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EFFECT OF ROOM TEMPERATURE AND ICED INJECTATES ON MEASUREMENT OF THERMODILUTION CARDIAC OUTPUT

THE UNIVERSITY OF ARIZONA

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EFFECT OF ROOM TEMPERATURE AND ICED INJECTATES ON MEASUREMENT OF THERMODILUTION CARDIAC OUTPUT

by

Patty L. Miller

A Thesis Submitted to the Faculty of the COLLEGE OF NURSING In Partial Fulfillment of the Requirements For the Degree of MASTER OF SCIENCE In the Graduate College THE UNIVERSITY OF ARIZONA

1984
STATEMENT BY AUTHOR

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[Signature] 4/10/89
CAROLYN L. MURDAUGH  Date
Assistant Professor of Nursing
To my many friends and to my husband
I dedicate this thesis. Their
unfailing support, encouragement,
and understanding helped make this
an attainable goal. Their belief
in me allowed me the freedom to
pursue my goals.
ACKNOWLEDGMENTS

Sincere gratitude and appreciation is extended to my thesis committee: Dr. Carolyn Murdaugh, Chairperson, Dr. Joyce Verran, and Dr. Rita Halpern for their countless hours of assistance and guidance. My research experience was educational and rewarding due to their efforts.

Special recognition is given to Lynda Walker and Cindy Rye who helped me with data collection. Without them, this project would have been most painstaking.

A special thanks to the staff of 6W at Arizona Health Sciences Center for their support and encouragement all during my educational experience and especially during the data collection phase of my research.
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ABSTRACT

An experimental study was conducted to compare cardiac output determinations obtained by two different techniques in adults. The convenience sample consisted of 13 patients in the Medical, Surgical, Cardiothoracic, and Coronary Care units who were 18 years of age or older and had a Swan Ganz catheter inserted. Thirty pairs of cardiac output determinations were obtained by utilizing both iced and room temperature injectate. A mean cardiac output was determined for each sample and a t-test was used to compare the results between techniques. Findings revealed that there was no significant statistical difference between techniques.
CHAPTER 1

INTRODUCTION

The thermodilution method of measuring cardiac outputs has been in widespread use since its introduction by Fegler in 1954 (Ganz and Swan, 1972). Clinical use developed rapidly because the technique is reliable, innocuous, relatively simple and permits repeated measurements. The intensive care unit nurse is primarily responsible for obtaining the cardiac output values.

A close correlation between cardiac output measured by the thermodilution method and the clinical course of the patient has been well established. Boyd and associates (1959) reported a mortality rate of 67 percent in a group of patients whose cardiac indices were less than two liter per square meter per minute in the immediate period following cardiac surgery. The thermodilution technique of cardiac output measurement is also valuable in evaluating the effectiveness of different inotropic drugs and the effectiveness of intra-aortic balloon pumping in low cardiac output states (Kohanna and Cunningham, 1977).

The thermodilution technique represents an application of the indicator dilution principle in which a known change in the heat content of the blood is induced at one point of the circulation and the resulting change in temperature detected at a point downstream (Ganz and Swan, 1972). Using a four-lumen thermodilution catheter, a known amount of cold fluid is injected into the right atrium. The temperature difference
between blood and the mixture of blood and cold injectate is measured by a thermistor sensor located near the tip of the catheter and a cold dilution curve is obtained. Temperature changes are measured in the pulmonary artery to obtain complete mixing of the injectate and blood at the level of the right ventricle.

Overview of Problem

The thermodilution method of obtaining cardiac outputs is based on the principle of temperature change obtained by injecting a known quantity of solution into the pulmonary artery. The temperature of the blood in the right atrium, right ventricle, and pulmonary artery shows cyclic changes synchronous with respiration. These changes may be caused by temperature differences in various venous beds and by respiratory changes in their relative contribution to the venous return (Ganz and Swan, 1972). The fluctuation of temperature in the pulmonary artery is about 0.01 to 0.02 degrees centigrade (°C), but the fluctuation in temperature can be greatly increased in the presence of abnormalities in respiratory pattern, i.e., Cheyne-Stokes respiration.

When measuring cardiac output with the thermodilution technique, the fluctuation in temperature represents a physiologic "noise". Therefore, the "signal", which is the injectate, must be achieved by amplifying the injectate input either by 1) increasing the injectate rate and/or 2) lowering the temperature of the injectate (Ganz and Swan, 1972). Cardiac output measurements are usually obtained with a ten milliliter (ml.) iced, zero to five degree centigrade injectate solution. Thus,
the injectate input has most commonly been augmented by lowering the temperature of the injectate.

Evonuk, et al. (1961) stated that iced injectate may have adverse effects on the heart and other cardiopulmonary hemodynamics. These cardiopulmonary hemodynamic effects were not described. However, the effects may be similar to those experienced by cardiac patients upon ingestion of cold substances or exposure to extremely low temperatures.

Evonuk, et al. (1961) used normal room temperature injectate in an early study and found the technique to be a very satisfactory method for estimating the cardiac output. Evonuk's study was undertaken partially in response to the above stated potential adverse cardiopulmonary effects. The investigator was also concerned about the possible loss of the injectate's temperature to the adjacent tissues in the injectate's passage through the pulmonary circuit. The investigators believed the loss of the injectate's temperature would be reduced using normal room temperature injectate rather than iced injectate (Evonuk, et al., 1961).

Callaghan, et al. (1976) studied the effects of different injectate volumes and temperatures on the accuracy of the technique. They found that cold injectate correlated slightly better with the dye dilution technique than did room temperature injectate, but the difference was not statistically significant.

Several studies have compared iced injectate values with those obtained utilizing room temperature injectate. Riedinger and Shellock (1983) reported no significant differences in cardiac outputs using
room temperature injectate when compared in iced (0° to 5°C) injectate. Killpack, et al. (1983) found that the average difference in cardiac outputs between iced and room temperature injectate was .3 liters per minute. The correlations obtained with thermodilution curves obtained from injectates at ice temperature and room temperature were not significantly different as reported by Pelletier (1979).

Standard nursing practice utilizes 10 ml. iced injectate to obtain cardiac output values in a local medical, coronary and cardiothoracic intensive care units. However, 10 ml. room temperature injectate is utilized in the surgical intensive care unit in the same institution. Further study is needed to determine if room temperature cardiac output values significantly differ with iced cardiac output values for several reasons: the effects of iced injectate on cardiopulmonary hemodynamics are unknown, to replicate previous studies which have shown no significant difference between the two methods, and to standardize nursing practice in a local institution.

Purpose

The purpose of this study was to compare cardiac output values obtained utilizing 10 ml. of iced (0° to 5°C) injectate with cardiac output values obtained utilizing 10 ml. of room temperature injectate to ascertain if any significant differences existed in the values obtained.
**Research Question**

Do cardiac output values obtained with 10 ml. iced (0° to 5°c) injectate differ significantly from cardiac output values obtained with 10 ml. room temperature injectate?

**Significance of Problem**

In critically ill patients, cardiac outputs may be performed every two to four hours to guide treatment and determine the patient's response to therapy. A sterile procedure is required to prepare and maintain iced syringes of injectate. The sterile injectate in the prepared syringes may accidentally submerge with the ice bath due to syringe leakage (Woods, 1983). Increased nursing time is required in the preparation and maintenance of iced injectate as compared to the preparation and maintenance of room temperature injectate because of the risk of contamination. Since the iced injectate must be allowed to reach the desired temperature before use, nursing hours are expended during the wait. Room temperature injectate does not require a waiting period for the proper temperature to be obtained before injection. Iced injectate may also effect cardiopulmonary hemodynamics whereas room temperature injectate would not pose this problem to the patient.

Findings of this study may prove beneficial to both the patient and the nurse. Decreasing the risk of contamination of the injectate, decreasing set-up time and maintenance of the injectate once in syringes, and decreasing the potential effect of the injectate on the cardiopulmonary hemodynamics would be advantageous.
Summary

Cardiac outputs obtained by the thermodilution method with a four-lumen pulmonary artery catheter is a widely accepted practice in critical care units. The nurse is primarily responsible for obtaining these values. The current nursing practice familiar to the investigator employs 10 ml. of iced (0° to 5°c) injectate. Several studies support using both 10 ml. iced injectate or lesser volumes of room temperature injectate. Less nursing time is required in the set-up and maintenance of 10 ml. room temperature injectate. Room temperature injectate may also decrease the risk of contamination because the syringes can be capped and used when needed. A 10 ml. room temperature injectate may also decrease the potential risk of effects on cardiopulmonary hemodynamics posed with 10 ml. of iced injectate.
CHAPTER 2

THEORETICAL FRAMEWORK

Cardiac output is defined as the amount of blood pumped during one minute by a ventricle. The two determinants of cardiac output are stroke volume and heart rate. The stroke volume is the amount of blood a ventricle pumps during each beat and is measured in milliliters (ml.). Multiplying the stroke volume by the number of beats per minute gives the milliliters of blood pumped per minute, or the cardiac output. The value then can be converted to liters per minute, the conventional units for recording cardiac output. Resting cardiac output can range from four to seven liter per minute depending on the body surface area (Sorrells and Watson, 1982).

The thermodilution method of determining cardiac outputs is an indicator dilution technique which uses temperature change as the indicator. A chilled or room temperature solution is added to the blood, and the resulting change in temperature to the blood is recorded at a distal site (Sorrells and Watson, 1982).

Figure one depicts the theoretical framework on which this study is based. The construct level will describe the relationship between changes in injectate temperature and cardiac output measurement. The concept level will describe the effects of iced (0° - 5°c) injectate versus room temperature (19° - 25°c) injectate on the thermodilution
Construct Level

Injectate Temperature  +  Cardiac Output Measurement

Concept Level

Iced  +  Room Temperature  ?  Thermodilution Cardiac Output Method

Operational Level

10cc 0-5°c D5W  +  10cc 19-25°c D5W  +

Cardiac output obtained with thermodilution Swan Ganz catheter and Edwards Laboratory cardiac output computer model 9520A

Figure 1 Theoretical Framework Relating Injectate Temperature and Cardiac Output Measurement
method of cardiac output determination. The operational level of the theoretical framework will be address in detail in Chapter 3.

**Construct Level**

Ganz and Swan (1972) devised a technique for measuring cardiac output with a four-lumen pulmonary artery catheter. A bolus of a cool liquid is rapidly injected into the superior vena cava or the upper part of the right atrium and the resultant change in temperature is detected in the pulmonary artery. As in other indicator-dilution techniques, uniform mixing of the indicator with blood over the whole vascular cross-section is a basic assumption for the validity of the method (Ganz and Swan, 1972). Cardiac outputs can be calculated from the change in the heat content of the blood induced by the injection of the cool bolus and from the temperature time curve. During the mixture of the blood and the injectate, the heat gained by the injectate is equal to the heat lost by the blood. This basis assumes that no indicator was lost from the system between the site of injection and the site of detection by heat conduction or energy conversion (Ganz and Swan, 1972).

The Stewart-Hamilton equation which is used for dye dilution cardiac output determinations must be modified for thermodilution cardiac output determinations. The modification is necessary since change in temperature becomes the important parameter rather than change in particle concentration. The formula modification includes the addition of the specific gravity and the specific heat of both the blood and the injectate because temperature change is modified by these parameters.
A correction factor is also added to correct for the increase in temperature while the injectate fluid transverses the catheter. The modified formula is as follows:

\[
C.O. = \frac{VX(T_B-T_I)}{A} \times \frac{S_I C_I}{S_B C_B} \times \frac{60 X K}{1}
\]

where:

- **C.O.** = Cardiac Output
- **V** = Volume of injectate in ml.
- **A** = Area of thermodilution curve in square millimeters (mm)
- **K** = Calibration constant in mm/°C
- **T_B, T_I** = Temperature of blood (B) and injectate (I)
- **C_B, C_I** = Specific heat of blood and injectate
- **S_B, S_I** = Specific gravity of blood and injectate
- \(\frac{(S_I C_I)}{(S_B C_B)} = 1.08\) when 5 percent dextrose is used
- \(60 = 60\) seconds/minute
- **C_T** = Correction factor for injectate warming

The calculation of cardiac output by the modified formula is performed by a battery powered computer which digitally displays the resulting cardiac output value.

Quantitation of the temperature change of the indicator represents a special problem connected with the use of heat as the indicator. When the cool fluid is injected through an intravascular catheter, the temperature of the injectate constantly changes as it passes through the
lumen because of heat exchange with the wall of the catheter and the surrounding blood. The temperature of the injectate, as used in the formula for calculation of cardiac output, is the mean value of the stream. A factor can be derived that will correct for the amount of temperature lost during passage through the injection lumen. The loss of temperature is caused by a decrease in the temperature difference between the blood and indicator. The correction factor \( C_T \) can be expressed as follows:

\[
C_T = \frac{T_B - T_{IL}}{T_B - T_I}
\]

where

- \( T_B \) = Blood temperature
- \( T_{IL} \) = Mean temperature of the injectate leaving the catheter
- \( T_I \) = Temperature of the injectate measured immediately before the injection (Ganz and Swan, 1972).

Thermodilution measurements of cardiac output values have shown that the correction factor is virtually not effected by the temperature of the surrounding blood or by the rate of injection and only slightly effected when the length of the intravascular segment of the catheter is changed from 35 to 25 or 45 centimeters (cm.). The temperature of the injectate measured immediately before the injection \( (T_I) \) is used in the formula for estimation of cardiac output and the factor \( (C_T) \) is included in the numerator for correction (Ganz & Swan, 1972).

In summary, the basis of determining cardiac outputs by the thermodilution technique has been described. This technique has been
adopted and perfected from the dye dilution method of obtaining cardiac outputs.

Concept Level

Several studies have compared cardiac output values obtained with 10 ml. iced (0°-5°c) injectate versus room temperature injectate. In an early study, Evonuk, et al. (1961) compared the results of cardiac output obtained utilizing normal room temperature isotonic saline versus the dye dilution method. One hundred and thirty two thermodilution and 132 dye dilution curves for estimating the cardiac output in small animals were recorded simultaneously. The coefficient of correlation between these simultaneous measurements was .96. Paired analysis showed the thermal measurements to be four percent greater than dye measurements. However, the reproducibilities and sensitivities were comparable (Evonuk, et al., 1961).

Pelletier (1979) assessed the reliability of the thermodilution method using injectates at normal room temperature as opposed to iced injectates. Eight patients were studied in the immediate post-operative period. Two successive measurements were performed within 60 seconds with 10 ml. injectates of five percent dextrose in water at 0°c and at 24°c in a random order. Cardiac output was obtained by a battery powered computer. No significant difference was found between cardiac outputs obtained at 0°c and those obtained at normal room temperature. Less than a ten percent difference was found in 90 percent of the measurements (Pelletier, 1979).
Woods (1983) studied 30 patients to determine the effects of five ml. room temperature injectate on the measurement of cardiac output as compared to cardiac output using 10 ml. iced injectate. No significant differences were found in cardiac output using five ml. room temperature and 10 ml. iced injectate. Also, no significant differences were found in mean cardiac output measurements using the two types of injectate in relation to sequence of injectate volume used. Cardiac outputs highly correlated ($r=.96$) with both types of injectate. Range of cardiac output (low, normal, high) was the only variable to show a significant correlation with the differences in cardiac output measurements using five ml. room temperature and 10 ml. iced injectate. The least difference (0.25 liters per minute) was seen in the low cardiac output range, which was defined as less than four liters per minute. The greatest difference (0.96 liters per minute) was seen in the high cardiac output range, which was defined as eight liters or more per minute (Woods, 1983).

Callaghan, et al. (1976) compared thermodilution cardiac output using cold saline ($2^\circ$C) and dye dilution cardiac output and also compared thermodilution cardiac output with room temperature ($23^\circ$C) and dye dilution cardiac output. No significant difference in values were obtained using the cold injectate versus the dye dilution method. The correlation coefficient was .92 for the cold injectate and dye dilution method. Results obtained with the room temperature injectate versus the dye dilution method also were not significantly different. The
correlation coefficient was .86 for the room temperature injectate and the dye dilution method (Callaghan, et al., 1976).

Killpack, et al. (1983) studied acutely ill patients (N=30) to compare cardiac output measurements obtained with five ml. versus 10 ml. of iced injectate and with iced versus room temperature (10 ml).

Difference in cardiac output in relation to five and ten ml volumes was not significant and cardiac output's correlated highly (r=.96).

Difference in cardiac output in relation to iced versus room temperature injectate was significant. However, the correlation between the two methods was high (r=.97). The average difference between cardiac outputs obtained with the two methods was .3 liters/minute (Killpack, et al., 1982).

Riedinger and Shellock (1983) studied 45 patients to evaluate the reproducibility and accuracy of performing thermodilution cardiac outputs using room temperature injectate with ice temperature injectate. The cardiac outputs ranged from 1.2 to 9.1 liters/minute. No significant difference was found when comparing cardiac output using room temperature injectate with results obtained using ice temperature injectate. The correlation coefficient between the two methods was .91, indicating good agreement between the two techniques (Riedinger and Shellock, 1982).

The reproducibility of iced and room temperature injection for thermodilution cardiac output measurements in 39 patients was studied by Kint, et al. (1982). Cardiac output with the cold injectate was found to be lower than cardiac output using room temperature injectate. The
variance of cardiac output within patients was found to be significantly lower with cold instead of room temperature injectate (Kint, et al., 1982).

In summary, several studies have been presented which have described results obtained utilizing room temperature versus iced injectate for cardiac output determinations. Although most results suggest no difference in values obtained with the two methods, controversial findings exist. Thus, the present study was necessary.

**Hypothesis**

The following research hypothesis was tested:

There is no significant difference between cardiac output obtained with iced injectate and cardiac output obtained with room temperature injectate.

**Operational Definitions**

The operational definitions were as follows:

**Iced injectate** - Ten milliliters of zero to five degrees centigrade dextrose in water which is injected into the proximal port of a four-lumen Swan Ganz catheter for cardiac output determinations.

**Room temperature injectate** - Ten milliliters of nineteen to twenty-five degrees centigrade dextrose in water which is injected into the proximal port of a four-lumen Swan Ganz catheter for cardiac output determination.
Thermodilution method - An indicator dilution technique which uses temperature change as the indicator for cardiac output determinations utilizing a four-lumen pulmonary artery catheter.

Summary

The chapter has described the physiology of temperature change and cardiac output determination utilizing the thermodilution method. The effects of iced (0°-5°C) injectate versus room temperature injectate on cardiac output determinations were also discussed. The theoretical framework was based on review of literature describing the thermodilution technique for cardiac output determinations and iced (0°-5°C) injectate versus room temperature injectate for cardiac output determinations.
CHAPTER 3

METHODODOLOGY

The study was designed to determine if cardiac outputs obtained utilizing ten ml. iced (0°-5°C) injectate differ significantly from cardiac outputs obtained utilizing ten ml. room temperature injectate. The data collection and analysis protocols used to accomplish the purpose are described in detail in this chapter.

**Study Design**

An experimental design was employed to study cardiac output values. Values obtained with iced injectate were compared to values obtained with room temperature injectate.

**Study Sample and Setting**

The sample was comprised of 30 paired specimens of cardiac outputs obtained from adult patients admitted to the cardiac, medical, cardiothoracic, and surgical intensive care units of a southwestern teaching hospital. The specimen was obtained from patients who have had a Swan Ganz catheter inserted. No more than three paired specimens were obtained per patient. The criteria for patient inclusion into the sample was as follows: 1) age 18 or older, and 2) a Swan Ganz catheter inserted.

The rationale for the age of 18 or older was to insure informed consent (Appendix A). The necessity of insertion of a Swan Ganz catheter
was determined by the physician. However, the intensive care unit nurses were responsible for obtaining the cardiac output values.

**Protection of Human Rights**

The research proposal and consent form was presented to the University of Arizona Human Subjects Committee for approval (Appendix B). All subjects were informed of their right to withdraw from the project at any time without incurring ill will. All questions were answered. To assure subject anonymity and confidentiality, both the subject and the specimens were assigned a code number and all data was coded accordingly.

**Data Collection Procedure**

Subjects who had a Swan Ganz catheter inserted were approached by the investigator and asked to participate in the study. After informed consent was obtained, demographic data was obtained from the chart (Appendix C). Four ten ml. syringes of iced five percent dextrose in water (D$_5$W) and four ten ml. syringes of room temperature D$_5$W were injected to obtain cardiac output values. The injectate sequence was performed in a pre-determined randomized order. Randomization was done to reduce error due to ordering effects. Cardiac output values obtained with the first injection of each sequence were discarded and the other three values were averaged for the cardiac output determination. Rationale for eliminating the first value is the first injection will contain the warmed fluid already in the catheter's dead space. Thus, the average temperature of the initial bolus or injectate will be higher than that of subsequent injections (American Edwards Laboratory, 1981).
Cardiac output determinations were obtained in sequence when the acronym "RDY" (ready) was displayed on the computer. This occurred within 15 to 30 seconds (American Edwards Laboratory, 1981).

The following procedures were followed to obtain the cardiac output determinations.

Cardiac Outputs with Iced Injectate

1) Fill plastic basin with ice for ice bath.
2) Remove 250 ml. bag of D_5W from refrigerator.
3) Remove five, 12 ml. syringes from refrigerator.
4) Insert needle with three-way stopcock in injection port of D_5W.
5) Remove syringe from syringe cover and insert syringe into stopcock and remove ten ml. of D_5W.
6) Place sterile cap on filled syringe.
7) Place filled syringe back into syringe cover and place in ice bath upright to prevent possible contamination.
8) Repeat steps 5 - 7 four times to obtain a total of five syringes filled with D_5W.
9) Remove barrel from one capped syringe containing iced D_5W.
10) Place thermistor probe in iced D_5W contained in syringe without barrel and return to ice bath.
11) Remove cardiac output battery from charger and place into cardiac output computer.
13) Attach connector cable to thermistor port of Swan Ganz catheter.

14) Turn on power.

15) Press blood temperature (blood temp) button and record value.

16) Press injection temperature (inject temp) button and wait until temperature reaches 5°C or less.

17) Press cardiac output button and wait for acronym "RDY" signal.

18) Turn three-way stopcock off to any intravenous infusion in the proximal port of the Swan Ganz catheter and disconnect intravenous tubing.

19) Remove syringe from ice bath and remove cap.

20) Place syringe in proximal port of Swan Ganz catheter.

21) Turn three-way stopcock until proximal port is open to syringe.

22) Press "start" button on computer.

23) Inject filled syringe at end-expiration at a rate of >10ml/four seconds (American Edwards Laboratory, 1981).

24) Record value from digital display.

25) Immediately repeat steps 19 - 24 for the three cardiac output determinations.

26) Disconnect connector cable from Swan Ganz catheter.

27) Remove battery from computer and return to charger.

28) Discard ice, basin, and syringes.
Cardiac Outputs with Room Temperature Injectate

1) Obtain 250 ml. bag of room temperature $D_5W$.
2) Obtain five, 12 ml. syringes.
3) Insert needle with three-way stopcock in injection port of $D_5W$.
4) Remove syringe from syringe cover and insert syringe into stopcock and remove 10 ml. of $D_5W$.
5) Place sterile cap on filled syringe.
6) Place filled syringe back into syringe cover and put into container upright.
7) Repeat steps 4 - 6 four times to obtain a total of five syringes filled with $D_5W$.
8) Remove barrel from one capped syringe containing $D_5W$.
9) Place thermistor probe in $D_5W$ contained in syringe without barrel and return to container.
10) Remove cardiac output battery from charger and place into cardiac output computer.
12) Attach connector cable to thermistor port of the Swan Ganz catheter.
13) Turn on power.
14) Press blood temperature (blood temp) button and record value.

16) Press cardiac output button and wait for acronym "RDY" signal.

17) Turn three-way stopcock off to any intravenous infusion in the proximal port of the Swan Ganz catheter and disconnect intravenous tubing.

18) Remove syringe from container and remove cap.

19) Place syringe in proximal port of Swan Ganz catheter.

20) Turn three-way stopcock until proximal port is open to syringe.

21) Press "start" button on computer.

22) Inject filled syringe at end-expiration at a rate of >10 ml/four seconds.

23) Record value.

24) Immediately repeat steps 18 - 23 for the three cardiac output determinations.

25) Disconnect connector cable from Swan Ganz Catheter.

26) Remove battery from computer and return to charger.

27) Discard container and syringes.

**Instruments**

**Data Form**

The following information was obtained with all samples.

1) Age

2) Sex
3) Diagnosis
4) Blood temperature of subject
5) Iced injectate values
6) Room temperature injectate values.

The blood temperature of the subject may be significant when comparing the two cardiac output values. This is due to the fact that the cardiac output determination is based on the change in temperature between the injectate and the blood as described in the previous chapter.

Cardiac Output Computer

The Edwards Model 9520A cardiac output computer was utilized to obtain the cardiac output values. The computer system has several positive features. Firstly, the computer is simple to operate. Secondly, the computer has an automatic temperature sensing system by the thermistor within the thermodilution catheter. Injectate temperature is automatically determined via a separate probe. The baseline is established as mean pulmonary artery temperature to improve repeatability. The computer has met all Canadian Standards Association criteria for patient safety. Iced or room temperature injectate may be used since the gain is automatically increased when room temperature injectate is utilized. Sophisticated analog circuitry allows determination of cardiac output range from 0.1 to 20 liters/minute. Cardiac outputs can be repeated when the ready signal appears only 14 seconds after the thermodilution curve is terminated. Cardiac output can be computed with body temperatures as low as $27^\circ$C. The computer has a built in self-test
feature to show that the computer is properly calibrated. The acronym "OK" appears on the display after the self-test cycle. An automatic battery indicator provides six to eight hours of continuous operation. When the battery charge becomes too low for accurate determinations, the acronym "BAT" (battery) appears. Cardiac output and temperature measurements are not displayed if a catheter fault occurs. When a catheter fault occurs, the acronym "CAT" (catheter) appears (American Edwards Laboratory, 1981).

Data Analysis Plan

The demographic data was analyzed with descriptive statistics. Frequencies were calculated for age, sex, and diagnosis.

The null hypothesis to be tested was as follows. There is no significant difference between cardiac output obtained with iced injectate and cardiac output obtained with room temperature injectate. Correlated t-tests were performed to ascertain any significant differences between the two methods of obtaining cardiac outputs. A significance level of 0.10 was set to decrease the likelihood of a Type II error. The alpha level of 0.10 provides for a more conservative test when attempting to support the null hypothesis and therefore reduces the probability of rejecting an alternative hypothesis of a difference between the two groups.

Limitations

The following limitations were recognized by the investigator.

1) The study was limited by the sample size of thirty cardiac output determinations comparing the two methods.
2) Investigator bias may have been operating since all the data was collected by one person.

3) A strip recorder was not used to precisely account for respiratory variations.

Summary

The chapter has described the development of an experimental design to investigate cardiac output determinations utilizing 10 ml. iced (0\(^0\text{C}\)-5\(^0\text{C}\)) injectate versus 10 ml. room temperature injectate. An explanation of the study setting, data collection protocol and data analysis plan was included. The study instruments, potential sources of bias and limitations were discussed.
CHAPTER 4

RESULTS OF DATA ANALYSIS

Chapter four describes the results of the data analysis. Characteristics of the sample are included as well as results of the hypothesis testing.

Description of Sample

A total of 30 pairs of cardiac output samples were obtained from thirteen subjects who met the study criteria. The mean age of the sample was 56 years with a range of 20 to 78 years and a standard deviation of 19.75 years. Five subjects were male and eight were female. The primary diagnoses of the subjects are listed in Table 1. The diagnoses included sepsis, congestive heart failure, status post-code arrest, cardiac tamponade, acute myelogenous leukemia, pneumonia, and chronic obstructive pulmonary disease.

Core Temperatures

The core temperature of the subjects was recorded before injection of the injectate to obtain the cardiac output determination. The mean core temperature prior to injection was $37.63^{\circ}C$ with a standard deviation of $1.20^{\circ}C$. The minimum temperature of the subjects was $35.20^{\circ}C$ and the maximum temperature was $40.20^{\circ}C$. 
Table 1  Primary Diagnoses of Subjects in Sample
(Frequencies, N = 13)

<table>
<thead>
<tr>
<th>DIAGNOSIS</th>
<th>N</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Congestive heart failure</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>Status post-code arrest</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>Acute myelogenous leukemia</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Sepsis</td>
<td>1</td>
<td>08</td>
</tr>
<tr>
<td>Cardiac Tamponade</td>
<td>1</td>
<td>08</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1</td>
<td>08</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>1</td>
<td>08</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>13</td>
<td>100</td>
</tr>
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</table>
Injectate Order

As previously stated, the order of the injectate sequence was controlled by random assignment. The investigator flipped a coin to determine the order of the injectate sequence. For example, after flipping a coin on subject number one, the first injectate sequence was performed utilizing the iced injectate. The second injectate sequence was performed immediately after the first sequence utilizing room temperature injectate. Iced cardiac output determinations were performed first in 16 of the paired samples. Room temperature cardiac output determinations were performed first in 14 of the paired samples.

Hypothesis Testing

The null hypothesis tested was: there is no significant difference between cardiac output obtained with iced injectate and cardiac output obtained with room temperature injectate. Correlated t-tests were performed on the mean cardiac output determinations obtained by the two methods. No significant difference was found between the two techniques. The minimum iced cardiac output determination was 1.13 liters per minute and the maximum determination was 10.70 liters per minute. The minimum room temperature cardiac output determination was 1.61 liters per minute and the maximum determination was 9.80 liters per minute. A t value of .321 was not significant. Therefore, the null hypothesis was accepted. The results of the t-test are shown in Table 2.
Table 2  Significance of Differences Between Iced Cardiac Output Determinations and Room Temperature Cardiac Output Determinations:  t-test (N=30)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>t-VALUE</th>
</tr>
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<tbody>
<tr>
<td>Group A</td>
<td>4.20</td>
<td>1.71</td>
<td>.321*</td>
</tr>
<tr>
<td>Group B</td>
<td>4.56</td>
<td>1.66</td>
<td></td>
</tr>
</tbody>
</table>

Key:  Group A = Iced Cardiac Output Determination
      Group B = Room Temperature Cardiac Output Determination

* Not Significant at ≤ 0.10
Summary

In conclusion, a comparison of cardiac output determinations obtained by two techniques resulted in no significant difference in values obtained with the two techniques. T-tests were performed on the mean cardiac output determinations obtained by iced and room temperature injectate.
CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

In the final chapter, the results of the data analysis are discussed. Conclusions drawn from the results and implications for nursing practice are presented. Limitations of the study and recommendations for further nursing research are suggested.

Conclusions

The null hypothesis tested was: there is no significant difference between cardiac output obtained with iced injectate and cardiac output obtained with room temperature injectate. The null hypothesis was accepted as the findings indicated that the cardiac output determinations did not differ significantly between the two methods. Therefore, room temperature injectate cardiac output determinations can be made with the knowledge that values obtained will not differ significantly from values obtained with iced injectate.

The current nursing practice familiar to the investigator employs 10 ml. of iced injectate. Several studies support using 10 ml. iced injectate or lesser volumes of room temperature injectate. Pelletier (1979) found no significant difference between cardiac outputs obtained at $0^\circ$C and those obtained at normal room temperature. Woods (1983) found no significant differences in cardiac output using five ml. room temperature and 10 ml. iced injectate. Reidinger and
Shellock (1982) found no significant difference when comparing cardiac output using room temperature injectate with results obtained using ice temperature injectate. No significant difference in the values obtained between the two methods in this study substantiates previous studies' findings.

**Implications for Nursing Practice**

No significant difference was found between the two cardiac output methods. An implication for nursing in light of this finding is the standardization of the procedure for obtaining cardiac outputs in a local institution. Currently 10 ml. iced injectate is utilized in the medical, coronary, and cardiothoracic intensive care units. The surgical intensive care unit utilizes 10 ml. room temperature injectate.

The investigator intends to inform the institution of the findings of this study. Therefore, an implication for nursing practice in the standardization of the procedure for obtaining cardiac outputs. Since room temperature injectate cardiac output values are reliable, the investigator would standardize the procedure utilizing room temperature injectate. This method provides for less risk of contamination of syringes, less nursing time required for set-up and maintenance of room temperature injectate, and less potential hemodynamic risk to the patient.
Limitations
The following possible limitations have been identified:
1) Small sample size,
2) A strip chart recorder was not available for use which would provide a more accurate cardiac output determination by taking into account respiratory variations.

Recommendations
Recommendations for further nursing research include:
1) Replication of the study with a larger sample size,
2) Replication of the study using a strip chart recorder to allow more accurate determination based on respiratory fluctuations.

Summary
In conclusion, the study examined the differences between cardiac output determinations obtained by two different methods. Thirty pairs of cardiac output determinations from thirteen subjects were examined. No significant differences were found between the two techniques. This study is significant for nursing practice in that it will allow standardization of a procedure at a local institution. Through this standardization several benefits will be gained. Utilization of room temperature injectate will decrease the risk of syringe contamination, decrease nursing time setting-up and maintaining the injectate, and lessen the potential adverse cardiopulmonary effect of using iced injectate.
APPENDIX A

CONSENT FORM
CONSENT FORM

Effect of Room Temperature and Iced Injectates on Measurement of Thermodilution Cardiac Output

The purpose of this study is to examine the validity of cardiac output determinations obtained by a new proposed technique. The proposed technique of cardiac output determination is obtained by injecting a quantified amount of dextrose in water (intravenous solution) into the Swan Ganz catheter which has been placed by your physician. The new technique may decrease potential effects on the heart and lungs associated with the current technique. Also, the new technique may reduce risk of contamination of the solution used and reduce set-up time and maintenance of the solution used to obtain the cardiac output determinations. However, the medical and nursing professions do not know if cardiac output determinations obtained with both methods are comparable.

Adults 18 and older who have a Swan Ganz catheter in place are being recruited. Your physician has approved this study which will take place in the intensive care unit.

If you agree to participate, the investigator will obtain four additional output determinations when cardiac outputs are ordered by your physician. This will result in an additional 40 ml. or approximately 2 3/4 tablespoons of solution which you will receive. One cardiac output sample will be obtained per day. No more than three cardiac output samples will be obtained from you. The results of the cardiac output determinations will then be compared with the results drawn by the technique presently in use in the intensive care unit.

To protect your confidentiality, all results will be coded. The results may be published in group form, but your identity will not be revealed. The only known risk to the study is that the extra fluid (2 3/4 tablespoons/day) may cause fluid overload problems. Although highly unlikely, this may result in lung congestion. You will be continuously monitored for this occurrence. In the event of any fluid overload, your physician will be notified and appropriate actions will be taken immediately. No additional cost will be incurred by you by participating in this study.

If you decide not to participate in this study, it will in no way affect your relationship with the institution, your physicians, nurses or the quality of care. You are free to withdraw from the study and to ask questions that you may have at any time.
I have read the above "Consent." The nature, demands, risks, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the project at any time without incurring ill will or affecting my medical care. I also understand that this consent form will be filed in an area designated by the Human Subjects Committee with access restricted to the principal investigator or authorized representatives of the particular department.

Subject ____________________________ Date ________________

Witness ____________________________ Date ________________
APPENDIX B

HUMAN SUBJECTS APPROVAL
Ms. Patty L. Miller  
College of Nursing  
Arizona Health Sciences Center  

Dear Ms. Miller:

We are in receipt of your project, "Effect of Room Temperature and Iced Injectates on Measurement of Thermodilution Cardiac Output", which was submitted to this Committee for review. The procedures to be followed in this study pose no more than minimal risk to the participating subjects. Regulations issued by the U.S. Department of Health and Human Services [45 CFR Part 46.110(b)] authorize approval of this type project through the expedited review procedures, with the condition that subjects' anonymity be maintained. Although full Committee review is not required, a brief summary of the project procedures is submitted to the Committee for their information and comment, if any, after administrative approval is granted. This project is approved effective 2 November 1983.

Approval is granted with the understanding that no changes will be made in either the procedures followed or in the consent form(s) to be used (copies of which we have on file) without the knowledge and approval of the Human Subjects Committee and the Departmental Review Committee. Any physical or psychological harm to any subject must also be reported to each committee.

A university policy requires that all signed subject consent forms be kept in a permanent file in an area designated for that purpose by the Department Head or comparable authority. This will assure their accessibility in the event that university officials require the information and the principal investigator is unavailable for some reason.

Sincerely yours,

Milan Novak, M.D., Ph.D.
Chairman
Human Subjects Committee

cc: Ada Sue Hinshaw, R.N., Ph.D.
College Review Committee
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LIST OF REFERENCES


