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Comparison of Pulmonary Artery, Tympanic, Oral, and Axillary Temperatures

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COMPARISON OF PULMONARY ARTERY, TYMPANIC, ORAL, AND AXILLARY TEMPERATURES

By

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ABSTRACT

COMPARISON OF PULMONARY ARTERY TEMPERATURE, TYMPANIC, ORAL, AND AXILLARY TEMPERATURES

By

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Hypothermia depresses the myocardium and shifts the oxygen dissociation curve to the left. Accurate temperature monitoring is essential. Studies conflict regarding the accuracy of sites other than the pulmonary artery (the gold standard) in temperature measurement of intubated patients. Using Roy's Adaptation Model as a conceptual framework, repeated measures analysis of variance found a significant difference between the pulmonary artery, tympanic, oral, and axillary temperatures when taken within 15 minutes of arriving to the cardiothoracic unit and then hourly for four hours after open heart surgery. Post hoc t-test showed significant differences during rapid temperature changes. When temperatures were stable tympanic and oral measurements were not statistically different from the pulmonary artery temperature. Except for immediately post-operative, axillary temperatures were statistically different from the pulmonary artery temperatures.

Dedicated to the staff of the cardiothoracic intensive care and the cardiac progressive care unit at Munson Medical Center and to my family: Marvin, Jennifer, Sarah, Heather and Michelle

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CHAPTER ONE

INTRODUCTION

Temperature measurement is extremely important in patients undergoing open heart surgery. In order to preserve vital organs, the perfusionist often induces hypothermia during the surgery. This hypothermia causes vasoconstriction and peripheral hypothermia. Before stopping the cardiopulmonary bypass machine, the perfusionist starts core temperature re-warming. As the surgery ends most patients appear normothermic by core temperature measurements. However, vasodilatation occurs as the warmed blood from the core returns to the extremities. The cold peripheral blood shifts to the core and the core temperature drops several degrees (Heidenreich, Giuffre, & Doorley, 1992). This afterdrop can be life threatening if not treated. Some of the complications from hypothermia include: shivering, increased oxygen consumption, platelet dysfunction, and delays in drug and anesthetic elimination. Hypothermia shifts the oxyhemoglobin dissociation curve to the left causing difficulty in oxygen delivery to the tissues (Barden & Hansen, 1995). Other complications of hypothermia include (Barden & Hansen):

> Myocardial depression, ventricular dysrhythmia, increased blood viscosity, decreased cerebral blood, and increased pulmonary and

systemic vascular resistance. Hypothermia also impairs the function of adenosine triphosphatase (ATP) and, therefore, all of the ATP dependent reactions at the cellular level. The reactions affect membrane stability, energy production, enzyme function, glucose utilization, cyclic adenosine monophosphate (c-AMP) production, and osmotic homeostasis. (p. 115)

The site selection of temperature monitoring is based on routine practice, the age of the patient, or the condition of the patient, rather than upon empirical data (Konopad, Kerr, Noseworthy, & Grace, 1994). The ideal method for temperature measurement in the critically ill patient is using a pulmonary artery catheter (Fallis, Gupton, & Kassum, 1994). When a pulmonary artery catheter is not available, nurses consider a rectal temperature to be the optimal site for temperature monitoring (Fallis, et al.). In addition to being embarrassing for the patient, authors have questioned the accuracy of the rectal temperature. Hypothermia causes a temperature lag of the rectal temperature when compared to the oral temperature (Fallis et al.). These authors found the temperature lag to be greatest 1 and 4 hours after open heart surgery. White, Baird, and Anderson (1994) question the accuracy of the rectal temperature measurement because of the distance of the thermometer from the central nervous system and the heart, and because the rectum has heat producing microorganisms that affect the measurement. Rectal temperatures are also time consuming, uncomfortable, and have been

associated with rectal perforations in the very young infant (Muma, Treloar, Wurmlinger, Peterson, & Vitae, 1991).

Oral temperatures in an intubated patient weren't considered to be accurate when compared with a mercury-in-glass thermometer, because the patient cannot form a tight seal around the thermometer. With the speed of the electronic thermometers, this seal is not as important as it was with the mercury-in-glass thermometers. (Konopad et al., 1994). According to Fallis et al. (1994), an oral temperature is usually lower than the rectal temperature, but correlates with the pulmonary artery temperature better than the rectal temperature with rapid changes in temperature. Konopad et al. concluded that the presence of an endotracheal tube does not affect the accuracy of an oral temperature.

The tympanic membrane temperature is easy to use, and gives information quickly. Little information is available about its accuracy as a method of core temperature measurement or its repeatability in comparison to other commonly used temperature methods (Erickson, & Kirklin, 1993).

Axillary temperatures are quickly, easily performed, comfortable for the patient, and without complications. However, its accuracy has been questioned (Muma et al., 1991).

Problem Statement

The pulmonary artery catheter is the ideal method for temperature monitoring. When the pulmonary artery catheter is unavailable, then the rectal

temperature is considered the next most accurate. However, the rectal route is uncomfortable and time consuming. Studies conflict about the correlation of oral and tympanic temperatures in the intubated patients with the pulmonary artery catheter. More research was needed to determine if the tympanic, oral, and axillary temperatures accurately correlate with the pulmonary artery temperature.

Purpose

The purpose of this study was to determine whether oral temperature measurement is accurate in adult intubated patients after open heart surgery and to investigate if tympanic, oral, and axillary temperatures compared to pulmonary artery temperatures in the same population. Mean pulmonary artery temperatures were compared to mean tympanic, oral, and axillary temperature sites. Further testing was undertaken to determine the stability of these differences over time. This study replicated the research of Heidenreich et al. (1992). Their study assessed the validity of noninvasive measures of temperatures to predict core temperature in the hypothermic patient. The review of literature showed an inconsistency about the accuracy of temperature monitoring from various sites. The practice of temperature measurement should be based on research instead of tradition. If tympanic, oral, and axillary temperatures are accurate in the intubated patient these routes should be used instead of the more invasive rectal temperature.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Conceptual Framework

Roy's Adaptation Model (Roy & Andrews, 1991) was utilized as the theoretical framework. The Roy model was based on the works of von Bertalanffy, a general systems theorist, and Harry Helson, a physiologic psychologist (Fawcett, 1995). Roy's Adaptation Model was developed for use in nursing practice, research, and education (Fawcett). Important concepts in a nursing theory include the theorist's definition of person, environment, health and nursing.

Roy and Andrews (1991) view the person receiving nursing care as an adaptive system. A system is defined as "a set of parts connected to function as a whole for some purpose, and it does so by virtue of the interdependence of its parts" (p. 7). The system is defined as having "inputs, outputs, and control and feedback processes" (p. 7). Roy and Andrews describe inputs as the stimuli which may come externally from the environment or internally from the self. "The person's response (output) is thus a function of the input stimuli and the person's individual adaptation level" (p.7). The response can either be adaptive or ineffective. Roy and Andrews state that the responses then act as feedback to the system to help determine whether to increase or decease the efforts to cope with the stimuli. According to Roy and Andrews, the adaptive system has two major internal control processes. These internal control processes are referred to as the regulator and cognator subsystems.

According to Roy and Andrews (1991) "the regulator subsystem responds automatically through neural, chemical, and endocrine coping processes; the person does not have to think about them" (p.14). The cognator subsystem responds to the external and internal stimuli that involve: psychological, social, physical, and physiological factors. The cognator subsystem uses "perceptual/information processing, learning, judgment and emotion" (p. 14). Roy and Andrews state the human system can adjust to changes in the environment, and also can change the environment. Roy and Andrews state that the environment is "the world around and within" (p.8).

Roy and Andrews (1991) describe the environment as constantly changing internal or external stimuli, and they categorized stimuli as: focal, contextual, and residual. The focal stimulus is the "internal or external stimulus most immediately confronting the person; the object or event that attracts one's attention" (p. 8). Roy and Andrews describe contextual stimuli as "all other stimuli present in the situation that contribute to the effect of the focal stimulus" (p.9). Residual stimuli are "environmental factors within or without the person whose effects in the current situation are unclear" (p.9).

An adaptation level is "the changing point that represents the person's ability to respond positively in a situation" (Roy & Andrews, 1991, p. 10). The adaptive response can be measured in one of four adaptive modes. The adaptive modes are the physiological mode, the self-concept mode, the role function mode, and the interdependence mode (p.12). Roy and Andrews describe the physiological mode as:

> The way the person responds as a physical being to stimuli from the environment. Behavior in this mode is the manifestation of the physiological activities of all the cells, tissues, organs, and systems comprising the human body. (p. 15)

Besides the physiological mode, Roy and Andrews (1991) view adaptation in three other modes. The other modes include: the self-concept mode, the role function mode, and the interdependence mode.

Health is a reflection on the ability to adapt (Roy & Andrews, 1991). According to Roy and Andrews "adaptive responses are those that promote the integrity of the person in terms of the goals of adaptation: survival, growth, reproduction, and mastery" (p. 12). Ineffective responses are "those that neither promote integrity nor contribute to the goals of adaptation" (p.12). The goal of nursing is "the promotion of adaptation in each of the four modes, thereby contributing to the person's health, quality of life, and dying with dignity" (p.20).

A temperature change demonstrates an adaptive response in the physiological mode using the regulator subsystem response. A person's temperature elevates because there is an "interaction between an endogenous pyrogen and the receptor near the thermosensitive neurons in the anterior portion of the hypothalamus" (Pontious et al., 1994, p. 58). Hypothermia during coronary artery bypass surgery is induced to enhance adaptation in order to preserve vital organs (Heidenreich et al., 1992). According to Roy and Andrews (1991) a stimulus is "that which provokes a response" (p.5).

Hypothermia provokes a temperature change. This change can be measured. The patient undergoing hypothermia may state s(he) feels cold, which would be monitored by the cognator subsystem. The purpose of this study was to determine which method of temperature measurement best assesses the adaptive response to hypothermia in an intubated patient.

Figure 1 represents Roy's Adaptation Model in which stimuli affect the person. The stimuli is referred to by Roy and Andrews (1991) as inputs. The stimuli can be focal, contextual, or residual. The stimuli are processed by the cognator or regulator mechanism, and then the person responds, which are the outputs. There is a feedback mechanism so the individual can monitor the adaptive response.

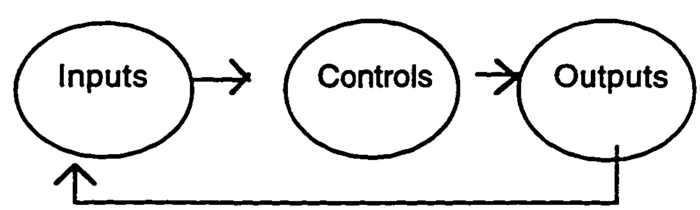

Figure 1: The relationship between inputs (stimuli), controls (the regulators), and the outputs (the adaptive response) from Roy and Andrews (1991).

For this study the person was the intubated patient. The external environment was the cardiothoracic unit. The goal of nursing was to monitor and protect the patient undergoing re-warming after being hypothermic. The induced hypothermia was the focal stimulus. The response measured was the effect hypothermia had on the measurement of temperature. The contextual stimuli in this study that may have had an effect are listed in Figure 2. These

factors were not recorded in this study. It could be a topic for consideration for future research. No residual stimuli had been identified. Figure 2 represents the relationship between temperature measurement and Roy's Adaptation Model.

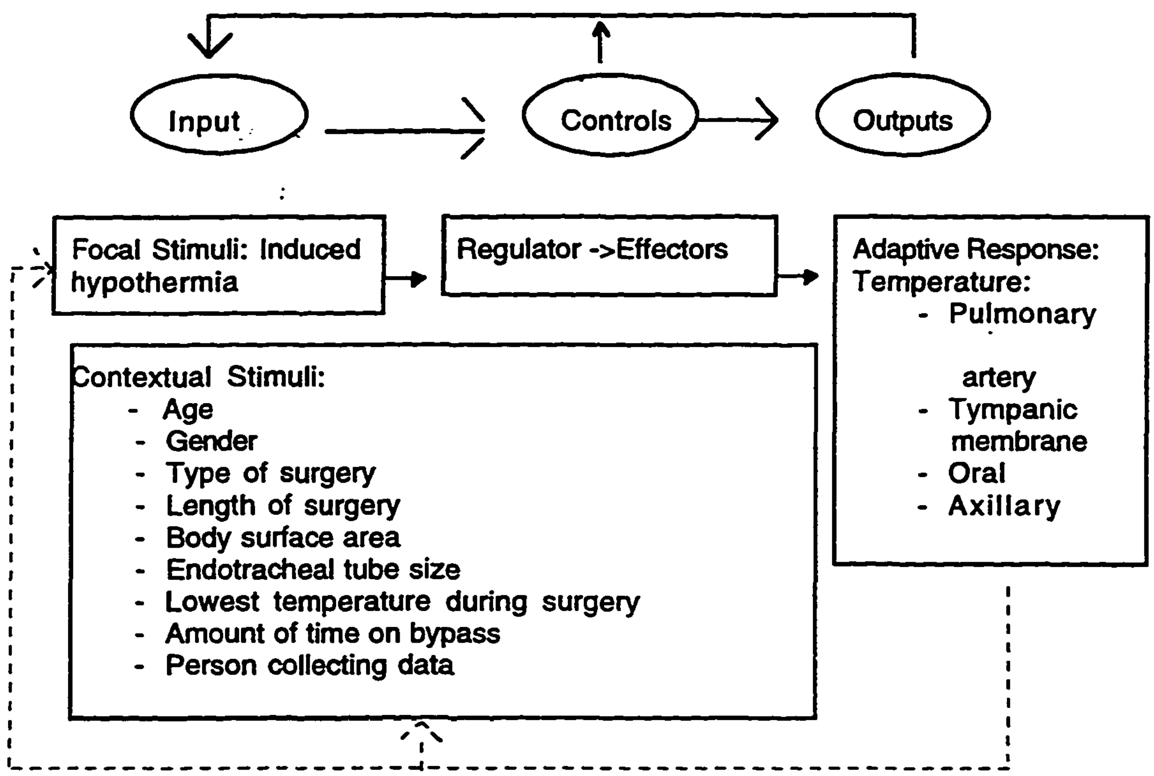

Figure 2: Diagram of the relationship between temperature measurement and Roy's Adaptation Model

Review of Literature

Studies of Temperatures in Adult Patients

In many intensive care units, nurses consider the use of rectal temperature measurements for the intubated patient to be more accurate

than oral temperature measurement (Konopad et al., 1994). These researchers used 65 patients as their own control in comparing oral, axillary, rectal, and tympanic membrane temperatures of patients that were with and without an endotracheal tube. Tympanic membrane, oral, axillary, and rectal temperatures were taken just before extubation, and shortly after extubation. Of the four temperature measurements a statistical, but not clinical, significant difference was found when measuring axillary (0.12^{0} C= 0.22^{0}F) and oral (0.08^{0} Celsius=0.15^{0}F) temperatures in patients with and without an endotracheal tube. A positive correlation was found between temperatures measured at the four measured sites (axillary, tympanic, oral and rectal). The correlation ranged from r=0.84 (axillary-tympanic) to r = 0.92 (oral-rectal). The authors concluded that tympanic membrane, oral, axillary, and rectal temperatures were accurate for patients who were ready for extubation and who were orally intubated. The presence or absence of teeth didn't affect temperature measurement in patients with an endotracheal tube. The presence of the endotracheal tube was shown to have no effect on the oral temperature measurement. Limitations to this study included the small sample size and the fact that the population was limited to patients who were ready for extubation.

Cashion and Cason (1984) stated that the rectal temperature had been traditionally the preferred temperature site for temperature measurement in an intubated patient. This measurement practice can be traced to when the mercury-in-glass thermometer required the patient to form a tight lip seal

around the thermometer and an intubated patient is unable to form the seal. The electronic thermometer was able to obtain accurate oral temperatures when the patient' s mouth is open, so the old practice needed to be re-evaluated. The authors used a convenience sample of 17 patients hospitalized for coronary artery bypass grafting. Preoperative oral and rectal temperature measurements were taken the day before surgery, and then repeated in 15 minutes. After the patient had coronary artery bypass graft surgery the patient had oral and rectal temperatures measured every hour for 5 hours (total of 6 readings). The results showed that with hypothermic patients the rectal temperature lagged behind oral temperature by between 0.420 and 0.667° F. (0.23-0.36° C) throughout the five hours after surgery with the exception of the third postoperative hour. The authors concluded that oral electronic temperature measurements on orally intubated patients were clinically accurate.

Fallis et al. (1994) used a convenience sample of 33 adult post open heart surgical patients to determine the accuracy of oral temperatures in adult critical care patients who were orally intubated. Oral, rectal, and the room temperatures were measured twice at one-half hour intervals the evening before surgery when subjects were not intubated and three times over an 8-hour periods after surgery while the subjects were intubated. Temperatures were taken 1, 4, and 8 hours postoperative. The pulmonary artery temperature served as a reference while the patient was intubated. The study supports the accuracy of oral temperatures in critically ill patients who were

intubated. The mean oral temperature measurements were not statistically ($p>0.05$) different from the mean pulmonary artery temperature measurements at any of the three measurement times after intubation. The oral temperature was not significantly affected by the temperature of the air flowing through the endotracheal tube. However, a significant difference ($p=0.0001$) between rectal temperatures and oral temperatures was observed in both subjects with and without an endotracheal tube. The rectal temperature increased at a slower rate than the oral and pulmonary artery temperatures. The researchers concluded that there was close agreement in oral and pulmonary artery temperature measurements of adult critical care patients who were orally intubated during the 8-hour period after open-heart surgery.

White et al. (1994) compared temperature measurements using a pulmonary artery catheter and a tympanic membrane thermometer. The researchers obtained 5 measurements on 19 postoperative cardiovascular surgical patients. The patients had undergone surgery that varied in duration from 3 hours and 45 minutes to 10 hours. All the temperature readings were obtained between 6 and 24 hours after surgery to allow for adequate re-warming time. Each subject served as his/her own control so that factors such as age, time of day, or presence of fever did not have to be accounted for. Age, room temperature, intubation status, time post surgery, and position were recorded. The researchers had two nurses take temperatures with two different thermometers in the same order: right ear: Thermometer 1, left ear:

Thermometer 1, right ear: Thermometer 2, and Left ear: Thermometer 2. The tympanic temperature was significantly different from the pulmonary artery temperature except from Thermometer 1 in the right ear. The researchers felt the differences in the ears were because the first reading was done when the thermometer was just taken off the charger and had a fresher battery. The tympanic thermometer measurements tended to be higher than the pulmonary artery catheter, but the differences were statistically, but not clinically significant. The researchers found differences between the right and left ear, but stated the differences were probably due to poor measurement technique. The researchers concluded that when the correct technique is used, than the tympanic temperature readings are clinically accurate.

Erickson and Kirklin (1993) used a convenience sample of 38 adult subjects with an indwelling pulmonary artery catheter to compare tympanic membrane, bladder, oral and axillary temperatures. Temperatures were taken every 20 minutes for four hours. The mean tympanic membrane temperatures fluctuated about 0.2° C. (0.37°F.) from the pulmonary artery core temperatures, but had more variability than bladder or oral methods. The axillary temperature readings were substantially lower (-0.68° C. [-1.26°F.] plus or minus 0.57° C. (1.05°F) than the pulmonary artery temperature and had high variability. Bladder temperatures correlated well with pulmonary artery values. The subjects in the sample were all cardiac patients. Some of the patients had undergone coronary artery bypass surgery. All but one of the subjects had a respiratory device. Patients who received warmed gases by an endotracheal

tube had more positive temperature offsets than patients who had unheated, less invasive cannula or mask. Unlike the previous mentioned studies, this study suggests that the presence of an endotracheal tube affects the oral temperature measurement.

Klein et al. (1993) compared the temperature measurement taken from the pulmonary artery, the tympanic membrane, and the rectum (using a calibrated glass mercury thermometer). The researchers used a convenience sample of 128 adult patients admitted to a surgical intensive care unit with an age range of 18 to 90 years old. If the patient had a pulmonary artery catheter, the researchers measured the pulmonary artery temperature and the rectal temperature. If there was no pulmonary artery catheter, the researchers measured the rectal and tympanic membrane temperature. They found that the rectal and tympanic membrane temperatures had a moderate correlation (r=0.525). The pulmonary artery and tympanic membrane temperatures highly correlated (r=0.909). The authors suggested that the tympanic temperature measurements would be an appropriate substitute for the pulmonary artery temperature. The authors also suggested in order to effectively track temperatures in a particular patient, the site for temperature measurement must be consistent.

Mravinac, Dracup, and Clochesy (1989) studied 55 adult hypothermic post-cardiac surgery patients using pulmonary artery, rectal, and urinary bladder temperatures. The subjects' temperatures were measured within one hour of admission to the cardiac surgical intensive care unit and then on an

hourly basis until they were normothermic (37º C=98.6ºF). Correlation of pulmonary artery and urinary bladder temperatures ranged from 0.78 to 0.94. The correlation of pulmonary artery and rectal temperatures ranged from 0.49 to 0.82. The correlation between urinary bladder and rectal temperature ranged from 0.46 to 0.85. During the hypothermic period, the pulmonary artery temperature readings were the highest, followed by the urinary bladder temperature measurement, and followed by the rectal temperature. The mean differences never exceeded 0.5º C. (0.9ºF.) during any point in the data gathering. The authors did not discuss how long it took for subjects to become normothermic. Oral temperatures were not measured.

Stone, et. al. (1995) studied 27 subjects who had cardiopulmonary bypass and were placed into a deep hypothermic circulatory arrest to have cerebral aneurysms surgically clipped. Brain temperatures were directly measured with a thermocouple embedded in the cerebral cortex. Temperature measurements were taken six times during surgery, and temperature measurement sites were compared with the brain temperature. "During rapid temperature change nasal pharyngeal, esophageal, and pulmonary artery temperatures corresponded to the brain temperature with smaller mean differences than those of the tympanic membrane, bladder, rectum, axilla, and the sole of the foot" (p. 344). The authors stated that the difference between brain temperature and the pulmonary artery temperature was because the cold cardioplegia and the flooding the thorax with iced saline altered the temperature disproportionately. The authors made a recommendation to

monitor temperatures from 3 sites to more accurately reflect the brain's temperature. As stated earlier, the pulmonary artery temperature has been considered the ideal method for temperature measurement. This article supports the need for more research on methods of temperature measurement

Articles Comparing Temperatures

Wells, King, Hedstrom, and Youngkins (1995) reviewed 19 studies that compared tympanic to oral, rectal, or core temperatures. The authors stated studies were not completely consistent in terms of accuracy, sensitivity, and specificity, but they do provide some direction for clinical care. Tympanic membrane temperatures correlated to oral r=0.57 to 0.90. In most studies the tympanic temperatures were lower than the rectal or oral temperature with a difference between tympanic and rectal temperatures of between -0.2 to 1.2°C. (0.4-2.2°F.). However, the tympanic temperatures were consistently lower, which suggest a lower temperature standard might be developed for the clinical use of tympanic membrane thermometers. The use of the ear tug in taking tympanic temperatures had a higher correlation in most studies. Some of the studies reviewed reported reduced sensitivity of tympanic membrane temperatures in children with high fevers (above 39° C =102.2°F.). Wells et al. suggested if tympanic membrane temperatures are above 38° C (100.4°F) the readings should be repeated with oral or rectal thermometers. This review supports the need for more research on temperatures.

Heidenreich et al. (1992) assessed which factors were associated with the fall in core temperature (afterdrop) following cardiac surgery. Variables that were measured included: age, body surface area, length of surgery, time since the end of surgery, temperature at the end of surgery, postoperative temperatures, and the amount of temperature fall in the postoperative period. Another purpose of the study was to determine the relationship between the methods of measuring temperatures. The sample size was 25 post-cardiac surgery patients. These researchers measured core temperature using the pulmonary artery, the bladder, and esophageal sites. They also measured noninvasive temperatures using oral and axillary electronic thermometers, and a forehead surface temperature indicator. Temperatures were recorded every 10 minutes for 2 hours. Factors that had a positive effect on afterdrop included age, and end-of-surgery temperature (the older the patient, or the warmer the patient the greater the afterdrop). Body mass had a negative effect on afterdrop (the larger the patient the less the afterdrop). This study suggested that re-warming patients as soon as the surgical case was completed had only a local and transient effect. The findings of the study suggested that none of the noninvasive temperature measurement instruments resulted in a regression coefficient that would indicate a valid measure of the core temperature. The researchers suggested that the reason for this is because for the hypothermic patient there is a true difference between the core temperature and the temperature of the mouth, axilla, and skin due to peripheral vascular constriction. The researchers found that the tympanic

membrane thermometer did not correlate with the core temperature (r ranged from 0.26 to 0.66). The authors stated that during surgery the bladder temperature and esophageal temperatures had a correlation of 0.91 with each other. The authors concluded that for the hypothermic patient, or patients undergoing rapid temperature fluctuations, the invasive core temperature measure (pulmonary artery, bladder, and esophageal sites) may be the only valid temperature measurement rather than the non-invasive sites (oral, axillary, and forehead surface).

Other Pertinent Studies

Romano et al. (1993) compared two brands of tympanic membrane thermometers, a digital axillary temperature, and an indwelling rectal probe in 20 pediatric patients requiring pulmonary artery catheter monitoring in an intensive care unit. For the sample, the rectal probes reflected core temperatures better than axillary measurement and both infrared tympanic thermometers. This article used a mean bias and variability for each method of estimating core body temperature when compared with pulmonary artery temperatures. The authors defined bias as "the systematic distortion of a statistical result. Ideally, the mean bias for each method should be zero, meaning that on average, there is no difference in temperatures measured by either method" (p. 1184). From the mean bias, the authors predicted the variability, which they defined as the standard deviation of the bias. The higher the variability the less confidently one can predict the core temperature from the other temperature site. The mean bias of the pulmonary artery compared

to rectal was 0.07ºC. (0.13ºF.) with a variability of 0.32ºC. (0.58ºF.); axillary 0.69ºC. (1.2ºF.) with a variability of 0.60ºC. (1.08ºF.), First TempOne -0.06ºC (-0.11ºF) with a variability of 0.58ºC (0.1.0ºF.), and Thermoscan -0.13ºC. (0.23ºF) with a variability of 0.39ºC. (0.70ºF). Even though the tympanic thermometers are cost effective because they save time in taking temperature, the researchers concluded that the tympanic membrane temperature would be preferable to the axillary temperature, but they should not replace the current core methods (pulmonary artery or rectal methods) of temperature monitoring.

Besides studying the accuracy of temperature measurement other studies concerning temperature have been done. Several studies researched the best method for re-warming patients after cardiac surgery. One of the studies by Murakami (1995) compared the temperatures of 32 patients who had undergone cardiac surgery and who were mildly hypothermic, and who were re-warmed using with either a fluid-filled circulating blanket (active-conductive external re-warming) or a reflective blanket (passive-reflective external re-warming). During the re-warming process seven subjects experienced core temperatures of greater than 38.3°C (100.9°F) during the 8 hours after the reflective blanket was removed . This increased the metabolic rate which increased the myocardial oxygen demands. It is essential to detect accurate temperature changes in patients that have undergone coronary artery bypass surgery, and to measure using the least invasive method that will provide accurate results.

Giuffre, Heidenreich, and Pruitt (1994) compared the time to re-warm hypothermic postoperative cardiac surgery patients treated with a forced air warmer or a non-infrared radiant heater. The subjects heated with forced warm air had significantly higher skin temperatures, lower incidence of shivering, and less severe afterdrop, suggesting that re-warming in these patients resulted from heat gained from the environment. This study suggests that in the hypothermic patient the core temperature is dependent on the current core temperature and the blood returning to the heart. Instead of disregarding the peripheral temperatures, these temperatures should be measured, and that measurement should be accurate.

Another study by Spaniol, Bond, Brengelmann, and Pozos (1994) found that lower skin temperatures were significantly related to shivering risk. For every 1°C. (1.8ºF.) greater skin temperature there was a decrease in the risk of shivering by approximately half ($p=.004$). When shivering initially occurs the heart rate was 13.6 beats per minute higher than without shivering. No significant difference were seen between the shivering and non-shivering groups in core temperature, age, weight, body surface area, type of anesthesia, or intra-operative temperature. The authors concluded that skin temperature, and not core temperature along with elevated heart rate predicted shivering. Shivering also may be more likely to occur in patients with a higher mean heart rate than the patients that did not shiver. The authors suggested using a thermal gradient (applying a formula which factors in both core and peripheral

sites, and then coming up with a number) between core and more peripheral sites could be used as a predictor for shivering.

Many studies discussing reliability of temperature monitoring vary in their results. Table 1 summarizes the studies done on the adult population. Table 2 contains a summary of articles related to studies which compare methods of temperature measurements. Table 3 summaries studies that relate with temperature measurement in the pediatric population.

Implications for the Study

To summarize, many studies have been done to determine the most accurate method to measure temperatures in an intubated patient. Konopad et al. (1994) concluded that the presence of an endotracheal tube did not affect the accuracy of an oral temperature. Klein et al. (1993) concluded that the tympanic measurement accurately reflected the pulmonary artery temperature measurement. However, Heidenreich et al. (1992) found that there was a true difference in noninvasive temperature measurement (tympanic membrane thermometer, oral electronic thermometer, an axillary temperature, and a forehead surface temperature) when compared with a pulmonary artery temperature when the patient was hypothermic. Some authors suggest that core temperature monitoring is the only reliable method of temperature measurement. Other authors suggest less invasive methods of temperature may be reliable. More research is needed.

Table 1

Summary of Research on Temperatures

Citation	Sample	Design	Variables and Measurement	Findings	Limitations
Konopad, E., Kerr, J. R., Noseworthy, T., & Grace, M. (1994)	65 orally intubated patients ready for extubation between 17-96 years old 17 female and 48 male	Comparison using patients as their own control of oral, axillary, rectal, and tympanic membrane temperatures with and without endotracheal tube	Used a t-test for paired samples in comparing temperatures with and without an endotracheal tube. Used analysis of variance for the effect of room temperature and endotracheal tube temperature on the oral temperature	Significant differences ($p<0.01$) were found between axillary and oral temperatures with and without an endotracheal tube. The differences of -0.12 to .08°C (0.21 to 0.14°F) weren't considered clinically important. No differences between tympanic and rectal temperatures with and without and endotracheal tube. Concluded that oral temperatures are accurate in patients with an endotracheal tube who are ready for extubation	Included patients who were ready for extubation. The authors stated the sample had a small number of neurological patients, but didn't include the diagnoses of the other patients.
Cashion, A. K. & Cason, C. L. (1984)	N=15 adult patients hospitalized for coronary artery bypass grafting in a 615 bed hospital with temperatures < 100^0 C	Analysis of variance between oral and rectal temperatures prior to and during intubation	Orally intubated patients had oral and rectal temperatures taken 15 minutes apart pre-operatively without an endotracheal tube and every hour for 6 times post-operatively with an endotracheal tube	Rectal temperatures lagged behind oral temperatures following hypothermia suggesting oral temperatures are more reliable in an orally intubated patient	Small sample

Table 1

Summary of Research on Temperatures (continued)

Citation	Sample	Design	Variables and Measurement	Findings	Limitations
Erickson, R. S. & Kirklin S. K. (1993)	N=38 Critical care unit patients in a university teaching hospital	Comparison of tympanic, pulmonary artery, bladder, oral and axillary temperatures	Repeatability was evaluated as the standard deviation of replicated measurements made at the same pulmonary artery temperature. Relationships with background variables were examined with correlation, t-test, and analysis of variance.	Tympanic membrane temperatures were a close estimate of pulmonary artery temperature but had a more variability than bladder or oral. Axillary temperatures had a wide variability and were much lower than the pulmonary artery temperature	Need to repeat on children. Need to examine the presence or absence of cerumen in the ear, and determine if straightening the ear canal will change the results.
Klein, et al. (1993)	128 adults over 18 years older in a surgical intensive care unit	Paired t-test to determine the differences in pulmonary artery and tympanic temperatures, and rectal and tympanic temperatures. Relationships were tested by using Pearson product moment correlation.	Compared rectal, tympanic, and pulmonary artery temperatures	Rectal and tympanic temperatures moderately correlated (r=0.53). Mean rectal temperatures were slightly higher than mean tympanic temperature. Pulmonary artery and tympanic temperatures correlated highly (r=0.91). Mean tympanic temperatures were slightly higher than mean pulmonary artery temperatures. Concluded: tympanic temperatures would be an appropriate substitute for pulmonary artery temperature.	No method to validate temperature measurement of the pulmonary artery catheter. Used multiple data collectors.

Table 1

Summary of Research on Temperatures (Continued)

Citation	Sample	Design	Variables and Measurement	Findings	Limitations
Mravinac, C. M., Dracup, K., & Clochesy, J. M. (1989).	N=55 hypo-thermic post cardiac surgery patients	Examined the relationships between urinary bladder, rectal, and pulmonary artery temperatures of cardiac patients after being re-warmed following induced hypothermia	Repeated measures analysis of variance. Pulmonary artery temperature served as standard for core body temperature	Correlation of pulmonary artery and urinary bladder temperature ranged from r=0.78 to 0.94. Correlation of pulmonary artery and rectal temperature ranged from r= 0.49 to 0.82. Correlation of urinary bladder and rectal temperature ranged from r=0.46 to 0.85. The researchers concluded urinary bladder temperature monitoring is a reliable indicator of core temperature during re-warming following cardiac surgery	Reference list had 15 sources--dates for references were from 1951 to 1987. The majority of the articles were written before 1980.
Stone et al. (1995)	N=27 Hypothermic patients who had cerebral aneurysm repaired	Compared eight body sites temperatures with brain temperature	Measured nasopharyngeal, esophageal pulmonary artery, brain, tympanic membrane, bladder, rectum, axilla and sole of foot temperatures.	No temperature monitoring sites accurately tracked the brain temperature	Not practical for general population since most patients do not have probes in their brains

Table 2

Articles Comparing Methods of Measurements

Citation	Sample	Design	Variables and Measurement	Findings	Limitations
Wells, N., King, J., Hedstrom, C. & Youngkins, J. (1995).	Literature review of 19 studies comparing oral, rectal, or core temperatures in children ages from 6 days old to 17 years old	Literature review	Descriptive	Tympanic temperatures moderately to strongly correlate with oral, rectal and core temperatures. However, in children <3 months old the tympanic membrane temperature was less accurate.	Compared previous studies. Did not build new information.
Heidenreich, T., Giuffre, M. & Doorley, J. (1992)	N=25 post cardiac surgery patients	Assessed factors associated with after drop (the fall in core temperature following completion of cardiac surgery) and determined the validity of noninvasive measures of temperature to predict core temperature in the hypothermic patient	Pulmonary artery, bladder, esophageal sites, tympanic, forehead, and surface temperatures were measured. Used regression coefficients measuring at 1°C (1.8°F) intervals.	Axillary r ranged from 0.17 to 0.52, oral r ranged from 0.25 to 0.65, surface r ranged from -0.04 to 0.24, tympanic ranged from 0.26 to 0.66. Tympanic temperature did not correlated with pulmonary artery temperature. True difference between core temperature, mouth, axilla, and skin due to peripheral vascular constriction in patients undergoing hypothermia. Concluded pulmonary artery temperature is the only valid temperature measurement	Sample size 25 (small)

Table 3

Other Studies

Citation	Sample	Design	Variables and Measurement	Findings	Limitations
Romano, et al (1993).	N=20 in a pediatric ICU population	Compared pulmonary artery, axillary, and rectal temperature with tympanic membrane temperatures.	Used bias and variability instead of correlation coefficient. Mean bias should be zero (meaning there is no difference between either method. Variability is measured by calculating the standard deviation of individual bias for all patients.	The mean bias and variability: Pulmonary artery vs. Rectal 0.07°C (0.13°F) Pulmonary artery vs. Axillary 0.69°C (1.24°F)Pulmonary artery vs. First Temp -0.06°C (0.11F) Pulmonary artery vs. Thermoscan -0.13°C (-0.23°F) Concluded that in a pediatric ICU population rectal probes reflect core temperature better than axillary or tympanic membrane. The Thermoscan performed in a similar to the rectal probe.	No attempt was made to assess inter-rater reliability.
Murakami, W. M. (1995).	N=32 white patients who had core temperatures of 33-35° C immediately after surgery.	Compared the effects of two external re-warming methods on body core temperatures and the rate of re-warming comparing people <65 years old and people ≥65 years old	Recorded temperatures every 15 minutes times 6 then every 30 minutes until temperature was 36.6°C (97.8°F) and then every 1 hour for eight hours. Measured the mean and standard deviation of the body core temperatures and the rate of re-warming by groups. Did a repeated measures three-way analysis of variance on core temperature.	Significant difference $p<0.005$ were found between both re-warming methods. The fluid filled blanket produced a quicker change in core temperature. Age did not significantly affect body core temperature. Age or external re-warming method did not significantly influence the rate of re-warming, although the total re-warming time was longer for those in the more advanced age group.	The authors stated that by the age categorization was too large, and may not have accounted for pre-existing physiological differences between the two groups.

Table 3

Other Studies (Continued)

Citation	Sample	Design	Variables and Measurement	Findings	Limitations
Spaniol, S. E., Bond, E. F., Brengelmann, G. L, Savage, M., & Pozos, R. S. (1994).	Convenience sample of 10 shivering and 10 non-shivering adults for hours during early recovery from cardiac surgery	Compared age, weight, body surface area, gender, intra-operative details, anesthetics, postoperative temperatures, hemodynamics and therapeutics to predict which patients shivered and which did not shiver after cardiac surgery.	Measured pulmonary artery, skin (facial, calf, and trunk) temperatures every 60 seconds. Measured heart rate and arterial pressure every 15 minutes. Cardiac output was measured 3 times. Electromyogram was recorded intermittently. Medications and treatments were noted.	Lower skin temperatures were significantly related to shivering risk (p=0.004). Heart rate was higher in patients that shivered by 13.4 beats per minute. No significant differences were noted between the shivering or non-shivering groups in core temperature, age, weight, body surface area, anesthetic agent, intraoperative temperature, surgery, circulatory bypass, or cardiac cross-clamp duration. Shivering was more likely to occur on hemodynamically unstable patients.	Well designed study

on the reliability of temperature measurement from the different sites of the body. This study helps to clarify the appropriate measurements of temperatures.

This study replicated a study by Heidenreich, Giuffre, and Doorley (1992). They studied the validity of various temperature monitoring sites' ability to predict the core temperature. This study measured the pulmonary artery, tympanic membrane, oral, and axillary temperatures of patients within 15 minutes of arriving to the cardiothoracic unit and then hourly for four hours (total of five readings) after open heart surgery. If oral temperatures or tympanic temperatures are accurate in an intubated patient this offers less invasive methods of assessing patients than using a rectai temperature if the pulmonary artery catheter is not available.

Of all the research articles included in review, only the study by Pontious, Kennedy, Chung, Burroughs, and Vogel (1994) used a conceptual framework. This study used Roy as the conceptual framework, testing Roy's conceptual framework for an adult population in a cardiothoracic unit.

Hypothesis

The hypothesis tested was that there would be no differences between tympanic membrane, oral, and axillary temperature measurements of body temperature compared to the pulmonary artery temperature in patients who had undergone open heart surgery. The

differences were analyzed using repeated measures ANOVA (analysis of variance). A t-test was used as a post hoc measure to determine where the differences were. The alpha (∂) was set at 0.01.

CHAPTER THREE

METHODOLOGY

Design

The temperature measurement of an intubated patient was a quasi-experimental design (there was no control group or random assignment of subjects). Each patient served as his/her own control. The independent variable was the induced hypothermia during cardiac surgery. The dependent variables were the measurement of temperatures in the following sites: the pulmonary artery, tympanic membrane, oral, and axillary. The pulmonary artery temperature served as the temperature to which the other sites were compared. The proposal for this study had stated that rectal temperatures were to be taken and these temperatures would be compared with the pulmonary artery, tympanic, oral, and axillary. However, the first six people that were asked to participate in the subject refused to participate stating that they felt rectal temperatures were too invasive. In order to get a sample population for the study, the researcher had to delete rectal temperatures from the study. The subjects' refusal to participate in the study because of the invasiveness of rectal temperatures supported the need for research determining the accuracy of less invasive methods of temperature measurement.

After open heart surgery within fifteen minutes of arriving to the cardiothoracic unit tympanic membrane, oral, axillary, and pulmonary artery

temperatures were taken. These temperatures then were taken every one hour for four additional hours (total of five sets). The cardiothoracic unit was a specialized area to which patients go following major heart or lung surgery. Instead of going to a recovery room patients went directly to this unit and stayed in this unit until they were stabilized, off the ventilator, and no longer in need of intensive monitoring.

The empirical indicators were the temperatures measured with the thermometers. The same IVAC II thermometer was used for the oral and axillary temperature using different probe covers, but the same probe. The same tympanic thermometer was used for all tympanic measurements.

Temperatures (pulmonary artery, tympanic membrane, oral, and axillary) were recorded within 15 minutes after the patient arrived to the cardiothoracic unit, and one, two, three, and four hours after surgery. Appendix A contains the data that was collected.

Sample and Setting

The subjects for this study were a convenience sample of 30 patients taken from those patients who underwent planned (not emergent) open heart surgery at Munson Medical Center, a regional referral hospital in northern Michigan. The subjects were adults (21 years or older), who spoke and read English and could give informed consent The subjects were intubated after surgery. Subjects were free from cardiogenic shock, frequent and uncontrollable ventricular dysrhythmias, and had no known oral pathology. Data collection would have been terminated if the patient had been on the

intra-aortic balloon counterpulsation pump, or if the subject need to return to the operating room after surgery. None of the subjects who had given informed consent needed the balloon pump, or needed to return to surgery.

Procedure

After the patient was placed on the surgical schedule, the investigator contacted each patient prior to the surgery. Some of the sample came to the hospital the day of surgery and some of the sample were hospitalized prior to the surgery. The investigator explained the study, and asked the patient to participate in a research project which would compare different temperature measurement methods while the patient was on a breathing machine after having open heart surgery. Each of the subjects was assured that if he/she does not wish to participate in the study, this decision would not impact any care received in the hospital. The investigator gave each patient an explanation of the study and a consent form. The explanation of the study contained information about why he/she was selected, the benefits and risks, and what the participation entails (see attached cover letter and consent form in B and C respectively). The letter was based on an eighth grade reading level which was the standard for patient reading material at the data collection site. The researcher's computer program analyzed the reading level of the written material. The proposed letter in Appendix B has a reading ease of 8.3 grade.

The investigator offered to share the results of the study with the patient as a reward for participating in the study. The investigator continued

to ask subsequent patients until the investigator had a total sample size of 30 patients.

After surgery the patient went to the cardiac thoracic unit. This unit was staffed by a small group of nurses, who were recruited to assist with data collection. The nurses were given in-service education on the procedure to be used for data collection of the temperatures. Because of the nurses' experience in taking temperatures, and their high qualifications to work in the cardiothoracic unit, inter-rater reliability was not tested.

Methods. All temperature measurements (pulmonary artery, tympanic membrane, oral, and axillary) were taken within 5 minutes of starting the measurements. The temperatures were measured at an interval level, which allows numbers to be added, subtracted, multiplied and divided (Talbot, 1995). The temperatures were taken within fifteen minutes after the subjected arrived in the cardiothoracic unit, and then every hour after for four hours (total of 5 measurements per subject).

The order of temperature recording was: tympanic membrane, oral, axillary, and then pulmonary artery. This order provided a method of rapid measurement so the time between measurements would take no more than two minutes.

Temperature measurement is considered a routine procedure in patient care. This study did not increase the risk to the patients in the hospital setting.

Instrument. The oral, and axillary temperatures were measured using the same IVAC II electronic thermometer. The oral temperature was measured

using an oral probe of an electronic thermometer with a slow slide technique into the left posterior sublingual pocket (located at the base of the tongue where it joins the floor of the mouth). "To do this the probe is inserted at the gum line behind the lower central incisors and slowly slid along the gum to the back of the mouth, taking 4 to 5 seconds to reach the posterior sublingual pocket. This facilitated pre-warming of the probe" (Cashion & Cason, 1984).

To measure the tympanic membrane temperature the same WelchAllen 9000 series tympanic membrane thermometer was used for every measurement. The ear canal has a temperature gradient. The canal is warmest at the tympanic membrane and coolest at the auditory meatus. The ear canal radiates energy in proportion to its temperature in the form of electromagnetic waves. Infrared ear thermometers (often called tympanic membrane thermometers) detect this thermal radiation (Erickson & Woo, 1994). The tympanic membrane thermometer offers an almost instantaneous temperature reading without contact with mucous membranes. This study used an adult sample, so the pinna of the ear was pulled back "to straighten out the cartilaginous canal and improve the view of the infrared ear membrane where the temperature is the warmest" (Erickson & Woo, p. 184). Since the tympanic thermometer can mathematically convert the temperature reading to the oral or rectal equivalent, the thermometer was set on the oral setting. When this researcher attempted to measure the calibration of the thermometers before beginning temperature measurements the oral mode had closer readings to the mercury-in-glass thermometer than the core mode. So, the oral mode was

used for the data collection. Table 4 contains the results of the calibration tests.

An axillary temperature was measured using an IVAC II electronic thermometer. The thermometer tip was pointed towards the person's head. This maintained proper position of the thermometer against blood vessels in the axilla (Perry & Potter, 1990). The investigator found nothing in the literature discussing the use of same probe cover for repeated measurements affects on temperature measurement. To be consistent for each measurement a different probe cover was used.

The pulmonary artery temperature was taken from "an indwelling thermistor tipped pulmonary artery catheter" (Fallis, Gupton, & Kassum, 1994, p. 300). The temperature was recorded from the cardiac monitor screen after checking and making sure that the transducer was zeroed for a normal pulmonary artery (PA) wave form. Two different brands of pulmonary artery catheters were inserted prior to surgery. One brand was the Abbot critical care thermodilution 8 French 5 lumen thermodilution catheter. The other brand used was an 8 French extraport fiberoptic pulmonary artery catheter model number P7100 EP 8 H.

Space was left on the data collection sheet for additional comments if residual stimuli were identified. No comments were offered on the data sheets.

Validity of the instrument. In the study by Fallis, Gupton, and Kassum (1994) the validity was tested by using the same thermometer which had interchangeable oral and rectal probes. The thermometer was placed in the

measurement mode and tested against a glass thermometer in a "well stirred water bath".

To test the reliability of the thermometers for this study, a Becton Dickinson basal mercury-in-glass thermometer was used as a control to compare the WelchAllen tympanic membrane thermometer and the Ivac II thermometer. Water was placed in an insulated cup, and temperature readings were taken at different temperature settings. Initially, the Diatek tympanic membrane thermometer was placed in the mode to convert the number into a core value. With this setting, the Diatek temperature reading was between 1.7 to 2.9º F (0.92-1.57ºC) higher than the mercury-in-glass thermometer. Some of the differences between the two readings can be explained by the fact that on the core more setting, the Diatek thermometer automatically converts the oral temperature the same temperature that would have been obtained if the reading was taken by a pulmonary artery catheter. The setting was then changed to the oral mode, which would calculate the temperature to the oral equivalent by a mathematical computation. The Diatek thermometer measured 0.1 to 2° F. (0.05-1.08ºC.) higher than the mercury-in-glass thermometer. Because of the wide variance of temperatures, readings were taken on human subjects. When the Diatek thermometer was on the oral mode there was no variation between the mercury-in-glass thermometer and the Diatek thermometer. When the Diatek thermometer was changed to the core setting than the Diatek measured 1.7 °F (0.92ºC.) higher than the mercury-in-glass thermometer. This higher value was attributed to the automatic mathematical

calculation that the thermometer makes when it converts the oral value to what the value would read if it was taken via the pulmonary artery. For the study the oral mode was used since this matched the mercury-in-glass reading.

The same methods were used to measure the reliability of the Ivac II thermometer which was used for oral and axillary readings. This thermometer had an oral and rectal probe, and the reliability of each probe was tested. The difference between the two methods of measurements ranged between 0.2 to 0.5°F (0.17-0.29ºC). Since the temperature had such a wide range when placed in water the instruments were tested on human subjects. Comparing the oral

Table 4

Reliability Results (in Degrees F.)

Source of Measurement	Becton Dickinson Mercy-in-glass	Diatek Tympanic Membrane	Ivac II Oral Probe	Ivac II Rectal Probe
Water in Insulated cup	96.7	98.4 core setting	97.1	96.9
Water in Insulated cup	98.3	101.2 core setting	98.4	98.4
Water in Insulated cup	98.7	100.5 core setting	99.1	99.2
Water in Insulated cup	96.2	96.3 oral setting	96.3	96.1
Water in Insulated cup	96.3	96.3 oral setting	96.0	96.3
Water in Insulated cup	97.7	99.7 oral setting	98.2	98.0
Water in Insulated cup	98.7	99.9 oral setting	98.8	98.9
Human subject oral measurement	97.7	97.7 oral setting	97.6	97.5
Human subject oral measurement	98.4	100.1 core setting	98.7	98.6

and rectal probes, there was a 0.1°F (0.06°C) difference between the probes. Table 4 contains the results of the measurements obtained dealing with the reliability of the thermometers.

External validity. The patients in this study were hypothermic and had undergone open-heart surgery. Patients with other disease conditions may have different amounts of vasoconstriction, which may not give the same results. This study may not be generalized to patients who are intubated with other disease conditions that affect the peripheral vascular resistance (e.g. septic shock, cardiogenic shock, and severe burns). Additional studies should be done on subjects with other medical conditions.

Sample Description

The sample size consisted of 30 subjects, 21 of the subjects were male (70%) and 9 of the subjects were female 30%). The age range was from 34 years old to 84 years old with a mean age of 63.2 years old and a standard deviation of 12.3. Table 5 shows a summary of the age, height, and weight. Table 6 shows the types of surgeries that the subjects underwent. Table 7 demonstrates the lowest recorded bladder temperature of each subject. This temperature was measured while the patient's heart was stopped and the subject was on the coronary artery bypass machine, which serves as a pump to drive blood through the patient's body. The bladder temperature is used during sugary, since the heart is stopped and the pulmonary artery measurement is not reliable, because the blood is being bypassed from the heart to the bypass machine.

Figure 3 demonstrates the relationship of the mean temperatures at the various time intervals. The graph demonstrates that there is a difference between the temperatures as the patient is warming, probably because of the peripheral vasoconstriction. As the patient warms, there is a smaller difference between the measured temperatures except the axillary temperature.

Table 5

Sample Demographics

Descriptor	Minimum	Maximum	Mean	Standard Deviation
Age	34	84	63	12.3
Height in inches	56	75	65	4.7
Weight in Pounds	101	250	175	39.2

Table 6

Types of Surgery

Type of Surgery	Frequency	Percentage
CABG (Coronary Artery Bypass Graft)	27	90.0
Valve Replacement	1	3.3
Valve Replacement and CABG	2	6.6
Total Cases	30	100.0

Table 7

Lowest Recorded Bladder Temperature (Degrees F)

Temperature	Frequency	Percent
87.8	1	3.3
89.6	6	20.0
90.6	1	3.3
91.4	4	13.3
93.2	15	50.0
95.0	1	3.3
95.7	1	3.3
96.8	1	3.3

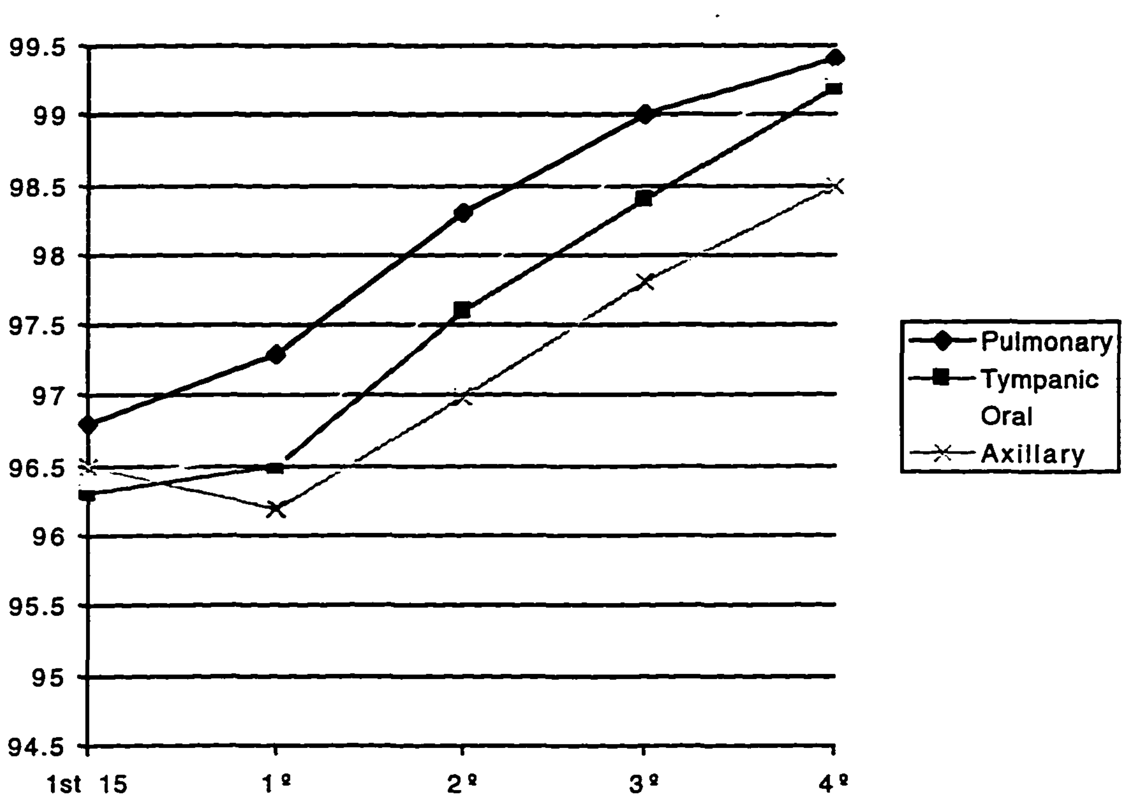

Figure 3. The relationship of the measured temperatures over time: the first 15 minutes after surgery and then every hour for 4 hours.

CHAPTER FOUR

RESULTS

.Data Analysis

A repeated measures ANOVA was done to test for a difference among the means. The F value was 24.32; and the p value was <0.001. There was a statistically significant difference between the tympanic membrane, oral, axillary, and pulmonary artery temperature. Therefore, the null hypothesis was rejected. There is a difference between the sites for temperature measurement.

A post hoc t-test was done to determine which sites were different. Table 8 shows the p-value results of the 2-tailed t-test comparing tympanic, oral, and axillary to pulmonary artery temperature. There was a statistically significant difference between tympanic, oral, axillary temperatures compared to the pulmonary artery temperature in most of the readings except within 15 minutes after surgery in all three methods of temperature measurements, and in fourth hour after surgery in the tympanic and oral temperature.

Table 9 shows the mean, minimum, maximum and standard deviation of the temperatures taken at the various intervals. The table also shows the differences between the various temperature sites when their means were subtracted from the mean pulmonary artery temperature. Both the tympanic

Table 8

T-test Results for Paired Samples of Pulmonary Artery Compared to Tympanic, Oral, and Axillary Temperatures in (N=30)

Time	p	t-value	Degrees of Freedom (n-1)
Within 15 min. Post-op			
Tympanic	0.012	2.68	29
Oral	0.029	-2.30	29
Axillary	0.097	-1.71	29
One hour Post-op			
Tympanic	<0.001*	-4.50	29
Oral	<0.001*	-4.47	29
Axillary	<0.001*	-6.62	29
Two hours Post-op			
Tympanic	<0.001*	-5.10	29
Oral	0.001*	-3.67	29
Axillary	<0.001*	-12.16	29
Three hours Post-op			
Tympanic	<0.001*	-5.06	29
Oral	0.002*	-3.33	29
Axillary	<0.001*	-7.64	29
Four hours Post-op			
Tympanic	0.045	-2.10	29
Oral	0.119	-1.61	29
Axillary	<0.001*	-8.07	29

Note. Asterisk indicates areas having a significant difference with p=0.001.

membrane and the oral temperatures were within 0.3°F (0.16°C) of each other. The mean oral temperature was always higher than the mean tympanic membrane temperature, except for the first hour post-operative. The differences in the means between the pulmonary artery and the tympanic temperature ranged from 0.24° to 0.71° F (0.13-0.38°C). The differences between the means of the pulmonary artery and the oral temperature varied between 0.14 and 0.58 °F (0.08-0.31°C). The differences between the means of the pulmonary artery and the axillary temperatures varied from 0.34 to 1.25°F (0.18-0.68°C). The differences were greatest when the subjects were warming up following surgery during the first and second hours post-operative. The differences were smallest within the first 15 minutes after surgery and after the patient was warm in the fourth hour after surgery. This difference could be measuring the effect that vasoconstriction has on the body, and the true might be a combination of both the peripheral and core temperatures..

Although, there was a significant difference between the pulmonary artery and the other readings (tympanic, oral, and axillary), the only clinically significant temperature differences were with the axillary temperature.

When the mean tympanic temperature was compared with the mean oral temperature, no significant difference was found at any point of time between the tympanic and oral temperature. Table 10 shows the results of the t-test for the tympanic and oral temperatures.

Table 9

Temperature Means (N=30) and Mean Difference (Mean Pulmonary Artery Minus the Mean Temperature [°F])

Time	Mean	Minimum	Maximum	SD	Mean Difference
Within 15 min.					
Pulmonary	96.8	95.2	99.6	1.1	0
Tympanic	96.3	93.7	98.2	1.2	0.5
Oral	96.4	93.5	98.1	1.1	0.4
Axillary	96.4	92.8	98.6	1.2	0.3
1 hour post-op					
Pulmonary	97.2	95.2	99.7	0.9	0
Tympanic	96.5	94.4	98.6	1.2	0.7
Oral	96.2	93.9	98.3	1.1	0.6
Axillary	96.2	92.9	99.3	1.2	1.0
2 hours post-op					
Pulmonary	98.3	95.9	100.4	1.0	0
Tympanic	97.6	95.0	99.8	1.1	0.7
Oral	97.8	94.6	100.4	1.4	0.5
Axillary	97.0	93.5	99.9	1.1	1.3
3 hours post-op					
Pulmonary	99.0	97.0	100.8	0.9	0
Tympanic	98.4	96.3	100.4	1.0	0.7
Oral	98.7	96.0	101.1	1.0	0.4
Axillary	97.8	95.0	100.3	1.2	1.2
4 hours post-op					
Pulmonary	99.4	97.7	101.8	0.9	0
Tympanic	99.2	96.9	101.5	1.0	0.2
Oral	99.3	97.4	99.2	0.9	0.1
Axillary	98.5	96.8	100.4	0.8	0.9

Table 10

T-test Results Between Tympanic and Oral Temperatures (N=30).

Time	p-value	t value	Degrees of Freedom
Within 15 minutes Post-op	0.483	-0.71	29
One hour Post-op	0.492	-0.70	29
Two hours Post-op	0.221	-1.25	29
Three hours Post-op	0.063	-1.94	29
Four hours Post-op	0.512	- 0.66	29

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Relationship of Findings to the Conceptual Framework

Roy and Andrews (1991) defined person as the recipient of nursing care. In this study, person included female and male subjects over the age of 21 who underwent open heart surgery.

The environment was defined by Roy and Andrews (1991) as a constantly changing internal or external stimuli which act upon the person. For this study the environment included the external conditions such as the operating room, and the intensive care unit, the blankets covering the patient, the intravenous fluids infusing into the patient, the cooling solutions used to decrease the temperature of the patient, and many other stimuli that affected the person. The environment is categorized as focal, contextual, and residual. The focal stimuli triggers an adaptive response. The focal stimuli was the induced hypothermia during open heart surgery. Contextual stimuli measured included: the patients' age, gender, type of surgery, length of surgery, body surface area, endotracheal tube size, the lowest temperature recorded during surgery, the amount of time on bypass, and the person collecting the data. The factors were used in the sample description, but statistical analysis was not done to determine their what impact had on the temperature measurements. This could be done in future research.

According to Roy and Andrews (1991) an adaptive response helps the person cope with the environment. The adaptive response measured was the temperature changes as the patient recovered from open heart surgery. The temperature changes were measured using the pulmonary artery catheter and comparing the obtained reading to the tympanic, the oral and the axillary temperature. There was a significant difference between tympanic, oral, axillary temperatures compared to the pulmonary artery temperature in most of the readings except within 15 minutes after surgery in all three methods of temperature measurements, and in four hours after surgery in the tympanic and oral temperature. During the first 15 minutes, the patients had been cold for a long period of time because they were in surgery. This long period of time allowed the patient to develop a homeostasis within his/her body. During the next three hours the patient was experiencing re-warming. Warm fluids and warm blankets helped the patient to become normothermic. During this time blood flow was shifting from the cold extremities to the warmer core. The temperature differences were probably true differences between the pulmonary artery and the tympanic, oral, and axillary routes. By the fourth hour the patient was warm and homeostasis was again attained, and the temperatures showed no significant difference. Further research should be done with the time extended to see if after homeostasis was achieved if the temperatures would continue to show no significant difference. Future research needs to be done to see if given additional time for homeostasis if the axillary temperature would show no significant difference between the temperature readings.

Relationship of the Findings to Other Studies

Based on the data analysis, during rapid temperature changes as the subjects underwent rapid warming after cardiothoracic surgery the null hypothesis was rejected. There was a significant difference in the tympanic, and oral temperatures compared to the pulmonary artery temperature. Flo and Brown (1995) defined a clinically significant temperature difference as a variation of 1ºF (0.54ºC). By this definition, the tympanic and oral temperatures were not clinically different. The widest mean difference was 0.7ºF (0.38ºC) and 0.6ºF (0.32ºC) respectively, but the axillary temperature was clinically different with being 1.3ºF (0.97ºC) lower than the pulmonary artery mean temperature. However, when the subjects were not having rapid changes in their body temperatures (immediately after surgery after the subjects had been cool and in the fourth hour after surgery) then there was no significant difference between the tympanic and oral temperature compared to the pulmonary artery temperature. There was no significant difference between the axillary and the pulmonary artery temperature in the first fifteen minutes after surgery, but there was a significant difference in the fourth hour after surgery.

Fallis et al. (1994) concluded that when temperatures were taken 1, 4, and 8 hours postoperative that there was close agreement in oral and pulmonary artery temperature measurements of adult critical care patients who were orally intubated during the 8-hour period after open-heart surgery. The study by Fallis et al. agrees with the findings of this current research that

after the patient becomes warm than there is no significant difference between the oral and pulmonary artery temperature as seen in 4 and 8 hour post operative. However, Fallis et al. found no significant difference in the first post operative hour. This current research found a significant difference in temperatures in the first hour after surgery. A possible explanation is that Fallis et al. set the p value at 0.05, and the p value for this study was 0.01.

The findings from this study partially agree with the study by Konopad et al. (1994), who stated that there was a significant difference ($p<0.01$) between both axillary and oral temperatures taken just before the patients were extubated (the removal of the breathing tube) and after the patients were extubated. They stated that the difference was not clinically significant. The difference for axillary was 0.12ºC (0.22ºF) lower and the oral was 0.08ºC (1.4ºF) higher. They found no significant difference between tympanic and rectal temperatures before and after the patient was extubated. The authors conclude that oral temperatures are accurate when taken in patients who are orally intubated and ready for extubation. Since these patients were ready for extubation, they probably were not experiencing rapid changes in their temperature. The fact that the authors found a significant difference between the oral temperatures when taken before and after intubation when the patient was not undergoing rapid temperature changes and this current study found no significant difference between an oral and pulmonary artery temperature when the temperature was not rapidly changing supports the need for further research.

This study also supports the findings of Erickson and Kirklin (1993). These researchers took tympanic, pulmonary artery, bladder, oral and axillary temperatures every 20 minutes for 4 hours in critical care units. The researchers used a mean offset, where they compared the difference between the measured temperature and the pulmonary artery temperature. They found that the tympanic, bladder, and oral temperatures were all within 0.07ºC (0.126ºF)plus or minus 0.41ºC (0.74ºF). In that the axillary temperature readings were substantially lower (0.68ºC=0.12ºF) than the pulmonary artery temperature and had high variability. The researchers concluded during times of rapid temperature changes the axillary temperature should not be used for monitoring, but the other sites were a close estimate of the pulmonary artery temperature and could be used for temperature monitoring.

Applications to Practice

More research needs to be done with patients that are normothermic and have an endotracheal tube. Although, the tympanic, oral, and axillary temperatures were statistically significant different when temperatures were rapidly changing, once the subjects temperatures stabilized, there was no significant differences between the pulmonary artery temperature and the other readings. In practice a tympanic, oral, and axillary temperature does not detect rapidly changing temperatures as well as the pulmonary artery temperature. Once a temperature becomes stabilized, then the tympanic and oral temperature could be used for "routine" vital signs. Both methods of temperature measures can be used interchangeably since they provide the

same information. The axillary temperature should not be used according to the results from this study.

Limitations of This Study

One of the limitations of the study was that not all the patients that were asked to participate in the study agreed to do so. The researcher noticed that the older the patient was, the less likely the patient was willing to agree to participate. Although age was measured in this study, the results may not apply to all the patients undergoing open heart surgery, because the mean age is skewed in this study. Other limitations include the small sample size. More research needs to be done with larger sample sizes.

Another limitation was that the pulmonary artery catheter was not tested to verify accuracy. The catheters were checked for placement by x-ray, and prior to the data collection the wave form was monitored, and the calibration was done. The product insert stated that the pulmonary artery catheter was accurate over a range of 31^{0} to 43^{0} $\pm .3^{0}$C (87.8º-109.4ºF plus or minus 0.54ºF) (Murakami, 1995).

Suggestions for Future Research

During this study one of the nurses in the cardiothoracic unit commented that instead of using an axillary temperature, the nurse measures a groin temperature, which seemed to correlate best to the patient's actual temperature better than the tympanic, oral, axillary, or pulmonary artery temperature. A study should be done comparing the groin temperature to a core temperature.

Residual factors that might alter the temperature readings that were not controlled for in this study include: the room temperature in the operating room, the medications administered during surgery, the type of anesthesia, the medications given post-operatively, the site in which the medications were administered, the endotracheal tube cascade temperature, the type of re-warming (blankets, radiant heat, or fluid filled), and the length of time the patient was cooled. Further research could be done which include these factors.

Another suggestion for future research could be done is to determine if the presence of axillary hair affects the accuracy of the axillary temperature.

Suggestions for Modifications

Since the rapidly changing temperatures were not statistically significant, more research should be with a longer time interval of data collection. This researcher found statistical significance in the fourth hour of data collection. The time should be extended for more hours post-operatively to see if the temperatures continue to be statistically significant once the patient is normothermic and not undergoing rapid warming.

Conclusions

The findings of the study partially supports that oral and tympanic temperatures are accurate temperature measurements in patients who were orally intubated after open heart surgery. However, these temperatures do not reflect the core temperature during rapid changes in the patient's temperature. The oral temperature measurement requires less nursing time,

and is less distressing to the patients than the frequently used rectal temperature when a pulmonary artery catheter is not available. However, if the temperature is rapidly changing, in situations such as re-warming after open heart surgery, the oral and tympanic temperature should not be used for temperature monitoring.

Another finding from this study was that there was no statistical difference between the oral and tympanic membrane temperatures in the intubated patient. Since the tympanic temperature is easy to use, and comfortable to the patient this would be an acceptable method of temperature measurement in patients who are intubated, but no having rapid temperature changes.

The axillary temperature was statistically and clinically different from the pulmonary artery, tympanic membrane, and oral temperature, and should not be used in when a patient is intubated.

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APPENDICES

Appendix A

Data Sheet for Temperature Measurement (Adaptive Response)

Patient's Name: ______________________ Hospital Number: ____________

Subject #: _______ Gender (circle): Male Female

Height (in inches): _______ Weight (in pounds): _______

Body surface (pounds/inch): _______ Age (in years): _______

Type of Surgery (circle): Coronary Artery Bypass, Valve, Other: (specify)_______

Time on Bypass (in minutes): ______ Length of Surgery (minutes): ______

Endotracheal tube size: _______

Lowest bladder temperature during surgery: ________

	Time	Tympanic temp.	Oral temp.	Axillary temp.	Pulmonary Artery temp.
Within 15 min. Postop					
1 hr. postop					
2 hr. postop					
3 hr. postop					
4 hr. postop					

Was Mouth Care Given? Yes__ No?__
If yes when was mouth care given? (Please circle all that apply)
Within 15 min., 1 hour postop., 2 hours postop., 3 hours postop., 4 hours postop.

Was a Bath Given? Yes__ No?__
If yes, when was the bath given? (Please circle all that apply)
Within 15 min., 1 hour postop, 2 hours postop, 3 hours postop, 4 hours postop.

Was an oral gastric tube inserted? Yes__ No__
Did the patient have an oral airway? Yes__ No__

What type of core temperature measurement was used? (Please circle):
Abbott Critical Care Thermodilution Catheter
Extra Port Fiberoptic Pulmonary Artery Catheter
Urinary Bladder Catheter

Additional Data which may influence the study:

____

____

____

*Person Collecting Data Initial Each Entry:

Initials:___ Name: ______________________
Initials:___ Name: ______________________
Initials:___ Name: ______________________

Appendix B: Explanation of Study

For many years it has been felt that a rectal temperature is the only accurate method of measuring temperature for people on the breathing machine (a ventilator). I am conducting a study to determine if an oral temperature, ear, or under the arm temperature would work as well as a rectal temperature for patients that have a temporary breathing machine. Since you are going to be having heart surgery and will be connected to a breathing machine for a short time after surgery, I am asking you to join the study. Your temperature will be taken by different routes to determine the best method to take temperature.

This study will include taking your temperature for five times after surgery by four routine or standard routes: in the heart (the wire will be in place), in the mouth, under the arm, and in the ear.

If you have any questions you can call me at work: (616) 922-1246. There is an answering machine, and leave a message, and I will get in contact with you as soon as I can.

If you have questions about the human ethics with this study you can contact Professor Huizenga, Chair of the Human Research Review Committee, at Grand Valley State University. The phone number is: (616) 895-2472.

The information collected from this study will be confidential, which means that people reading the results from the study will not know who you are. The information gained will be written as a research article, which will report results as a group and not as individuals, so your identity will remain anonymous. I would be glad to share the results of the study with you. There is a consent form on the next page. If you want to receive the results, just check the space provided.

Thank you for considering this study,

Linda Walter, RN, CCRN, BSN

(616) 922-1246

Appendix C: Consent Form

I understand that this is a study comparing various ways to take temperatures in patients while patients are on the breathing machine following open heart surgery. The knowledge gained may help determine the best method for taking temperatures after surgery. I also understand that:

1. participation in this study will involve having my temperature taken by mouth, under my arm, and with an ear thermometer upon admission to my room following surgery and then every hour the next four hours (a total of five times).

2. that I have been selected for participation because I am anticipating open heart surgery.

3. it is not anticipated that this study will lead to physical or emotional risk to myself.

4. the information that is collected will be kept strictly confidential and that the data will be coded so that the identification of the individual participants will not be possible.

5. a summary of the results will be made available to me upon my request.

I acknowledge that:

I have been given an opportunity to ask questions regarding this research study, and that these question have been answered to my satisfaction.

In giving my consent, I understand that my participation in this study is voluntary and that I may withdraw at any time by telling Linda Walter without affecting the care that I receive from my physician or the staff at Munson Medical Care Facility.

The investigator, Linda Walter, has my permission to review the record of my hospital care.

I hereby authorize the investigator to release the information obtained in this study to the scientific literature.

I understand that I will not be identified by name.

I have been given Linda Walter's phone number so that I may contact her at any time if I have questions.

"I acknowledge that I have read and understand the above information, and that I agree to participate in this study."

____
Participant's Signature Date

"I am allowing Linda Walter to use the information gathered from the study".

____
Participant's Signature Date

______I am interested in receiving summary of the study results. If you are interested, please write the mailing address to where you want the results sent in the space below:

____
Name

____
Address

____
City State Zip Code