient's coordination is adversely affected. The gastrointestinal system develops decreased motility, and there is diminished appetite, especially for protein rich foods resulting in a net protein loss. Bladder evacuation is inhibited with stagnation of urine in the renal pelves especially in recumbent positions (Steinberg, 1980). The respiratory and integumentary systems also can be profoundly affected.

Predisposition to respiratory infections occurs with prolonged supine positioning (Browse, 1965). Ray et al. (1974) demonstrated the benefit of frequent turning, which was operationalized as from every 30 minutes to every hour, to maintain or restore optimal lung function and to minimize pathological changes in the lung tissue.

The high incidence of decubitus ulcers in patients who remain in one position for long periods of time has been recognized since the 1800s (Parish, Witkowski, & Crissey, 1983). Kosiak (1959) found that development of decubitus ulcers, influenced by compressive pressure which interferes with capillary blood flow, is due to an inverse relationship between the intensity and duration of pressure. Studying 16 dogs, he found that irreversible cellular changes occurred with pressures sustained over two hours, while fewer or no changes occurred with intermittent pressure of less duration. Prevention of decubitus ulcers begins with minimizing excessive pressure on bony prominences with periodic and regular repositioning.

Complications of immobility such as decreased lung function and decubitus ulcers increase morbidity, length of hospital stay and cost of care (Steinberg, 1980). Evidence that frequent turning and repositioning of patients minimize such complications has led to the establishment of turning regime as a standard part of nursing care. While the required frequency of repositioning has not been determined, the recommended and widely used frequency is every two hours (Parish, Witkowski, & Crissey, 1983).

Sleep Deprivation

Beginning in the 1960's, a high incidence of psychosis was documented in the cardiac surgical population. Researchers suggest that intensive care unit (ICU) psychosis is related to sleep deprivation (Kornfeld, Zimberg, & Malm, 1965; Layne & Yudofsky, 1971; Orr & Stahl, 1977).

Sleep has distinguishing physiological characteristics. Continuous electroencephalographic (EEG) studies document the cyclic and rhythmic nature of sleep. The five distinct stages of sleep extend over 90 to 120 minutes and are repeated four to five times during an average night of sleep (Brezinova, 1974; Kales, Jacobson, Kales, Kun & Weissbuch, 1967).

Behavioral deficits and decreased perceptual, cognitive, and psychomotor abilities have been reported in controllled studies using healthy sleep deprived subjects (Fiorica, Higgins, Iampietro, Lategola, & Davis, 1968; Kollar et al., 1969). Subjects also exhibited increase in fatigue, irritiability, aggressive behavior, depressive moodshifts, misperceptions, hallucinations, mild nystagmus, mild tremors, slowing of speech and ptosis of the eyelids.

Researchers propose that the critical care environment fosters sleep deprivation. Hilton (1976) collected data on ten respiratory intensive care unit patients to determine the quantity and quality of sleep and factors which disturb their sleep. She found total sleep time consisted of six minutes to 13.3 hours during 24 hours with averages from 2.6 to 5.8 hours per 24 hours. The subjects were predominently in Stage 1 sleep and deprived of the other stages. Hilton concluded that the quantity of sleep the subjects received was less than normal and the quality of sleep was poor due to the abnormal amounts of time spent in Stage I sleep The most frequent sleep disturbing factors were noises created by staff, continuous patient assessment, and therapeutic procedures.

Evidence of disturbances in ICU patients' sleep due to the environment and activities in the unit is growing (Ballard, 1981; Woods, 1972). Direct and indirect monitoring of vital signs were found to be the most frequent interrruptions of sleep (Orr & Stahl, 1977; Woods, 1972) while ICU patients ranked "being awakened by nurses" and "not knowing when to expect things will be done to them" high on a list of stressful situations (Ballard, 1981). Researchers recommend reducing disturbances from activities by coordinating nursing care activities to minimize sleep deprivation in ICU patients (Kornfeld, Zimberg, & Malm, 1965; Lazarus & Hagen, 1968).

Hemodynamic Pressure Measurement

Since the advent of pulmonary artery catheters in 1970, continuous hemodynamic monitoring has been a standard part of the intensive care unit nurse's responsibility. Continuous pulmonary artery (PA) pressure monitoring provides current information on patients' hemodynamic status.

The value of the PA catheter in the management of the critically ill patient has been documented. Sarin, Yalav, Clement and Braimbridge (1970) found that in the normal heart, right atrial pressure correlates well with left atrial pressure. However, in the presence of pathological processes in the heart, this correlation between the right and left atrial pressures does not occur (Risk, Rudo, Falltrick, Feeley, and Don, 1978). PA catheters provide information on left ventricular function. With the tip of the catheter positioned in the distal PA, the normal, unobstructed pulmonary vasculature serves as the fluid filled extension of the catheter tubing that terminates in the left atrium (LA). During diastole, the pulmonary capillary wedge pressure correlates closely with the mean left atrial pressure, reflecting left ventricular end-diastolic pressure, a significant indicator of left ventricular function (Lappas, Lell, Gabel, Civetta, & Lowenstein, 1973).

Hydrostatic Pressure

Fluid filled areas of the body such as the heart and blood vessels are subject to the properties of liquid. Pressure in a static liquid is exerted equally in all directions; therefore, a change of pressure at any point in the liquid results in a similar change in the entire volume of liquid. In a column of fluid, pressure varies with height in a linear fashion. Thus, the greater the vertical distance from a point of measurement to the top of a fluid column, the higher the pressure is (Cywinsky & Tardieu, 1980).

Physiological pressure transducers must be placed at the same level as where the tip of the catheter lies, or at the zero reference level, in order to reflect accurate pressures (Mendel, 1974). If the catheter tip is lower than the transducer, a pressure lower than the intracardiac pressure will be reflected. Similarly, if the tip is above the transducer, a higher pressure will be reflected. The transducer measuring central venous pressure (CVP) is placed at the level of the right atrium. Although the tip of the pulmonary artery catheter is situated in the pulmonary artery (PA), the pulmonary artery and capillary bed serve as an extension of the catheter with the end point in the LA (Buchbinder & Ganz, 1976). For PA pressure measurements to reflect left atrial pressures, the transducer is placed at the level of the LA.

Anatomy

The heart is situated in the middle of the mediastinum, partially overlapped by the lungs and with two thirds of the organ to the left of the midline. The heart is posterior to the sternum and costal cartilage of the third, fourth, and fifth rib. The apex is anterior to the rest of the heart due to a forward tilt of the heart (Silverman & Schlant, 1978).

The atria are separated from the ventricles externally by the atrioventricular sulcus, a groove which circles heart between atria and ventricles. The right atrium (RA) forms the right lateral cardiac border and is situated above, behind and to the right of the right ventricle. Most of the RA is anterior to and to the right of the left atrium. Anteromedially, the RA appendage protrudes from the RA and overlaps the aortic root (Silverman & Schlant, 1978).

The left atrium (LA) is located superiorly and posteriorly to other cardiac structures with the esophagus lying adjacent to the left atrium's posterior surface. The aortic root impinges on its anterior wall. The RA is situated to the right and anterior to the LA; the left ventricle (LV) is to the left, anterior, and inferior to the LA. The aortic valve is posterior to the right ventricle, occupying a position close to the middle of the heart (Silverman & Schlant, 1978).

Reference Levels

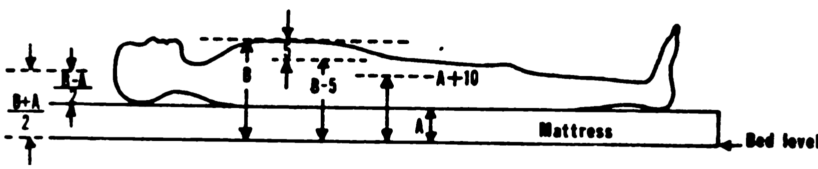
The use of standard external reference points to determine transducer placement assures comparable pressures despite different observers, clinicians, and institutions. Over the years, many different zero reference levels for the RA have been proposed using either external anatomical structures or other environmental fixtures, such as the bed surface. Moritz and von Tabora defined the zero reference level for the RA as five centimeters (cm.) ventral from the sternal insertion of the fourth rib (Debrunner & Buhler, 1969). Lyons (1938) advocated use of a point 10 cm. above the back. Weil, Shubin, & Rosoff (1965) used one half the thoracic diameter as their reference level (Figure 1).

To determine the validity of several reference levels, Debrunner and Buhler (1969) compared the central venous pressure in 26 patients

FIGURE 1

REFERENCE LEVELS FOR PRESSURE MEASUREMENT

1. Sternal angle — B
2. Five cm below sternal angle — $B - 5$
3. Back — A
4. Midchest — $\frac{B - A}{2} + A = \frac{B + A}{2}$
5. Ten cm above the back — $A + 10$



Reference levels for the pressure measurement.

Note. From From cardiac catheterization data to hemodynamic parameters (p. 31) by Yang, S. S., Bentivoglio, L. G., Maranhao, V., & Goldberg, H., (1978), Philadelphia: F. A. Davis. Copyright 1978 by F. A. Davis. Reprinted without permission.

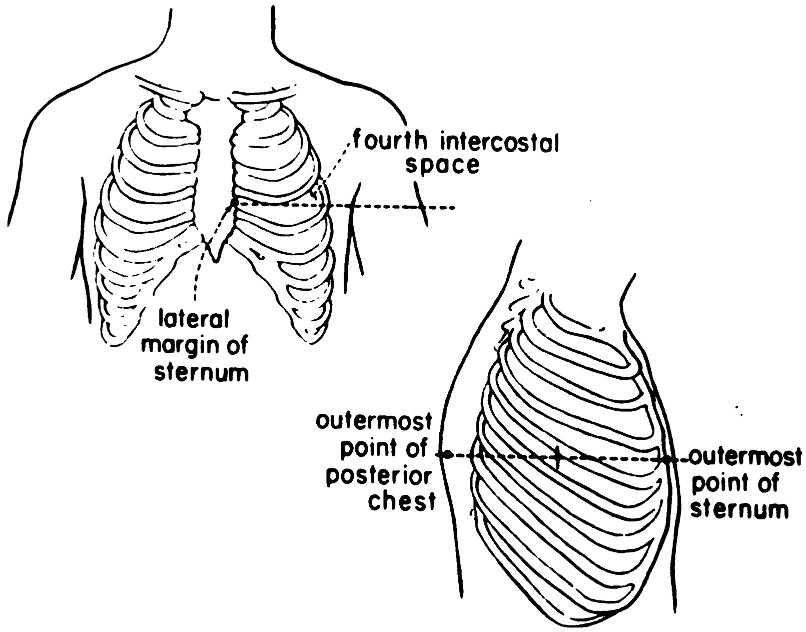
using seven different zero reference points. They found that all the reference points except that located ten cm. above the back were similar. Statistical values were not reported.

While the reference levels were originally developed to approximate right atrial location in the supine patient, these and other levels are used to locate both the right and left atria (Yang, Bentivoglio, Maranhao, & Goldberg, 1978; Mendel, 1974). Chandraratna (1975) used M Mode echocardiography to compare the anterior chest wall to mid LA distance to three zero reference levels - 1) five cm. from the sternal angle, 2) ten cm. from the back, and 3) the midchest level. He found that the distance five cm from the sternal angle consistently did not match the distance from the anterior chest wall to the LA. However, Chandraratna found the distances ten cm. from the back and the midchest level did match the distance from the anterior chest wall to the LA and concluded that they can be used as accurate zero reference levels for left atrial measurements.

Winsor and Burch (1945) identified an external anatomical reference point that could be used with patients lying on their back with different backrest elevations. Measuring the venous pressure in the dorsal vein of the hands of 164 normal adults, they determined a reference point defined by the intersection of two planes - the frontal plane which passes through the midpoint of a line from the outermost points from the anterior to the posterior chest and the cross sectional plane that passes through the fourth intercostal space (Figure 2). The researchers found that with transducers placed at this intersection, venous pressures in the hand were consistent with the subject supine or sitting with the head of the bed raised at

FIGURE 2

PHLEBOSTATIC AXIS



Note. From "Effect of body position upon pulmonary artery and pulmonary capillary wedge pressures in noncritically ill patients" by S. L. Woods and L. W. Mansfield, 1976, Heart and Lung, 5, p. 84. Copyright 1976 by C. V. Mosby. Reprinted without permission.

angles of 25, 35, 45, 55, and 90 degrees.

While Winsor and Burch recommended using this axis only with venous pressures, their reference point, called the phlebostatic axis, has been accepted as a valid and reliable reference point from which to measure both CVP and PA pressures (Laulive, 1982; Woods, 1976). The advantage of the phlebostatic level is that it provides a constant reference point despite the elevation of the backrest (Figure 3).

There is insufficient detail reported to evaluate the methods used by Winsor and Burch or to replicate the study. It appears that for the time during which the study was conducted, the method was the most appropriate one to use. But it is possible that variables affecting pressure either were not considered or were not measurable at that time due to the state of technology.

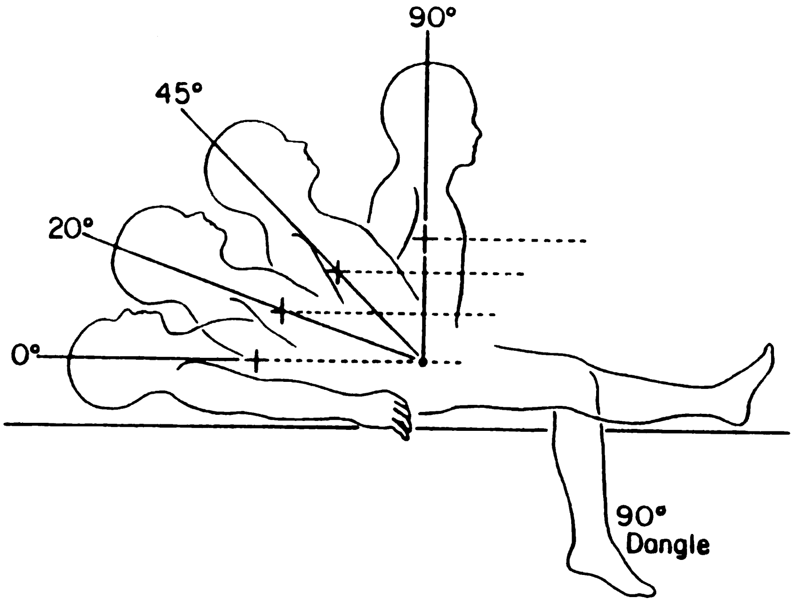
Frequently, clinicians use the horizontal level of the midaxillary line interchangeably with that of the midanterior-posterior diameter. Laulive (1982) defined the zero reference level for the right atrium using Winsor and Burch's phlebostatic axis. However, when describing her methodolgy, she used the midaxillary line, the midpoint between the anterior and posterior axillary folds.

The Effect of Backrest Elevations on Pressure Measurements

Recently, researchers have examined the effects of various positions on PA pressure measurements (Chulay & Miller, 1984; Laulive, 1982; Prakash, Parmley, Dikshit, Forrester, & Swan, 1973; Woods & Mansfield, 1976). While studying the hemodynamic effects of elevation of the head of the bed in patients with myocardial infarctions, Prakash et al. (1973) used a point five centimeters vertically below

FIGURE 3

PHLEBOSTATIC AXIS IN FIVE POSITIONS



Note. From "Effect of body position upon pulmonary artery and pulmonary capillary wedge pressure in noncritically ill patients" by S. L. Woods and L. W. Mansfield, 1976, Heart and Lung, 5, p. 85. Copyright 1976 by C. V. Mosby. Reprinted without permission.

the sternal angle in the fourth intercostal space as the zero reference level in the supine patient. When the patient's position was changed to the erect position, the pressure transducer was leveled to "the previously marked point." It is unclear whether this point refers to the one used when the patient was supine or a new reference point determined by the previously mentioned method. In addition, the use of a reference point that Chandraratna (1975) concluded was not valid for left atrial measurements threatens the validity of the reported results.

Other researchers have investigated the effects of various positions on PA pressure measurements using the reference level defined by Winsor and Burch (1945). Woods and Mansfield (1976) found that the PA systolic (PAS), diastolic (PAD), mean (PAM), and capillary wedge (PCW) pressures were not significantly different as the backrest was raised from the supine position to 45 degrees. They found significant change in the PAS when the backrest was raised from the supine position to 90 degrees and when the patients were sitting at the edge of the bed ($p < 0.05$).

Researchers replicating Woods and Mansfield's study (1976) in samples of both medical and surgical ICU patients obtained similar results (Chulay & Miller, 1984; Laulive, 1982). Chulay and Miller (1984) found no significant changes in the PA pressures with backrest positions up to 60 degrees ($p<.05$) supporting Woods and Mansfield's conclusion that repositioning the patient to the flat position for PA pressure measurements is unnecessary provided the patient is lying on his back with the backrest position no higher than 60 degrees. Laulive did not report the level of significance found.

Retailliau, Leding, and Woods (1985) compared the mean left atrial pressures (LAP) of 32 post cardiac surgery patients positioned flat and with pressures taken with 30 degree backrest elevation. They found the difference between the LAP in the two positions to be statistically significant ($p < 0.001$, $F=12.2$). However, when they compared the mean change in LAP obtained with position change with the mean fluctuation of the LAP, they found no significant difference ($p > 0.01$).

The Effects of Lateral Positions on Pressure Measurements

Researchers have not identified a zero reference level for use with laterally positioned patients. Kennedy, Bryant, and Crawford (1984) attempted to locate the LA in patients in the lateral decubitus position by examining the chest roentgenograms of ten patients with pleural effusions. Comparing the x-rays taken with the patients supine and in the right and left lateral decubitus positions, the researchers used the change of the carina position as an indication of left atrial shift. They hypothesized that "since the left atrium is anchored to the lungs by the pulmonary veins, any shift of the left atrium when the patients turn to their sides would by accompanied by a shift in midpulmonary structures" (p. 155). Repositioning resulted in shifts of the carina from one to seven millimeters, from which they concluded that the minimal shift seen in the carina meant the location of the atrium would not change significantly with the patient in the lateral decubitus position. Using these results and the known anatomy of the LA, they determined the zero reference point of patients in lateral decubitus positions as the point where lines at the fourth intercostal space and midsternum or midline of the spinal column intersect (Figure 4).

The validity of their study is threatened by the use of results from a small, specific sample of ten patients with pleural effusions to develop a method of leveling transducers for all patients in lateral decubitus positions. Measuring only shifts in the carina, the investigators failed to demonstrate that the shifts in carina were similar to the left atrial shifts as their hypothesis stated.

Using their zero reference level for patients in the ateral decubitus position and Winsor and Burch's phlebostatic axis for supine patients, Kennedy et al. (1984) measured PA pressures in supine and right and left lateral decubitus positions and found no significant difference ($p <.05$) in the pressures. The researchers concluded that accurate measurements of the pressure can be obtained with the patients in the lateral decubitus position provided the transducer is level to the LA. The validity of this study is threatened by the use of the reference level the researchers developed in their pilot study.

Wild (1984) measured pulmonary artery (PA) and pulmonary capillary wedge (PCWP) pressures in 30 critically ill adults using two reference points. When the patients were supine, she used the phlebostatic axis identified by Winsor and Burch (1945), and when they were in the 30 degree lateral recumbent position, she used the fourth intercostal space at the midsternal line identified by Kennedy et al., (1984). She found the variation in the pressure measurements from the supine to the lateral positions was statistically ($p < 0.01$) and clinically significant and concluded that, at the present time, patients must be supine in order to obtain accurate pressure

FIGURE 4

EXTERNAL REFERENCE POINT FOR 90 DEGREE LATERAL POSITION

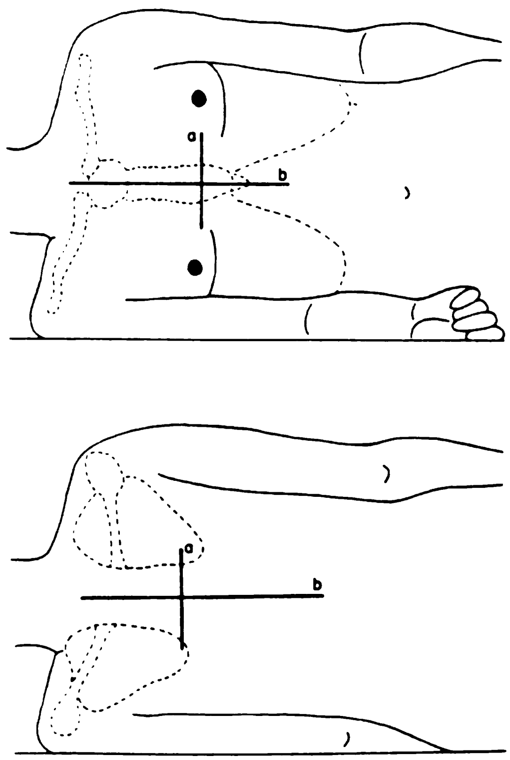


Fig. 2. Determination of anterior and posterior measuring points for lateral decubitus positions. **Top,** Line *a* represents the fourth intercostal space and line *b* is the midsternal line. **Bottom,** Line *a* represents the fourth intercostal space (T_4-T_6 level) and line *b* is the midline of the spinal column.

Note. From "The effects of lateral body positioning on measurements of pulmonary artery and pulmonary artery wedge pressures" by G. T. Kennedy, A. Bryant, and M. H. Crawford, 1984, Heart and Lung, 13, p.156. Copyright 1984 by C. V. Mosby. Reprinted without permission.

measurements. She did not recommmend use of the midsternal reference point developed by Kennedy et al. (1984) for the lateral positions, but instead recommended further investigation of an atrial reference level for patients positioned in various degrees of lateral turn.

Keating, Boyard, Eichler, and Reed (1986) conducted a study similar to Wild (1984), utilizing the phlebostatic axis as the reference level when patients were in the supine position and the level of the fourth intercostal space and midsternal line when patients were in the 45 degree lateral position. Although maintenance of the 45 degree position was not standardized in their study, the investigators found significant differences in the PA and PCW pressures ($p < .001$, $F = 6.08$) with pressures lower when the patient was in the lateral positions and higher in the supine position. Based on their findings, Keating et al. do not support the practice of obtaining PA and PCW pressure measurements in lateral positions.

The Effect of Lateral Positions on Atrial Locations in Cadavers

A pilot study was conducted by this investigator on cadavers to determine if there is variation in the location of the atria between the supine and lateral positions. The cadavers ($n = 4$) were positioned supine flat and 30 and 45 degrees laterally to the right and left. After specific points in the right and left atrium were marked with pins, the horizontal plane through each of the points was marked onto a fixed pole, using a carpenter level and pen. The cadavers were turned and supported in the various lateral positions. The height of the horizontal planes through through the fixed points in the left and right atria were marked onto the pole when the cadavers were in the 30 and 45 degree lateral positions.

All four cadavers had measurements made on the right atrium, two had a second set of measurements on the right atrium, and two had measurements on the left atrium. Every measurement made with the cadaver in the 30 degree lateral position whether turned to the left or right demonstrated a large elevation of the level of the atria. The smallest change within a single subject for the right atrium was four centimeters while the largest was 11.9 cm. The level of the left atrium changed from 5.6 cm to 11.4cm.

Data suggest there is vertical displacement with lateral positioning. Because of the differences in characteristics between the fixed cadavers' hearts and the active fluid filled hearts of living subjects, the information from this study is only applicable to cadavers. However, it does suggest there is a rationale for exploration of this phenomena in live subjects. It was determined to be necessary to study living subjects to obtain data applicable to patients.

Echocardiography

To study living subjects, a method of viewing the cardiac chambers in relation to the external surface of the body is needed. Cross-sectional echocardiography is one such method. It permits safe viewing of cardiac structures and their spatial relationships to one another and to the chest wall (Weyman, 1982).

Summary

Accurate hemodynamic pressure measurements are essential in the management of critically ill patients. External reference points used for pressure measurement need to be validated.

Nurses need to provide adequate rest for the ICU patient by minimizing the interruptions of sleep without sacrificing essential aspects of care. In the 1960's, researchers were recommending reducing disturbances from noise and activities to minimize sleep deprivation in ICU patients (Kornfeld, Zimberg, & Malm, 1965; Lazarus & Hagen, 1968). To decrease patients' disturbances due to the conflict between the positions for monitoring and patient care, nurses ideally should take pressure measurements in the positions the patients are in.

Several studies address the reliability of pressure measurements in patients positioned on their back with the backrest elevated up to 60 degrees using the phlebostatic level identified by Winsor and Burch (1945) as the zero reference level (Chulay & Miller, 1984; Laulive, 1982; Woods & Mansfield, 1976). Finding no significant differences in PA pressures in different positions, researchers suggest that it is unneccessary to lower the backrest to the flat position for pressure measurements. However, the validity of the reference level has not been established. In addition, evidence that accurate measurements can be obtained in laterally positioned patients is lacking due to the inability to determine a proper reference level for the lateral positions.

Geometric Model

In order to determine distances using echocardiography, a model based upon geometric theories of angles and right triangles was developed. The model allows quantification of distances from the right or left atrium to the bed surface in different lateral positions.

In the cross-sectional diagram of the chest at the level of the fourth intercostal space (Figure 5), Y is the placement point of the transducer on the chest, C is the mid-right atrium or mid-left atrium. The transducer is placed perpendicular to chest wall. An extension of the line intersects the dorsal body wall at X and the bed surface at R.

To determine the distance from the atria to the bed surface in the supine position (D), the distance from the transducer to the mid-right or mid-left atrium (A) is subtracted from the distance from the transducer to the bed surface (H). Therefore, $D = H - A$.

To determine the distance from the atria to the bed surface in the lateral positions (D'), the distance of the line from the transducer perpendicular to the bed surface which intersects with the line perpendicular to A (A') is subtracted from the distance from the transducer to the bed surface (H') (Figure 6). Therefore, $D' = H' - A'$.

To find distance D', A is used to determine A'. $A' = A \times \cos \theta$. The following explains how the geometric model was devised and used.

Prove $< XQR = < XYZ$

Assumptions:
Line YS is perpendicular to the bed surface
Line YX is perpendicular to the chest wall and wedge surface.

$< XQR = \theta =$ angle of wedge pillow
QZS = right triangle
$< ZSQ = 90$ degrees
If $< ZQS = \theta$, then $< QZS = 90 - \theta$.
If $< QZS = 90 - \theta$, then $< YZX = 90 - \theta$.

FIGURE 5

CROSS-SECTIONAL DIAGRAM OF THE CHEST

IN THE SUPINE POSITION

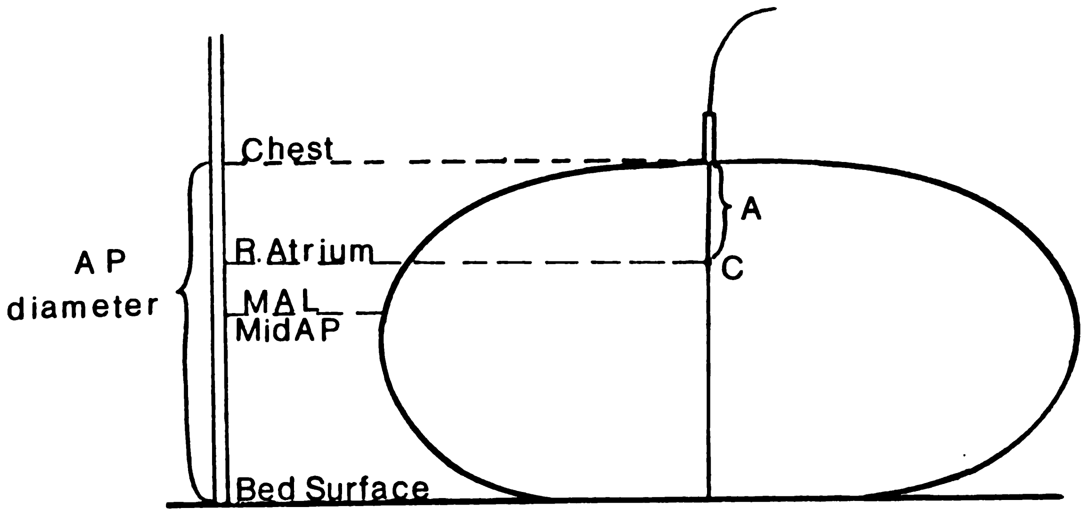
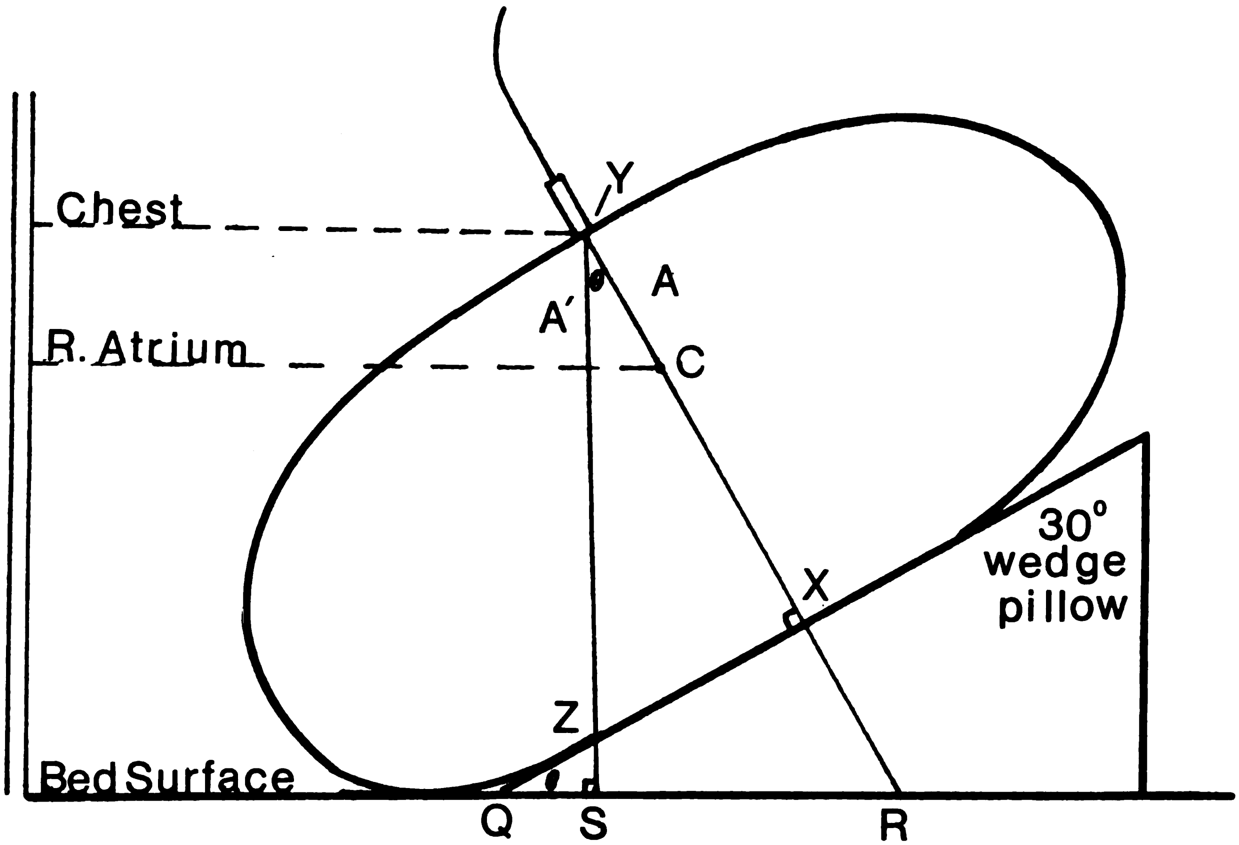


FIGURE 6

GEOMETRIC MODEL FOR LATERAL POSITION



If Line YX $\perp$ to QX, then $< YXZ = 90$.

If $< YZX = 90 - \theta$, and $< YXZ = 90$, then $< XYS = \theta$.
Therefore, $< XQR = < XYS = \theta =$ angle of foam wedge.

Cosine = in a right triangle, the function of an acute angle that is the ratio of the adjacent side to the hypotenuse.

Cosine $< XYZ = A'/A$
$A' = A \times \text{cosine} < XYZ$.
$= A \times \cos 30$

$D' = H' - A'$

(Kee, N. L., 1985).

If it was not possible to obtain a visually acceptable picture of the heart with the transducer perpendicular to the chest wall, the degree of deviation from the perpendicular positions was obtained with a protractor. This angle of deviation (μ) was corrected for in the above calculations by using the correction factors in Table 1.

The equation used would be $A' = A \times \cos(\theta + \mu)$. If the subject was turned to the left and the transducer deviated to the left the angle would be added to θ ; if the subject was turned to the right with the transducer deviated to the left, the angle would be subtracted. If the subject was in the 90 degree position, μ was added to 0 ($\theta = 0$).

Operational Definitions

Phlebostatic axis: the point identified on the exterior thorax by the intersection of the anterior fourth intercostal space and the midanterior posterior lines.

Mid-right atrium: the midpoint of the distance between the tricuspid annulus and the posterior wall of the right atrium in the short axis parasternal echocardiographic view of the aorta.

Mid-left atrium: the midpoint of the distance between the posterior aortic root wall and the posterior wall of the left atrium in the short axis parasternal echocardiographic view of the aorta.

TABLE 1

Correction Factors for Geometric Model

Subject turned 30 to Left

If end of transducer handle tilted to:

Left, add (90-X)
Right, subtract (90-X)

Tilt to Left

X	deviation	cos(30+(90-X))
90	0	cos30 =.866
85	+5	COS35 =.819
80	+10	COS40 =.766
75	+15	COS45 =.707
70	+20	COS50 =.642
65	+25	COS55 =.573

Tilt to Right

X	deviation	cos(30-(90-X))
90	0	cos30 =.866
85	-5	cos25 =.906
80	-10	cos20 =.939
75	-15	cos15 =.966

Subject turned 30 to Right

Left, subtract (90-X)
Right, subtract (90-X)

Tilt to Left

X	deviation	cos(30-(90-X))
90	0	cos30 =.866
85	-5	COS25 =.906
80	-10	COS20 =.939
75	-15	COS15 =.966
70	-20	COS10 =.985
65	-25	COS 5 =.996

Tilt to Right

X	deviation	cos(30+(90-X))
90	0	cos30 =.866
85	+5	cos35 =.819
80	+10	cos40 =.766
75	+15	cos45 =.707

Subject turned 90 to Left

Tilt to Left

X	deviation	cos(0+(90-X))
90	0	cos 0 = 1
85	+5	cos 5 =.966
80	+10	cos10 =.985

Supine: the position in which the subject is flat on the back with head elevated on one pillow.

Lateral: the position in which the subject is turned onto the right or left side with head elevated on one pillow.

Horizontal plane: the plane parallel to level ground as determined by a carpenter level.

Midaxillary line: the imaginary line which lies halfway between the anterior and posterior axillary lines of the axillary folds.

Midchest or Midanterior-posterior diameter: the midpoint between the sternum of the supine subject and the bedsurface with subject lying flat against the bedsurface.

Bed surface: the uppermost horizontal plane of the mattress on which the subjects lie.

Assumptions

1) The circumference of the body is symmetrical in shape.

2) Mid-anteriorposterior diameter is equal to half the distance from the chest surface at the sternum at the fourth intercostal space to the bed surface.

Hypotheses

Ten null hypotheses for this study were proposed.

They are:

There is no significant difference between

1) the distance from the phlebostatic axis of the supine patient to the bed surface and the distance from the mid-right atrium to the bed surface.

2) the distance from the mid-right atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the left.

3) the distance from the mid-right atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the right.

4) the distance from the mid-right atrium to the bed surface when the subject is supine and when positioned laterally 90 degrees to the left.

5) the distance from the phlebostatic axis of the supine patient to the bed surface and the distance from the mid-left atrium to the bed surface.

6) the distance from the mid-left atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the left.

7) the distance from the mid-left atrium to the bed surface when the subject is supine and when positoned laterally 30 degrees to the right.

8) the distance from the mid-left atrium to the bed surface when the subject is supine and when positioned laterally 90 degrees to the left.

9) the distance from the midaxillary line of the supine patient to the bed surface and the distance from the mid-right atrium to the bed surface.

10) the distance from the midaxillary line of the supine patient to the bed surface and the distance from the mid-left atrium to the bed surface.

Chapter Three

METHODOLOGY

Design

The study used a quasiexperimental repeated measures design. Each subject served as his own control. The dependent variable was the distance from the right atrium and left atrium to the bed surface. The independent variable was the position of the subject. Positions used were supine, 30 degree right lateral, 30 degree left lateral, and 90 degree left lateral. In addition, of interest were the distances of the phlebostatic axis and midaxillary line to the bed surface of each subject in relation to the distances from each atria to the bed surface. These two reference points, identified with the subject in the supine position, were constant distances and not affected by changes in the subject's position. They are nonmanipulated dependent variables.

The Committee on Human Research at the University of California, San Francisco approved the project. Data were collected over a four month period.

Setting

The study was conducted at a large university medical center on a metropolitan campus of health science schools in the western United States. It is a graduate campus with a health science focus.

The echocardiograms were performed in the medical center's echocardiography department. The department provides inpatient and outpatient echocardiographic services for the medical center. The department has three rooms for adult patients and two for pediatric patients. Each room has one or two guerneys, each with a firm mattress and an echocardiographic imaging machine.

Sample

A sample of 25 healthy volunteers greater than 18 years of age was studied. Subjects excluded were those 1) with known or suspected heart disease and murmurs, 2) with structural abnormalities of the chest wall and/or spine, 3) pregnant women, and 4) those who could not tolerate the supine, 30 degree left and right lateral positions and the lateral decubitus position.

The subjects included 18 females and seven males, aged 23 to 44 (mean age = 30.68). The mean height was 65.9 inches and the mean weight was 141 pounds. Data of 25 subjects were available for analysis of all reference points except for the left lateral decubitus position (L90) where the sample included ten females and seven males, aged 23 to 38 (mean age = 30.47). Data were not available for L90 for eight of the subjects because L90 position was added to the procedure after their data had been collected.

Instruments

The echocardiographic images were recorded with the IREX Echocardiographic Imager (Meridian Model, Johnson & Johnson). The images were viewed on an echocardiographic viewer (JVC BR-64000) and measured using a light pen system (Diasonics/Varian). The light pen was calibrated before each measuring session using the standard described in the technical manual.

A carpenter level was used to determine the horizontal plane passing through external points (Stanley, 42-187), a metric ruler was used to measure distances (Stanley, 10-189), and a protractor was used to measure angles (C Thru Ruler, 376). The scale measured subjects' weight (Continental Scale Corp., Healthometer). The scale was balanced before each use as described in the instrument manual.

A foam wedge was used to maintain subject position at 30 degrees. The angle of the foam wedge was determined to be 30 degrees with the protractor. The two observers used the test-retest method to verify the angle. Two observers participated in the data collection and measurements for interrater reliability ($R = .984$).

Procedure

After subjects were recruited, appointments were scheduled in the echocardiography lab. During the scheduled appointment, the following procedure was performed with each subject. Subject's 4 through 11 were not turned into the left 90 degree position since the position was added to the procedure after their data were collected.

1. Informal written consent was obtained (Appendix A).
2. The subject's height and weight were measured.
3. The subject was placed supine on the bed surface.
4. The zero reference level (phlebostatic axis) at intersection of the anterior fourth intercostal space and midanterior-posterior lines was marked on the subjects's skin with a pen.
5. The levels of the horizontal planes from the phlebostatic axis and

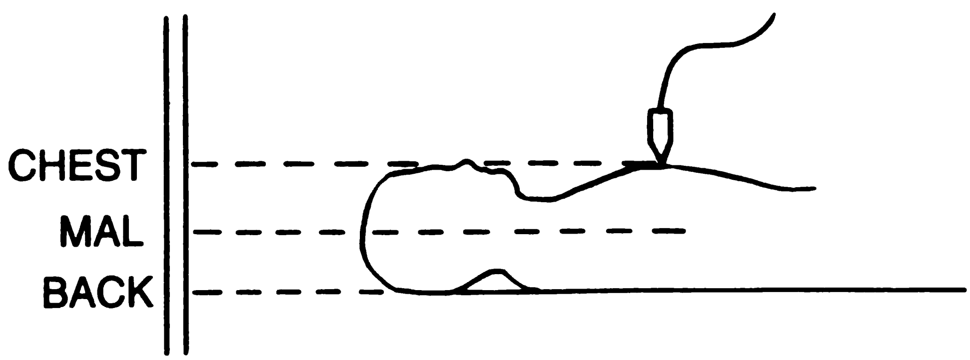
from the bed surface were marked on tape fixed onto a vertical pole (Figure 7).

6. The short axis parasternal view of the aorta was recorded with echocardiography at the end of a normal expiration.
7. The horizontal plane from the tip of the transducer placed on the chest in the third or fourth intercostal space was determined with the carpenter's level and marked on the tape fixed onto the pole.
8. The angle of deviation from 90 degrees of the transducer was measured with the protractor and recorded on the data collection sheet (Appendix B).
9. The subject was turned onto his right side, and the foam wedge was placed under the subject with its narrow edge in line with his right side.
10. Steps 6 through 8 were repeated.
11. The subject was turned onto his left side with the edge of the foam wedge situated along the subject's left side.
12. Steps 6 through 8 were repeated.
13. The subject was turned in the 90 degree left lateral position.
14. Steps 6 through 8 were repeated.

All data were recorded on the data collection sheet. The echocardiograms were done by Jay Simonson, MD, Research Fellow, under the supervision of Nelson Schiller, MD. Subject positioning and measurements were done by the primary investigator and accuracy was validated by Jay Simonson, MD. The distance from the chest wall to the mid-right and left atria was measured on the echocardiographic viewer by Jay Simonson, MD and the primary investigator.

FIGURE 7

HORIZONTAL PLANES OF PHLEBOSTATIC AXIS AND BED SURFACE



The distances from the transducer on the chest wall to the mid-right and mid-left atria in all positions were measured with the light pen system (Figure 8). The distances were used in the geometric model (Kee, 1985) to determine the distance from the mid-right and mid-left atria to the bed surface. The echocardiographic view employed was the short axis through the base of the heart taken near the aortic valve level to maximize the size of the atria and to center the atria in the middle of the field.

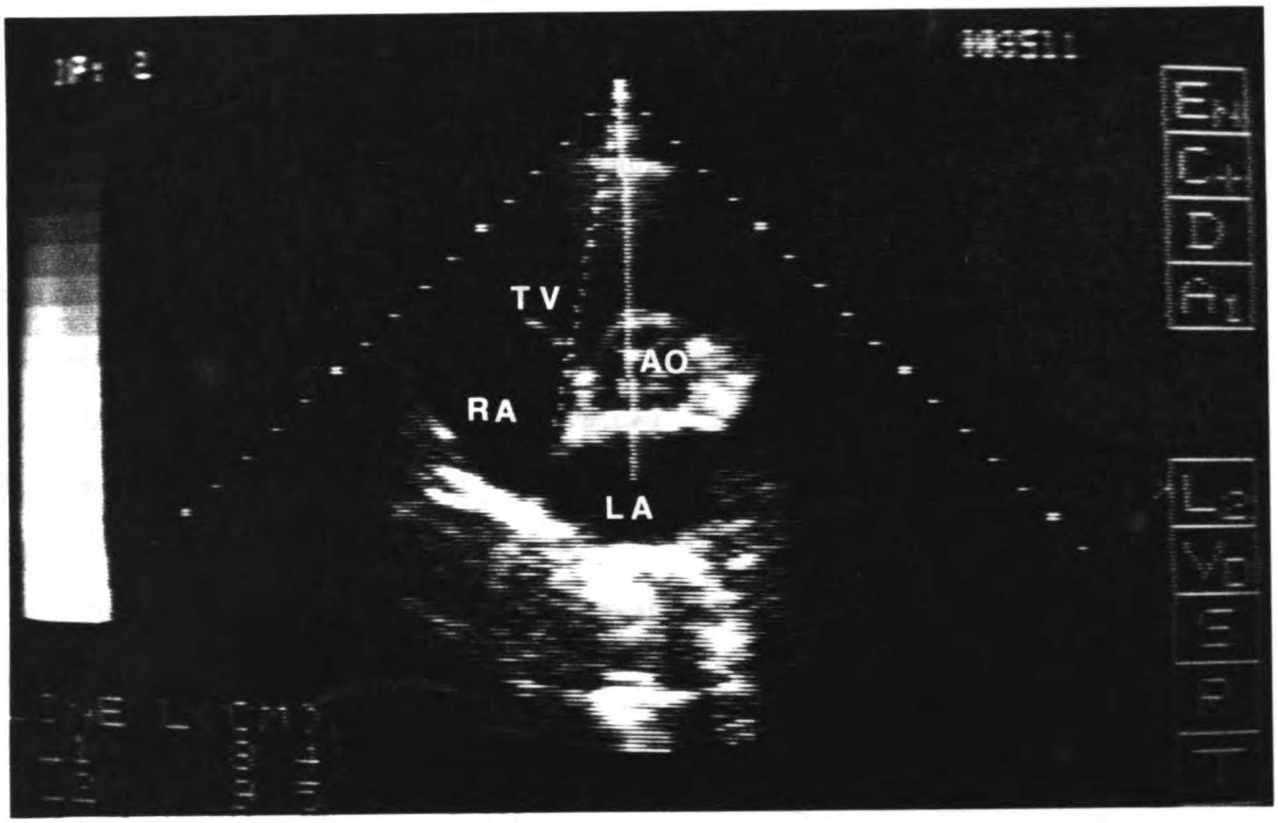
Data Analysis

The values for the RA and LA in the supine position (RA supine and LA supine, respectively) were used as the gold standard for zero reference levels for intracardiac pressures. Potential zero reference levels including the phlebostatic axis (midAP), the midaxillary line (MAL), and the RA and LA in lateral positions (RA R30, LA R30, RA L30, LA L30, RA L90, LA L90) were compared with the RA and LA supine.

Analysis of variance (ANOVA) for repeated measures was used on the data from the RA and LA to determine the differences in the reference points for the respective atrium. Post hoc Scheffe's test were performed to identify where the significant differences in the data lie with alpha preset at 0.05.

FIGURE 8

PARASTERNAL SHORT AXIS VIEW OF AORTA



TV = Tricuspid Valve
RA = Right Atrium
LA = Left Atrium
AO = Aorta

Chapter Four

RESULTS

Data Analysis

Data were analyzed on 25 subjects for all variables except in the left 90 degree position (L90). Since data on eight subjects for RA L90 and LA L90 were not obtained, data in these positions were analyzed on the 17 subjects with available data.

In 25 subjects, distances from the various reference points to the bed surface ranged from 5.3 to 15.87 cm. MAL, MidAP, RAsupine, LAsupine, RA L90 and LA L90 had the smallest values while RA L30, LA L30, RA R30, LA R30 had the larger values. Table 2 shows the distances for each subject in each position that was recorded for the individual.

The sample means for all the reference points except for RA L90 and LA L90 ranged from 7.64 to 12.53 ± 0.88 to 2.56cm SD (n=25); mean values for RA L90 and LA L90 were 9.27 and 9.41 ± 1.99cm SD respectively (n=17). Table 3 lists the mean distance per position.

Repeated measures ANOVA demonstrated significant differences between the group of reference points for the right and left atria on data of 17 and of the 25 subjects ($p < 0.001$, F=167.97, right; F=107.81, left). Tables Four and Five illustrate this.

Post hoc comparisons with Scheffe test identified differences between the potential reference levels. In the RA, the MAL is not significantly different from the midAP and the RA supine positions.

TABLE 2

Individual Measurements of Distances From Various Reference Levels To Bed Surface in Centimeters

ID	MAL	MIDAP	RASUPINE	RAL30	RAR30	RAL90	LASUPINE	LAL30	LAR30	LAL90
*1	8.7	7.15	7.11	12.16	12.04	10.90	6.12	11.93	11.37	10.90
2	10.3	9.15	11.54	15.76	15.83	8.63	10.41	14.84	14.58	8.53
3	8.7	7.35	7.81	11.44	12.03	7.19	6.43	10.67	11.14	6.96
4	6.8	6.45	6.80	8.70	9.1	-9.00	5.57	7.27	7.82	-9.00
5	6.5	7.75	9.50	10.80	12.90	-9.00	7.77	9.67	10.53	-9.00
6	9.0	7.95	9.4	13.00	15.20	-9.00	8.51	12.80	13.71	-9.00
7	7.0	7.0	7.63	12.70	11.80	-9.00	6.53	11.72	10.67	-9.00
8	5.3	7.20	7.21	11.07	11.32	-9.00	6.52	10.33	10.01	-9.00
9	11.0	8.75	10.98	14.49	13.93	-9.00	9.89	13.57	12.89	-9.00
10	6.6	8.00	9.33	13.13	13.53	-9.00	8.37	12.28	12.75	-9.00
11	8.6	7.70	8.92	13.47	12.16	-9.00	8.17	13.02	11.58	-9.00
12	9.0	8.50	10.91	12.60	13.52	9.0	9.37	11.30	12.58	9.00
13	5.8	6.50	6.71	10.79	10.10	8.20	5.77	9.56	9.01	8.20
14	7.9	6.85	8.48	12.05	11.96	8.93	7.13	10.99	10.65	8.86
15	6.5	7.50	8.66	11.09	12.25	7.03	7.48	10.33	11.49	6.93
16	8.2	7.3	7.95	12.96	13.01	8.60	6.90	11.83	11.82	8.60
17	6.1	6.10	6.49	10.38	9.86	7.60	5.90	9.75	9.20	7.60
18	7.8	8.35	9.60	11.80	12.87	8.60	7.44	9.76	10.99	8.60
19	8.5	6.55	7.29	12.43	10.96	10.15	5.42	11.43	9.15	9.98
*20	10.5	9.20	11.64	15.87	15.66	11.09	10.09	14.03	13.40	10.64
*21	8.3	8.60	9.80	12.47	14.60	12.30	7.90	11.13	13.06	12.30
*22	9.8	7.85	9.23	13.62	10.21	6.73	7.97	12.77	8.63	6.60
*23	7.5	8.00	8.95	13.03	10.35	11.00	8.08	11.97	9.39	11.00
*24	10.1	9.05	10.68	13.49	12.02	9.90	9.18	11.95	9.90	10.54
*25	9.3	8.10	8.69	14.06	10.02	14.05	8.03	13.74	9.53	12.30

ID = subject identification number
* = male subject
MAL = midaxillary line
MIDAP = midanterior-posterior diameter
RASUPINE = right atrium, supine position
RAL30 = right atrium, 30 degree left lateral position
RAR30 = right atrium, 30 degree right lateral position
RAL90 = right atrium, 90 degree left lateral position
LASUPINE = left atrium, supine position
LAL30 = left atrium 30 degree left lateral position
LAR30 = left atrium 30 degree right lateral position
LAL90 = left atrium 90 degree left lateral position
-9.00 = missing data

TABLE 3

Mean, Standard Deviation, and Range

of Distances from Bed Surface in Centimeters (n=25)

Position	Mean	S.D.	Range
MAL	8.15	±1.55	5.3 - 11.0
MidAP	7.72	± .88	6.1 - 9.2
RA supine	8.84	±1.53	6.49 - 11.64
LA supine	7.64	±1.43	5.42 - 10.41
RA R30	12.29	±1.85	9.1 - 15.83
LA R30	11.03	±1.76	7.82 - 14.58
RA L30	12.53	±1.63	8.7 - 15.87
LA L30	11.55	±1.70	7.27 - 14.84
RA L90 (n=17)	9.41	±1.99	6.73 - 14.05
LA L90 (n=17)	9.27	±1.80	6.6 - 12.3

TABLE 4

Repeated Measures Analysis of Variance

RIGHT ATRIAL REFERENCE LEVELS, n=25

Source	df	SS (H)	MSS	F	p
Between subjects	24	201.2935			
Within subjects	100	617.0493			
Position (P)	4	539.9065	134.9766	167.970	0.0000
P x SwGps	96	77.1431	0.8036		

alpha = .05

Table 5

Repeated Measures Analysis of Variance

LEFT ATRIAL REFERENCE LEVELS, n=25

Source	df	SS (H)	MSS	F	p
Between Subjects	24	187.4942			
Within Subjects	100	446.3817			
P	4	365.1086	91.2771	107.816	0.0000
P x SwGps	96	81.2734	0.8466		

alpha = .05

However, the midAP was found to be significantly different from the the RA supine ($p < 0.001$). While the differences between RA R30 and RA L30 are not statistically significant, the differences between each of them and MAL, midAP, and RA supine are significant ($p < 0.001$) (Table 6).

Table 6

Comparison of Right Atrial Reference Levels, n = 25

MAL > midAP	
MAL < RA supine	
MAL < RA L30	*
MAL < RA R30	*
midAP < RA supine	*
midAP < RA L30	*
midAP < RA R30	*
RA supine < RA L30	*
RA supine < RA R30	*
RA L30 > RA R30	

* significant at alpha level .05, posthoc Scheffe'analysis.

Similar trends were found in the LA. However, in the LA, the MAL, midAP diameter and LA supine were not significantly different from each other. As in the RA, the LA R30 and L30 are not significantly different from each other, but are different from the MAL, midAP, and supine positions ($p < 0.001$). (Table 7)

Post-hoc tests on data of 17 subjects were done to determine whether the positions of RA L90 and LA L90 were significantly different from the other potential reference levels. The distance from the RA to the bed surface in the L90 position was significantly different from the midAP, RA R30 and RA L30 ($p < 0.001$) (Table 8).

The distance from the LA to the bed surface in the L90 position was significantly different from the midAP, LA supine, LA L30 and LA R30 ($p<0.001$) (Table 9).

Table 7

Comparison of Left Atrial Reference Levels

n = 25

MAL > midAP	
MAL > LA supine	
MAL < LA L30	*
MAL < LA R30	*
midAP > LA supine	
midAP < LA L30	*
midAP < LA R30	*
supine < LA L30	*
LA supine < LA R30	*
LA L30 > LA R30	

* significant at alpha level .05, post hoc Scheffe analysis

Table 8

Comparison of Right Atrial Reference Levels

n= 17

MAL > midAP		
MAL < RA supine		
MAL < RA L30	*
MAL < RA R30	*
MAL < RA L90		
midAP < RA supine		
midAP < RA L30	*
midAP < RA R30	*
midAP < RA L90	*
RA supine < RA L30	*
RA supine < RA R30	*
RA supine < RA L90		
RA L30 > RA R30		
RA L30 > RA L90	*
RA R30 > RA L90	*

* significant at alpha level .05, posthoc Scheffe analysis

Table 9

Comparison of Left Atrial Reference Levels

n = 17

MAL > midAP	
MAL > LA supine	
MAL < LA L30	*
MAL < LA R30	*
MAL < LA L90	
midAP > LA supine	
midAP < LA L30	*
midAP < LA R30	*
midAP < LA L90	*
LA supine < LA L30	*
LA supine < LA R30	*
LA supine < LA L90	*
LA L30 > LA R30	
LA L30 > LA L90	*
LA R30 > LA L90	*

* significant at alpha level .05, posthoc Scheffe analysis

Data were subjected to paired differences t-test to determine whether statistical differences between the RA and LA values existed. When the data of the RA and LA for identical body positions were compared, the LA was consistently and significantly lower than the RA in the supine, L30 and R30 positions ($p < 0.001$). The distances for RA L90 and LA L90 were not significantly different. The data for the RA and LA were highly positively correlated ($r > .95$) (Table 10).

Table 10

Distances of Left atrium vs. Right atrium from Bed Surface

Paired differences t-test

alpha = .05

	n	Means (cm.)	S.D.	S.D.(Diff)	t-test	Correlation
LA SUPINE		7.638	1.430		t -14.271	r 0.962
	25			0.421	df 24	df 23
RA SUPINE		8.840	1.53		p 0.0000	p 0.0000
LA L30		11.546	1.693		t -10.907	r 0.963
	25			0.453	df 24	df 23
RA L30		12.534	1.626		p 0.0000	p 0.0000
LA R30		11.034	1.761		t -11.996	r 0.959
	25			0.523	df 24	df 23
RA R30		12.289	1.849		p 0.0000	p 0.0000
LA L90		9.267	1.795		t -1.229	r 0.975
	17			0.466	df 16	df 15
RA L90		9.406	1.985		p 0.2368	p 0.0000

Data were compared by gender of subjects using independent t-test. In all variables except RA R30 ($p < 0.0545$) and LA R30, the data for the men were larger than the women's. The difference was significant for MAL, midAP, RA L90 ($p < 0.05$), and LA L90 ($p < 0.01$).

Table 11
Distances of Variables from Bed Surface, Male vs. Female
Independent groups t-test

Dependent Variable		Male	Female	Separate Variances		Pooled Variances
MAL	n	7	18	t	2.60	2.20
	mean (cm.)	9.171	7.756	df	16.13	23
	S.D.	1.066	1.554	p	0.0192	0.0378
MidAP	n	7	18	t	2.31	2.14
	mean (cm.)	8.279	7.497	df	12.96	23
	S.D.	0.720	0.852	p	0.381	0.433
RA Supine						
	n	7	18	t	1.27	1.24
	mean (cm.)	9.443	8.606	df	11.53	23
	S.D.	1.460	1.536	p	0.230	0.228
RA L30	n	7	18	t	2.30	2.03
	mean (cm.)	13.529	12.148	df	14.58	23
	S.D.	1.226	1.623	p	0.037	0.055
RA R30	n	7	18	t	-0.24	-0.27
	mean (cm.)	12.129	12.352	df	9.02	23
	S.D.	2.232	1.748	p	0.817	0.793
RA L90	n	7	10	t	2.74	3.13
	mean (cm.)	10.853	8.393	df	7.47	15
	S.D.	2.247	0.934	p	0.275	0.007
LA Supine						
	n	7	18	t	1.34	1.23
	mean (cm.)	8.196	7.421	df	13.17	23
	S.D.	1.228	1.476	p	0.204	0.232
LA L30	n	7	18	t	2.30	1.85
	mean (cm.)	12.503	11.173	df	18.41	23
	S.D.	1.060	1.768	p	0.033	0.772
LA R30	n	7	18	t	-0.47	-0.49
	mean (cm.)	10.754	11.143	df	10.32	23
	S.D.	1.884	1.755	p	0.647	0.631
LA L90	n	7	10	t	2.92	3.28
	mean (cm.)	10.611	8.326	df	8.06	15
	S.D.	1.916	0.944	p	0.019	0.005

Level of significance set at alpha = .05

Based upon the data analysis, the hypotheses of the study are accepted or rejected as follows:

Hypothesis 1: There is no significant difference between the distance from the phlebostatic axis of the supine patient to the bed surface and the distance from the mid-right atrium to the bed surface. This hypothesis was rejected ($p<0.001$).

Hypothesis 2: There is no significant difference between the distance from the mid-right atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the left. This hypothesis was rejected ($p<0.001$).

Hypothesis 3: There is no significant difference between the distance from the mid-right atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the right. This hypothesis was rejected ($p<0.001$).

Hypothesis 4: There is no significant difference between the distance from the mid-right atrium to the bed surface when the subject is supine and when positioned laterally 90 degrees to the left. This hypothesis was accepted (p=NS).

Hypothesis 5: There is no significant difference between the distance from the phlebostatic axis of the supine patient to the bed surface and the distance from the mid-left atrium to the bed surface. This hypothesis was accepted (p=NS).

Hypothesis 6: There is no significant difference between the distance from the mid-left atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the left. Hypothesis 6 was rejected ($p<0.001$).

Hypothesis 7: There is no significant difference between the distance from the mid-left atrium to the bed surface when the subject is supine and when positioned laterally 30 degrees to the right. This hypothesis was rejected ($p<0.001$).

Hypothesis 8: There is no significant difference between the distance from the mid-left atrium to the bed surface when the subject is supine and when positioned laterally 90 degrees to the left. Hypothesis 8 was rejected ($p<0.004$).

Hypothesis 9: There is no significant difference between the distance from the midaxillary line of the supine patient to the bed surface and the distance from the mid-right atrium to the bed surface. This hypothesis was accepted (p=NS).

Hypothesis 10: There is no significant difference between the distance from the midaxillary line of the supine patient to the bed surface and the distance from the mid-left atrium to the bed surface. Hypothesis 10 was accepted (p=NS).

Table 12 summarizes the findings of this study.

Table 12: Summary of Hypotheses

Hypothesis 1 -	rejected	MidAP = RA supine
2 -	rejected	RA supine = RA L30
3 -	rejected	RA supine = RA R30
4 -	accepted	RA supine = RA L90
5 -	accepted	MidAP = LA supine
6 -	rejected	LA supine = LA L30
7 -	rejected	LA supine = LA R30
8 -	rejected	LA supine = LA L90
9 -	accepted	MAL = RA supine
10 -	accepted	MAL = LA supine

Chapter Five

DISCUSSION

Findings

Use of valid zero reference levels for pressure transducers is essential for accurate pressure measurements. To eliminate the potential confounding effects of hydrostatic pressure on pressure measurements, transducers must be placed in the same horizontal plane as the chamber of the heart to be measured. Thus, for central venous or right atrial pressure measurements, the transducer should be placed at the level of the right atrium, and for pulmonary artery or left atrial pressures, at the level of the left atrium (Cywinski & Tardieu, 1980).

The phlebostatic axis, the junction of the fourth intercostal space and the midpoint of the anterior-posterior diameter (Winsor & Burch, 1945), has been accepted as a reliable external reference point for the mid-right and mid-left atrium. Acceptance of this reference point is based upon research conducted in 1945 that measured venous pressures in the hands of subjects positioned with the head of the bed raised to different levels. The anatomic validity of this reference point for intracardiac pressure measurements in supine patients has not been established. In addition, the validity of the phlebostatic axis has not been examined for use in laterally positioned patients.

To determine the validity of the phlebostatic axis, the distance from the axis to a fixed external point was compared to the distance of the right and left atria in the supine position to the same fixed external point, which in this study was the bed surface. To determine the validity of the phlebostatic axis in lateral positions, the distances from the RA and LA to the bed surface in the supine position were compared to those in different lateral positions.

The data of twenty-five normal, healthy subjects were analyzed with repeated measures analysis of variance, and post hoc analysis was performed with the Scheffe' test. The repeated measures analysis of variance indicated significant differences existed within the group, while the Scheffe' indicated where the differences were.

While the phlebostatic axis is not significantly different for the LA in the supine position, it is statistically significantly less than the RA in the supine position ($p < 0.001$) when data of 25 subjects were analyzed. However, this refers to a mean difference of 1.1 cm., the equivalent of .85 mmHg. The difference is not clinically significant for any intracrdiac pressure.

The statistical significance was not apparent during comparison of the RA and phlebostatic axis of 17 subjects ($p = 0.07$) but was when data of 25 subjects were examined. The significant difference obtained with the larger sample may be due to the characteristics of Subjects 18 through 25, six of whom were male, and the difference in anterior-posterior diameter (AP diameter) of these subjects. AP diameters of all subjects ranged from 12.2 cm.to 18.4 cm. with a mean of 15.4 cm. The AP diameter of the six male subjects ranged from 15.7 cm. to 18.4 cm. with a mean of 16.9 cm. From the data analyzed on this sample, hypothesis one is rejected while hypothesis five is accepted. These results suggest that the reference level for the RA is not consistently in the same horizontal plane as the midAP diameter for persons with enlarged AP diamters. More subjects, particularly males, need to be studied to get a more representatve sample of the population.

In this group of subjects, there is no significant difference between the midaxillary line (MAL) of the supine subject and the right or left atrium in the supine subject. Therefore, hypotheses nine and ten are accepted. This is evidence that the MAL can also be used as a reference point for the right and left atria in the supine patient. In addition, comparison of the phlebostatic axis and the MAL showed no significant differences between the two reference points. The practice of using the MAL and midAP diameter interchangeably is supported. However, because the location of the MAL is not affected by an enlarged AP diameter, the MAL may potentially reflect the location of the right and left atrium more consistently than the midAP diameter.

All of the distances for both the RA and LA obtained in 30 degree lateral positions were significantly larger than those in the supine position ($p < 0.001$). Therefore, hypotheses two, three, six, and seven are rejected. The 30 degree right and left lateral positions were also significantly larger than the midAP and MAL ($p < 0.001$). This is expected since the two reference points are not significantly different from the RA and LA supine positions except between the RA supine and midAP. The difference between the RA supine and midAP is small; thus, the expectations remain the same.

The findings of the 30 degree lateral positions explain the significant differences observed by Wild (1984) and Keating et al. (1986) while comparing PA pressures obtained in the supine position with those from lateral positions. The results suggest that the zero reference level of the right and left atria in the supine patient cannot be used for the patient positioned laterally at 30 degree angles.

In each atrium, the differences in the distances obtained with the subject in the 30 degree right position and the 30 degree left lateral position were not statistically significant. This implies that a reference level used for the 30 degree right lateral position can also be used for the 30 degree left lateral position. However, it is not known whether this would be appropriate for subjects turned at angles other than 30 degrees. Neither Wild (1984) nor Keating et al. (1986) compared the pressure measurements obtained with patients turned onto the different sides.

The distances of the RA in the L90 position were not significantly different from the RA supine. Therefore, hypothesis four is accepted. This suggests that the level of the phlebostatic axis of the supine subject can be used as the same reference point for the RA in the L90 position. However, a significant difference was observed when left atrium was compared in the two positions ($p < 0.01$) leading to rejection of hypothesis eight.

The difference in the distances of the right and left atrium may be due to the more posterior position of the LA. While the mean distances of the RA and LA in the L90 position are not significantly different (9.41 and 9.27cm., respectively), the mean distances of the atria in the supine positions are significantly different (RA supine - 8.90cm., LA supine - 7.64cm., $p<0.001$). Data from only 17 subjects were analyzed due to the later addition of this position to the procedure. More data on RA L90 and LA L90 need to be accrued before the practice of maintaining the transducer in the position of the phlebostatic axis when the patient is in the 90 lateral positions can be confirmed.

It is difficult to compare the results of this study with those of Kennedy et al. (1984). The relationship between the external reference point for 90 degree lateral positions defined by the investigators and the phlebostatic axis is unknown.

In the secondary analysis of data, other relationships become apparent. Comparison of data on the RA and LA produce significant differences between the two atria in the supine, R30 and L30 positions ($p < 0.001$), but not in the L90 position. The relationship between the two atria is positively correlated ($r=.95$) with distances from the LA to the bed surface consistently smaller than the RA. This correlation is expected knowing that the LA is positioned posteriorly to the RA (Silverman & Schlant, 1978). The differences in the distances between the two atria in the different body positioned ranged from 0.139 to 1.255cm. Clinically, this would translate to a maximum difference of .966 mmHg. Therefore, this provides evidence that reference levels for the right atrium can be used for the LA without a clinically significant difference in pressure.

A relationship between the sex of the subject and the values for various variables was revealed. The data from seven men were consistently larger values than that from the 18 women. This was significant for the distances from the bed surface to the phlebostatic axis, MAL, RA L90 ($p < 0.05$), and LA L90 ($p < 0.01$). Slightly smaller values for RA R30 and LA R30 positions were obtained for the men than the women, although the differences between men and women is not significant. This suggests that differences in body size and shape between the sexes may contribute to the change which occurs. Because the sample of men is small (n=7), more data on male subjects are needed before the significance of the relationship can be determined.

Significance

The results of this study suggest that intra-atrial pressures should rise due to the increase in distance from the transducer. The clinical significance of the pressure changes depends upon the amount of change which occurs and the pressure which is being observed.

For every centimeter the atrium is higher than the pressure transducer, there is a corresponding rise in pressure of .77 mmHg. A similar decrease in pressure values occurs if the atrium is below the transducer (Yang et al., 1978).

A change in pressure of 1-2mmHg may have little clinical significance in a patient's status. Three to 4mmHg also may have little significance if observed in pressures such as the pulmonary artery systolic pressure (normal range 20-30mmHg). However, 3 to 4mmHg rise in RA or LA pressure (range: 4-12mmHg) may cause a clinician to consider a change in a patient's treatment.

The recommendation at the present time is that the reference level for the supine patient should not be used for a patient turned laterally to the right or left. Instead, the patient should be repositioned onto his back for accurate pressure measurements. However, should this not be feasible or practical at the moment, caution should be taken when evaluating patients in lateral positions.

Sleeping patients need not be disturbed and repositioned onto their backs with every pressure measurement. However, clinicians should not institute changes in treatment based upon elevations in pressure which occur subsequent to assuming a side lying position.

Limitations

This study was conducted on normal, healthy individuals without known heart disease or structural deformities of the thoracic cavity. It is not known how atrial or ventricular hypertrophy commonly found in cardiac patients would affect the change in atrial positions. In addition, the sample size in this study is limited. In particular, the number of men is small and needs to be enlarged to ensure a representative sample of the normal population and to allow for further correlation of data. Replication of the study with another group of normal subjects would confirm these findings and allow application of them in clinical practice to patients with normal heart structures.

Future Research

This study is the initial step in the development of a reference level for lateral body positions. To proceed with the process, correlations of the amount of change that occurs from the supine position to lateral positions to the person's body size need to be made. More data on men and descriptive statistics on body sizes of subjects such as height, weight, chest circumference, and shoulder width will help determine whether a correlation exists. Studying the effects of various angles of lateral turn on the amount of change in atrial position from the supine position will add important information.

Clinical studies can be conducted to determine whether the pressures rise with changes in patient positions from supine to lateral 30 degree position as is expected with the increase in height from the transducer. Ideally, this study would be replicated in patients with indwelling intracardiac catheters so that pressure measurements are obtained with the echocardiograms in the different positions. However, there is difficulty obtaining precise measurements on the softer hospital bed surface, and this methodolgic problem needs to be overcome before such studies can be undertaken.

APPENDIX A

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

CONSENT TO BE A RESEARCH SUBJECT

Dr. Simonson and Ms. Kee are doing a study to learn more about the position of the atria in different body positions with echocardiography. I have volunteered to be a subject in this study.

If I agree to participate, Dr. Simonson will perform an echocardiographic examination on me. This will be done in the Echocardiography Department at UCSF.

There are no known risks involved with echocardiography procedures.

There will be no medical benefit to me. The study may produce information of use to nurses and physicians in the future.

I will not be paid for the study nor will I have to pay for the echocardiography.

I have received a copy of this form and the Experimental Subject's Bill of Rights to keep.

I have the right to refuse to participate or to withdraw without jeopardy to my employment, my grades, or my care at this medical center.

______________________ ____________________________

Date Subject's Signature

APPENDIX B

Right Atrial Location with Position Change

Name: ____

Date: ____________________ Tape Number ____________________

Age/DOB: ____________________ Sex ____________________

Hgt/Wgt/BSA ____

Chest Circumference ____

Diagnosis/Symptoms: ____

Comments:

	0	30 Left	90 Left	30 Right
H				
A RA / LA				
μ				
$A' = A * \cos(\beta + \mu)$ RA / LA				
$D = H_{RA} - A'_{LA}$				

All distances in centimeters. All angles in degrees.

H= The distance from the transducer to the bed surface. In the supine position this is the thoracic A-P diameter.

A= Distance from the transducer tip to the mid-atrial septum in the short axis parasternal view. All measurements are at end-systole at end expiration.

μ= Degree of deviation from the 90 angle of the transducer with the chest wall. Positive if the deviation is to the right and negative to the left.

D= Calculated distance of the right atrium from the bed surface.

REFERENCES

Ballard, K. S. (1981). Identification of environmental stressors for patients in a surgical intensive care unit. Issues in Mental Health Nursing, 3(1-2), 89-108.

Brezinova, V. (1974). Sleep cycle content and sleep cycle duration. Electroencephalography and Clinical Neurophysiology, 36, 275-283.

Browse, N. L. (1965). The physiology and pathology of bedrest. Springfield, Illinois: Charles C. Thomas.

Buchbinder, N. & Ganz, W. (1976). Hemodynamic monitoring. Anesthesiology, 45(2), p. 146-155.

Chandraratna, P. A. N. (1975). Determination of zero reference level for left atrial pressure by echocardiography. American Heart Journal, 89(2), 159-162.

Chulay, M. & Miller, T. (1983). The effect of backrest elevation on pulmonary artery and pulmonary capillary wedge pressures in patients after cardiac surgery. Heart and Lung, 13(2), 138-140.

Chulay, M., Brown, J., & Summer, W. (1982). Effect of postoperative immobilization after coronary artery bypass surgery. Critical Care Medicine, 10(3), 176-179.

Cywinski, J. & Tardieu, B. (1980). The essentials in pressure monitoring blood and other body fluids. Boston: Martinus Nijhoff Publishers.

Debrunner, F. & Buhler, F. (1969). "Normal central venous pressure," Significance of reference point and normal range. British Medical Journal, 3(5663), 148-150.

Fiorica, V., Higgins, E. A., Iampietro, P. F., Lategola, M. T., &

Davis, A. W. (1968). Physiological responses of man during sleep deprivation. Journal of Applied Physiology, 24(2), 167-176.

Forrester, J. S., Diamond, G., & Swan, H. J. C. (1971). Pulmonary artery catheterization. Geriatrics, 26, 65-71.

Hilton, B. A. (1976). Quality and quantity of patients'sleep and sleep-disturbing factors in a respiratory intensive care unit. Journal of Advanced Nursing, 1(6), 453-468.

Kales, A., Jacobson, A., Kales, J. D., Kun, T., & Weissbuch, R. (1967). All night EEG sleep measurements in young adults. Psychonomic Science, 7(2), 67-68.

Keating, D., Bolyard, K., Eichler, E., & Reed, J. III. (1986). Effect of sidelying positions on pulmonary artery pressures. Heart and Lung, 15(6), 605-610.

Kee, N. L. (1985). Personal communication.

Kennedy, G. T., Bryant, A., & Crawford, M. H. (1984). The effects of lateral body positioning on measurements of pulmonary artery and pulmonary artery wedge pressures. Heart and Lung, 13(2), 155-158.

Kollar, E. J., Pasnau, R. O., Rubin, R. T., Naitoh, P., Slater, G. G., & Kales, A. (1969). Psychological, psychophysiological and biochemical correlates of prolonged sleep deprivation. American Journal of Psychiatry, 126(4), 488-497.

Kornfeld, D. S., Simberg, S., & Malm, J. R. (1965). Psychiatric complications of open-heart surgery. New England Journal of Medicine, 273(6), 287-292.

Kosiak, M. (1959). Etiology and pathology of ischemic ulcers. Archives of Physical Medicine and Rehabilitation, 40(1), 62-69.

Lappas, D., Lell, W. A., Gabel, J. C., Civetta, J. M., & Lowenstein,

E. (1973). Indirect measurements of left atrial pressure in surgical patient pulmonary-capillary wedge and pulmonary-artery diastolic pressures compared with left atrial pressure. Anesthesiology, 38(4), 394-397.

Laulive, J. L. (1982). Pulmonary artery pressure and position changes in the critically ill adult. Dimensions of Critical Care Nursing, 1(1), 28-34.

Layne, O. L. & Yudofsky, S. C. (1971). Postoperative psychosis in cardiotomy patients. New England Jounal of Medicine, 284, 518-520.

Lazarus, H. R. & Hagens, J. H. (1968). Prevention of psychosis following open-heart surgery. American Journal of Psychiatry, 124(9), 1190-1195.

Lyons, R. H., Kennedy, J. A., & Burwell, C. S. (1938). The measurement of venous pressure by the direct method. The American Heart Journal, 16, 675-693.

Mendel, D. (1974). A practice of cardiac catheterization. Edinburgh: Blackwell Scientific Publications.

Orr, W. & Stahl, M. L. (1977). Sleep disturbances after open heart surgery. American Journal of Cardiology, 39, 196-201.

Parish, L. C., Witkowski, J. A., & Crissey, J. T. (1983). The decubitus ulcer. New York: Masson Publishing.

Prakash, R., Parmley, W. W., Dikshit, K., Forrester, J., & Swan, H. J. C. (1973). Hemodynamic effects of postural changes in patients with acute myocardial infarction. Chest, 64(1), 7-9.

Ray, J. F. III, Yost, L., Moallen, S., Sanoudos, G. M., Villamena, P., Paredes, R. M., & Clauss, R. H. (1974). Immobility, hypoxemia, and pulmonary arteriovenous shunting. Archives of Surgery, 109(4), 537-541.

Retailliau, M. A., Leding, M. M., & Woods, S. L. (1985). The effect of the backrest position on the measurement of left atrial pressure in patients after cardiac surgery. Heart and Lung, 14(5), 477-483.

Risk, C., Rudo, N., Falltrick, R., Feeley, T., & Don, H. F. (1978). Comparison of right atrial and pulmonary capillary wedge pressures. Critical Care Medicine, 6(3), 172-175.

Sarin, C. L., Yalav, E., Clement, A. J., & Braimbridge, M. V. (1970). The necessity for pressure measurement of left atrial pressure after cardiac surgery. Thorax, 25(2), 185-189.

Silverman, M. E. & Schlant, R. C. (1978). Anatomy of the normal heart and blood vessels in J. W. Hurst, R. B. Logue, R. C. Schlant, & N. K. Wenger (Eds.) The Heart (4th ed.). San Francisco: McGraw-Hill, pp. 19-32.

Steinberg, F. U. (1980). The immobilized patient. New York: Plenum Publishing Corp.

Weil, M. H., Shubin, H., & Rosoff, L. (1965). Fluid repletion in circulatory shock. Journal of the American Medical Association, 192, 668-674.

Weyman, A. E. (1982). Cross-sectional Echocardiography. Philadelphia: Lea & Febiger.

Wild, L. (1984). Effect of lateral recumbent positions on measurment of pulmonary artery and pulmonary artery wedge pressure in critically ill adults. Unpublished masters thesis, University of Washington, Seattle.

Winsor, T. & Burch, G. E. (1945). Phlebostatic axis and phlebostatic reference levels for venous pressure measurements in man. Proceedings of the Society for Experimental Biology and Medicine, 58, 165-169.

Woods, N. F. (1972). Patterns of sleep in postcardiotomy patients. Nursing Research, 21(4), 347-352.

Woods, S. L. (1976). Monitoring pulmonary artery pressures. American Journal of Nursing, 76(11), 1765-1771.

Woods, S. L. & Mansfield, L. W. (1976). Effect of body position upon pulmonary artery and pulmonary capillary wedge pressures in noncritically ill patients. Heart and Lung, 5(1), 83-90.

Yang, S. S., Bentivoglio, L. G., Maranhao, V., Goldberg, H. (1978). From cardiac catheterization data to hemodynamic parameters. Philadelphia:F. A. Davis.