DETERMINATION OF ORAL TEMPERATURE ACCURACY

IN ORALLY INTUBATED ADULT CRITICAL CARE PATIENTS

UTILIZING ORAL, RECTAL, AND PULMONARY ARTERY TEMPERATURES

BY

WENDY M. FALLIS

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DETERMINATION OF ORAL TEMPERATURE ACCURACY IN ORALLY INTUBATED ADULT CRITICAL CARE PATIENTS UTILIZING ORAL, RECTAL AND PULMONARY ARTERY TEMPERATURES

BY

WENDY M. FALLIS

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF NURSING

DEDICATION

TO MY PARENTS, ETHEL (FRASER) AND DOUGLAS DICKSON,

WHO ALWAYS ENCOURAGED ME TO DO MY BEST

TO BRUCE,

GLENN CAMERON, AND LEANDRA MELISSA

FOR THEIR PATIENCE, UNDERSTANDING, AND SUPPORT

ABSTRACT

A long standing belief in nursing has been that oral temperature measurements are not accurate in orally intubated patients. As a result rectal temperature measurements continue to be taken on patients in the critical care area who have an oral endotracheal tube in place.

A convenience sample of 33 adults admitted for scheduled open-heart surgery was used to determine if oral temperature measurements were accurate in adult critical care patients with an oral endotracheal tube in situ. Nine females and 24 males with a mean age of 63.36 years (range 31-77 years) served as their own controls. Utilizing a repeated measures quasi-experimental design, oral, rectal, and ambient temperatures were measured twice at a one-half hour interval the evening prior to surgery when subjects were not intubated and three times over an eight hour period in the postoperative period following intubation. Pulmonary artery (core) temperatures served as a reference and were measured along with endotracheal tube content temperatures of intubated subjects.

Although a significant difference ($p = .0001$) in rectal-oral temperature discrepancy between non intubated and intubated subjects occurred, the results of the study supported the accuracy of oral temperatures in critically ill intubated patients. Mean oral temperature measurements were not significantly different ($p < .05$) from mean pulmonary artery temperatures at any of the measurement times following intubation and a mean difference of

0.008 (0.17 SD) °C was noted. This was not affected by endotracheal tube content temperature. Significant high correlations (p = .0001) between oral and pulmonary artery (r = .92 to .96) and oral and rectal (r = .90 to .96) temperature measurements also were revealed following intubation. It was concluded that oral temperature measurements, which are more convenient, less time consuming for nurses, and more importantly, less distressing to patients than rectal temperature measurements, consistently demonstrated close agreement with core temperature measurements in orally intubated patients during a thermally dynamic eight hour period.

Additional analysis of non intubated subjects revealed that age was not significantly correlated ($p > .05$) with oral or rectal temperature measurements and that oral and rectal temperatures of males were not significantly different ($p > .05$) from females.

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CHAPTER I

PURPOSE OF THE RESEARCH

Body temperature measurement, an important vital sign, is based on determining the body's internal (core) temperature and is used by medical and nursing personnel to plan patient care, indicate abnormal bodily processes, and determine treatment regimes. However, in order to be of use to health care personnel, measurement of body temperature must be accurate and reliable. Although a seemingly easy procedure, the patient's condition, the instruments available, the pros and cons of various sites, and a variety of additional factors known to affect measurements must be taken into consideration prior to temperature being monitored. Of the factors known to alter oral temperature, data is inconclusive as to the effect of oral endotracheal tube (ETT) placement on this measurement. Further research is indicated in order to support or refute the use of the oral cavity as an appropriate site for temperature measurement with orally intubated critical care patients.

The purpose of this research was to investigate the accuracy of oral temperature measurements in intubated adult patients in the critical care area. Although the literature abounds with studies that have investigated many aspects of body temperature, little research is available relating to the effect of oral intubation on oral temperature measurements.

Of the studies examined, only two were specifically undertaken to investigate this area. The conflicting statistical results of these investigations indicate that further research is required.

STATEMENT OF THE PROBLEM

Body temperature measurement is one of the most frequently performed procedures in hospitals (Wertz, 1986; Valenti & Takacs, 1981) and in critical care settings (Franceshi, 1991). For critically ill or unstable patients, body temperature measurement is an important assessment tool. Accuracy of temperature measurements is needed in order to diagnose illnesses, determine or evaluate effectiveness of treatments, and assess need for diagnostic tests or medications (Abbey et al., 1978; T. H Benzinger, 1969a; Cunha & Gobbo, 1984).

Pulmonary artery (PA) temperature is considered an accurate reference standard for body temperature (Closs, 1987; Eichna, Berger, Radar, & Becker, 1951; Poole & Stephenson; 1977). In critical care settings, PA temperature is displayed on a hemodynamic monitoring screen when a pulmonary artery thermodilution catheter is in situ. In these same settings, a long standing nursing practice has been to take rectal temperature measurements on patients who are orally intubated (Franceshi, 1991; Laurent, 1979) and who have no PA

temperature monitoring device in place. Rectal temperatures are monitored because of inconclusive empirical data to support the use of oral temperature measurements for these patients. The fact that the patient has a tube inserted into the trachea through the mouth and that the mouth frequently remains open as a result (Konopad, 1990) has led nurses to believe that oral temperature measurements may not be accurate. Additionally, oral mucosal irritation and the temperature of tube contents have the potential for altering the surrounding tissue temperature (Heinz, 1985).

Although temperature can be measured in a wide variety of body sites, the mouth, the rectum, and less frequently, the axilla are the sites most commonly used by nurses in clinical areas to obtain measurements of body temperature (Erickson, 1980a; Laurent, 1979). In recent years the tympanic membrane has been investigated as an alternative site (Erickson & Yount, 1991; Konopad, 1990; Shinozaki, Deane & Perkins, 1988; Webb, 1973) and is becoming more widely used.

Other body sites have been used to measure temperature. These include the esophagus (Cooper & Kenyon, 1957; Edwards, Belyavin & Harrison, 1978; Webb, 1973), skin (Bergeson & Steinfeld, 1974; Masters, 1980), as well as intracardiac (Earp & Finlayson, 1991; Shinozaki, Deane, & Perkins, 1988) and intravascular (Eichna, 1949) areas. Investigations into the use of the vagina (Cooper & Abrams, 1984) and the urinary bladder (Fox, Fry, Woodward, Collins, & MacDonald, 1971) also

have been undertaken.

Unless contraindicated, the oral cavity is the preferred and most frequently used site for recording temperatures (Closs, 1987; Graves & Markarian, 1980; Hardy & Bard, 1974; Heinz, 1985; Laurent, 1979). Benedict and Slack (1911) report the mouth as one of the natural cavities of the body suitable for this purpose. Oral temperature measurements are not only less psychologically distressing (Henderson & Nite, 1978; Konopad, 1990) but more hygienic (Royston & Abrams, 1982) and more convenient (Henderson & Nite, 1978; Laurent, 1979; Tandberg & Sklar, 1983) than rectal temperature measurements. However, this site is contraindicated in infants and young children, and patients who are restless, uncooperative, or with injuries or surgery to this area (Erickson & Storlie, 1973; Feldstein, 1969). At one time this site also was contraindicated for patients unable to close their mouths, however, with the introduction of the electronic thermometer, this no longer remains a concern (Erickson, 1976).

When it is not feasible for nurses to measure oral temperatures, the rectum is the site chosen as an alternative. Normally regarded as a good index of arterial blood temperature (Kuzucu, 1965), the rectum, however, has been demonstrated to reflect rapidly occurring changes in body temperature slower than the oral cavity (T. H. Benzinger, 1969b; Gerbrandy, Cranston, & Snell, 1954; Houdas & Ring, 1982; Tanner, 1951).

It has been suggested that the rectum should be used for temperature measurements only when other sites are not appropriate or practical (Blainey, 1974; Henderson & Nite, 1978). Konopad (1990) reports that the highly invasive and personal nature of rectal temperature measurements make this site much less acceptable than the oral site. The use of this site should especially be questioned for patients whose oxygenation status is already compromised (Lim-Levy, 1982). Contraindications to the use of the rectal site include trauma, surgery, hemorrhoids, fecal impaction, diarrhea, or rectal bleeding (Erickson & Storlie, 1973; Lipsky, 1986). Although at one time believed also to be contraindicated in cardiac patients for fear of reflex slowing of the heart, this practice has not been supported in the literature (Earnest & Fletcher, 1969; Gruber, 1974).

The axilla does not always provide adequate representation of deep body temperature (Abrams, Royston, Humphrey, & Wolff 1980; Closs, 1987) and is the site least favoured for body temperature measurement in adults (Erickson, 1980a). The axilla is considered to be an artificial cavity of temperature measurement (Benedict & Slack, 1911). As a result of the exposure to environmental temperatures as well as the presence of perspiration and hair, measurement of temperature at the axilla site is considered unreliable (Erickson & Storlie, 1973; Graas, 1974) and time-consuming (Benedict & Slack, 1911; Lim-Levy, 1982). Lim-Levy notes that

the use of either the axilla or the rectum for temperature measurements requires nurses to expend additional time and energy.

Determining what is "normal" body temperature has proven difficult. Temperatures vary between individuals and within the same individual at different times and at different sites. Inconsistency in defining the limits of normal body temperature is noted with lower limits of 35.8 ^{o}C to 36.4 ^{o}C and upper limits of 37.5 ^{o}C reported (Abbey, 1982; Bates, 1983). However, an internal temperature of around 37 ^{o}C (98.6 ^{o}F) is usually considered as "normal" (T. H. Benzinger, 1969b; Closs, 1987; Dubois, 1951; Houdas & Ring, 1982). As George (1965) succinctly reports, when the location changes, so does the reading. Mean differences in temperatures at various sites between individuals have been reported and contrary to popular belief, the use of a constant 0.5 ^{o}C to determine the temperature at the mouth from that taken in the rectum or the axilla has not been supported in the literature (Nichols, Ruskin, Glor, & Kelly, 1966; Sellars & Yoder, 1961).

Numerous factors have been reported that affect overall body temperature or local tissue temperature. Physiological factors known to affect body temperature such as circadian rhythm (Benedict & Slack, 1911; Conroy & Mills, 1970; Ganong, 1989), hormones such as those relating to the menstrual cycle (Bruya, 1981; Ganong, 1989; Houdas & Ring, 1982), and age (Fox, Woodward, Exton-smith, Green, Donnison & Wicks, 1973;

Thatcher, 1983) have been studied. However, no evidence could be located in the literature which attested to the fact that the normally constant variation in temperature between sites in an individual was a factor of these physiological variables.

Studies examining additional factors with the potential to influence temperature measurements in adults have been undertaken. Activity, body position, and room temperature are such factors. In addition, the ingestion of food or fluids (Breinig, 1975; Brim & Chandler, 1948; Forster, Adler & Davis, 1970; Sugarek, 1986; Verhonick & Werley, 1963), activity of the mouth such as gum chewing (Brim & Chandler, 1948; Verhonick & Werley, 1963), smoking (Bjorn, 1973; Brim & Chandler, 1948; Terndrup, Allegra, & Kealy, 1989; Woodman, Parry, & Simms, 1967), dentition (Beck & St. Cyr, 1974; Konopad, 1990), the placement of a nasogastric tube (Heinz, 1985), depth and rate of respiration (Cranston, Gerbrandy, & Snell, 1954; Durham, Swanson, & Paulford, 1986; Tandberg & Sklar, 1983); and oxygen therapy (Dressler, Smejkal, & Ruffolo, 1983; Graas, 1974; Hasler & Cohen, 1982; Lim-Levy, 1982; Yonkman, 1982) have been investigated as factors influencing oral temperature. Studies also have been undertaken to determine the effect of metabolic activity of fecal material on rectal temperature measurements (Rubin, Horvath, & Mellette, 1951).

The effect of mouth open versus mouth closed on oral

temperature measurement has been investigated indicating clinically insignificant changes in oral temperature with either alternative (Cooper & Abrams, 1984; Erickson, 1976; Jones, 1973; Konopad, 1990). Although breathing occurs through the tube and not the mouth in subjects with an oral ETT in place, the mouth frequently remains open (Konopad, 1990). The open mouth allows for the exchange, albeit to a lesser degree than with mouth breathing, of cooler ambient air in the oral cavity. Additionally, sites in the front of the mouth may be affected to a different degree than the more insulated sites in the posterior sublingual areas of the mouth. Therefore, the conclusions reached by investigators into the effect of open versus closed mouth and environmental temperatures on oral temperature, as well as site selection in the mouth must be considered. The effect of environmental temperatures and site selection in the rectum are also considerations for rectal temperature measurements (Mead & Bonmarito, 1949).

With the advent and widespread use of predictive electronic thermometers, the difficulty in determining when a final temperature had been reached, as was the case with mercury-in-glass thermometers, no longer remains a problem. Electronic thermometers are capable of signalling when end temperature measurements have been attained. As well, mouth position (open versus closed) no longer remains a crucial factor in oral temperature measurement with the use of this

instrument (Cashion, 1982; Erickson, 1976; Konopad, 1990). However, exact placement of the probe in the oral or rectal cavity becomes more critical due to its extreme sensitivity (Beck & Campbell, 1975). The use of the posterior sublingual site in lieu of the frontal area of the oral cavity for the measurement of oral temperature has been determined to result in higher temperature measurements (Cooper & Abrams, 1984; Erickson, 1976, 1980b; Wironen, 1975). Nasogastric tube insertion (Heinz, 1985) and oxygen per nasal prongs, however, have been determined to have no significant effect on oral temperature measurements (Graas, 1974; Hasler & Cohen, 1982; Lim-Levy, 1982). Further research into the effect of variables such as oxygen via mask and dentition on oral temperature measurements, as well as the effect of fecal material on rectal temperature measurements are required.

Conflicting results of studies investigating the accuracy of temperatures measured at the oral site in orally intubated patients indicate that further research also is necessary in this area. Only two studies could be located in the literature that were undertaken to specifically investigate oral temperature accuracy in intubated patients (Cashion, 1982; Konopad, 1990). Inconclusive data from these studies have resulted in the inability to support or refute the use of oral temperatures as an accurate indicator of body temperature for critical care patients with an oral endotracheal tube in place. Consequently, nurses continue to take rectal

temperatures on this population. The use of the rectum as a site for temperature measurement requires increased energy expenditure on the part of both the nurse and the patient and consumes more nursing time (Fox et al., 1971; Lim-Levy, 1982; Mercury vs Electronic, 1972). Franceshi (1991) notes that "Often critically ill patients are weak, making it difficult to position them for rectal temperature measurement. Positioning can also be a difficult task for the patient and the nurse when much apparatus is attached to the patient. An inordinate amount of time and energy can be expended obtaining a rectal temperature measurement..." (p. 227).

The use of the rectal site also results in increased physical and/or psychological stress for patients. Embarrassment, anxiety, physical discomfort, particularly in those with hemorrhoids, and potential for injury are reported (Blainey, 1974; Cashion, 1982; Konopad, 1990; Kresovitch-Wendler, Levitt, & Yearly, 1989; Lim-Levy, 1982). Intensive care patients are already under considerable stress. According to Powell and Little (1982), in intensive care settings, emotional disturbances may occur as a result of "The busy, noisy, continually lighted setting.... [and] long-term painful procedures coupled with changes in self-image..." (p. 3). Intubation is an added stressor which is compounded by the discomforts resulting from rectal temperature measurements (Giuffre, Heidenreich, Carney-Gersten, Dorsch, & Heidenreich, 1990). Therefore, any procedure that can reduce stress for

these individuals must be examined.

Lastly, the use of one site for temperature measurements throughout a patient's hospital stay results in the collection of more consistent and reliable information on which to base decisions for patient care. (Konopad, 1990; Laurent, 1979). If temperatures are recorded rectally or via the pulmonary artery when patients are intubated, and orally when extubated, "the inaccuracy in determining the individual's temperature pattern, when different instruments are used and temperatures from different sites are recorded [must be considered]." (Lim-Levy, 1982, p. 152) Cashion (1982) suggests that, in view of the fact that electronic thermometers are capable of accurately measuring oral temperatures with the mouth open, the traditional site (rectal) of temperature measurement in orally intubated patients needs to be reconsidered. Lukasiewicz (1983) in a review of studies investigating the effect of oxygen therapy on oral and rectal temperatures concluded that studies to determine the accuracy of oral temperatures on the patient with an oral ETT are needed. She states "As long as the sublingual pockets are accessible, oral temperatures on intubated patients may also reduce the time, discomfort, and hazards of rectal temperatures." (p.73) Lastly, Franceschi (1991) offers additional support by asserting that a protocol for measurement of temperature that is based on research is clearly needed in the critical care area. The study outlined herein was undertaken to assist in

establishing this protocol.

CONCEPTUAL FRAMEWORK

The conceptual framework for this research is based on physiological theory relating to regulation of temperature in humans and its application to the clinical area.

In humans, individual well-being, daily performance, and life itself depends on precise regulation of body temperature. This precise thermoregulation comes about as a result of multiple bodily inputs and temperature control mechanisms orchestrated mainly by a central temperature control centre. According to T. H. Benzinger "Against high loads of both externally or internally forced flows of heat, physiological responses produce heat flows of opposite direction and nearly equal magnitude..." thereby maintaining temperature homeostasis (1969b, p. 673).

Temperature is controlled by the central nervous system (CNS) with the hypothalamus being the main thermoregulatory body. T. H. Benzinger postulated a thermally sensitive anterior hypothalamic area, a heat maintenance posterior hypothalamic area, and an interrelationship between the two with the anterior inhibiting the posterior area (cited in Carlson, 1962).

The proposal of a "set point" for temperature regulation in the mid eighteen hundreds, with later studies to support

this, has led to the general belief that human body is regulated around a narrowly defined set temperature (T. H. Benzinger, 1969b; Bruck, 1983). Although individuals vary in the temperature at which their body is maintained (Ganong, 1989), temperature homeostasis results in a relatively constant central temperature. According to Cooper (1969b), "Only in disease is the central temperature allowed to slip far from its usual set level." (p. 1067)

The division of the body into two separate but interrelated entities, a core and a shell (Cooper, 1969b; Houdas & Ring, 1982), allows for easier understanding of body temperature. The core consists mainly of the contents of the cranium, abdominal, and thoracic areas and some of the muscles. The shell is composed of the remaining periphery but modifications to this area occur with environmental conditions (DuBois, 1951). Fluctuations in body temperature are greater in the periphery than in the core, however, temperature also varies in different organs of the body and within each organ (Houdas & Ring, 1982).

Thermoregulation of core temperature depends on a balance between heat production and heat loss. Heat production occurs as a result of muscular activity (including shivering), basal body (obligatory) metabolism, food metabolism, and in newborns, brown fat metabolism (Cooper, 1969b; Houdas & Ring, 1982). Changes in vasomotor tone (vasodilation) and sweating allow for heat loss (Cooper, 1969b). In order for body

overheating not to occur, the heat produced by the core must be transferred to the shell and then to the environment. It is through the mechanisms of conduction, radiation, convection, and evaporation that this occurs (T. H. Benzinger, 1969b; Houdas & Ring, 1982). However, heat transfer can only occur when a temperature gradient exists between the shell and its surrounding environment. When ambient temperatures are cooler than the skin, heat flows away from the body. Heat flow occurs in the opposite direction when the temperature of the ambience is higher than the body (Houdas & Ring, 1982). In this situation, evaporative heat loss then becomes the only mechanism for external heat flow.

The mechanisms used for control of human thermoregulation are both voluntary and involuntary with peripheral (skin) and core temperature receptors playing a role. The inhibition or excitation of sweating and metabolic heat production as well as vasomotor changes are involuntary CNS controlled mechanisms for temperature control (T. H. Benzinger, 1969a). Behavioral thermoregulation, a voluntary process, results from subjective sensations of heat or cold and thermal comfort or discomfort. The use of clothing, heating or cooling devices, as well as changes in posture or activity are daily behavioral actions for temperature regulation (Cooper, 1969b; Houdas & Ring, 1982).

Within the narrow limit set by the body for thermoregulation, periodic fluctuations of temperature are

noted. Body temperature oscillates rhythmically throughout an approximately 24 hour period (Conroy & Mills, 1970; Cooper, 1969b) in synchrony with external signals producing a circadian rhythm. Bodily activity (DuBois, 1951), external signals such as the earth's rotation (Aschoff, 1970), and periodic transference of heat from the body to the environment (Houdas & Ring, 1982) have been suggested as possible explanations for this phenomenon. Circadian changes result in higher bodily temperatures in the evening and lower temperatures in the early morning. Daily fluctuations ranging from 0.5 to 1.0 ^{o}C have been reported (Cooper, 1969b; Ganong, 1989).

In women, superimposed upon circadian variations in temperature is another well known rhythm, that of the menstrual cycle. A rise in basal temperature at the time of ovulation with a lowering of temperature in the postmenstrual period occurs as a result of this cycle (Cooper 1969b; Cooper & Abrams, 1984; Ganong, 1989; Houdas & Ring, 1982).

Aside from cyclical variations in temperature, other factors can result in central temperature changes. Digestion, activity, and ambient temperature are examples of these (Cooper, 1969b; Houdas & Ring, 1982). Additionally, levels of thyroid hormone secreted determine basal metabolic rate (Cooper, 1969b).

Serious imbalances of temperature regulation arise when the body cannot cope with excessive thermal loads. The result

of this is hypo or hyperthermia. In clinical settings patients at risk for this are those undergoing surgery, infants, the terminally ill, and those with extensive burns (T. H. Benzinger, 1969a) or neurological impairments of the hypothalamic area (Cooper, 1969b). The use of anaesthetic agents also puts patients at risk. Anaesthesia impairs autonomic defences as well as extinguishing the behavioral responses to heat and cold stress (T. H. Benzinger, 1969a).

Measurement of Core Temperature

Ideally the hypothalamus is the best site for core temperature measurement. However, because of the inaccessibility of this area, other sites have been sought. For routine measurement, the site chosen should preferably be insulated from the environment, easily accessible, and reflecting the temperature of the core.

Because body heat is transferred from the core to the periphery, skin temperature measurement is reflective of body temperature. However skin temperature is influenced by both internal and external conditions (Benedict & Slack, 1911; Houdas & Ring, 1982) and therefore is not considered a reliable indicator of body temperature. DuBois (1951) states that measurements of skin temperature are subject to even more error than measurements of rectal temperature. Rectal temperature measurements are most often reported as representing internal body temperature. The relative inertia

of temperatures at the rectum, however, has led to this site being questioned as suitable for body temperature measurement especially during rapid thermal changes. Similarly, oral temperature also has been considered to reflect true deep body temperature but only when conditions are strictly controlled (Houdas & Ring, 1982). Temperature measured in the pulmonary artery, as a result of mixing of venous blood from the warm viscera and cool skin at this site, is considered to reflect mean body temperature (Houdas & Ring, 1982).

Cranston et al. (1954) state that "The temperature of a tissue depends on the temperature of the arterial blood delivered to it, the local heat production, the heat exchange with its surroundings and the rate of blood flow through it." (p. 355) It then follows that erroneous measurements of central temperature can occur as a result of local factors affecting measurement sites deemed as suitable reflections of core temperature. Alterations in the temperature of tissues at a site as a result of local inflammatory conditions, activity, the introduction of cold or warm fluids either by ingestion or infusion, the local application of heat or cold, and the insertion of tubes are such factors. These factors must be taken into consideration when selecting the best site for temperature measurement in order that central body and not local tissue temperature is determined.

Application of Conceptual Framework to the Clinical Area

Although the body maintains temperature within a narrowly defined set limit, alterations in body temperature as a result of imbalances of heat production and heat loss can occur. Routine temperature measurements in clinical areas are necessary to determine when imbalances are occurring in order that appropriate action can be undertaken to correct the imbalance and/or treat the underlying cause. Conversely, body temperature may reflect whether the action undertaken has or has not been successful. In critically ill patients, an increased production of heat, reflected by an increased metabolic rate occurs (Wilmore, Brennan, Harken, Holcroft, & Meakin, 1988-92). Even small increases of central temperature result in an increased rate of oxygen consumption (M. Benzinger, 1969; T. H. Benzinger, 1969a). Therefore, the accurate monitoring of temperature and attempts to maintain it within the normal range are important.

With the inaccessibility of the hypothalamus, sites, which are not only accessible but which also reflect central temperature, must be used. Equally important is the consideration of factors that may influence the measurement of temperature at particular sites. This consideration is necessary in order to determine the appropriateness or inappropriateness of a specific locale for temperature measurement.

The insertion of an oral ETT must be considered as a

potential factor influencing measurements of central temperature taken at the sublingual site. Local changes at the site as a result of inflammatory processes leading to increased heat production, local cooling as a result of environmental influences, or temperature of tube contents influencing heat exchange are potential reasons for the sublingual site to be considered as no longer suitable for measurement of temperature once a tube is inserted. However, if it can be ascertained that the sublingual site is not significantly altered by the insertion of an oral ETT then measurements of oral temperature can continue to be considered as reflecting core temperature measurements even with this tube in place. Conversely, if it is shown that temperatures at this site are significantly altered by oral intubation then an appropriate alternative site must be selected and used.

STUDY HYPOTHESIS

The purpose of this study was to determine if oral temperatures are accurate in orally intubated patients. To determine this, the rectal minus oral temperature discrepancy of patients who were not orally intubated was compared to that of patients who were orally intubated in order to determine if a significant difference existed. The hypothesis tested was:

The discrepancy between rectal and oral temperatures of adult patients with an oral endotracheal tube is not significantly different from that of adult patients without an oral endotracheal tube.

Using PA temperature as a reference, additional analysis was undertaken for intubated subjects to determine if a significant difference existed between temperatures measured at this site and those measured at the oral and rectal sites. The stability of these differences over time also was examined.

ASSUMPTIONS

The assumptions of this study were as follows:

1. There is a positive correlation between rectal and oral temperature measurements.
2. There is a positive correlation between pulmonary artery and oral temperatures measurements.
3. There is a positive correlation between pulmonary artery and rectal temperatures measurements.
4. In the postoperative period, pulmonary artery blood temperature provides a reliable index of central temperature.
5. Determination of accuracy of the IVAC 2080A electronic

thermometer in the monitor mode assumes accuracy of the thermometer in the predictive mode.

The strength of assumptions 1, 2, and 3 was examined in this study.

DEFINITION OF TERMS

For this study, theoretical and operational definitions were:

Oral Temperature: The degree of warmth of the oral cavity determined primarily by blood flow and to a lesser extent by ambient conditions and expressed as a numerical value on some scale of temperature. Operationally defined, this is the measurement of temperature in degrees Celsius of the left or right posterior sublingual pocket of the oral cavity of a person as measured with an electronic thermometer and oral probe.

Rectal Temperature: The degree of warmth of the rectal cavity determined primarily by blood flow and expressed as a numerical value on some scale of temperature. Operationally defined, this is the measurement of temperature in degrees Celsius of the rectum, 7.5 cm past the anal verge of a person as measured by an electronic thermometer and rectal probe.

Pulmonary Artery Temperature: The degree of warmth of the contents of the pulmonary artery. This is operationally defined as the measurement of temperature in degrees Celsius of venous blood in a main branch of the pulmonary artery as measured by a thermistor on a thermodilution catheter.

Adult Patients: Those persons who have reached the age of legal responsibility and who are being cared for in a facility designated as a place for the sick or injured. Operationally defined, these are persons equal to or greater than 18 years of age admitted to an acute care hospital for an open heart surgical procedure.

Oral Endotracheal Tube: This is defined as the insertion of a hollow apparatus into the trachea via the oral cavity for the purpose of maintaining and/or protecting an open airway. Operationally defined this is the placement of a cuffed endotracheal tube into the trachea through the mouth with the external opening connected to a heated and humidified oxygen source.

SUMMARY

Temperature measurement is a frequent occurrence in critical care areas. Not all patients who are orally intubated have PA catheters in place to quickly and conveniently measure blood temperature. For patients without this device, a common practice is to take rectal temperature measurements.

The advantages of taking oral temperatures in lieu of rectal temperatures are many. Compared with the rectal site, oral temperature measurements are not only less time consuming and require less adjunct equipment (eg. lubricant, disposable gloves) but, more importantly, result in potentially less physical discomfort and psychological stress for patients. However, in order for nurses to determine if oral measurements can be relied upon as a valid indicator of body temperature in adult critical care patients who are orally intubated, further research is required. The purpose of this research was to add to nursing knowledge related to temperature monitoring in the critical care area by determining if oral temperatures were accurate in orally intubated adult critical care patients.

CHAPTER II

LITERATURE REVIEW

Literature relating to this study was searched manually and through computer indices using Cumulative Index to Nursing and Allied Health Literature (Cinahl), Medline, Canadian Directory of Completed Masters Theses in Nursing (CAMN), and Dissertation Abstracts International data bases. Body temperature, intubation, endotracheal tube, and thermometers were used as the major descriptors.

Body temperature, an index of biological function, is also an important indicator of health status. Traditionally measurement of temperature has been a nursing function (Bjorn, 1973; Blainey, 1974; Guiss, 1973). Temperature measurements are taken, recorded, and used in planning and evaluating patient care, however, the techniques used to assess temperature are usually based on individual nursing judgements or personal preference (Laurent, 1979; Yonkman, 1982).

Temperature monitoring is one of the most routine procedures performed in hospital (Valenti & Takacs, 1981; Wertz, 1986). So routine that, according to Sims-Williams (1976), there is danger of it becoming more of a ritual than a useful patient observation. She proposes that "it is time to take stock and give this apparently simple procedure a second look." (p. 481) Temperature monitoring also has been

designated as one of the simplest parameters of well being (Erickson, 1980a). However, the importance and complexity of this simple and routine measurement has not been underestimated by researchers. The literature abounds with studies relating to various aspects of body temperature and body temperature measurements both in children and in adults. As a result, guidelines were selected in order to limit the literature review. Studies included in the review had to focus on oral, rectal, and PA temperatures and relate to the following specific areas: instrument selection; placement times and sites for temperature measurement; temperature differences between sites; and inherent and extraneous factors affecting temperature measurements. In addition, literature reviewed had to pertain to thermometry in the adult population, be published in the English language, and provide supporting data for results. Exceptions were made to the latter if publications assisted in providing continuity and/or clarity to the review.

In reviewing the articles retrieved, major methodological problems such as non probability sampling, small sample sizes, and the use of individuals that were healthy often were noted. Interrater reliability was frequently not reported in studies using more than one investigator. Lack of instrument accuracy and reliability tests as well as statistical testing are additional deficits. Internal and external validity of the studies are weakened as a result of these deficiencies.

Instruments for Temperature Measurement

The use of valid and reliable instruments in a research study are important. Wood and Brink (1989) suggest that tools that have been tested for reliability and validity be used. Erickson (1980b) recommends the use of the same reliable instrument when measurements are repeated in order to allow better comparison of readings and better correlations with other clinical observations. Thermometers have long been used to measure temperatures of various objects and are considered valid instruments for this purpose. Hughes, Patterson, Thornton, Williams, Lott, and Dodge (1985) report that "The thermometer in clinical use today is basically that developed over a century ago, measuring heat conducted from skin or mucus membranes to an adjacent probe." (p. 301)

Although subjective observation of body temperature have been used since time immemorial, the accuracy of this method of temperature measurement has not been supported (Bergeson & Steinfeld, 1974) and it is only within the last century that more objective measurements have become routine (T. H. Benzinger, 1969a). Varying instruments have been suggested and tested for temperature monitoring, from liquid crystal skin temperature detectors (Allen, Horrow, & Rosenberg, 1990) to infrared thermometry (Hancock, 1987; Shinozaki et al., 1988), however, mercury-in-glass and more recently, electronic thermometers, have been the most commonly used instruments in

the clinical setting. Walker and Selmanoff (1965) report the thermometer as the first "scientific instrument" (p. 72) routinely used by nurses.

Whatever the instrument selected for temperature measurement, of importance is that it be accurate, reliable, safe, and able to provide a reading within a relatively short time period. Ease of use and cost are additional factors that must be considered (Erickson, 1980a). In specialized clinical areas such as operating rooms (OR) and intensive care units (ICU), more invasive techniques of temperature monitoring may be used. These may involve placement of temperature probes in nasopharyngeal, esophageal, or PA sites.

Mercury-in-Glass Thermometers

Traditionally, mercury-in-glass thermometers, which operate on the principle of thermoexpansion (liquids expand with increased temperature), have been used to accomplish temperature measurements. The validity of this instrument as a measurement of body temperature is well supported, however, the accuracy of it at times has been questioned (Beck & St. Cyr, 1974; Sims-Williams, 1976).

Dimonds and Andrews (1954) investigated the accuracy of 465 clinical glass thermometers tested against a reference thermometer in a constant temperature water bath. Of these, 15% were inaccurate by 0.5 to 1.0 ^{o}F, and 7% had more than 1 ^{o}F error. Variation in error below and above the standard

thermometer ranged from -1.6 ^{o}F to 3.3 ^{o}F.

Nearly 25% of 24 new rectal and 24 new oral clinical glass thermometers tested for accuracy by Puriton and Bishop (1969) were noted to be imprecise. Inaccuracies of 0.40 to 3.0 ^{o}F were reported at varying temperatures. These investigators stressed the need for an accurate temperature measurement device especially in a critical care setting. A similar inaccuracy rate was found by Beck and Campbell (1975). Abbey et al. (1978) reported over 2% of 212 new clinical glass thermometers from four manufacturers were inaccurate. After two months in use and eight months in storage, the inaccuracy rate was nearly 24%.

In addition to the careless reading of glass thermometers, which also may serve as a source of error, individual and environmental hazards related to the use of mercury-in-glass thermometers have been reported. The danger for individuals appears to be not so much from the mercury as from the broken glass. (Pugh Davies, Kassab, Thrush, & Smith, 1986). The metallic mercury used in glass thermometers oxidizes too slowly in the GI tract and therefore does not pose as a threat if swallowed (Mofenson & Greensher, 1973; Pugh Davies et al., 1986). However, Beck and Campbell (1975) note that mercury discharge to the air and sewers as a result of glass thermometer breakage could pose a threat to the environment.

Multiple studies have been undertaken to determine the

time required for glass thermometers to register body temperature. Maximum (defined as the time required for 90% of subjects to reach maximum temperature) and optimum (defined as the placement time required for 90% of subjects to reach maximum temperature less 0.2 ^{o}F) placement times for this instrument have been investigated. A difference of 0.2 ^{o}F is considered to be clinically insignificant (Nichols et al., 1966)

While a three to five minute insertion time for oral temperature measurements has been used in clinical settings and is considered to be sufficient by some investigators (Graves & Markarian, 1980), it has been determined to be inadequate by others. Nichols and Kucha (1972) in a secondary analysis of data from six investigations (N = 390) concluded an eight minute optimum oral placement time is necessary for accurate oral temperature measurements. This is further supported by Robichaud-Ekstrand and Davies (1989).

Nichols (1972a) undertook a secondary analysis of results from five investigations of rectal thermometer placement times completed by herself and cohorts between 1966 and 1972. Placement time for 90% of subjects to reach maximum rectal temperature was reported as 4 minutes with optimum placement time (N = 403) of 2 minutes.

Closs (1987), however, offers the view that it is not the instrument but the oral cavity that accounts for the source of error in oral temperature measurements. In a laboratory study

undertaken to determine the time required for a mercury thermometer to reach 37 ^{o}C in a water bath compared with the time in the left posterior sublingual pocket to reach maximum temperature in 10 healthy adults, the water bath reading reached maximum temperature in 15 seconds whereas the sublingual maximum reading required four minutes. Closs concluded that the mercury thermometer is capable of rapid registration of temperature change but that the sublingual pocket required considerable time to reach maximum temperature. The investigator further adds that "It is essential that thermometer positioning, placement time and environmental factors are all well controlled if an accurate assessment of temperature is to be made." (p.37) Similar findings were reported by Sloan and Keatinge (1975). DeNosaquo, Kerlan, Knudsen, and Klump (1944) reported a slightly longer equilibrium time of 90 seconds in a thermostatically controlled air bath at temperatures of 94 to 106 ^{o}F for oral clinical thermometers.

Electronic Thermometers

The introduction of the electronic thermometer and its subsequent widespread use have eliminated many of the problems encountered with mercury thermometers. Electronic thermometers operate on the principle of thermoresistance, that is, changes in temperature result in alterations in resistance to electrical conduction; as temperature increases,

resistance decreases (Holdcroft, 1980).

According to Health Devices ("Clinical electronic thermometers", 1972) electronic thermometers are basically composed of a probe that senses temperature and a device which reads it out. Temperatures may be computed at the probe via two means, continuous (steady state) or predicted. Steady state thermometers constantly indicate body temperature after equilibrium between the sensor and the tissue in contact with the sensor has been achieved. These thermometers, although not as dependent on operator technique, require a longer waiting time and lack indicators to tell when equilibrium has been reached. For these reasons they are infrequently used in the clinical area. Predictive thermometers are most frequently used in the clinical setting. These thermometers measure temperature at two time points and then predict a final temperature reading, requiring approximately 30 seconds to do so (Beck & Campbell, 1975; Closs, 1987; Ferguson, Gohrke, & Mansfield, 1971). An inconvenience of the predictive design circuit, unlike that of the steady state, is that its accuracy cannot be tested in a water bath (Beck & Campbell, 1975; Beck & St. Cyr, 1974). Incorporated into the design of the predictive circuit is the thermal characteristics of the measurement site and the probe covers. Testing in a medium different from that which it was designed for will produce erroneous results. However, thermometers that can be operated in either the predictive or steady state

mode can be tested in a water bath, but, this does not test all of the predictive circuitry ("Temperature monitors", 1990). Predictive thermometers also require consistent and specific standardized technique in order to ensure that measurements are accurate and reliable.

The advantages of the electronic thermometer in regard to fast response time, (Angerami, 1980; Closs, 1987; Erickson, 1976; Jones, 1973; McAlpine, Martin, Lennox, & Roberts, 1986; Sugarek, 1986; Tate, Gohrke, & Mansfield, 1970) as well as convenience to both patients and nurses (Beck & Campbell, 1975; Takacs & Valenti, 1982; Tate et al., 1970) have been described in the literature. Electronic thermometers result in less patient disturbance, increased patient safety as a result of plastic or metal probe use instead of glass, and less demands on nursing time (Guiss, 1973). Takacs and Valenti (1982) further add that they may be even more relevant in high acuity areas such as intensive care units and emergency rooms where "demands on nursing time are most crucial." (p. 370)

The extreme sensitivity of the electronic thermometer probe to detect temperature and the accuracy of this instrument also have been reported. Beck and Campbell (1975) tested six electronic thermometers (IVAC 811 and Becton-Dickinson Ace-T) for clinical study. All instruments were within $\pm 0.2\ ^{o}F$ range of accuracy required. This same degree of accuracy was reported by Ferguson et al. (1971) who tested

an electronic thermometer over a range of 95-105 ^{o}F and compared it to a National Bureau of Standards thermometer. The electronic thermometer was accurate within $\pm$ 0.2 ^{o}F (0.1 ^{o}C) over the entire range. Contributing to instrument accuracy is the fact that it can be calibrated by the practitioner (Ferguson et al., 1971; Tate et al., 1970). Errors as a result of reading the thermometer and attempting to estimate when final temperatures have been reached as in the case of mercury thermometers are decreased when electronic thermometers are used (Beck & Campbell, 1975; Lipsky, 1986). The accuracy of the instrument is reportedly not affected by the use of probe covers (Erickson, 1980b; Pugh Davies et al., 1986).

A "drawdown" effect reportedly occurs when heat is transferred from the warmer body tissues to the cooler thermometer tip (Beck & Campbell, 1975; DeNasaquo et al, 1944; Erickson, 1980b). The use of a slow insertion technique to prewarm the oral temperature probe and therefore decrease tissue cooling has been suggested (Beck & St. Cyr, 1974; Erickson, 1980b). This technique involves inserting the probe in the front pocket of the mouth and slowly moving it along the gumline toward the posterior sublingual pocket, taking four to five seconds to reach this area. Erickson (1980b) reported this technique resulted in both a statistically significant ($p < .01$) higher temperature (.05 ^{o}C) and faster response time (2.3 seconds) compared with direct placement (N

= 50). Since these results were not clinically significant, Erickson concluded that the slow slide technique be used for research purposes.

Arterial Catheter Thermistors

In critical care settings, electronic thermometers that continuously measure blood temperature are used when cardiac output or other hemodynamic measurements are required. Thermistor tipped thermodilution catheters, introduced via a central vein into a pulmonary artery, are used for this purpose. Correct placement of the tip of this catheter can be ascertained by observing an undamped PA trace on the display screen. Runciman, Ilsley, and Roberts (1981) utilized Swan-Ganz catheters in their investigation of thermodilution cardiac output measurements on animals. Six quadruple lumen Swan-Ganz catheters were tested in a constant temperature water bath between 34.2 and 43.11 ^{o}C with some catheters having been used up to 10 times each. The catheters proved accurate within a range of -0.07 to +0.08 ^{o}C. The authors concluded that the performance of this instrument was excellent and although calibration is not easy or convenient, they are not likely to be the cause of significant error. They also suggested that temperature readings be taken at the same point in the respiratory cycle in order to avoid cyclic changes in PA temperature due to respirations.

Shellock and Rubin (1982) reported an accuracy of $\pm$ 0.01

°C for Swan-Ganz quadruple lumen catheters. The number of catheters tested was not reported.

Gotchall, Comried, Bredlau, and Moseley (1989), after noting the falsely elevated temperature readings of one PA catheter (Opticath), undertook a survey of intensive care units. They reported that only 7 of 20 units routinely validated PA thermistor temperature readings with another thermometric device. Four of these performed this every shift, one performed it every four hours, and two performed it daily. These authors caution that sole reliance on one temperature monitoring device or on one site needs to be questioned and recommend that PA catheter thermistors be routinely validated with another thermometric device.

Body Sites for Temperature Measurement

Laurent (1979) reports that the site chosen for temperature taking is equally as important as the instrument used for the measurement. In the clinical area, several factors are taken into consideration in determining the best site for individual temperature measurement. Blainey (1984) succinctly lists the criteria for selecting a particular site:

- its proximity to major arteries
- its insulation from such external influences as eating, drinking, or smoking
- the absence of inflammation

- the degree of precision required
- the patient's overall status
- the patient's age. (p. 1859)

Cooper et al. (1964a) suggest as requirements a site that is not influenced by changes in environmental temperature or local blood flow; where measurements are convenient, produce no harm or pain; and that reflects quick and quantitative changes of the arterial blood temperature. Finally, Bruck (1983), reports that since changes in temperature over time are what is important, finding a site that is accessible and represents body core but that also produces little variation in temperature as a result of instrument placement is, for all practical purposes, what is needed.

Pulmonary Artery

The temperature of blood within the pulmonary artery closely parallels the temperature of the blood perfusing the brain. (Holtzclaw, 1992) It is the site for all returning venous blood and has traditionally been considered the best reflection of core temperature (Closs, 1987; Eichna et al., 1951; Poole & Stephenson, 1977). The temperature of blood in the heart is composed of temperatures of blood from both the periphery and from the central parts of the body. (Carlsten & Grimby, 1958; Milewski, Ferguson & Terndrup, 1991) Erickson and Yount (1991) report PA temperature as the 'gold standard' for comparison of temperatures. However, measurement at this

site necessitates that hemodynamic monitoring be required and a central catheter be inserted, therefore only selected critically ill patients will receive or require this.

Rectal Cavity

In everyday practice, the rectum has been viewed as the optimum site for base-line observations or when core temperature assessment is needed (Benedict & Slack, 1911; Eichna et al., 1951; Grayson, 1951; Nadel & Horvath, 1970). Rectal temperature also is viewed as more accurate than oral or axilla temperatures (Blainey, 1974; Feldstein, 1969; Grayson, 1951; McAlpine et al., 1986) and less susceptible to external temperatures and local conditions (Clark & Edholm, 1985; Terndrup et al., 1989). Although temperatures at this site are generally higher than PA temperatures (Laurent, 1979), Webb (1973) reports the rectum as a peripheral temperature measurement site that "poorly and inconsistently reflects the value and changes of the central body core. The site of the probe is far from the main output channels of the heart and from the central nervous system, where the thermoregulatory centers are located." (p. 729)

Temperature measured in the rectum usually registers the highest of all commonly used sites (Bruck, 1983; Cranston, 1966; Feldstein, 1969) although the explanation of this remains unclear. Metabolic activity of fecal material has been suggested as being responsible (M. Benzinger, 1969;

Pickering, 1958), however research does not support this. Rubin et al. (1951) in an attempt to determine the effect of fecal bacteria on rectal temperature administered an oral sulfonamide over seven days to five healthy young males. Rectal temperature was monitored prior to and throughout the course of treatment. Although a marked decrease in fecal bacterial content followed the drug ingestion, significant changes in rectal temperature were not observed. The investigators concluded that the temperature of the perfusing blood, not bacterial activity, was responsible for maintaining temperature at the rectal site. The small sample size is a limitation of the study.

Rectal temperatures were higher than esophageal temperatures in a study undertaken by Cranston et al. (1954). In 24 observations of seven subjects, mean differences between the two sites were 0.24 ± 0.02 ^{o}C.

Laurent (1979) compared rectal, oral, and axilla temperatures taken with an electronic thermometer to PA blood temperatures (core temperature) measured at end expiration with a Swan-Ganz thermodilution catheter in 34 critically ill patients serving as their own controls. Temperatures were measured in rapid succession at 5 and 10 minutes following peripheral probe insertion. When compared to mean temperatures at the other sites, temperatures measured in the rectum were highest. Mean rectal minus PA difference was 0.2 oC (range of differences 0.8 to -0.8 ^{o}C). This difference,

although found to be statistically significant ($t(33) = -2.81$; $p < .01$; two-tailed) was not considered clinically significant. Laurent concluded that temperatures taken at the rectal site best reflected core temperature.

Ilsley, Rutten, and Runciman (1983) as part of a larger study compared oral, axillary, forehead skin, bladder, and rectal temperature measurements taken with various devices to PA temperatures in five afebrile subjects undergoing major vascular surgery. When taken with electronic thermometers, rectal temperatures were higher than simultaneously measured PA temperatures by a mean of 0.23 $\pm$ 0.14 ^{o}C, however, mean bladder temperatures were highest (0.27 $\pm$ 0.18 ^{o}C). Not reported is exact placement of devices in the various cavities and interrater reliability. These factors as well as the small sample size are limitations of this study.

Milewski et al. (1991) reported mean rectal-PA differences of 0.4 °C in nine adult ICU patients. The correlation between these sites was 0.93. Rectal-tympanic correlation was lower at 0.74.

Rectal temperatures were significantly greater than oral temperatures by 0.7 °C and tympanic membrane temperatures by 1.5 °C in a study of 21 healthy volunteers undertaken by Zehner and Terndrup (1991). Baseline mean temperatures were 37.7 $\pm$ 0.3 °C for the rectal site, 37.0 $\pm$ 0.3 °C for the oral site, and 36.2 $\pm$ 0.6 °C for the tympanic site.

Although not a problem under stable conditions, studies

have shown that with quickly fluctuating temperatures, such as those that can be seen in patients recovering from cold cardioplegia, rectal temperature tends to lag behind other core temperature measurements (Gerbrandy, Cranston, & Snell, 1954; Gerbrandy, Snell, & Cranston, 1954; Lilly, Boland, & Zekan, 1980; Mellette, 1950; Molnar & Read, 1974b; Tanner, 1951). For this reason, practitioners are warned against using rectal temperature measurements in practice when subjects are in a state of thermal imbalance during which rapid temperature changes are occurring (Cooper, 1969b; Houdas & Ring, 1982; Nadel & Horvath, 1970). However, it may be used in situations of slower temperature changes such as during fever (Cranston, 1966).

Wendt, Snell, Goodale, and Cranston (1956) compared oral and rectal temperatures following intravenous (IV) injection of a pyrogen for therapeutic purposes in 31 patients. They reported that oral and rectal temperatures responses were similar and concluded that both sites were appropriate for measurement of temperature during pyrogen-induced febrile responses.

Gerbrandy, Cranston and Snell (1954) investigated the effect of intravenous infusions of bacterial pyrogens on oral and rectal temperature changes and hand heat elimination of 13 subjects acting as their own controls. Oral temperatures were taken sublingually. Exact placement of thermocouples in the rectum was not reported. Rectal temperature rise occurred

significantly later than both sublingual temperature rise (t = 2.26, $p < .05$) and hand heat elimination (t = 2.89, $p < .01$). The onset of changes in sublingual temperature and hand heat elimination were not significantly different. Mean time of onset of temperature rise for the sublingual site was 19.2 ($\pm$ 5.4) minutes and for the rectal site 25.5 ($\pm$ 7.8) minutes. Gerbrandy et al. concluded that "As an indicator of the times of onset of temperature changes occurring at the central temperature receptors, the rectal temperature must be considered inferior to the mouth temperature." (p. 620) and within limits "valueless in this respect." (p. 624)

Eichna et al. (1951) concluded that differences between rectal and intracardiac temperatures were not clinically significant for afebrile subjects (n = 24) but this was not so for febrile subjects (n = 6). These investigators compared temperatures taken in the right heart and major vessels leading to it with rectal temperatures taken three inches above the anal orifice. For afebrile subjects, temperatures in the right heart, PA, and femoral artery were essentially the same but significantly lower ($p < .01$) than mean rectal temperatures by 0.25 ^{o}C. For febrile subjects, right heart temperatures were 0.2 to 0.8 ^{o}C lower than rectal temperatures. The small sample size for the febrile group precludes any definite conclusions. Similar results were reported by Eichna (1949) but again small sample sizes were used. According to the latter investigator, deviations of the

rectal temperature especially during changing body temperatures may give a false notion of the degree of fever present.

Cooper and Kenyon (1957) using thermocouples compared temperatures in the rectum, esophagus, and aorta of 10 patients undergoing surgery with induced hypothermia. They noted that rectal temperatures fell slower than esophageal temperatures during cooling and rose slower than para-aortic temperatures during rewarming. A lag of as much as 0.65 ^{o}C was observed. They concluded esophageal temperature to be a better index of aortic temperature than rectal temperature.

Molnar and Read (1974b) investigated the responses of rectal, tympanic, esophageal, and stomach temperatures to rapidly changing blood temperatures during extracorporeal circulation in 20 patients undergoing open heart surgery. Rectal temperatures did not respond as quickly to thermal blood changes compared with other sites. After more than an hour under hypothermia, temperatures at the other sites were essentially the same as blood temperature, whereas rectal temperatures remained 1.2 - 1.6 ^{o}C higher. Molnar and Read concluded that during cooling rectal temperatures fall slowest and during rewarming rise latest. A lower rate of blood flow in this area is proposed as the reason for this inertia.

Stupfel and Severinghaus (1956) compared rectal and esophageal temperatures of patients undergoing surgery with induced hypothermia (N = 17). Rectal temperatures lagged

behind esophageal temperatures during cooling in 15 subjects. Similar findings were observed by M. Benzinger (1969) who noted rectal temperatures lagged behind esophageal and tympanic temperatures by 15-20 minutes. Benzinger expressed serious doubts about the use of rectal temperatures in the OR and wrote "The essential criterion of any useful measurement, whatever its limits of error is its consistency within those limits. Rectal temperature ... is inconsistent." (p. 1209)

Lilly et al. (1980) compared esophageal, rectal, and PA blood temperatures to urine temperature during rewarming of subjects following major surgery under general anaesthesia. Rate of esophageal temperature rise was faster than rectal but both were slower than PA and urine temperatures. Once temperatures reached 34 ^{o}C, the rates of change for all sites were similar and parallel. Specific rectal and esophageal placement sites were not reported, limiting the validity of the findings.

Although the rectal site may be inappropriate for patients with rapid temperature changes, the use of this site for temperature measurements has been demonstrated to produce no untoward signs or symptoms in cardiac patients. The once-held belief that taking rectal temperatures in cardiac patients may result in vagal reflex slowing of heart rate has been unsubstantiated in the literature. In addition, anatomically this is not possible (Kirchoff, 1981) as the rectum is innervated by the sacral division of the

parasympathetic nervous system and not the thoracic division of which the vagus nerve is a part (Erickson & Storlie, 1973; Snell, 1973).

Gruber (1974) investigated changes in heart rate and rhythm in patients with an acute myocardial infarction (MI) when rectal temperatures were taken. These variables were monitored on 19 subjects during five phases of the rectal temperature procedure: baseline, instruction, turning, insertion, and following removal of the thermometer. No ectopic rhythms were observed on any subjects during the procedure. Turning resulted in the highest mean increase in heart rate (12.5 beats per minute). Thermometer insertion resulted in less cardiac rate changes than the other phases of the procedure. McNeal (1978) replicated Gruber's study using 15 subjects and reported the same findings.

Earnest and Fletcher (1982) studied the effect of gentle rectal examination of 86 patients diagnosed with acute MI within 24 hours of their admission to ICU. The procedure resulted in no angina pectoris nor adverse clinical or electrocardiographic changes.

Little mention is made in the literature as to the effect the presence of solid fecal material in the rectum has on rectal temperature measurements. Although unsubstantiated by research, Blainey (1974) reports soft stool in the rectum makes it difficult to determine if the thermometer is located in stool or against the rectal wall and hard stool may prevent

placement of the thermometer to the depth recommended. Additionally, fecal material surrounding a thermometer may result in a sluggish response to temperature changes in the rectum (Stupfel & Severinghaus, 1956). Lastly, Benedict and Slack (1911) suggest that the thermometer should not be placed in fecal mass and if there is a possibility of this, an enema should be used to remove the fecal matter. As to the time necessary for the rectal temperature to stabilize following the enema, the authors state only that "sufficient time" should elapse before temperature observations are made. However, studies to specifically investigate this area have not been undertaken.

Oral Cavity

The oral cavity is the site most often used in everyday clinical practice (Erickson & Yount, 1991). Temperatures measured in the mouth have been shown to correlate well with other core temperature measurements (Cranston, 1966; Laurent, 1979) and to reflect rapid temperature changes better than the rectum (Cranston, 1966). Oral temperatures are generally lower than rectal and higher than axilla, however, the traditional assumption of a constant 0.5 ^{o}C (1.0 ^{o}F) difference between temperatures measured in the mouth and those measured in the rectum or axilla is not supported in the literature.

Animal studies undertaken by Hellekant (1972) show that

in resting conditions, the blood flow per gramme of tissue is higher in the tongue than in most other muscular organs of the body. Dubois (1951) states that oral temperatures are of great value and "represent a mixture of core temperature and the gradient from the cool skin. If this mixture happens to be in the right proportion, the changes in oral temperature would represent changes in average body temperature more accurately than rectal readings." (p. 486)

Nichols et al. (1966), using mercury in glass thermometers, measured simultaneous oral, rectal, and axilla temperatures on 60 healthy volunteers for 12 minutes. Variations of 0 to 2.8 ^{o}F between rectal-oral readings and, 0 to 4.2 ^{o}F between oral-axilla temperatures were reported. Most subjects had higher rectal than oral temperatures and higher oral than axilla temperatures. An exact 1 ^{o}F difference between readings was reported in only 5% of oral-axilla measurements and 8% of rectal-oral measurements. Exact placement site in the oral cavity, rectum, and axilla as well as interrater reliability between investigators were not reported.

Agarwal, Garg, Ghandi, and Kapoor (1990) using clinical thermometers reported oral-axilla differences of 0 to 1.8 ^{o}F (0 to 1 ^{o}C) for 100 volunteer patients. Sixty subjects had differences of 0.22 ^{o}C or less while 12 patients had differences greater than 0.66 ^{o}C. They concluded that attempts to extrapolate axilla temperatures to oral

temperatures should not be undertaken. Not reported are tests of instrument accuracy and reliability as well as specific insertion times for the two sites.

Royston and Abrams (1982) in a two part study investigated rectum and mouth as sites for basal body temperature measurements and concluded both were satisfactory for this purpose. Day-to-day patterns of oral and rectal temperature changes were similar for subjects recording both these temperatures (N = 8) and a mean temperature difference of 0.20 ^{o}C was noted between sites. Self-recording and lack of instrument validity and reliability tests are limitations of this study.

Tanner (1951) investigated the relationship between rectal and oral temperatures and heart rate in 46 healthy young men at rest. Mid morning oral and rectal temperatures were measured on two occasions eight days apart. Although rectal temperatures were higher than oral temperatures with a mean difference of 0.71 $\pm$ 0.040 ^{o}F (0.395 $\pm$ 0.02 ^{o}C), a correlation coefficient of 0.843 was reported for temperatures at these sites.

Cranston et al. (1954) reported sublingual temperatures consistently lower than rectal temperatures. In 93 experiments on 40 seated subjects (room temperature 19-24 ^{o}C) the mean difference was 0.35 $\pm$ 0.01 ^{o}C.

Sellars and Yoder (1961), using mercury thermometers, obtained 1431 simultaneous measurements of rectal and oral

temperatures under varying environmental temperatures and exercise on 10 healthy males over five 10 day periods. The assumption of a 1 ^{o}F difference between oral and rectal temperatures was not supported in this study. A mean rectal temperature of 99.0 ^{o}F and mean oral temperature of 97.6 ^{o}F was reported with differences of 0.5 to 1.5 ^{o}F or greater in 91.9% of the readings. The small sample size, lack of interrater reliability and possibly insufficient oral thermometer placement time of three minutes (Nichols & Kucha, 1972) are serious limitations of this study.

Laurent (1979) reported mean oral temperature was significantly ($p < .001$) lower than mean PA temperature in 34 subjects with a variety of respiratory assistance devices. Although the mean difference was - 0.6 ^{o}C (range of differences 0.3 to -1.3 ^{o}C), a significant correlation ($p < .001$) between PA and oral temperatures ($r = .854$) was noted.

Erikson and Kirklin (In Press) reported a mean bias of 0.05 $\pm$ 0.26 °C between PA and oral temperatures in 38 critically ill adults with varying respiratory assistance devices. Measurements were recorded every 20 minutes for four hours. They concluded that oral temperatures agreed closely with PA temperatures.

Cooper et al. (1964a) also reported high correlations between mouth and ear temperature ($r = .915$, $p < .001$) during experiments with immersion of an extremity in hot water ($N = 18$). External auditory canal temperatures were on average

0.05 $\pm$ 0.18 ^{o}C lower than sublingual temperatures during stable conditions.

Erickson and Yount (1991) compared tympanic membrane and oral temperatures in 60 adults undergoing major abdominal surgery. Temperatures were measured four times during the preoperative period. Mean tympanic-oral temperature difference remained fairly stable and within a range of 1.1 to 1.5 ^{o}F (0.6 to 0.8 ^{o}C) during these times. Moderately high significant correlations were demonstrated between these sites at each measurement time (r = .77 to .85, p < .001). The investigators concluded that either site is satisfactory for routine intermittent temperature measurement during the perioperative period.

Oral temperatures also have been compared to other core site measurements. Sloan and Keatinge (1975) compared oral and esophageal temperatures. Sublingual temperatures were consistently within 0.45 ^{o}C of esophageal temperatures in warm environments (25-44 ^{o}C) and were often close to but occasionally above or below esophageal temperatures in rooms of 18-24 ^{o}C. In very cold environments, sublingual temperatures were reported as possibly unreliable due to cold saliva. Cooper and Abrams (1984) investigated the oral cavity as a site for basal body temperature measurements. Simultaneous oral (four sites) and vaginal temperatures were taken on 11 women immediately upon awakening. Oral temperatures shifted in the same direction and to the same

degree as vaginal temperatures leading to the conclusion that the mouth was a satisfactory site for basal body temperature measurements.

Temperatures Within Sites

Just as there are variations in temperatures at different sites in the body, there are differences within sites as well (Houdas & Ring, 1982). Discrepancies in temperature within the oral and rectal cavities have been measured and reported. Often these differences are highly significant. Anatomic differences such as blood vessel location or superficiality (Beck & Campbell, 1975) or blood flow through a region (Rubin et al. 1951) have been suggested as reasons for these variations.

Oral Cavity

In the mouth, the largest differences have been noted between the anterior and posterior sites. Kung, Ochs, and Goodson (1990) report that the gradient observed in the mouth is a "natural consequence of the cooling of the blood as it travels along the arteries from the posterior region to the anterior region." (p. 562) Beck and Campbell (1975) report that maximum mouth temperatures can be obtained in the "heat pocket", an area located at the right or left side of the frenulum where the base of the tongue joins the floor of the

mouth. According to Kung et al. "The intimate contact of the highly vascularized tongue with the lower jaw ...." (p. 562) contributes to this.

Bjorn (1973), using an electronic thermometer, investigated temperature differences within the mouth before and after smoking (N = 30). Significant differences ($p < .001$) in baseline temperatures were reported between the anterior sublingual and left (0.43 ^{o}F) and right (0.51 ^{o}F) posterior sublingual sites. Non significant differences (0.08 $\pm$ 0.07 ^{o}F) were noted between right and left sublingual sites ($t(29) = 1.68$, $p > .10$). Bjorn concluded that the frontal sublingual site is an inappropriate choice for body temperature measurement. Jones (1973) analyzed 300 temperature measurements taken with an electronic thermometer (N = 50) in a study to determine temperatures at three different sites in the oral cavity with mouth open and mouth closed and reached the same conclusion. Right and left posterior sublingual temperature measurements were significantly different ($p < .001$) from frontal sublingual temperatures, regardless of mouth position, however, mean temperature differences of 0.214 ^{o}F for mouth open and 0.10 ^{o}F for mouth closed were noted between right and left posterior pockets. Measurement of open mouth temperatures first may have resulted in alterations in subsequent closed mouth temperatures.

Wironen (1975) replicated Jones' (1973) study but

measured closed mouth temperatures first. Significant differences again were found between anterior and posterior sublingual sites with higher temperatures in the posterior pockets. Unlike Jones' study, however, non significant differences ($p > .05$) were found between left and right posterior sites with mouth open (0.06 ^{o}F) or closed (0.04 ^{o}F). Wironen concluded that right or left posterior sites and not frontal should be used for sublingual temperatures. These conclusions were supported by Erickson (1976; 1980b). Erickson recommended either posterior sublingual site be used for temperature measurement and the use of the same reliable thermometer for repeated temperature measurement.

Near zero mean differences (0.01 $\pm$ 0.38 ^{o}C) between sites in left and right sides of oral cavity were reported by Kung et al. (1990). Posterior sites were reported to have smaller standard deviations than anterior sites.

These studies support the posterior sublingual sites of the oral cavity for temperature measurements. The closeness of this site to branches of the lingual artery (an offshoot of the external carotid artery) and its easy accessibility are prime advantages. Additionally, replication of thermometer placement can be accomplished here (Blainey, 1974; Mead & Bonmarito, 1949).

Rectal Cavity

That the rectum is subject to less variation due to

thermometer placement, has been questioned (Mead & Bonmarito, 1949). Information in the literature with regard to the site in the rectum where maximum temperature occurs suggests depths of 5-8 cm. The importance of using a consistent site within the rectum for repeated measurements also is demonstrated by these studies. Benedict and Slack (1911) reported a depth of 6-7 cm from the anus as the point of highest temperature. Rectal temperature was measured to a depth of 12 cm and no fall in temperature beyond the 6 cm point was noted. Houdas and Ring (1982) state that anal and not rectal temperature is what is most often measured and in order to obtain a true rectal temperature, a thermometer must be inserted at least 8 cm in depth.

Guiss (1973) measured rectal temperatures on 49 recent postoperative subjects to determine the effect of depth and angle of rectal thermometer insertion on temperature measurements at this site. Consecutive rectal temperature measurements were taken at a depth of 1 1/2 (3.75 cm) and 3 inches (7.5 cm) from the anal sphincter and at an anterior and posterior angle to the rectal wall. Using t-tests for paired observations, significantly higher mean temperatures ($p < .001$) were noted at the 3 inch compared with the 1 1/2 inch depth for both the anterior and posterior position. Non significant differences were found for temperatures taken in the anterior compared with the posterior position at either depths. Guiss' study was a replication of an earlier study

undertaken by Tate (1968). As reported by Guiss, Tate also determined temperatures to be higher at the three inch depth. However, Tate's study revealed significant differences ($p < .001$) between anterior and posterior temperature measurements.

Factors Affecting Temperature

Local or body temperature may be influenced by physiological factors or by external stimuli or local conditions. Differences in degree and duration of response to these thermal stimuli have been demonstrated. Definitive conclusions for many of these variables, however, were frequently not forthcoming in the literature as a result of either insufficient studies or varying or conflicting results.

Age and Gender

The literature indicates that age may play a role in normal temperature. Fox et al. (1973) in a three month study investigated body temperatures in the elderly (=/> 65 years). Over 1,000 randomly chosen subjects had sublingual, hand, and urine temperatures measured in their homes. Deep body temperatures below 35.5 ^{o}C were reported in 10% of the sample. Circadian rhythm and environmental temperatures were not controlled for and this may have influenced the findings. These investigators concluded that the elderly are less successful in producing and conserving body heat. Higgins

(1983) also reported lower mean oral temperatures of 97.7 ^{o}F (36.5 ^{o}C) for 60 healthy men and women between the ages of 65 and 90 years. When data were analyzed according to half decade age ranges; as age increased, mean temperature decreased. Women had a slightly higher temperature (98.1 ^{o}F) compared with men (97.9 ^{o}F). Placement site within the mouth is not reported and may have affected the validity of the findings.

Thatcher (1983) using two groups of 50 elderly volunteers aged 60-94 years ($\underline{M}$ 72.8 years) reported non significant correlations ($\underline{r}$ = -.13 and $\underline{r}$ = -.20, $\underline{p}$ > .05) between body temperature and age. The combined mean oral temperature of 97.89 ^{o}F (36.6 ^{o}C) was, however, significantly different ($\underline{p}$ < .0001) from 98.6 ^{o}F (37 ^{o}C), the temperature usually stated as normal. Thatcher concluded that findings from this study are contrary to the belief that temperature declines with age. Exact placement of the thermometer in the oral cavity is not reported and is a limitation of the study.

Sublingual and palate temperatures were measured on 20 young (22-25 years) and 20 old (65-77 years) subjects by Maeda, Stoltze, User, Kroone, and Brill (1979). No significant differences in temperature were noted at any of the sites. However, elderly males had a significantly lower temperature in both the sublingual and palatal sites than young males ($\underline{p}$< .001), whereas no significant difference was noted for elderly compared with young females. These

investigators conclude that the lowering of oral temperature as a result of aging appears in males not females and could be indicative of the more severe circulatory disease in the male population. Lack of control of rhythmic changes in body temperature as a result of Circadian and menstrual cycles may have confounded the results of the study.

Closs, Macdonald, and Hawthorn (1986) investigated factors affecting perioperative body temperature of 31 surgical patients. They identified age as significantly correlated (r = .535, p < .001) with perioperative reduction in core temperature.

Sugarek (1986) reported that mean initial temperature decrease and recovery time following iced water ingestion by 92 afebrile subjects increased directly with age. The age-related changes were highly significant (p = .0001).

Body Fat

Body fat provides increased insulation between the core and the periphery of the body (Houdas & Ring, 1982). T. H. Benzinger (1969b) states that obese individuals have "superior thermal isolation of their body core...." (p. 710) It has also been suggested that the amount of fat in the submental pad may be a factor in insulating the mouth cavity from room temperature (Beck & Campbell, 1975). Morrison, Conn, and Hayward (1980) investigated the effect of initial body temperature and physique on the rate of rewarming following

accidental hypothermia of 14 subjects. No significant relationship was determined between anthropometric variables and core rewarming rates.

Closs et al. (1986) investigated the effect of body composition on perioperative core and skin temperature measurements. Body composition was defined as being composed of insulative tissue (fat) or metabolically active tissue (fat-free). Of the constituents of body composition, body fat was demonstrated to be the most important predictor of magnitude of core temperature decrease ($p < .005$). Smaller drops in core temperature were noted for patients with larger amounts of body fat. The investigators report this as a reasonable finding since anaesthetics and muscle relaxants used intraoperatively drastically reduce thermogenesis in metabolically active tissue.

Emotions

Emotional excitement has been reported to account for a rise in temperature (Blainey, 1974; Ganong, 1989). Ganong (1989) reported an increase in temperature with emotional excitement and apprehension during the time of admission to hospital possibly as a result of unconscious muscle tensing. For critically ill patients, Powell and Little (1982) note that painful procedures and "The busy, noisy, continually lighted setting of an intensive-care unit..." may result in emotional disturbances. Renbourn (1960) investigated the

effect of stress on body temperature in young men (19-25 years) and boys prior to sporting events. Sublingual temperatures were taken for five minutes and pulse rate for one minute. Although non significant differences in pulse rate were noted, adult contestants (n = 24) showed a significant ($p < .05$) increase in mean oral temperature (0.5 ^{o}F) compared with a control group (n = 21) of comparable age. This elevated oral temperature for the experimental group was concluded to be due to "emotional hyperthermia." Boys aged 12 to 14 years showed an even greater increase in mean oral temperature (1.0 ^{o}F) prior to the sporting events compared to a control group leading Renbourn to further conclude that this phenomenon may decrease with age. The validity of the findings is limited by the narrow age range and the lack of reports of instrument accuracy and reliability.

Localized Infection/Inflammation

Localized infections may cause temperatures to rise at the affected site. Although not supported by research, Tate et al. (1970) reports that if an infection is on one side of the mouth temperatures may read higher on that side. Kung et al. (1990) attempted to determine if inflammatory conditions resulting from diseased teeth resulted in higher temperatures at those sites. Temperatures at six different sites on the teeth of 14 subjects with advanced periodontitis were compared with 11 subjects with healthy teeth. Mean site temperature

for the two groups was calculated as the difference between site temperature and sublingual temperature. Diseased teeth had significantly higher temperatures than anatomically equivalent healthy teeth ($p < .01$). The small sample size is a limitation of the study.

Dentition

The effect of dentition on oral temperature has not been clearly established. Beck and St Cyr (1974) and Beck and Campbell (1975) report that the presence of natural teeth results in a more stable temperature in the heat pocket of the oral cavity. They state that a lowering of oral temperature may occur as a result of the high heat conductivity of oral prostheses and recommend these be removed before oral temperatures are measured. Studies undertaken to specifically investigate the effect of this variable on temperature measurements were not located in the literature.

Erickson (1976) in an investigation of thermometer placement for oral temperature measurements of 50 febrile patients performed additional analyses of the data for the effect of dentition on temperatures at this site. The small sample size for edentulous subjects precluded any definite conclusion for this group, however, mean variation for subjects with partial dentures ($n = 16$) was lowest (0.62 ^{o}F), edentulous subjects ($n = 4$) the highest (1.18 ^{o}F), and subjects with natural teeth ($n = 30$) in between (0.73 ^{o}F).

Konopad (1990) also performed additional analysis of data to determine if the presence or absence of teeth had an effect on oral temperature measurements of patients with and without an oral endotracheal tube. No significant difference ($p > .01$) was reported in the oral temperatures of patients with ($n = 37$) and without ($n = 28$) teeth either while the tube was in place or following its removal.

Ingestion of Hot or Cold Fluids

The ingestion of hot or cold fluids produces a localized transient effect on oral temperatures. Studies have been undertaken to determine effect and duration of effect following ingestion of these fluids. However, the variations in ingestion time, temperature of the liquids, and insertion times for glass thermometers make comparisons of study results difficult. Brim and Chandler (1948) investigated the effect of ingestion of hot and cold liquids, smoking, and gum chewing on oral temperature measurements. Fifty tests of each independent variable were performed. Temperatures were measured with a glass thermometer before, immediately after, and every five minutes for 20 minutes following treatment. By 20 minutes 41 of 50 tests continued to deviate from baseline following hot liquid ingestion and 7 of 50 tests had not returned to baseline following cold liquid ingestion. No recommendations were forthcoming from the investigators as a result of the varied reactions and temperature fluctuations.

Validity of the findings is weakened because temperature of the liquids and ingestion time were not controlled, sample size was not reported, and the three minute placement time may have been insufficient for accurate oral temperatures recordings.

Woodman et al. (1967) refined a part of Brim and Chandler's study and investigated the effect of iced water ingestion and smoking on oral temperature measurements. Iced water was ingested over two minutes and a five minute placement time for the thermometer was used. A significant mean drop ($p < .0005$) in oral temperature ($0.70 \pm .36$ ^{o}F) for the experimental group ($n = 22$) compared with the control group ($n = 22$) was reported following the treatment. Duration of effect was not investigated.

Forster et al. (1970) studied the effect of iced water ingestion on oral temperature measurements of febrile (=/> 99 ^{o}F, $n = 9$) and afebrile ($n = 10$) subjects. Oral temperatures were measured with a thermistor every 30 seconds for 15 minutes. Although statistical results are not reported, the investigators reported no significant difference in patterns of oral temperature lowering between febrile (5.25 ^{o}F) and afebrile (5.68 ^{o}F) patients. An effect time of generally 15 minutes for both groups was reported. The small sample size is a limitation of the study.

Sugarek (1986) investigated the effect of iced water ingestion over two minutes and recovery time (defined as a

return to within 0.5 ^{o}F of baseline) on the posterior sublingual temperature of 92 afebrile volunteers divided into three age categories. Temperatures were measured with a predictive thermometer before ice water ingestion and every two minutes for 30 minutes following treatment. A highly significant ($p < .001$) mean temperature change occurred immediately following treatment. Increasing age resulted in greater mean initial decreases in oral temperature and longer recovery times: 3.1 ^{o}F and 28 minutes for 60 years or greater, 2.4 ^{o}F and 22 minutes for 40-59 years, and 1.6 ^{o}F and 20 minutes for under 40 years. Dependant on the subject's age, a 15 to 30 minute delay in taking temperature following iced water ingestion is recommended. Tests for accuracy and reliability of the instrument are not reported limiting the findings of the study.

A seven minute waiting period following ingestion of hot or cold liquids is recommended by Terndrup et al. (1989) They investigated the effect of these variables plus smoking on simultaneously measured oral, rectal, and bilateral tympanic membrane temperatures (N = 22) recorded at intervals between 1.5 and 15 minutes. Liquids were maintained at a controlled temperature and ingested over one minute. No significant changes in rectal or tympanic temperatures were reported. However, a significant decrease in mean oral temperature immediately following iced water ingestion which persisted over five minutes and a significant increase in oral

temperature with a more prolonged effect time following hot liquid ingestion (significant at 7 minutes, $p < .05$) resulted. The small sample and lack of interrater reliability measurements, exact placement of the rectal probe, and tests of instrument accuracy and reliability weaken the validity of the findings.

Breinig (1975) in a well controlled study recommended a 25-30 minute waiting period following ingestion of hot liquids. Hot tea was ingested over three minutes by 28 afebrile volunteers with a significant mean increase ($t(27) = 11.6$, $p< .01$) in oral temperature following. By 25 minutes, 89.3% of subjects and by 30 minutes 96.4% of subjects had returned to baseline temperatures with a mean of 17.4 minutes required.

Intravenous Infusions

The infusion of hot or cold fluids intravenously may alter temperature, the extent of the alteration dependent on the quantity and temperature of the fluid, the rate of infusion, and the site used. Blood is stored at 4 ^{o}C (Holdcroft, 1980; Roe, 1973). Non blood products are generally stored at room temperature. Infusion of non blood products therefore, results in a smaller temperature gradient than that which occurs when blood is given. Roe (1973) reports that rapid infusion of one litre of blood at 4 ^{o}C will result in a fall in body temperature of close to 0.5 ^{o}C.

Minimal temperature changes will occur with 500 ml or so of fluids given at room temperature over 1-2 hours. Cooper and Kenyon (1957) note that a difference in temperature between right and left sides of the heart results when a large and rapid intravenous infusion of fluid at a temperature different from that of the blood is given. They report this and exposure of the heart itself as the only times heart temperature cannot be considered as a reliable indicator of body temperature.

Gerbrandy, Snell, and Cranston (1954) investigated the relationship between hand heat elimination and temperatures measured in the mouth, rectum, and esophagus of healthy subjects who had hot saline infused intravenously or an extremity immersed in hot water. In 15 experiments on 9 subjects, the infusion of hot saline (43.5 ^{o}C) at varying rates via a arm or leg vein resulted in sublingual temperature rise in all experiments but one in which the fluid was infused very slowly via the leg. Sublingual temperature correlated closely with hand heat elimination (r = .805, p < .001). Rectal temperatures also rose in four experiments, but never as high as oral temperatures, and remained unchanged in the remaining experiments. Rectal temperature rise also was slower than sublingual temperature rise. Gerbrandy et al. concluded rectal temperatures were inferior to sublingual temperatures and that the latter provided a more reliable indicator of changes in body heat than rectal temperatures

when hot fluids were infused.

Smoking

Smoking has been shown to have a statistically but questionable clinically significant effect on oral temperature when done prior to measurement. Duration of effect for this external factor, however, has not been determined. In 50 tests of oral temperature following normal smoking, Brim and Chandler (1948) noted that 16% of test temperatures remained unchanged and 50% were still above or below (-0.6 to 1.6 ^{o}F) control temperatures at the end of 20 minutes. No definite conclusions were drawn from the study. Lack of control over brand of cigarettes and time taken to smoke a cigarette, both of which may influence the temperature measurement, are limitations. Statistically significant differences (t (49) = 2.03, $p < .05$, two-tailed) in mean oral temperatures of 22 male volunteers who smoked a control cigarette over two minutes compared with a control group of equal size were reported by Woodman et al. (1967). Smoking resulted in a mean increase in temperature of 0.09 $\pm$ 0.12 ^{o}F, the clinical significance of which was questioned. Duration of effect was not determined.

Bjorn (1973) in a well controlled study compared temperature differences in three sublingual sites before and after smoking. Healthy volunteers serving as their own controls (N = 30) had sublingual temperatures measured with a

predictive thermometer prior to and immediately after smoking a control cigarette for five minutes (± 1 minute). Again duration of effect was not investigated but smoking resulted in a significant mean increase in temperature at all three sites ($p < .001$) with the greatest changes and widest variations reported at the frontal pocket. Bjorn concluded that smoking does affect temperature, more so at the front pocket of the mouth than in the posterior sublingual sites.

Gum Chewing

The effects of continuous mouth movement, such as gum chewing, on temperature have not been sufficiently studied. Brim and Chandler (1948) stated 18% of 50 test measurements showed no change in oral temperature following 30 minutes of gum chewing and 44% had variations of -0.4 to 1.4 ^{o}F 20 minutes after gum chewing has ceased. They concluded that gum chewing may raise or lower oral temperature. Duration of effect could not be determined as measurements were taken for only 20 minutes following treatment. Sample size is not reported and the three minute placement time for mercury thermometer may have been insufficient for temperatures stabilization.

Oxygen Therapy

The effect of oxygen via nasal prongs up to 6L/minute on oral temperature has been well documented and found to have no

significant effect (Graas, 1974; Hasler & Cohen, 1982; Lim-Levy, 1982). However, data is inconclusive in the area of oxygen via mask on this measurement. Dressler et al. (1983) compared oral and rectal temperature differences of 30 cardiovascular surgical patients receiving oxygen therapy by mask. A mean difference of 1.46 ^{o}F was reported. Although statistically significant, the clinical significance of this difference was questioned by the investigators. Depth of rectal probe insertion and tests of instrument reliability were not reported, weakening the validity of the findings. Hasler and Cohen (1982), using a counter balanced design, measured oral temperatures of 40 healthy volunteers before and after three oxygen therapies. Non significant differences for oxygen therapy via nasal prongs and aerosol masks ($p = 1.0$) were reported. Significant differences ($p = .014$) were found, however, for oxygen via venti-masks. The differences were not considered clinically significant for the three therapies. Yonkman's (1982) study did not support Hasler and Cohen's results regarding oxygen via aerosol mask. Thirty young female volunteers received heated and cooled aerosol via face mask with sublingual temperatures measured before, during, and after treatment. Statistically significant results were reported for both cool and heated aerosol ($p < .005$). However, the mean change in temperature was not greater than 0.3 ^{o}C and the investigator concluded that the effect, therefore, may not be clinically significant.

Felton (1978) questioned if removal of oxygen masks for oral temperature measurements significantly affected arterial blood oxygen levels. Arterial blood samples were drawn before and at intervals between 4 and 10 minutes after mask removal on 10 stable postoperative ICU patients. A mean drop in arterial blood oxygen of 33.5 mm Hg resulted after four minutes of mask removal and nearly 20 minutes was required for a return to baseline following mask replacement. Felton recommended the use of rectal temperature measurements for patients requiring oxygen via mask. Whether this recommendation would pertain to temperature measurements with electronic thermometers, which require much shorter placement times, is not addressed.

Intubation

Earp and Finlayson (1991) mention that the presence of gastric tubes and endotracheal tubes may limit access to the mouth for temperature monitoring. There has been limited study on the effect of these tubes on sublingual temperatures. Heinz (1985) using a convenience sample of 20 adult patients serving as their own controls investigated the effect of nasogastric tube insertion on simultaneously measured sublingual and rectal temperatures. Oral temperatures were measured in the right or left posterior pockets and rectal temperatures three inches past the anal orifice. A non significant mean difference between oral and rectal

temperatures of subjects with (1.31 ^{o}F) and without (1.13 ^{o}F) NG tubes was reported ($t(19) = 1.29$, $p > .05$). The length of time between pre and post experimental measurements (1-6 days), the small sample size, and the use of two instruments for temperature measurement are limitations of the study. Reliability tests of the instrument also are not reported. Of interest is that six patients refused to participate in the study stating they "detested" rectal temperatures.

An in-depth review of the literature revealed that the effect of oral intubation with an ETT on sublingual temperature measurements has not been thoroughly studied. Endotracheal intubation is "The method most widely used to institute and maintain an open airway...." (Wade, 1977, p. 144) and entails passing a tube through the nose or mouth into the trachea. It is indicated for patients requiring prolonged ventilation, those with obstructed airways or when normal airway reflexes are not functioning (Albanese & Toplitz, 1982). Near the distal opening of an adult ETT is a fragile but flexible cuff. Inflation of the cuff with a minimum occluding volume of air is performed immediately following insertion of the tube to prevent leakage of air around the tube. A minimum occluding seal is present when, upon auscultation over the cricoid, escaping air can no longer be detected.

When patients are connected to a ventilator, a swivel adaptor is placed between the tube and the "Y" connector of

this humidified oxygen source. A small capped hole on the swivel adaptor is present to allow for the insertion of a suction catheter if suctioning of pulmonary secretions is required.

As a result of intubation, the gases necessary to sustain life no longer enter the trachea directly via the mouth but instead via this tube. Breathing through the mouth (mouth breathing) or the nose (nose breathing), as we know it, therefore no longer occurs. In animal studies, Wessel, Gordon, and Paul (1966) reported that intubation with mechanical ventilation interfered with "...the heat transfer to the inspired air from the respiratory tract cephalad to the upper trachea." (p. 1410)

Multiple parameters related to respiration are monitored when patients are intubated and connected to a ventilator. Among these is the temperature of the inspired gases. Holdcroft (1980) suggests that the probe for recording the inspired gases should be placed as close as possible to the patient.

Two studies have been undertaken to specifically investigate the effect of oral intubation on oral temperature measurements. Cashion (1982), using a single factor repeated measures analysis of variance reported no significant difference ($F(5, 70) = 1.852$; $p > .05$) in the variation between sublingual and rectal temperatures of patients (n = 15) with and without an oral ETT who had undergone coronary

artery bypass graft (CABG) surgery. Oral and rectal measurements were taken with an IVAC 811 thermometer in the predictive mode twice before surgery 15 minutes apart (subjects not intubated) and postoperatively, upon admission to ICU and then hourly thereafter for five hours (patients intubated). Oral temperatures were measured in the left posterior sublingual pocket using slow slide technique and rectal measurements taken three inches into the anal canal. Mean differences of 0.734 ^{O}F for non intubated subjects, and 0.420 to 0.667 ^{O}F for times one through six for intubated subjects, were reported. Rectal temperature lag, resulting in rectal temperatures being cooler than they should have been, was proposed as the reason oral and rectal temperature differences were narrower during intubation than before intubation. The small sample size and lack of both measurement of ETT temperature and control over ordering effect are limitations of the study.

Although the main purpose of Konopad's (1990) study was to compare oral temperatures of patients with and without an oral ETT, rectal, axilla, and tympanic temperatures also were recorded. Temperatures were taken once immediately before and after removal of the tube on 65 stable adult intensive care medicine patients ready for extubation. An IVAC 2080 electronic thermometer in the steady-state mode was used for oral, rectal, and axilla measurements. Oral temperatures were taken in the posterior sublingual pocket opposite the ETT and

rectal temperatures two inches past the anal opening. Slow slide technique was used at both sites. Following extubation, patients were placed on oxygen via mask (n = 6) and via nasal prongs (n = 59) with oxygen levels ranging from 2 to 10 litres per minute. Results indicated a statistically ($p < .01$) but not clinically ($0.08 \pm 0.20\ ^{o}C$) significant difference between oral temperature measurements with and without an oral ETT in place. Oral temperatures were higher with the ETT in place and were not significantly affected by the temperature of the ETT contents. No significant differences ($p > .01$) were reported for rectal or tympanic membrane temperatures. Lack of interrater reliability and control over ordering effect as well as the undetermined effect of oxygen via mask (Dressler et al., 1983; Yonkman, 1982) weaken the validity of the findings. The difference in sample size between Cashion's and Konopad's study as well as the more stringent alpha level in the latter may have accounted for the differing statistical results. However, both investigators concluded that their studies supported the use of oral in lieu of rectal temperature measurements for orally intubated patients.

Laurent (1979), using a Yellow Springs telethermometer, compared oral, axilla, and rectal temperatures to pulmonary artery blood temperatures of 34 critically ill patients. A secondary purpose was to determine if oral and pulmonary artery temperature differences were related to differing respiratory therapies. Patients were grouped into four

categories according to respiratory therapy received (no oxygen therapy, oxygen therapy by nasal prongs, nasal ETT, and oral ETT). Oral temperatures were measured in the right or left sublingual pockets and rectal probes inserted to a depth of three inches. Analysis of variance revealed that oral temperature measurements were not significantly affected ($p > .05$) by oral ETT intubation or by the other three respiratory therapies. The small number of subjects in the orally intubated group ($n = 5$) weakens the validity of the results.

Twenty-five of the 38 subjects in the study undertaken by Erickson and Kirklin (In Press) to compare methods for core temperature measurement had an oral ETT in place. Temperatures were measured every twenty minutes over a 4-hour period. Oral temperatures were 0.12 ± 0.11 °C higher than PA temperatures. The investigators concluded that oral temperatures agreed closely with PA temperatures in intubated patients.

Lastly, Heidenreich, Giuffre, and Doorley (1992) investigated invasive and less invasive temperature monitoring of 25 hypothermic post cardiac surgery patients who also were intubated. Six women and 19 men with a mean age of 65.3 years participated. Temperatures were measured every 10 minutes for two hours following routine ICU admission. Mean temperature ($\pm$ SD) was 34.7 ± 1.4 °C at the PA site, 34.6 ± 1.4 °C at the oral site, and 35.2 ± 1.2 at the tympanic membrane site. Using the results of regression analysis to indicate the

degree with which non invasive sites predicted core temperature, the investigators concluded that in hypothermic patients undergoing rapid temperature changes, only invasive measurements of core temperature may be valid. In addition, they noted that the poor showing of the tympanic temperature warranted further investigation.

With the exception of these and the urging of Lukasiewicz (1983) and Franceschi (1991) for further studies to determine the effect of oral intubation on oral temperature measurements, little mention is made in the literature relating to this area. This may be the result of many studies having been undertaken using either healthy subjects or hospitalized subjects located in non critical care areas. Most intubated subjects are in intensive care units.

Respiratory Rate and Depth

The effect of respiratory rate and depth as well as open mouth breathing have been questioned as possible factors influencing oral temperatures as well. Cranston et al. (1954) in a comparison of temperature changes at oral, rectal, and esophageal sites under varying conditions reported that when subjects hyperventilated for 1-3 minutes through the nose, sublingual temperatures decreased by 0.04-0.19 ^{o}C (n = 5) and rectal temperatures decreased by 0.05 ^{o}C (n = 3). These investigators suggest that the fall in rectal temperature during hyperventilation suggests that a cooling occurs

throughout the body and that local cooling of the mouth is only partly responsible for sublingual temperature drop. The small sample size is a limitation of the study.

Tandberg and Sklar (1983) investigated the effect of tachypnea (=/> 21 breaths per minute) on oral and rectal temperature differences. Non tachypneic subjects (n = 118) had mean differences of 0.53 $\pm$ 0.04 ^{o}C. This difference was significantly ($p < .001$) larger for the tachypneic subjects (0.93 $\pm$ 0.05 ^{o}C)(n = 192). A positive relationship (r = .49) between respiratory rate and rectal-oral temperature differences was noted. Rectal temperatures were recommended for patients with an increased respiratory rate. Lack of interrater reliability and tests for instrument reliability weaken the findings. Durham et al. (1986) supported Tandberg and Sklar's findings and also recommended rectal temperature measurements for tachypneic subjects.

The results of a study by Neff, Ayoub, Longman, and Noyes (1989) do not support the results of the previous two investigators. Seventy-eight healthy volunteers serving as their own controls were used to determine the effect of open mouth breathing, hyperpnea, and tachypnea, either alone or in combination, on sublingual and tympanic membrane temperatures. Audio feedback and monitoring of chest excursion were used to increase respiratory rate and depth. Non significant differences in temperature at both site were found for either tachypnea or hyperpnea. The use of healthy subjects in this

study whose respiratory patterns were guided by the investigators compared with patients in the previous studies who presented with varying respiratory rates and tidal volumes may have resulted in the discrepancy between the findings.

Open Versus Closed Mouth

Studies indicate that mouth breathing results in no clinically significant affect on oral temperature measurements. Cooper and Abrams (1984) in their study of basal body temperatures simultaneously measured temperatures in the vagina and at four sites in the mouth before and after five minutes of mouth breathing. They reported that mouth breathing had no significant effect ($p > .05$) on the recorded temperature of the posterior sublingual or buccal trough sites and concluded that for these two areas evaporative heat loss during mouth breathing was apparently insignificant.

Erickson (1976) investigated oral temperature differences at three sublingual sites and the effect of open versus closed mouth position on sublingual temperature measurements of 50 hospitalized febrile adults. A statistically ($F(1, 49) = 8.000$; $p < 0.01$) but not clinically (0.08 ^{o}F) significant difference was found with mouth open versus mouth closed. She concluded that the mouth open position allowed for visualization and maintenance of accurate probe placement and that the effect of the open mouth position on oral temperature readings was clinically unimportant.

Jones (1973) noted that the open mouth resulted in a statistically significant effect on the left (0.13 ^{o}F; $\underline{t}$ = 2.68; $\underline{p}$< .025) but not on the right posterior sublingual site of 50 healthy volunteers. She concluded that the closed mouth was not necessary for temperature measurements if an electronic thermometer and the posterior sublingual pockets were used. Wironen (1975) replicated Jones' study but modified it by measuring closed mouth temperatures first. Wironen concluded that mean temperature differences at the right and left posterior sublingual sites were slightly higher with the mouth closed (</= 0.1 ^{o}F). These differences were statistically significant at p values of .05 and .02 for the right and left sublingual pockets respectively, leading her to suggest that the open mouth temperatures taken first in Jones' study may have cooled the mouth, thus affecting subsequent closed mouth temperatures.

Neff et al. (1989) supported Wironen's findings and determined that open mouth breathing produced a significant ($\underline{p}$< 0.01) decrease in posterior sublingual temperature (0.31 ^{o}C) compared with closed mouth breathing (0.04 ^{o}C).

Robichaud-Ekstrand and Davies (1989) also noted mouth breathing subjects had a lower sublingual temperature (0.19 ^{o}C) compared with nose breathing subjects (N = 48). This difference was reported to be significant, however, the lack of interrater reliability and tests of validity and reliability of the 25 electronic thermometers used in the

study seriously weaken the validity of the findings.

Although Konopad's (1990) study was not designed to examine the effect of open versus closed mouth on oral temperature, additional data analysis was performed to determine this. Non significant differences in oral temperature ($p > .01$) were reported for mouth open ($n = 26$) versus mouth closed ($n = 39$) in subjects with or without an oral ETT in place.

Ambient Temperature

The effect of ambient temperature on temperature measurements has been questioned. Beck and St. Cyr (1974) state that more than 20 minutes is required for temperature stabilization upon entering a new ambience. Nichols and Verhonick (1967), as part of a larger study, reported that environmental temperatures affected rectal temperature readings ($N = 60$). Less range of temperature differences was noted in the warm room (0 to 0.6 ^{o}F) compared with the cool room (0 to 1.4 ^{o}F). While 31% of subjects had identical maximum readings in both environments, 31% had higher readings in the warm room (95 ^{o}F) and 37% had higher readings in the cool room (65 ^{o}F). An insufficient temperature stabilization time (10 minutes) in each environment (Beck & St Cyr, 1974) may have confounded the results.

In varying warm environments, Mariaux, Sagot, and Candas (1983) demonstrated sublingual temperatures accurately

estimated esophageal temperatures (N = 5). Data supported oral temperature as a better estimator of core (esophageal) temperature than rectal temperature both under steady state (r = .974) and varying warm ambient conditions (r = .948). A limitation of the study is the small sample size. Similar findings were reported by Livingstone, Grayson, Frim, Allen, and Limmer (1983) who compared skin, rectal, esophageal, auditory canal, GI tract, and sublingual temperatures of five young males in neutral and cold environments. They concluded that at normal ambient temperatures, temperatures at internal sites provided "comparable and consistent estimates of a core temperature." (p. 1029-30) Cold exposure, however, altered this relationship resulting in a decline in oral and auditory canal and a rise in rectal temperature. Facial cooling and local heat production in the GI tract are proposed as reasons for these changes respectively. The small sample size is a limitation of the study.

Fox et al. (1971) subjected 12 young male volunteers to room temperatures of 22 ^{o}C and then 14 ^{o}C. Rectal temperatures were less influenced by cooler environmental conditions than sublingual temperatures leading the investigators to recommend the former site for the determination of hypothermia. The shorter than recommended oral placement time for glass thermometers (five minutes) and failure to report accuracy and reliability tests of the instrument as well as exact placement sites in the mouth and

rectum weaken the validity of the findings.

Activity and Postural Changes

Activity and changes in position such as moving from standing to lying or vice versa have been shown to affect body temperature. When temperature changes occurred slowly, comparable changes in measurement were noted at various sites. However, during rapid temperature changes such as occurred with intense exercise, rectal temperature lag was once again demonstrated. Cranston et al. (1954) investigated the effect of muscular activity (tensing of muscles) without limb movement on oral, rectal, and esophageal temperatures. In six experiments with three subjects, sublingual temperature fell 0.08-0.22 ^{o}C but rectal temperature fell in four experiments (0.06 - 0.10 ^{o}C), rose in one (0.03 ^{o}C) and did not change in the other. For two subjects esophageal temperatures decreased by 0.20-0.33 ^{o}C. The investigators suggest that the decrease in temperature noted with mild exercise performed without position change could be the result of heat transfer from the blood to the cooler muscles.

Strydon, Morrison, Booyens, and Peter (1956) using underground labourers (N = 229) undertook a study to determine the accuracy with which oral temperature reflected rectal temperature during work in heat. Following 2-3 hours of moderately hard and continuous work in above average temperatures, rectal and oral temperatures were measured for

three minutes each. A correlation coefficient of 0.830 and a mean difference of 1.22 $\pm$ .64 ^{o}F between oral and rectal temperatures, with all but one rectal temperature higher than oral, were reported. These investigators concluded that the difference between oral and rectal temperatures was not significantly influenced by environmental conditions and work rate and that the mean oral-rectal difference remained constant over a wide range of body temperatures. The results may have been influenced by the possibly insufficient time for oral thermometer placement. Calibration of the instruments also is not reported. The 2-3 hours of continuous work would have provided adequate time for stabilization of temperatures at both the oral and rectal sites.

Edwards et al. (1978) reported a slower return to baseline following the completion of light exercise (bicycle ergometer) for 12 young subjects. When oral temperatures had returned to pre-exercise levels, rectal temperatures remained 0.11 ^{o}C above baseline. Exercise resulted in larger changes in oral (0.19 ^{o}C) compared with rectal temperature (0.09 ^{o}C). Tests for accuracy and reliability of instruments are not reported. The small sample size is a further limitation of the study.

Greenleaf and Castle (1972) investigated the effects of exercise and environmental temperatures on the relationship between external auditory canal and skin and rectal temperatures. Temperatures were measured at rest, during 60

minutes of exercise, and in recovery. During the first 30 minutes of exercise, auditory canal and rectal temperatures rose at about the same rate. Whereas auditory canal temperatures levelled off at approximately 30 minutes, rectal temperatures required 65 minutes to reach equilibrium.

Mariaux et al. (1983) concluded that sublingual temperatures are accurate indicators of esophageal temperatures. They noted that during exercise, the difference between rectal-esophageal temperatures increased from 0.2 ^{o}C at rest to 0.4 ^{o}C following two hours of exercise and continued to increase during initial recovery, yet oral-esophageal differences barely changed under the same conditions. They suggest the rich supply of blood that the tongue receives from the lingual branch of the external carotid artery may provide the explanation of why sublingual temperature measurements are sensitive to the rapid changes in central blood temperature.

During 30-70 minutes of rest, Cranston et al. (1954) reported temperatures at three measurement sites (rectum, mouth, and esophagus) for 11 subjects responded similarly and demonstrated a slow fall in temperature. They also noted that standing resulted in a rise and lying in a fall, in temperature at these same sites. Kleitman and Doktorsky (1933) monitored rectal temperatures of four subjects and reported the same results with positional changes. Cranston et al. suggest that these changes could be the result of

increases and decreases in cool venous return upon lying and standing respectively. The small sample size for both these studies limit the generalizability of the findings.

Application of Heat and Cold

Alterations in temperature may occur as a result of the application of heat or cold (Burton-Fanning & Champion, 1903; Hersch, Woodbury, & Bierman, 1943), or the immersion of an extremity or the body in hot or cold baths. The effect of immersion of an extremity on sublingual and external auditory canal temperatures was undertaken by Cooper, Cranston, and Snell (1964a). In 54 experiments (n = 16), immersion of an arm in a hot water bath (44 ^{o}C) produced similar rises in both oral and auditory canal temperatures. A high correlation was noted (r = .915, p < .001). They also noted that facial flushing (n = 1) resulted in a rise in ear temperature but no change in sublingual temperature.

The immersion of 12 subjects up to their necks in a hot bath (41 $\pm$ 0.5 ^{o}C) in a study by Edwards et al. (1978) resulted in a greater rise in sublingual temperature than rectal temperature. Whereas oral temperature rose 1.28 ^{o}C, rectal temperature increased 0.57 ^{o}C. Following removal from the bath rectal temperature continued to rise for a longer time (6 minutes compared with 1.5 minutes) and was slower to return to baseline than temperatures measured at the sublingual, esohageal, and auditory canal sites. The

investigators concluded that rectal temperature measurement should not be used to monitor transient changes in core temperature.

Postoperative Temperature Changes Over Time

"Temperature monitoring is a standard nursing function after open heart surgery and is vital for patient welfare. It is essential for hemodynamic evaluation and for the prediction of rewarming patterns, onset of shivering, and overshoot phenomena." (Earp & Finlayson, 1991, p. 265). Studies of patients undergoing CABG surgery with cold cardioplegia have shown that following temperature afterdrop, the most significant changes in temperature occur within the first eight hours post-operatively (Kassum & Thomson, 1992; Sladen, 1985). Cooper and Kenyon (1957) report that following surgery with induced hypothermia, rewarming occurred at the rate of 1-2 ^{o}C per hour over the first four hours.

Sladen (1985) observed postoperative temperature changes for 73 subjects during the first 12 hours following open heart surgery during which core cooling to 29.5 $\pm$ 1.7 ^{o}C occurred. Rectal temperatures were measured with a Yellow Springs telethermometer. Mean rectal temperatures rose from 34.7 to 38.3 ^{o}C over the first 8 ($\pm$ 2) hours following ICU admission, with a decrease towards normal following this. The most rapid rate of temperature increase occurred between 2-4 hours.

Kassum and Thomson (1992) investigated perioperative hemodynamic and temperature changes for 58 open heart surgery patients and reported similar findings. Core temperatures were measured using Swan-Ganz pulmonary artery catheter thermistors for 24 hours following admission to ICU. Cold cardioplegia during surgery resulted in core temperatures of 25-28 ^{o}C. Following surgery a temperature overshoot of greater than 38.5 ^{o}C occurred in 34.5% of the sample.

Additional support for these postoperative temperature changes is provided by Dominiguez DeVillota, Barat, Astorqui, Damaso, and Avello (1974). These investigators observed 16 subjects following open heart surgery in which hypothermia (n = 13) and normothermia (n = 3) were used. Rectal temperatures monitored postoperatively revealed significant increases in temperature at four hours following ICU admission with a peak of 39.3 $\pm$ 0.7 ^{o}C at eight hours.

The pathophysiological basis for the rapid temperature rise following major surgery remains unclear. Holdcroft and Hall (1978) reported a rapid increase in heat production following surgery on 23 young healthy women. Infectious processes are often assumed to be the cause of fever in critical care patients, however, negative blood cultures for 20 patients with temperatures over 38.5 ^{o}C were reported in the study by Kassum and Thomson (1992). Hypothalamic insult, the effect of drugs, or decreased heat loss as a result of peripheral vasoconstriction have been suggested as possible

causes (Kassum & Thomson, 1992; Molnar & Read, 1974a; Niemenen, Rosow, Triantfillou, Schneider, Lowenstein, & Philbin, 1983; Sugarek, 1985) Holtzclaw (1992) suggests a febrile response should be anticipated when injury, surgery, or inflammatory responses disrupt cell walls.

SUMMARY

A comprehensive literature review was undertaken to locate articles relating to body temperature, instruments for temperature measurement, and factors affecting measurement of temperature. Literature relating to the effect of oral intubation on sublingual temperature measurements was specifically focused on because of the purpose of the study.

The literature review revealed that there is little conclusive evidence for many of the common practices relating to temperature monitoring in the clinical area. That temperatures differ at various sites and within sites and that no definite conversion factor exists to determine temperature of one site from that at another strongly points to the need for both a consistent technique and a consistent site for temperature measurement. The need for accurate and reliable instruments and control of external factors that may affect temperature measurement is supported by the studies reviewed. The literature also points out the need for additional studies or replication of studies in many of the areas relating

particularly to the effect of external factors on temperature measurement. Insufficient empirical evidence to support the accuracy of oral temperature monitoring in patients with an oral endotracheal tube in place suggests this as one of the areas requiring further investigation. Dressler et al. (1983) succinctly sum up the literature relating to oral versus rectal temperature measurements. They state that "there are few physiologically sound reasons for the use of the rectal site for temperature measurement..." (p.374) and that oral temperatures, if properly taken, may provide an accurate measurement of body temperature in critically ill patients.

CHAPTER III

STUDY DESIGN AND METHOD

This chapter will outline the design and methodology used for this quantitative study. The sample size, criteria for selection, setting, instruments, procedure, and methods of data collection and analysis are reported. Changes made to the present study as a result of a pilot test also are discussed. The numerical data obtained from this study was used to determine if the discrepancy between oral and rectal temperature measurements of intubated patients is significantly different from that of non intubated patients. To accomplish this, a design, similar to that undertaken by Cashion (1982), was selected. Cashion measured pre and post intubation oral and rectal temperatures of adult patients (N = 15) undergoing open heart surgery. Temperatures were measured twice preoperatively when patients were not intubated, and six times over the first five hours following admission to ICU when patients were intubated. Although using less frequent postoperative temperature measurements, the present study took into consideration the limitations of Cashion's study and attempted to refine these. A larger sample size was used and ordering effect was controlled for. In addition to oral and rectal temperature measurements, ETT and PA temperatures were measured and recorded in the

postoperative phase up to eight hours postoperatively. The decision to obtain PA blood temperature measurements was made as a result of investigations, including Cashion's, identifying the relative inertia of rectal temperatures with rapidly changing core temperatures (Cooper & Kenyon, 1957; Eichna, 1949; Lilly et al., 1980; Molnar & Read, 1974b; Stupfel & Severinghaus, 1956). Should there be a significant difference in the rectal-oral discrepancy of non intubated and intubated subjects, a comparison of the differences between PA-oral and PA-rectal temperatures would assist in determining which site, if not both, was contributing to this discrepancy.

RESEARCH DESIGN

A repeated measures quasi-experimental design, in which open heart surgery patients served as their own controls, was used. The discrepancy between oral and rectal temperature measurements was the dependant variable; the placement of an oral ETT in subjects, the experimental intervention. Oral and rectal temperatures were taken on five occasions for each subject, twice preoperatively, when no oral ETT was in place, and three times postoperatively following insertion of the tube. Statistical analysis was then used to determine if the mean rectal-oral temperature discrepancy for non intubated subjects was significantly different from the mean rectal-oral temperature discrepancy for intubated subjects. Since open

heart surgery patients emerge from the OR not only intubated but with a PA thermodilution catheter in situ, PA temperatures also were measured during the postoperative phase. Additional analysis determined if mean PA temperatures differed significantly from mean oral and rectal temperatures and the stability of these differences over time.

Convenience sampling was selected with no attempt at randomization. This was the result of the limited number of patients undergoing open heart surgery at the facility chosen for this investigation.

This study was undertaken in two phases. A pilot test completed in the fall of 1991 (Fallis, 1991) constituted the first phase. As a result of the pilot test changes to the design of the present study were made. These changes are noted and the rationale for them discussed. Phase two was the completion of the present study, complete details of which are presented herein.

The Pilot Test

The pilot test was undertaken to determine if changes needed to be made in the design of the study or to the data collection forms. Pilot testing also allowed the investigator to become familiar with the various instruments and techniques for instrument calibration and temperature measurements. In addition, unit routines which might complicate the collection

of data could be determined.

Following the attainment of access to the facility, verbal consent from the cardiovascular surgeons, six subjects about to undergo open heart surgery were invited and agreed to participate in the pilot test. Written informed consent from the patients was obtained the day before surgery. Following a thirty minute period during which extraneous variables known to possibly affect temperature were controlled for, oral and rectal measurements were taken. Measurements were taken twice preoperatively the evening before surgery at a one-half hour interval and three times in the postoperative period within eight hours following admission to ICU. Room temperature, ETT temperature, and PA temperature also were measured. The latter two temperatures were measured in the postoperative phase only. An IVAC 2080A electronic thermometer was used for oral, rectal, and ETT temperature measurements. A Swan-Ganz PA catheter thermistor measured PA blood temperatures. The sequence of oral and rectal temperature measurements was alternated with every second subject recruited and ETT temperatures were measured as close to oral temperature measurements as possible. Since PA temperatures were continuously displayed on the hemodynamic monitor, they were quickly recorded at end expiration between oral and rectal temperature measurements.

Complete measurements were obtained on four of the six subjects. Two subjects met the exclusion criteria and had to

be dropped from the pilot test during the postoperative period; one emerged from the operating room (OR) with an intra aortic counter pulsation balloon pump and; an electric blanket was placed on a second subject at the time of the first set of postoperative temperature measurements.

Calibration of the IVAC 2080A thermometer against a precision thermometer in a well stirred water bath over a range of temperatures from 28 to 42 ^{o}C determined the accuracy of the instrument to be within the $\pm$ 0.1 ^{o}C reported by the manufacturer. Tests for accuracy of the Swan-Ganz catheter thermistors were not undertaken during the pilot study.

As a result of the pilot test, changes were made to both the data collection forms and to the design. For example, in order to control for the effect of fecal material on rectal temperature measurements, the initial design called for preoperative temperatures to be measured following subjects having received bowel preparation (Sodium Phosphate enema) the evening before surgery. However, pilot testing revealed that this preparation was not consistent for all open heart surgery patients. In addition, no information could be found in the literature to determine the duration and effect of bowel preparation on rectal temperature. Therefore, in order to ensure consistency between subjects, the decision was made to measure temperatures of all subjects prior to any bowel preparation.

The times of temperature measurements following the open

heart surgical procedure also changed as a result of the pilot test. Initial design called for temperatures to be taken at two, four and eight hours following admission to ICU. This was changed to one, four and eight hours in the present study. First, access to the patient by the investigator following routine assessment and admission procedures to ICU was possible before two hours; and second, the temperature increases noted in the subjects within the first two hours of admission needed to be included in the data in order to provide as wide a range of temperatures as possible. Once this problem was identified and discussed with the ICU nurses, access to the subject within 45 to 60 minutes of admission to ICU resulted.

Lastly, the initial design called for the use of the monitor mode for oral and rectal temperature measurements because calibration of the IVAC thermometer against a water bath is recommended by the manufacturer in this mode only. Calibration in the predictive mode is not suggested because the thermal characteristics of water differ from those of the mucosal tissues. However, pilot testing revealed that this mode required from four to five minutes to determine a final temperature. Although this mode remained necessary for the measurement of ETT temperatures, in the complex care of "fresh" open heart surgical patients, the investigator felt that using this mode in the present study for the oral and rectal temperatures might be too time consuming during this

critical time, resulting in interference in the care of the subject. Although use of the alternative predictive mode would necessitate the assumption that the instrument, if determined accurate in the monitor mode also would be accurate in the predictive mode, the predictive mode was selected for the present study. Furthermore, this mode is used daily by nurses in the clinical area and is used most frequently in temperature studies undertaken in this area. The changes made as a result of the pilot study were incorporated into the design of the present study.

The Formal Study

The present study used a prospective timeframe. Multiple repeated measurements were taken on each subject who consented to participate and who met the selection criteria. The cardiovascular surgeons also had to be in agreement with their patients participating. Five sets of temperature measurements were taken on each subject during the study. Data collection occurred until a sample of 40 subjects who were able to complete the study had been obtained. It was expected that this would take approximately eight weeks. The resulting data was then subjected to quantitative analysis. Upon completion of the study, subjects who had indicated to the investigator that they desired a summary of the study, had this mailed to them.

The Sample

Consultation with the Manitoba Nursing Research Institute statistician was undertaken to determine sample size. To achieve a power of 90% with alpha set at 0.05 in testing (two-tailed) between the intubated and non intubated groups, it was calculated that a minimum of 32 subjects would be required to determine a significant difference of 0.2 ^{o}C (Cohen, 1969). In order to account for possible subject loss or data omission, a sample of 40 subjects was selected.

The sampling frame consisted of patients admitted to the study site who met the following selection criteria.

Selection Criteria:

- 18 years of age or greater
- undergoing scheduled open heart surgery in which warm or cold cardioplegia is used
- in no acute distress
- able to read and understand English
- agreeable to signing a written consent form
- orally intubated following surgery
- no recent oral or rectal surgery (within 1 month)
- no rectal anastomosis or sclerosed hemorrhoids
- no oral or rectal inflammation or infection

Patients were excluded from the study who meet the following

exclusion criteria.

Exclusion Criteria:

- requiring oxygen via face mask
- hyperventilating (respiratory rate > 20 per minute)
- intra-aortic counterpulsation balloon pump required
- uncontrollable ventricular arrhythmias
- extubated less than eight hours postoperatively
- unstable postoperatively requiring return to the OR

Additionally, subjects who had an electric heating or cooling blanket in place or refrigerated blood/ blood products or fluid challenge infusing at the time of temperature measurements were excluded.

Upon determining that any of the exclusion criteria had been met or the protocol violated, subjects were withdrawn from the study. Subjects requesting withdrawal from the study had their request respected.

The Setting

A large teaching hospital in Western Canada was approached for permission to access their site and patients. Approximately eight open heart surgeries are performed weekly at this institution. Patients scheduled for open heart surgery are normally admitted to the Cardiovascular Thoracic

(CVT) Unit prior to surgery and it was here that they were approached by the investigator for participation in the study. The same patients who consented to participate were followed by the investigator to the Surgical Intensive Care Unit (ICU) following their surgery.

Protection of Human Rights

The protection of human rights was maintained throughout the study. After receiving the surgeons' approvals (see Appendix A), potential subjects were approached by the investigator the day before their surgery. In consultation with their nurse, this occurred after patient teaching regarding the usual preoperative, surgical, and postoperative routine for open heart surgery had taken place. Consequently patients were aware that a breathing tube (ETT) as well as an intravenous (PA) catheter for hemodynamic and temperature monitoring would be in place following surgery. Potential subjects were provided with a complete explanation of the study (Appendix B) and informed that the reason they were invited to participate was because they would have a breathing tube in place after surgery. They also were informed that the investigator would take all temperature measurements. Preoperatively these would include oral, rectal, and room temperature; postoperatively they would include oral, rectal, and heart (pulmonary artery) temperature, as well as room and

endotracheal tube temperature. Oral and rectal temperatures would take approximately one minute each; endotracheal tube temperature measurements would take approximately three minutes. PA temperatures would be obtained by observing the hemodynamic monitoring screen. The patient also was asked to grant permission to the investigator to record information from the chart relating to their surgical procedure.

The investigator explained the purpose of the study and the procedures to be used to potential subjects and requested their consent to participate. It was stressed that there would be no direct benefit to them as a result of taking part in the study, that participation was voluntary, and declining to participate would not affect their care in any way. Their right to withdraw from the study at any time should they agree to participate also was stressed.

Patients were informed that their name would not appear on any of the data sheets, thus assuring their anonymity. Instead each would be given a code number and this number would identify them. Only the investigator would be knowledgeable of the patient's identity and this information would be kept in a separate locked file. They also were told that only the investigator's thesis committee and a statistician would have access to the coded data sheets, thus assuring confidentiality of the information. After ensuring that they met the selection criteria, patients willing to participate were asked to read and sign a written consent.

Any indication of reluctance to participate was respected. A mailed summary of the results was offered to each participant.

The collection of data involved minimal physical risk to subjects and little discomfort was expected to be associated with the various measurements. Patients with sclerosed hemorrhoids, recent rectal or oral surgery, or inflammation or infection of these sites were excluded from participating. The potential for some psychological discomfort, such as embarrassment, from having a rectal temperature taken was anticipated. However, since temperature taking is a routine event in hospitals, this procedure was not expected to provoke undue anxiety. The use of a calm, non threatening approach by the investigator as well as the provision of explanations of each step of the procedure were used to reduce anxiety. In addition, patients were allowed to view the instruments and were encouraged to ask questions for further clarification. Privacy to the patient was ensured and any unnecessary exposure avoided. Every attempt was made to ensure that the study protocol did not interfere with the provision of patient care.

Physiological Variables Measured

The major physiological variables identified in this study were:

Oral Temperature: Oral temperature was measured using the left or right posterior sublingual pocket of the oral cavity. The sublingual pocket is the area where the base of the tongue joins the floor of the mouth on the left or right side of the frenum.

Rectal Temperature: Rectal temperature was measured in the rectum 7.5 centimetres past the anal verge.

Pulmonary Artery Temperature: Pulmonary artery temperature was measured in a main branch of the pulmonary artery.

Extraneous Variables Measured

Two extraneous variables were measured. These were:

Endotracheal tube temperature: ETT temperature was defined as the temperature 1.25 centimetres inside the "Peep Keep" port of the swivel adaptor that attaches the ventilator tubing to the ETT.

Air temperature: The ambient temperature of the immediate vicinity of the subject was measured. Immediate vicinity was defined as the 60 cm area surrounding the subject at head level. Ambient temperature was measured by a digital thermometer which recorded temperature in degrees Fahrenheit.

This was later converted to degrees Celsius.

The Instruments

The following instruments were utilized in this study:

IVAC 2080A TEMP PLUS II: The IVAC TEMP PLUS II, model 2080A thermometer which displays temperatures in degrees and tenths of degrees Celsius was used to measure oral and rectal as well as ETT temperature. This digital electronic battery operated instrument with accompanying oral and rectal probes has a reported accuracy of $\pm$ 0.1 °C and performs self-tests and auto calibration (IVAC Corporation, 1987). In addition to indicating if battery levels are low, need replacing, or the probe is broken, a tissue contact pinwheel on the display screen indicates if good tissue contact is maintained. The IVAC 2080A uses a thermistor at the tip of a plastic and stainless steel probe to detect temperature changes. Thermistors are "...extremely sensitive transducers which convert a rise in temperature to a decreased resistance to electrical current." (Erickson, 1980b, p. 159)

Two modes, predictive and monitor, are available for use with this instrument. The predictive mode uses the initial rate of temperature rise following insertion of the probe to predict the patient's temperature. The thermal characteristics of the measurement site are taken into account

in the design of the predictive circuit. The thermometer, when used in this mode, is capable of measuring temperatures from 31.6 to 42.2 oC. and an audible tone signals a final temperature reading. Temperature is displayed on a display panel. This mode requires less than one minute to reach a final temperature and is normally used in the clinical setting for oral and rectal temperature measurements. It was used in this study for the same purpose.

The monitor mode does not predict temperature but measures it continuously. This mode requires a minimum of three minutes to reach a final temperature, however, no signal indicates when this temperature has been reached. In this mode, the IVAC thermometer is capable of measuring temperatures between 26.7 and 42.2 ^{o}C. Because the thermal characteristics of ETT contents differ from those of oral or rectal mucosal tissue, the monitor mode and not the predictive mode was used to measure ETT temperature.

Swan-Ganz Thermodilution Paceport Catheter: The disposable Paceport catheter was used to measure PA blood temperature. The tip of this balloon-tipped flow directed catheter rests in a main branch of the pulmonary artery. A thermistor, which continuously measures temperature, is located proximal to the tip and core temperature is continuously displayed on the screen of the hemodynamic monitoring system. The accuracy of the Paceport catheter thermistor is reported to be $\pm$ 0.3 ^{o}C at

temperatures between 31.0 and 41.0 ^{o}C. (Baxter Healthcare Corporation, 1990)

KANOMAY Model 6907: Ambient temperature was measured using a Kanomay Model 6907 digital thermometer. This instrument measures temperature in degrees and tenths of a degree Fahrenheit and displays it on a display panel. Testing of this instrument was not undertaken.

Ensuring Validity and Reliability of the Instruments

Calibration of the IVAC 2080A against a total immersion precision mercury in glass thermometer (error <0.10% of scale) in a well-stirred water bath over a range of temperatures from 28 to 42 ^{o}C occurred prior to and following data collection. "Calibration of research instruments both before and after use validates the original testing and provides presumptive evidence of reliability when used to obtain the study measurements." (Erickson, 1980b, p. 159)

Calibration of the IVAC thermometer was performed with both oral and rectal probes. The instrument was placed in the monitor mode and probes were inserted 6 cm into the water bath and tested at one-half degree intervals over the range of 28.0 to 42.0 °C. Daily calibration of the thermometer prior to the beginning of each day's measurements also was done by the investigator using a probe simulator. The simulator verified

temperature measurements of the unit at five settings between 26.8 and 42.2 °C and allowed detection of a broken probe.

The effect of sheath covers on the accuracy of the instrument also was determined. Ten probe covers from the same lot as that used in the study were inserted 6 cm into the water bath and tested at temperatures of 35, 37, and 39 °C.

Reliability tests of the IVAC electronic thermometer were performed by inserting the oral and rectal probes with and without probe covers 10 times each into a controlled temperature water bath set at 36°C and 38 °C. Probe covers used for reliability testing were from the same lot used for the study.

Tests of accuracy of the Swan-Ganz Thermodilution Paceport catheter thermistors also were performed against the same precision mercury-in-glass thermometer in a well-stirred water bath at temperatures of 30, 35, and 40 °C. This was undertaken at the completion of the study. Paceport catheters used by each subject were tagged with the subject's code number and, following removal, collected for testing.

The Procedure

An outline of the procedure to be followed for this study is provided in Figure 1. The investigator was directly involved and the sole conductor of the study. Following approval from the Faculty of Nursing Ethical Review Committee

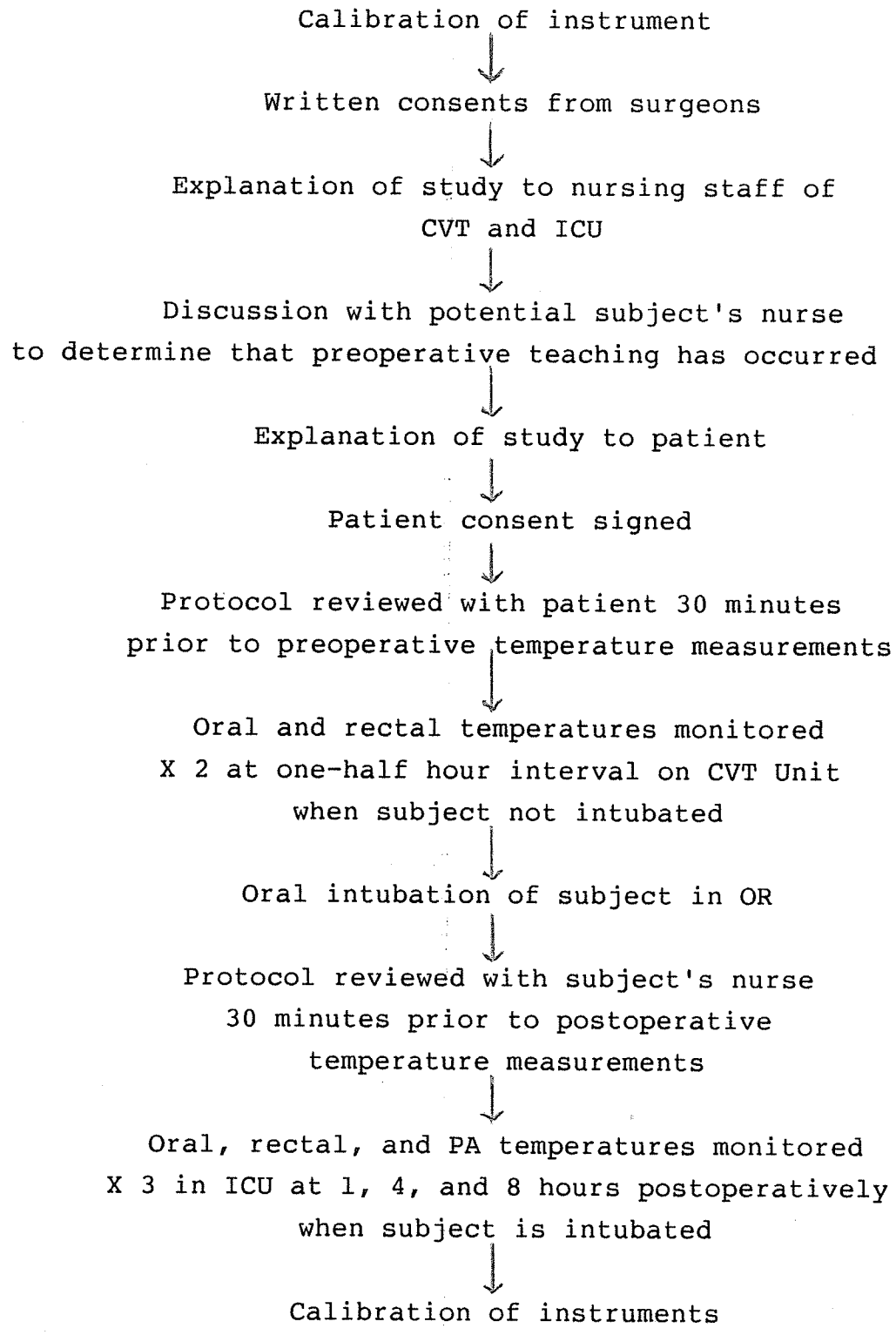


Figure 1. Protocol Procedure

at the University of Manitoba, permission from the agency utilized, and the surgeons' consents, the researcher ensured that the staff on the two hospital units (CVT and ICU), where the study was conducted, were aware of the nature and the purpose of the research. To achieve this goal, the investigator attended a staff meeting of these units. This meeting provided nursing staff with the opportunity not only to meet the researcher but to ask questions. An explanation of the study, including possible future benefits to patients and staff as well as the variables needing to be controlled, was provided. The researcher stressed that every attempt would be made to ensure limited interference in the schedule of routine care for the subjects during the undertaking of the study. A copy of the study results was offered to the Head Nurse of the two units for dissemination to staff.

The investigator determined from the surgery schedule posted on the CVT unit the patient(s) who were scheduled for open heart surgery the following day. Following a discussion with the patient's nurse to ensure that the patient had preoperative teaching and/or a chance to view the open heart surgery video, the investigator approached the potential participant. The investigator provided an explanation of the research and after answering any questions and ensuring that the selection criteria had been met, invited the patient to participate in the study. Subjects agreeing to participate were asked to read and sign a consent form. (see Appendix C)

Following this they were informed that the investigator would return later the same evening at 2030 hours to begin the protocol prior to the first and second set of measurements. These times were chosen to avoid interfere with visiting hours and bedtime medications and treatments. Subjects were assured that the investigator would review the protocol with them again prior to the measurements in addition to leaving a list of instructions for them at their bedside (see Appendix D).

Wood and Brink (1989) report that during data collection, steps should be taken by the researcher to control for anything that is likely to affect the reliability of the data. Erickson (1980b) also asserts that "For research, relatively tight controls should be imposed on extraneous variables that could modify oral temperatures and confound study findings." (p. 164) Therefore potentially confounding factors known to affect oral or rectal temperatures were controlled for or measured in this study in an attempt to tighten the design. Those variables unable to be controlled or measured were recorded.

In order to control for extraneous variables known to affect temperature, subjects were requested to lie quietly and to not eat, drink, smoke, chew gum, brush teeth, use mouthwash, bathe, or immerse an extremity in water for 30 minutes prior to the temperature measurements. This 30 minute time period also allowed the patient to adjust to the room temperature.

No attempt was made to control for the possible short-term effects of emotional excitement on body temperature. However, the investigator used a calm approach, and provided ongoing instructions and privacy. Any unnecessary exposure was avoided. Further to this, each subject was allowed to view the various instruments and was reassured that they would produce little or no discomfort.

The effect of circadian rhythm or the menstrual cycle on body temperature was not controlled for. Instead, it was hoped that these cyclical variations would provide increased fluctuations in body temperature. Additionally the investigator could not control for the time the subjects exited the operating room and therefore, at what time of day the postoperative measurements would be taken.

In an attempt to control for the effect of ambient temperature on the open mouth, patients preoperatively were requested to close their mouths when oral temperatures were being taken. However, in the postoperative phase, with an oral ETT in place, this was not possible. Therefore, ambient temperature was measured preoperatively and postoperatively. Prior to the oral and rectal temperature measurements being taken the room thermometer was placed at the level of and within 60 cm of the patients head. Room temperature was recorded at the completion of all other measurements in order to allow time for stabilization of this temperature.

Due to inconclusive evidence as to the effect of

dentition on oral temperatures, subjects with a denture or partial plate were asked to remove these 10 minutes prior to the first set of temperature measurements. Full or partial plates are routinely removed prior to surgery in patients undergoing general anaesthesia. As there was no information in the literature to determine the time required for mouth temperatures to stabilize following removal of these prosthetics, 10 minutes was assumed to be sufficient time for this adjustment. This additional visit to the patient 20 minutes into the protocol to ensure that this was carried out also provided the investigator with the opportunity to determine if the study protocol was being followed by the subjects.

Immediately prior to each set of measurements being taken, the investigator reviewed the list of extraneous variables (see Appendix E and F) with the patient preoperatively and the subject's nurse postoperatively to ensure they had been controlled.

Ideally all temperature measurements should have been taken simultaneously in order to control for the effect of time on temperature. However, with one investigator performing all the measurements this was not possible. Therefore, oral (O) and rectal (R) temperatures were taken one immediately following the other. As well, in order to control for ordering effect, the sequence of the oral/rectal measurements was reversed with every other set of measurements

and with every other subject. A toss of a coin prior to the commencement of data collection determined which sequence of measurements would be used first. When it was necessary to eliminate subjects once data collection had begun, the next subject recruited followed the sequence of the eliminated subject. This ensured that equal numbers of subjects were in each sequence group. An example of the sequence of preoperative measurements for Times 1 and 2 during which subjects were not orally intubated is provided.

	Time 1	Time 2	
Subject # 1:	O-R	R-O	(see Appendix E)
Subject # 2:	R-O	O-R	(see Appendix F)

For oral and rectal measurements the IVAC 2080A thermometer was placed in the predictive mode and the slow insertion technique used. Preoperatively, the oral probe with probe cover was inserted into the front of the patient's mouth, taking three to five seconds to move it along the gumline to the right or left posterior sublingual pocket. The probe was held in position by the investigator. Subjects were not allowed to reposition the probe and were asked to keep their lips closed and breathe through their nose during this time.

The rectal probe with a lubricated probe cover was used to measure rectal temperature. This was slowly inserted into

the rectum, taking three to five seconds to reach a depth of 7.5 cm past the anal verge, and held in position by the investigator. Both oral and rectal probes were left in place until the audible beep signalled that a final temperature had been reached. The probe was then removed, the probe cover discarded, and the reading recorded immediately on the subject data collection form. (see Appendix E and F) Recording of ambient temperature took place upon completion of the oral and rectal temperature measurements.

At the completion of the first set of measurements, the subject was requested to follow the same protocol for an additional 30 minutes, following which, the second set of measurements was taken.

Oral and rectal temperatures again were measured following the subject's surgery and routine admission to ICU. One, four, and eight hours post admission to ICU were the times selected for measurements in order to provide a wide range of temperature measurements (Kassum & Thomson, 1992; Sladen, 1985). Prior to temperature measurements, the investigator reviewed the study protocol with the subject's nurse to ensure extraneous variables as listed on the data collection form were controlled. Extraneous variables that were controlled for in ICU included: no suctioning of the oral cavity for 15 minutes, minimal occlusive ETT seal, no extremity immersed, no hot or cold applications to the face or neck, no bathing or mouth care for 30 minutes, and no

refrigerated blood products or fluid challenges infusing. Inability to adhere to the protocol would result in the subject's withdrawal from the study. Measurements again were taken one immediately following the other and the sequence of oral-rectal temperature measurements reversed with every second set of measurements.

Postoperatively, the procedures for the oral and rectal temperature measurements were identical to those taken preoperatively with the exception that oral temperatures were measured in the posterior sublingual pocket opposite to the ETT and the patient's mouth was not necessarily closed. In addition, prior to this measurement, the investigator using auscultation confirmed that a minimal occlusive seal around the ETT cuff was present, thereby ensuring that air from the lungs did not bypass the cuff and influence oral temperature measurements. If a cuff leak was detected, the subject's nurse was asked to rectify this situation prior to temperature measurements being taken.

ETT temperature also was measured in order to control for the effect of this temperature on the temperature of the oral cavity. The IVAC thermometer was placed in the monitor mode and an oral probe with probe cover inserted into the "PEEP KEEP" insert of the patient's swivel adaptor. More precise measurements of the ETT temperature (in 0.1 ^{o}C gradations) than that which is normally displayed by the ventilator could be obtained using this method. This procedure was tested and

proved satisfactory for measuring ETT temperature during the pilot study. This measurement was taken immediately before or after oral temperature measurements depending on the sequence to be followed for that patient. (see Appendix E and F) Since no signal indicates when measurements are complete in the monitor mode, the temperatures were required to remain constant for three consecutive respiratory cycles prior to temperatures being recorded.

PA temperatures also were measured in the postoperative phase. This temperature is continuously displayed on the screen of the hemodynamic monitoring system. PA temperature measurements were taken at end expiration and recorded between the oral and rectal temperature measurements. Swan-Ganz catheters were tagged with each subject's code number for identification purposes and collected following removal for tests of accuracy.

Ambient temperature again was recorded immediately following the other measurements. An example of the sequence of postoperative measurements for subjects for Time 3, 4, and 5 is provided. These times represent 1, 4, and 8 hours following admission to ICU respectively.

	Time 3	Time 4	Time 5
Subject # 1:	ETT-O-PA-R	R-PA-O-ETT	ETT-O-PA-R
Subject # 2:	R-PA-O-ETT	ETT-O-PA-R	R-PA-O-ETT

Lastly, demographic data was recorded for each subject in order to describe the subjects, determine generalizability of the study results, and for ease of future replication (see Appendix G). This data included: age in years; gender; surgery performed; time of and PA temperature on admission to ICU; weight; height; body surface area (BSA); time spent in operating room; warm or cold cardioplegia (perfusion temperature) used during surgery; and refrigerated blood or blood products infused during the study. In addition, medications received by the patient within eight hours prior to temperature measurements, although not able to be controlled for, were recorded.

Data was collected on all subjects in this manner throughout the study. Once information and measurements were completed on a minimum sample of 40 subjects, the data was analyzed.

Data Collection

Each subject was given a code number and all data for each subject recorded immediately following the measurement. Immediate recording aids in ensuring that data is not omitted or forgotten. Temperature measurements during the preoperative phase when subjects were not intubated (Time 1 and 2) and during the postoperative phase when an oral ETT was in place (Time 3, 4, and 5) were recorded on Subject Data

forms 2A or 2B. (Appendix E and F) Demographic data was recorded on the Demographic Data form. (Appendix G)

In addition, data relating to the tests of accuracy and reliability of the IVAC 2080A thermometer and the accuracy of the Swan-Ganz Thermodilution Paceport catheter thermistors were recorded.

Data Analysis

Data analysis occurred at the completion of the study utilizing the Statistical Analysis System (SAS). An alpha level set at .05 was used to determine statistical significance for the data. To test the study hypothesis that the rectal-oral temperature discrepancy in non intubated patients is not significantly different from that of intubated patients, a one-factor repeated-measures analysis of variance was used. Simple linear regression analysis was utilized to determine the effect of ambient and ETT content temperature on rectal-oral temperature discrepancy.

Additional analysis was undertaken to determine the PA-oral and PA-rectal temperature differences and the consistency of these differences over the three intubated time periods. The effect of ETT content temperature on the temperature differences also was determined using simple linear regression

analysis.

It was assumed that a positive correlation between oral and rectal, oral and PA, and rectal and PA temperatures existed. However, correlational analysis, using Pearson's product moment correlation coefficient was used to determine the strength of these correlations. Tests for normal distribution of data was performed to support the underlying assumption of the statistical test.

Descriptive statistics were used to report data relating to: age, height, weight, BSA, duration of surgery, time on bypass, time of admission to ICU, all temperature measurements, and the times temperatures were recorded. This procedure also was employed to describe patient characteristics of gender, type of surgery, use of refrigerated blood or blood products, use of warm or cold cardioplegia, and medications.

SUMMARY

A repeated measures quasi-experimental design was used to compare the discrepancy between rectal and oral temperatures of intubated and non intubated subjects undergoing scheduled open heart surgery at a large teaching hospital in Western Canada. Forty adult subjects serving as their own controls and who had signed an informed consent had oral and rectal

temperatures taken with a calibrated IVAC 2080A predictive electronic thermometer on five occasions; twice before surgery when not intubated and three times postoperatively when intubated. Because studies have revealed that rectal temperature may not be a stable reference point during rapidly changing temperatures, PA temperatures were measured with a Swan-Ganz Thermodilution Paceport catheter thermistor in the postoperative phase. The accuracy of this instrument was determined following data collection. Ambient temperature and ETT temperature also were measured.

The procedure that was used to carry out this quantitative study as well as the instruments, sample, setting, and protection of human rights have been described.

CHAPTER IV

RESULTS

Data collection occurred over a seven and a half week period during the months of June and July of 1992. Complete data was collected on 40 volunteer subjects. Surgery delays resulted in eight patients requiring repeated preoperative temperature measurements. Seven of the 40 subjects were later eliminated as a result of unusual circumstances. Data from these seven subjects were not included in the final analysis, leaving a sample size of 33.

This chapter contains the results of data collection and subsequent analysis of the data. Level of significance was set at 0.05. Temperature measurements are reported as mean plus or minus standard deviation. The accuracy and reliability of instruments was examined. Information relating to participants and non participants as well as the results of temperature measurements with and without the ETT are reported. Testing of the null hypothesis was undertaken to determine if the discrepancy between rectal and oral temperatures of non intubated patients differed significantly from that of intubated patients. Analysis of PA minus oral and PA minus rectal temperature differences of intubated patients was used to determine if there were significant differences between these sites following intubation and the

stability of these differences over time. As assumed, the positive correlations expected between the oral, rectal, and PA sites were upheld. The strength of these correlations are reported. Lastly, variables possibly affecting temperature measurements were examined.

Validity and Reliability of Instruments

IVAC 2080A Electronic Thermometer

The same IVAC 2080A thermometer with accompanying oral and rectal probes was used for all patients in the study. Testing of the IVAC 2080A for validity and reliability occurred prior to and at the completion of data collection. Accuracy of the instrument remained at $\pm$ 0.1 °C upon testing against a precision mercury thermometer in a well-stirred water bath at half degree intervals between the range of 28.0 and 42.0 °C. (see Appendix H)

To determine if probe covers affected the accuracy of the instrument, 10 probe covers from the same lot as that used in the study each were tested at 35.0, 37.0, and 39.0 °C. Accuracy of the instrument was not affected by use of probe covers and remained at $\pm$ 0.1 °C. (see Appendix I)

Reliability of the instrument was determined by inserting the oral and rectal probes 10 times each into the water bath at temperatures of 36.0 and 38.0 °C. The IVAC 2080A remained reliable throughout the testing. Temperatures with both oral

and rectal probes were consistently +0.1 °C higher than the standard thermometer during the repeated insertions. (see Appendix J)

Daily calibration of the instrument also was undertaken by the investigator using a probe simulator. The instrument remained accurate within ± 0.1 °C over the entire data collection period.

From the above testing it was determined that the IVAC 2080A thermometer was both a valid and reliable instrument for temperature measurements.

Swan-Ganz Thermodilution Paceport Catheter

The individual Swan-Ganz Thermodilution Paceport catheters used by subjects were tagged and collected following removal. One subject required a second catheter when nursing staff encountered difficulties obtaining cardiac output measurements; both catheters were collected. The thermistor of each catheter was tested against a precision mercury thermometer in water bath temperatures of 30.0, 35.0, and 40.0 °C. All catheter thermistors were determined to be accurate within ± 0.1 °C. (see Appendix K)

Patient Demographics

Fifty-eight patients who met the inclusion criteria were invited to participate in the study. All were admitted to

hospital for scheduled open heart surgery. Of these, four initially entered the study but were later eliminated as a result of meeting exclusion criteria; three patients consented but were discharged home prior to surgery and were not re-admitted before the end of the data collection period; and 11 patients declined to participate. Forty subjects remained and completed the study.

Subjects Meeting Exclusion Criteria

Of the four subjects who met the exclusion criteria, two were admitted to ICU on the intra-aortic counter pulsation balloon pump. One patient died in the OR and one subject returned to the OR as a result of post-operative complications.

Subjects Eliminated From Data Analysis

Seven subjects who completed the study were later eliminated prior to data analysis in order to ensure that data entered for analysis was valid. Of these, two patients had an oral airway in situ in addition to an oral ETT and two participants had an orogastric tube in lieu of a nasogastric tube. Insufficient research into the effect of oral airways and orogastric tubes on temperature measurements, led to the decision to eliminate subjects receiving these treatments. An additional two patients were eliminated when last minute changes in the surgical schedule necessitated preoperative

temperatures be measured two, in lieu of one, evening prior to surgery as per protocol. Lastly, one patient's routine differed from the other subjects in that an additional operative procedure was performed the evening prior to open heart surgery. Consequently, this subject was eliminated from data analysis as well.

Patients Refusing to Participate

Eleven patients declined to participate in the study. Three initially consented then later declined prior to the beginning of the study protocol. Reasons cited by patients for not participating are provided in Table 1. Two patients cited a dislike for having rectal temperatures taken as the reason for not entering the study.

Table 1

Reasons Cited for Not Participating in Study (N = 11)

Reason	Number of patients
Anxiety, too much on mind already	3
Did not like rectal temperatures	2
Already participating in another study	1
Poked and prodded enough	1
Spouse preferred patient not to participate	1
No reason offered	3

Patients who refused to participate were compared to the sample in an attempt to determine if there was a significant difference between the two groups. For ethical reasons, demographic information relating to the non participants was limited to that which was provided on the posted OR slating schedule. This included age, gender, and "planned procedure". Since "planned procedure" could not be verified, this information was not used. Calculation of the 95% confidence interval for the variables of age and gender for both groups revealed that non participants did not differ significantly from participants. (see Table 2) Additionally, 9.1% of both the non participants and the sample were undergoing repeated surgery (CABG Redo).

The Sample

Demographic information relating to the sample is listed in Tables 2 and 3. All subjects underwent open heart surgery. As evidenced in Table 2, the majority of subjects were male. The ages of subjects ranged from 31-77 years with one subject between 30-39 years; three subjects between 40-49 years; three subjects between 50-59 years; 17 subjects between 60-69 years; and nine subjects between 70-79 years.

Coronary artery bypass grafting constituted the major surgical procedure for the sample with five subjects (15.2%) receiving two grafts, 14 (42.4%) receiving three grafts, eight (24.2%) having four grafts, and one patient (3.0%) requiring

five grafts.

Table 2

Characteristics of Participants, Non Participants, and Hospital Population

Characteristic	Participants (N = 33)	Non participants (N = 11)	Hospital population (N = 189)
Gender			
Male	24 (72.7%)	9 (81.8%)	133 (70.4%)
95% CI[a]	(.575,.879)	(.590,1.05)	(.639,.769)
Female	9 (27.3%)	2 (18.2%)	56 (29.6%)
95% CI[a]	(.121,.425)	(-.046,.410)	(.231,.361)
Mean age (years)	63.36 ± 9.57[b]	60.2 ± 10.25[b]	61.8[c]
Range	31-77	44-77	19-82
95% CI[a]	(60.09,66.63)	(54.14,66.26)	

Note. [a]CI = Confidence interval [b]Mean± SD. [c]SD unavailable.

Table 3 provides the distributions of subjects' height,

weight, body surface area (BSA), duration of surgery, and time

Table 3

Distribution of Height, Weight, Body Surface Area (BSA), Duration of Surgery, and Time on Bypass (N = 33)

Variable		n	M	SD
Height (in cm)			168.9	11.33
	140-159	7		
	160-179	21		
	180-199	5		
Weight (in kg)			82.7	16.35
	50-69	7		
	70-89	17		
	90-109	8		
	110-129	1		
BSA (in m^2)			1.94	2.21
	1.5-1.7	8		
	1.8-2.0	15		
	2.1-2.3	9		
	2.4-2.6	1		

Table 3 continued

Variable	n	M	SD
Duration of surgery (in minutes)		330.1	102.44
121-240	7		
241-360	15		
361-480	9		
481-600	2		
Time on bypass (in minutes)		148.6	46.10
61-120	12		
121-180	13		
181-240	7		
241-300	1		

on bypass. Body surface area was calculated from height and weight data. The height of subjects ranged from 146-190 cm; weight ranged from 50.0 to 126.5 kg; and BSA ranged from 1.5 to 2.5 metres squared. Duration of surgery ranged from 172 to 600 minutes and time on bypass from 84 to 255 minutes.

The mean admission time of patients to ICU following surgery and oral intubation was 1540 hours (range 1220 to 2000 hours). Mean PA temperature of subjects on admission was

35.849 ± 0.79 °C. The lowest admission temperature was 33.60 °C and the highest was 37.50 °C. The use of cold or warm cardioplegia in the OR would account for this wide range. Nine subjects (27.3%) underwent surgery with warm cardioplegia whereas cold cardioplegia was used for 24 subjects (72.7%). Mean PA admission temperature of warm cardioplegia subjects was 36.422 ± 0.59 °C (range 35.80-37.50 °C). This was significantly different (Wilcoxin Score p = .0100) from the mean admission temperature of 35.633 ± 0.76 °C (range 33.60-37.00 °C) for the cold cardioplegia subjects.

Comparison of Sample to Hospital Population

Hospital statistics for an approximate six month period in the preceding year were examined to determine the representativeness of the sample to the population of patients undergoing open heart surgery at the institution involved. The 95% confidence interval for the variables of age and gender were calculated. The mean age and percentage of males to females in the sample was not significantly different from that of the hospital population. (see Table 2) Similarly, the majority of patients in both the sample and the hospital population underwent coronary artery bypass grafting during the open heart surgery.

Temperature Measurements With and Without an Endotracheal Tube

A total of 165 oral, 165 rectal, and 99 PA temperatures were measured and recorded (N = 33). These are reported in Appendix O. In order to test the null hypothesis, non intubated and intubated mean rectal and oral temperatures were compared and mean rectal minus oral differences were calculated. A significant narrowing of the rectal-oral difference was noted in the intubated subjects compared with the non intubated patients. Correlational analysis was performed for temperature measurements at the oral, rectal, and PA sites. Moderately high to high correlations were noted in the subjects with correlations being higher following intubation. Mean PA-rectal and PA-oral temperatures differences were analyzed and the stability of these differences over time determined. When compared to PA temperatures, measurements at the oral site were noted to be more stable over time than those at the rectal site. Data relating to these findings follows.

Rectal-Oral Temperature Differences

Oral and rectal temperatures were measured twice on the evening before surgery (Time 1 and 2) during which time subjects were not intubated. The mean time of Time 1 measurements was 2102 hours (range 2045 to 2130 hours) and of Time 2 measurements was 2140 hours (range 2115 to 2200 hours).

The mean rectal-oral difference at Time 1 was 0.494 ± 0.25 °C. For Time 2 this difference was 0.412 ± 0.21°C. Mean temperatures for these sites are listed in Table 4.

Table 4

Rectal and Oral Temperature Measurements (°C) for Subjects Without an Oral Endotracheal Tube (N = 33)

	Rectal		Oral		Difference (Rectal-Oral)
Time	M±SD	Range	M±SD	Range	M±SD
1	37.446±.26	36.9-38.0	36.952±.30	36.3-37.5	.494±.25
2	37.321±.26	36.8-37.9	36.909±.29	36.4-37.6	.412±.21

Following oral intubation of subjects in the OR, and subsequent admission to ICU, oral and rectal temperatures again were measured on three occasions. All temperatures for intubated subjects were obtained during the first eight hours postoperatively. However, since there was no control over the time subjects exited the OR and subsequently were admitted to ICU, measurement Times 3, 4, and 5 varied widely between subjects. The mean time of temperature measurements for Time 3 was 1625 hour (range 1310 to 2050 hours); for Time 4 was

1931 hours (range 1615 to 2355 hours); and for Time 5 was 2334 hours (range 2017 to 0405 hours). Mean oral and rectal temperatures taken at Time 3, 4, and 5 when subjects were intubated are outlined in Table 5.

Table 5

Rectal and Oral Temperatures (°C) for Subjects With an Oral Endotracheal Tube (N = 33)

	Rectal		Oral		Difference (Rectal-Oral)
Time	M±SD	Range	M±SD	Range	Mdiff±SD
3	36.188±.82	33.9-37.7	35.970±.87	33.2-37.1	0.218±.39
4	37.527±1.03	34.5-39.6	37.339±.85	35.3-39.0	0.188±.35
5	38.133±.58	37.1-39.4	37.927±.55	36.9-39.2	0.206±.29

Figure 2 depicts the mean oral and rectal temperatures for Times 1 through 5.

Testing of Null Hypothesis

A single factor repeated measures analysis of variance was undertaken to test the null hypothesis that the rectal-

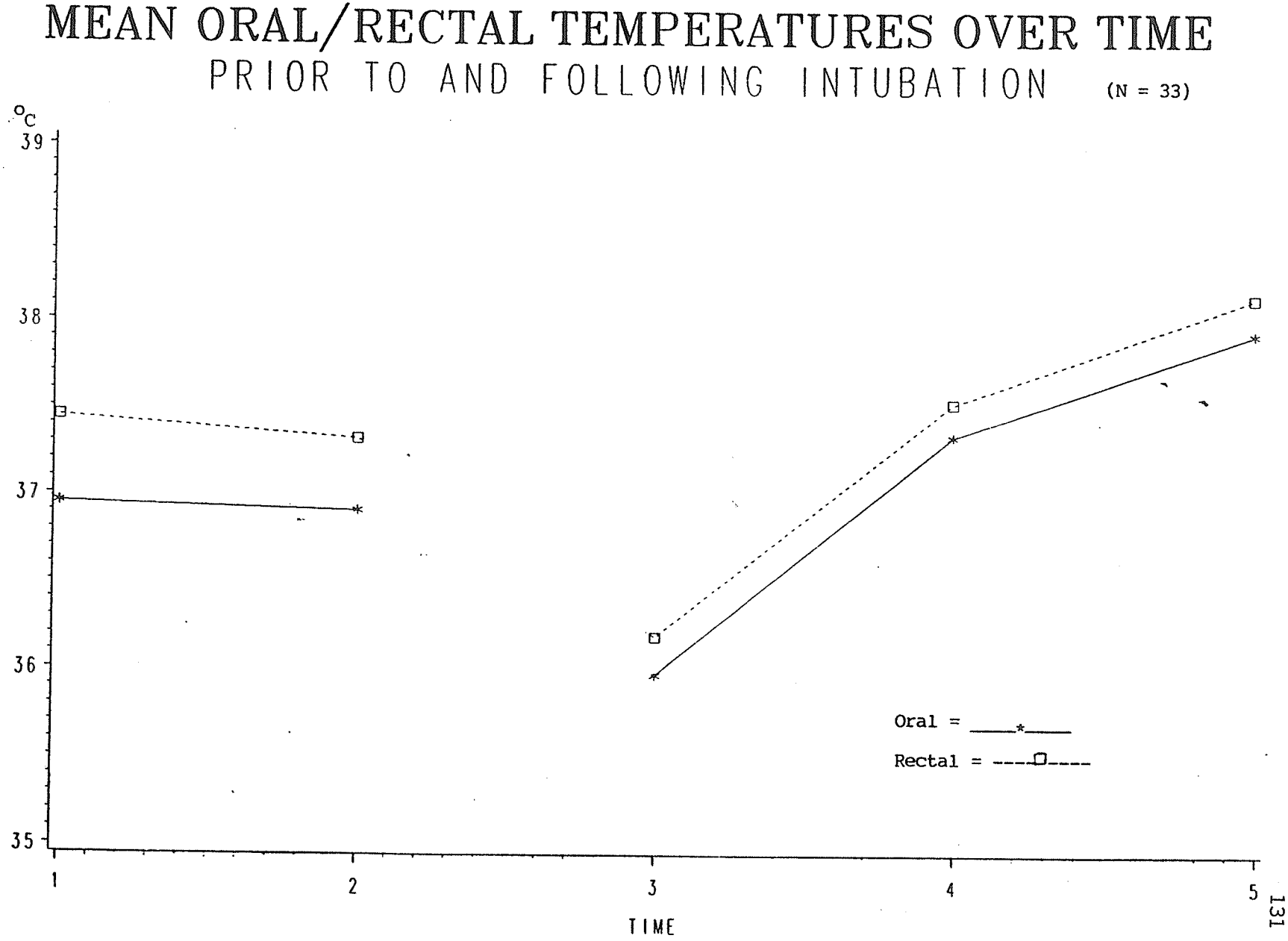

MEAN ORAL/RECTAL TEMPERATURES OVER TIME
PRIOR TO AND FOLLOWING INTUBATION (N = 33)
°C
39
38
37
36
35
Oral = ____*____
Rectal = ----□----
1
2
3
4
5
TIME
NOTE: TIME 1 & 2 ARE NONINTUBATED. TIME 3.4 & 5 INTUBATED

Figure 2.

oral temperature discrepancy for non intubated subjects (average of Time 1 and 2) was not significantly different from that of intubated subjects (average of Time 3, 4, and 5). As noted in Table 6, the mean rectal-oral discrepancy for non intubated subjects was 0.453 ± 0.17 °C (range 0.10 to 0.80).

Table 6

Mean Rectal-Oral Temperature Differences (° C) Between Non Intubated and Intubated Subjects (N = 33)

	Non intubated	Intubated
Site	M ± SD	M ± SD
rectal	37.383 ± 0.25	37.283 ± 0.67
oral	36.930 ± 0.26	37.079 ± 0.64
R-O difference	0.453 ± 0.17	0.204 ± 0.20

Following surgery and intubation the mean rectal-oral discrepancy decreased to 0.204 ± 0.20 °C (range -0.10 to +0.53). The overall mean rectal-oral temperature discrepancy between the non intubated and intubated subjects was 0.249 °C and this was significant (F = 32.85; df 1, 164; p = .0001). The null hypothesis was not supported.

Additional testing using a t-test (Least Significant Difference) revealed that the mean rectal-oral differences for Times 1 and 2 were not significantly different from each other nor were the mean rectal-oral differences for Times 3, 4, and 5 significantly different from each other. However, mean rectal-oral differences at Times 1 and 2 were significantly different from those at Times 3, 4, and 5.

Correlation Analysis for Oral, Rectal, and PA Temperatures

PA temperatures were taken during the postoperative phase when subjects had both an ETT and a PA catheter in place. PA catheter temperatures served as the standard for core temperature. PA temperatures ranged from 33.60 to 37.70 °C for Time 3, 35.20 to 38.90 °C for Time 4, and 36.70 to 38.90 °C for Time 5. The mean PA temperature for intubated patients (Time 3, 4, and 5) was 37.087 $\pm$ 0.63 °C. Temperature overshoot (PA temperature >38.5 °C) occurred in five subjects, all of whom underwent surgery with cold cardioplegia. Seven subjects experienced no PA temperature greater than 37.5 °C and more than half of the subjects (20) did not reach core temperatures of greater than 37.8 °C..

As anticipated, the study's three assumptions that there was a positive correlation between the oral-rectal, PA-oral, and PA-rectal sites were upheld. (see Table 7) Normality of the data allowed for the use of Pearson's product moment correlation analysis. Analysis revealed moderately high

Table 7

Correlation Analysis for Temperature Measurements at Rectal-Oral, PA-Oral, and PA-Rectal Sites (N = 33)

Time	Sites	r	p
1[a]	rectal-oral	.677	0.0001
2[a]	rectal-oral	.698	0.0001
3[b]	rectal-oral	.895	0.0001
	PA-oral	.937	0.0001
	PA-rectal	.898	0.0001
4[b]	rectal-oral	.951	0.0001
	PA-oral	.958	0.0001
	PA-rectal	.960	0.0001
5[b]	rectal-oral	.873	0.0001
	PA-oral	.923	0.0001
	PA-rectal	.926	0.0001

Note. [a]Subjects are not intubated. [b]Subjects are intubated.

positive correlations between oral and rectal sites prior to intubation and high positive correlations between all sites following intubation. All correlations were significant ($p < .0001$). Rectal-oral correlations were noted to be higher during Times 3, 4, and 5 when patients were intubated compared with preoperative Times 1 and 2 when subjects were not intubated.

Analysis of PA-Rectal and PA-Oral Temperature Differences

The largest increases in temperature occurred at all sites within the first four hours postoperatively. Mean PA temperatures increased by 1.258 °C between Time 3 and Time 4 and by 0.427 °C between Time 4 and Time 5. For the same time periods, rectal temperatures increased by 1.339 °C and 0.606 °C respectively, and oral temperatures increased by 1.369 °C and 0.588 °C respectively. PA temperatures were compared to temperatures taken at the oral and rectal sites for these same times and mean PA-oral and PA-rectal differences were calculated. (see Table 8)

Inspection of these temperatures revealed that during intubation, mean rectal temperatures were higher than mean PA temperatures, with the mean difference gradually increasing from 0.082 °C at Time 3 to 0.342 °C at Time 5. Overall, the mean difference between rectal and PA temperature measurements for Time 3, 4, and 5 was 0.195 $\pm$ .20 °C. Mean oral temperature was lower than mean PA temperature at Time 3 by

Table 8

Mean Rectal, PA, and Oral Temperature Measurements (°C) for Intubated Subjects (N = 33)

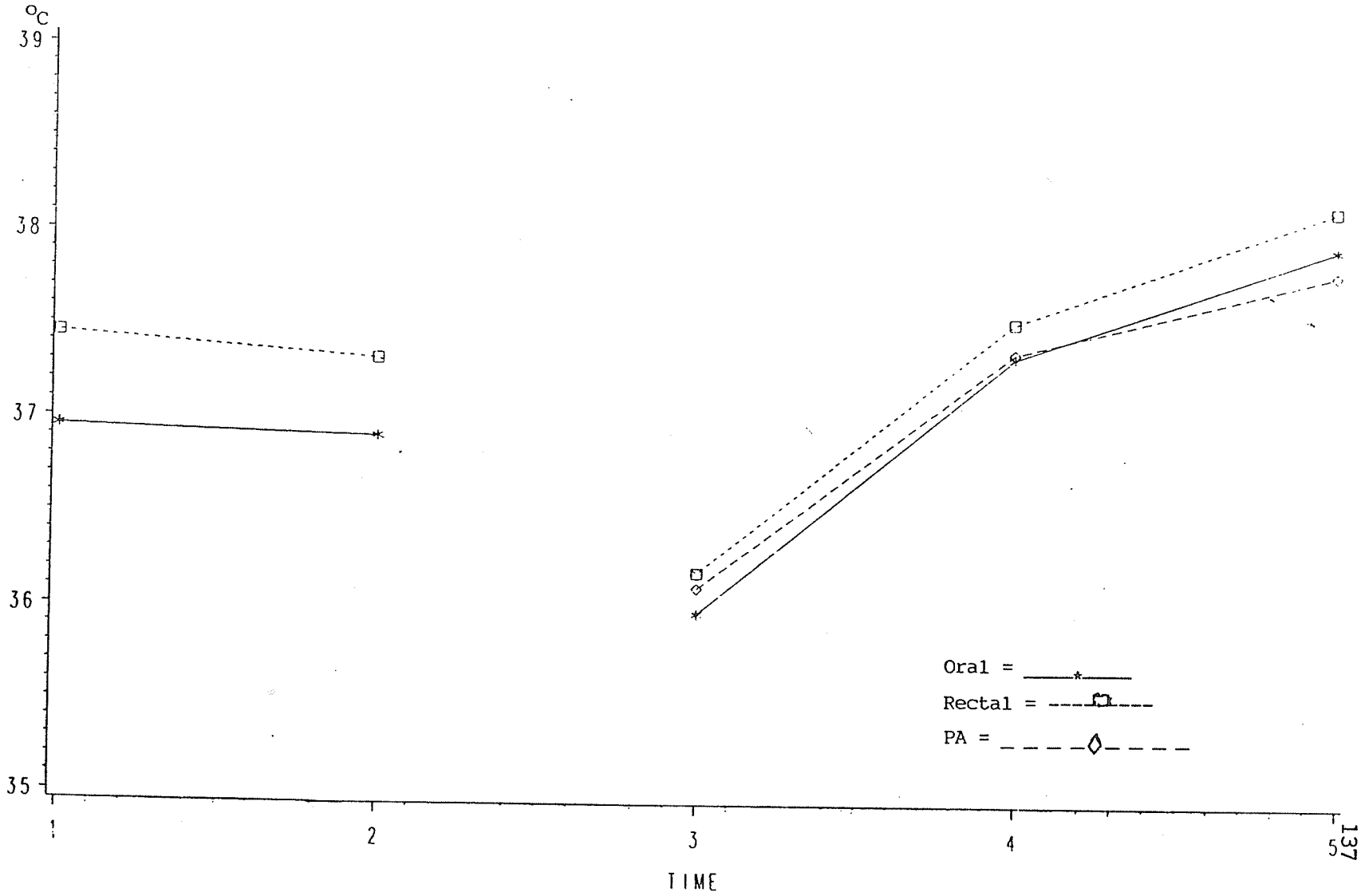
	Route			Difference	
Time	Rectal M±SD	PA M±SD	Oral M±SD	PA-R M diff±SD	PA-O Mdiff±SD
3	36.188±.82	36.106±.82	35.970±.87	-0.082±.37	-0.136±.30
4	37.527±1.0	37.364±.93	37.339±.85	-0.164±.30	0.024±.27
5	38.133±.58	37.791±.51	37.927±.55	-0.342±.22	0.136±.21

0.136 °C, gradually approached it towards Time 4, and was higher by 0.136 °C at Time 5. The overall mean difference between oral and PA temperature over the three intubated time periods was 0.008 ± 0.17 °C. Figure 3 depicts mean PA temperatures in relation to mean oral and rectal temperatures.

Temperature differences between the reference PA temperature and the oral and rectal sites were further analyzed for stability over time. T-tests were used to determine if mean oral and rectal temperatures differed significantly from mean PA temperatures at each of the three

MEAN ORAL/RECTAL/PA TEMPERATURES OVER TIME

PRIOR TO AND FOLLOWING INTUBATION (N = 33)



NOTE: TIME 1 & 2 ARE NONINTUBATED. TIME 3.4 & 5 INTUBATED

Figure 3.

time periods when patients were intubated. PA and oral temperature differences were consistently non significant through Time 3 to 5. PA-rectal temperature differences, although non significant at Time 3 and 4, were significantly different at Time 5, indicating instability in rectal temperature measurements over time. The results of this analysis are reported in Table 9.

Table 9

Analysis of PA-Oral and PA-Rectal Temperature Differences for Intubated Subjects (N = 33)

Sites	Time 3		Time 4		Time 5	
	F	p	F	p	F	p
PA-Oral	.429	.5147	.012	.9121	1.077	.3033
PA-Rectal	.164	.6873	.460	.5002	6.503	.0132

Variables Possibly Affecting Temperature

Data analysis was undertaken for the two major independent variables of ambient and ETT temperature in order to determine their effect on the dependent variable of rectal-oral temperature discrepancy. Information relating to

medications, refrigerated blood or blood products, presence or absence of nasogastric tube, and dentition was recorded in order to provide a more thorough description of the sample.

Ambient Temperature

Ambient temperature was measured at each measurement time for each subject. Temperatures were recorded in degrees Fahrenheit and later converted to degrees Celsius using a standard conversion formula. (see Appendix L) Ambient temperatures were recorded in patients' rooms on the CVT unit for non intubated subjects and later in the surgical ICU when subjects were intubated. Ambient temperatures ranged from 20.11 to 25.11 °C. Mean ambient temperature was 23.50 $\pm$ 0.69 °C for non intubated subjects and 22.44 $\pm$ 0.98 °C for intubated subjects. Ambient temperatures were cooler in ICU than on the CVT unit and became progressively lower over time. Mean, standard deviation, and range of ambient temperatures for Times 1 through 5 are listed in Table 10.

Regression analysis was performed to determine if ambient temperature significantly affected rectal-oral temperature discrepancy at Times 1 through 5. No significant effect was noted. It was concluded that the independent variable of ambient temperature did not have any predictive power in relation to the dependant variable of rectal-oral temperature difference either prior to or following oral intubation. (see Table 11)

Table 10

Mean Ambient Temperatures (°C) at Time 1-5 (N = 33)

Time	M	SD	Range
1[a]	23.56	0.68	23.33-25.11
2[a]	23.45	0.71	22.00-24.83
3[b]	22.74	1.13	20.22-24.83
4[b]	22.43	1.12	20.22-24.89
5[b]	22.14	1.19	20.11-24.50

Note. [a]Subjects are not intubated. [b]Subjects are intubated.

Table 11

Regression Analysis for Ambient Temperature on Rectal-Oral Temperature Difference Time 1-5

Time	df	F	p
1[a]	1,31	0.194	0.6623
2[a]	1,31	0.068	0.7966
3[b]	1,31	0.699	0.4095
4[b]	1,31	1.285	0.2657
5[b]	1,31	0.231	0.6344

Note. [a]Subjects are not intubated. [b]Subjects are intubated.

Correlation analysis also revealed non significant correlations ($p > .05$) for ambient and oral temperature measurements ($r = 0.23$ and $r = -0.06$) and ambient and rectal temperature measurements ($r = 0.19$ and $r = -0.02$) for Time 1 and 2 respectively.

Temperature of Endotracheal Tube Contents

The temperature of ETT contents was measured in the postoperative period following intubation (Times 3-5) to determine if the dependant variable of rectal-oral discrepancy was significantly affected by this independent variable. Mean ETT temperature was 34.66 $\pm$ 0.52 °C (range 32.45 to 36.35 °C). The mean, standard deviation, and range of ETT temperatures are listed in Table 12.

Table 12

Mean Temperatures of ETT Contents (°C) of Intubated Subjects Time 3-5 (N = 33)

Time	M	SD	Range
3	34.14	0.753	32.45-35.65
4	34.85	0.705	32.90-36.35
5	34.98	0.587	33.40-35.95

Regression analysis was performed to determine if the rectal-oral temperature discrepancy postoperatively when subjects were intubated was significantly affected by ETT content temperature. No significant difference in rectal-oral temperature discrepancy was noted as a result of temperature of ETT contents at any of the measurement times when subjects had an ETT in place. (see Table 13)

Table 13

Regression Analysis for ETT Content Temperature on Rectal-Oral Temperature Difference of Intubated Subjects (N = 33)

Time	df	F	p
3	1,31	2.302	0.1394
4	1,31	2.051	0.1621
5	1,31	0.881	0.3553

Additional regression analysis was undertaken to determine the effect of ETT content temperature on PA-oral and PA-rectal temperature difference. ETT temperature did not significantly affect PA-oral or PA-rectal temperature differences during intubated Time 3, 4, or 5. (see Table 14 and 15)

Table 14

Regression Analysis for ETT Content Temperature on PA-Oral Temperature Difference of Intubated Subjects (N = 33)

Time	df	F	p
3	1,31	0.015	0.9029
4	1,31	0.080	0.7788
5	1,31	0.851	0.3635

Table 15

Regression Analysis for ETT Content Temperature on PA-Rectal Temperature Difference of Intubated Subjects (N = 33)

Time	df	F	p
3	1,31	2.214	0.1469
4	1,31	1.956	0.1719
5	1,31	0.102	0.7513

Medications

Information relating to medications received by subjects within eight hours prior to or at the time of temperature measurements was recorded. (see Appendix M) This information was obtained from subjects' medication records, ICU patient flow sheets, and OR records. No attempt was made to control for drugs or to measure the effects of medications on temperature. With the exception of one patient who was given a sublingual medication at Time 3, no oral or rectal medications were taken by patients at the time of temperature measurements.

Blood or Blood Products

No patients received refrigerated blood or blood products within eight hours prior to or during preoperative temperature measurements. However, frozen plasma, packed cells, whole blood, or platelets were infused in 19 (57.6%) subjects during the operative procedure and 14 (42.4%) subjects within eight hours post surgery. (Appendix N) No subjects had to be excluded from the study as a result of receiving refrigerated blood or blood products at the time of temperature measurements.

Nasogastric Tubes

No patients had a nasogastric tube in place at Times 1 and 2 preoperatively. In the postoperative phase, 30 subjects

(90.9%) had a nasogastric tube in situ throughout temperature measurement Time 3 through 5. Two subjects at Time 3 and one subject at Time 5 did not have this tube in place.

Dentition

Roughly half of the subjects (48.5%) had natural teeth with the remaining half (51.5%) having an oral prosthetic device(s). Of the 18 subjects with an oral prosthesis, eight had both an upper and lower denture, six had an upper denture with natural lower teeth and four had a partial plate. All subjects with oral prostheses removed these prior to temperature measurements preoperatively as per protocol. These same devices were removed prior to patients going to the OR. Consequently, all subjects had the same dentition preoperatively when not intubated and postoperatively when intubated.

Age and Gender

In an attempt to extrapolate as much information as possible from the data, additional analysis was performed for the variables of age and gender with oral and rectal temperatures of non intubated subjects.

To determine if age correlated with oral or rectal temperatures of subjects, Pearson product moment correlation coefficients were determined. Correlations for age and oral temperatures at Time 1 (r = -.325) and at Time 2 (r = -.202)

were non significant at $p = .0654$ and $p = .2594$ respectively. Similar non significant correlations were noted for age and rectal temperatures at Time 1 ($r = -.229$, $p = .2001$) and at Time 2 ($r = -.145$, $p = .4213$).

The mean non intubated oral temperature for males (n = 24) was 36.940 $\pm$ 0.28 °C compared with 36.906 $\pm$ 0.18 °C for females (n = 9). Mean rectal temperatures did not differ and were 37.383 $\pm$ 0.26 °C for men and 37.383 $\pm$ 0.24 °C for women. A non parametric procedure (Wilcoxin test) was undertaken to determine if there was a significant difference in oral or rectal temperatures for males and females. No significant difference was noted between males and females for the oral ($p = .7291$) or the rectal ($p = .9838$) site. The small cell sizes warrant that caution be exercised when viewing these results.

SUMMARY

Data collection for the study occurred over seven and a half week period during June and July of 1992. Forty subjects completed the study with data analysis being performed on 33. The majority of subjects were male, between the ages of 60-69 years, and had received three bypass grafts.

The IVAC 2080A electronic thermometer and Swan-Ganz Paceport catheters were determined to both be accurate within $\pm$ 0.1 °C. Reliability of the former also was demonstrated.

A one factor repeated measures analysis of variance was

undertaken to test the null hypothesis. The mean rectal-oral discrepancy between the non intubated and intubated subjects was 0.249°C and this was statistically significant. The null hypothesis was not supported leading to the conclusion that the mean rectal-oral difference of non intubated subjects is significantly different from that of intubated subjects. Ambient temperature and ETT content temperature did not significantly affect rectal-oral temperature difference.

Significant positive correlations were reported between oral, rectal, and PA temperature measurements both prior to and following intubation. Correlations were noted to increase following the insertion of the oral endotracheal tube.

Using mean PA temperature as a reference point, analysis revealed that mean PA-oral temperature differences remained stable during the intubated time periods but PA-rectal differences did not. ETT temperature also did not significantly affect PA-oral or PA-rectal temperature differences.

Information relating to dentition, presence or absence of nasogastric tubes, medications, and blood or blood products was reported but not analyzed.

Non significant correlations were noted for the variable of age with oral and rectal temperatures of non intubated subjects. Males had a slightly higher oral temperature than females but this was not significant.

CHAPTER 5

DISCUSSION, NURSING IMPLICATIONS, AND RECOMMENDATIONS

Incorporated in this chapter will be a discussion of the findings and limitations of the study as well as the implications for nursing practice and education. Recommendations for further areas of nursing research also will be included. Although the initial intent of the study was not to examine factors such as age, gender, and the febrile response a discussion of these results is included.

Discussion of Findings

The human body is amazing in its ability to finely regulate body temperature, using various means to promote heat gain or heat loss as required. Thermoregulation of core temperature is dependent on this balance between thermogenesis and thermolysis. In the clinical area, visible signs of the body's adjustment to thermal stress are evident. Patients involuntarily shiver, vasodilate, and sweat or voluntarily request removal or application of heating and cooling devices in order to achieve thermal comfort. In instances when patients are unable to express the need for, or are unable to make voluntary changes on their own, vigilant health personnel must intercede for them. When excessive thermal loads occur

that respectively raise or lower body temperature above or below normal, the degree and direction of the excess load must be determined in order that appropriate action can be taken. Measurements of body temperature are used to determine this.

Body temperature monitoring has been and continues to be an important nursing function in the clinical setting both inside and outside of the critical care area. In order to objectively determine if temperature balances are or are not being maintained, measurements of temperature that are not only accurate but that are reflective of core temperature are necessary. This can only be accomplished when temperature monitoring devices are valid and reliable; the techniques used by personnel are consistent; and nursing staff are informed and take into consideration the accuracy of, and factors that may alter, temperature at various sites. False high or false low temperature measurements may result in adverse clinical management of patients and treatments, drugs, or tests that are unnecessary, time consuming, and costly.

Although a variety of sites are available for temperature monitoring, the oral, rectal, and more recently the tympanic site are used most frequently in the clinical area. In critical care settings, pulmonary artery temperatures also are available when hemodynamic measurements are required. Inconclusive data as to the effect of many factors that affect temperatures at these sites persist. One of these factors is the presence of an oral ETT and its effect on oral temperature

measurement.

The purpose of this study was to add to the body of knowledge of temperature measurements by determining if oral temperatures are accurate in orally intubated patients. That is, do oral temperatures present an accurate reflection of core temperature when patients have an oral ETT in place. In order to determine this, a repeated measures quasi-experimental design was used. Subjects served as their own controls and temperatures were measured twice at two sites (rectal and oral) prior to intubation and thrice at these same sites plus the PA site following intubation. Ambient temperatures and ETT content temperatures also were monitored. Analysis of data ensued which included: one-factor repeated-measures analysis of variance to test the null hypothesis that rectal-oral temperature difference was not significantly different in non intubated and intubated subjects; correlation analysis between all sites; and t-testing to determine if mean oral and rectal temperatures of intubated subjects differed significantly from mean PA temperatures over time. In addition, regression analysis was used to determine if ambient and ETT temperatures significantly affected rectal-oral temperature difference and if PA-oral and PA-rectal temperature differences were significantly affected by ETT temperature. Analysis revealed the following: a significant narrowing of rectal-oral temperature difference following intubation that was not significantly affected by ambient or

ETT temperatures; moderately high to high positive correlations between sites, which were significant; consistently non significant differences between oral and PA temperatures but not between rectal and PA temperatures over time; and PA-oral and PA-rectal differences that were not significantly affected by ETT temperatures.

Although rectal-oral temperature differences significantly narrowed from pre to post intubation times, the results of this study indicated that oral temperature measurements closely approximated core (PA) temperature in orally intubated adult patients during a thermally dynamic eight hour period. A secondary finding of the study was that rectal temperatures, although demonstrating high positive correlations with temperatures at the oral and PA site, were inconsistent in tracking PA temperatures during this same time period. A discussion of these findings as well as those relating to the instruments used in the study and the sample follows.

The Instruments for Body Temperature Measurements

Both the IVAC 2080A electronic thermometer and the disposable Swan-Ganz Thermodilution Paceport catheters proved valid for monitoring of body temperature. No problems were encountered during the study period with the use of either of these instruments. Probe covers did not alter the accuracy of

the instrument. Reliability of the IVAC thermometer also was supported. Testing of the Paceport catheter thermistors for reliability was not undertaken as, with the exception of one subject, the same catheter remained in situ for each patient during the full post intubation time period of temperature measurements.

Results of this study support the findings of Beck and Campbell (1975) and Ferguson et al. (1971) who reported ± 0.2 °F (0.1 °C) accuracy of electronic thermometers. The findings of this study also concur with the claim of the manufacturer that the IVAC instrument is accurate within ± 0.1 °C.

Similarly this investigator would agree with the conclusion of Runciman and colleagues (1981) that Swan-Ganz catheter thermistors provide excellent performance and are not likely to be the cause of significant error. Although the manufacturer claims an accuracy of ±0.3 °C between temperatures of 31-41 °C, the catheter thermistors used in this study were noted to be accurate within ± 0.1 °C for temperatures between 30-40 °C.

Patient Characteristics

Eighty-one percent of patients approached to partake in the study of temperature monitoring agreed to do so. It was anticipated that a higher percentage of patients would decline to participate, due not only to the use of the rectal site

for, but to the frequency of, temperature measurements. Additionally, open heart surgery patients are already under a considerable amount of stress due to the critical nature of the surgery facing them. Unlike Heinz's (1985) study where six patients declined to participate because they detested rectal temperature measurements, only two patients in this study specifically reported a dislike of temperature measurements at this site as the reason for not participating.

The 33 patients who were entered for data analysis were not significantly different in age or gender to either the patients who refused to participate or to the hospital population of open heart surgery patients admitted during an approximate six month time period of the previous year. Although information pertaining to the type of surgery undergone by patients refusing to participate could not be obtained due to ethical reasons, the most frequent type of cardiac surgery undertaken by both the sample and the hospital population was the same - CABG surgery. By determining that the sample was similar to both the non participants and to the hospital population supports the generalizability of the study's findings to these groups.

Ambient Temperature

Regression analysis revealed that ambient temperature did not significantly affect rectal-oral temperature difference at

any of the non intubated and intubated measurement times. Although the range of temperature measurements for the five measurement times was 5.0 °C (20.11 to 25.11 °C), mean ambient temperature difference between non intubated and intubated subjects was 1.06 °C.

Further analysis also revealed non significant correlations for oral and rectal temperatures of non intubated subjects (Time 1 and 2) with ambient temperature. This would indicate that as ambient temperatures changed, corresponding changes in oral and rectal temperatures did not occur. However, the possibility that ambient temperature may not have been extreme enough to produce significant changes at these sites, must be considered.

Endotracheal Tube Content Temperature

Statistical testing revealed that ETT temperature did not play a significant role in mean rectal-oral temperature discrepancy for the three measurement times when subjects were intubated. Although ETT content temperature range was 3.9 °C (32.45-36.35 °C), mean ETT content temperature rose less than one degree (0.84 °C) from Time 3 to Time 5. That ETT temperatures may not have been extreme enough or varied widely enough from body temperature may have resulted in this non significant finding. The other alternative is that ETT content temperature changed both oral and rectal temperatures

in the same direction and to the same degree, thus not interfering in this discrepancy.

ETT content temperature also did not significantly affect PA-oral or PA-rectal temperature differences during Time 3, 4, or 5 when subjects were intubated. The same reasoning noted above could be applied to these situations as well.

Temperature Measurements With and Without an Oral ETT Tube

This study investigated oral temperature accuracy in 33 orally intubated adult cardiac surgery patients serving as their own controls. Oral and rectal temperatures were measured on two occasions prior to intubation, mean temperatures computed for each site, and a mean rectal-oral difference calculated. Following surgery and the insertion of an oral endotracheal tube in the OR, rectal, oral, and PA temperatures were measured on three occasions at one, four, and eight hours post admission to ICU. Mean temperatures were calculated for each site and overall mean rectal-oral, PA-rectal, and PA-oral differences determined. Examination of these differences ensued. Correlation analysis of temperatures at the various sites also was undertaken for each measurement time.

Correlation Analysis

The assumption that positive correlations would be found

between the three sites was supported. Analysis revealed moderately high positive correlations between oral-rectal sites before intubation (r = .677 to .698) and high correlations between oral-rectal (r = .873 to .951), PA-rectal (r = .896 to .960), and PA-oral (r = .923 to .958) sites following intubation. All correlations were significant (p = .0001). This would indicate that the temperature measurements at one site related strongly and in the same direction to temperature measurements at another site. The higher correlations following intubation suggest temperatures were more consistent between these sites during the time that an oral ETT was in place. These findings support those of Laurent (1979) who reported significant positive correlations between PA-oral and PA-rectal temperatures and Milewski et al. (1991) who reported a correlation of 0.93 between rectal and PA temperatures.

Testing of Null Hypothesis

A repeated measures analysis of variance was used to test the null hypothesis and to determine if the rectal-oral temperature difference of subjects without an ETT was significantly different from that of subjects with an ETT. Analysis revealed that the mean rectal-oral temperature difference narrowed following intubation from 0.453 °C to 0.204 °C with an overall discrepancy between the two groups of 0.249 °C. This discrepancy was statistically significant and

the null hypothesis was not supported. Narrowing of rectal-oral temperature difference following intubation also was reported by Cashion (1982). However, the small sample size (N = 15) may have accounted for the difference being non significant in her study.

Although a change in temperature may be statistically significant, a consideration of its clinical significance also must be undertaken. Clinical significance is defined as that temperature change that would affect nursing or medical actions or judgements (Nichols et al., 1966; Woodman, Parry, & Simms, 1967). A change in temperature of 0.2 °C is considered clinically significant. (Neff et al., 1989; Audiss, Brengelmann, & Bond, 1989) Therefore the 0.249 °C rectal-oral temperature difference must be considered clinically significant as well.

That this narrowing of rectal-oral difference was the result of cooler rectal temperatures, warmer oral temperatures, or both following surgery and intubation must be deliberated. In fact, the data suggests the latter to be the case. In times of rapid temperature change such as that following hypothermia, rectal temperatures have demonstrated a lag when compared to temperatures at other sites resulting in rectal temperatures being cooler than they should be. The inconsistency between rectal and PA temperatures as demonstrated by the gradually widening difference from Time 3 to time 5 in this study would support that this occurred. It

is further supported by the results of the regression analysis that revealed this difference was not the result of ETT temperature changes. In addition, the consistently small difference between oral and PA temperatures, suggests that oral temperatures were warmer and better reflected PA temperatures when patients were intubated. Regression analysis revealed that PA-oral difference was not significantly affected by ETT temperatures leading to the conclusion that the close agreement between oral and PA temperatures is perhaps the result of more stable mouth conditions.

Testing of PA-Rectal and PA-Oral Temperature Differences

Because the null hypothesis was not supported, further analysis was undertaken using mean PA temperature as a reference to determine if there was a significant difference between temperatures at the PA site and temperatures measured at the oral and rectal sites when patients were intubated. This also would determine the stability over time of temperatures at the oral and rectal sites in relation to those at the PA site. Analysis revealed stable oral temperatures and unstable rectal temperature measurements in intubated patients.

A comparison of mean temperatures taken at the oral and PA sites in intubated subjects revealed that temperatures in the posterior sublingual site consistently tracked PA

temperatures in the eight hours following ICU admission. Oral temperature measurements remained within ±0.136 °C of PA temperature measurements when subjects had an oral ETT in place; differences that were neither statistically nor clinically significant and that were not significantly affected by ETT temperature. Indeed, when subjects were intubated, mean oral temperature for Time 3, 4, and 5 was 0.008 ± 0.17 °C different from mean PA temperature.

Mean PA-rectal temperature differences, on the other hand, more than quadrupled from Time 3 to Time 5 (0.082 to 0.342 °C) and although not significantly different at Time 3 and 4, were significantly different from each other at Time 5. This instability of rectal temperature measurements, also reported by M. Benzinger (1969), again suggests the lagging that occurs at this site during periods of thermal imbalance. That rectal lag has occurred at Time 3 and 4 is further supported by the results of other investigators. Eichna et al. (1951) reported that rectal temperatures were significantly ($p < .01$) higher than PA temperatures in afebrile subjects by 0.25 °C. Ilsley et al. (1983) and Milewski et al. (1991) reported rectal-PA differences of 0.23 °C and 0.4 °C respectively. In light of this, a significant difference between PA and rectal temperatures at Time 3 and 4 when mean PA temperatures were less than 37.5 °C should have occurred. However, this was not the case. The non significant differences in temperatures of 0.082 °C and 0.164

°C noted at these times indicates rectal temperatures were cooler than they should have been, resulting in less of a difference between this site and the PA site. With the slower rate of temperature rise between Time 4 and Time 5, it is suggested that rectal temperatures finally were able to rise sufficiently to achieve this significant difference once more.

Webb (1973) noted that the rectum poorly and inconsistently reflected central temperature and the results of this study would support this. The results also support those of Molnar and Read (1974b). In their study of 20 patients undergoing open heart surgery they noted rectal temperatures did not respond as quickly as other sites to thermal blood changes. They concluded that during rewarming, rectal temperatures rise latest. Cooper and Kenyon (1957) and Stupfel and Severinghaus (1956) reported similar conclusions in patients undergoing surgery with induced hypothermia. These same physiologic changes in rectal temperature as a result of the hypothermic temperatures during surgery would appear to have occurred in this study as well. It is further supported by the fact that PA-rectal difference was not significantly affected by ETT temperature during any of these same time periods.

Just as lower rate of blood flow has been suggested as the cause of rectal temperature lag (Molnar & Read, 1974b), the high rate of blood flow in the tongue (Hellekant, 1972; Mariaux et al., 1983) as well as the more stable oral

conditions may be the cause of the oral temperatures more closely resembling PA temperatures when subjects are intubated. These findings agree with those of other investigators. Although the purpose of Heidenreich and colleagues (1992) study was not to investigate the effect of intubation, a mean PA-oral difference of 0.1 °C in 25 intubated cardiac surgery patients during the first two hours postoperatively was noted. Erickson and Kirklin (In Press) also reported mean oral temperatures were 0.12 $\pm$ 0.11 °C higher than PA temperatures in 25 subjects with an oral ETT. Lastly, Konopad (1990) reported orally intubated subjects had a statistically but not clinically significant higher oral temperature (0.08 $\pm$ .20 °C) than non intubated subjects. Although it may be suggested that the heated gases through the ETT tube may have been responsible for the close agreement between PA and oral temperatures, the statistically non significant effect ($p > .05$) of ETT temperature on PA-oral difference at Time 3, 4, and 5 indicate this is not the reason.

The close approximation between oral and PA temperature measurements when an ETT is in place may be explained by the fact that variables that may lower oral temperature locally when no oral ETT is in place either are not present or present to a lesser extent when the ETT is in situ. Following intubation, the mouth, with some exceptions, remains essentially closed or almost closed. Although an aperture may

still be present as a result of the presence of the ETT tube, this has been reported to have no significant effect on oral temperature measurements. (Konopad, 1990) Of more importance is the fact that intubation eliminates the indrawing of cooler ambient air directly into the oral site and the loss of heat normally transferred from the upper airways to inspired air (Wessler et al., 1966). Once oral suctioning and mouth care are controlled for, the logical result is an overall gain in oral temperature which more closely reflects the temperature of the blood perfusing that area.

The results of this study suggest that oral temperatures are not only stable over time but are in close agreement with core temperature measurement in intubated subjects during a thermally dynamic eight hour period following cardiac surgery. Although a significant rectal-oral difference was noted between non intubated and intubated subjects, it is proposed that this was due to two processes: physiologically induced changes at the rectal site as a result of hypothermia resulting in temperatures being cooler than they should have been; and more stable conditions at the oral site resulting in oral temperatures more closely approximating core blood temperatures. The data from this study and the results of previous investigations would support this reasoning.

It is concluded that the posterior sublingual site is a reliable and accurate site for temperature measurement in orally intubated subjects during the thermally dynamic eight

hour period following open heart surgery. This conclusion was reached as a result of the stability of oral temperatures over time when subjects were intubated; the non significant differences, both statistically and clinically, between temperatures measured at the PA and oral sites; the non significant effect of ETT content temperature on PA-oral difference; as well as the high correlations noted between the PA and the oral site.

The results of this study would support those of Gerbrandy et al. (1954) who concluded that sublingual temperatures reflect central temperature changes better than rectal temperatures. They also support those of Cashion (1982) and Konopad (1990) who concluded that oral temperatures were accurate in orally intubated patients.

Age and Gender

It has been suggested that males, and the elderly may have decreased oral temperatures as a result of the tendency for more advanced vascular disease in these groups. It also is thought that the elderly are not as successful at producing and maintaining body heat. Results of this study suggest otherwise. Neither age nor gender played a significant role in oral or rectal temperature measurements.

Using non intubated oral and rectal temperature measurements, non significant negative correlations ($p > .05$)

were found for the variable of age with oral (r = -.20 and -.30) and rectal (r = -.15 and -.23) temperatures. These findings support those of Thatcher (1983) who reported similar non significant correlations (r = -.13 and -.20) between age and oral body temperature as well.

Contrary to Higgins (1983), this investigator found that for non intubated patients, males had a slightly higher (0.034 °C) but non significant ($p > .05$) mean oral temperature than females. Mean rectal temperatures were identical for males and females and also non significant ($p > .05$). The small cell sizes for gender necessitate that these findings be viewed with caution. The difference in findings between this study and that of Higgins may have resulted from this as well.

Postoperative Febrile Response

Following admission to ICU it was noted that the most rapid temperature changes in subjects occurred within the first four hours postoperatively. These findings support those of Dominiguez DeVillotta and colleagues (1974), Kassum and Thomson (1992) and Sladen (1985). Kassum and Thomson reported 34.5% of subjects in their study of cardiac surgery patients (N = 58) all of whom underwent surgery with cold cardioplegia displayed a core temperature greater than 38.5 °C. A smaller percentage (15.15%) of subjects in this study experienced this temperature overshoot, however, the use of

subjects who underwent surgery with both warm and cold cardioplegia may have accounted for this difference. Although the small sample size precludes drawing any conclusions from this, it is of interest to note that none of the nine subjects in this study who underwent open heart surgery with warm (normothermia) cardioplegia, experienced temperature overshoot.

Limitations

In viewing the results of this study, the limitations which may have inadvertently weakened the validity of the findings must be kept in mind.

The inability of the researcher to take simultaneous temperature measurements at the various sites is a limitation. To limit this threat measurements were taken in rapid sequence. However, simultaneous measurements may have resulted in more accurate temperature readings between sites.

The researcher's inability to remain with subjects throughout the entire thirty minute protocol period prior to temperature measurement is a limitation. Although non intubated subjects and nurses of intubated subjects were questioned and reported no deviations from the protocol prior to temperature measurements, remaining with the patient for the control period would have ensured this.

Reactivity to the testing itself may have altered

temperature results. The use of repeated measurements and attempts to put subjects at ease before temperature measurements, although decreasing this threat, may not have eliminated it.

The possible influence of drugs on temperature measurements will remain a limitation. In the perioperative period, open heart surgery patients are on multiple medications and controlling for these would have been difficult.

Errors of perception by the investigator or inconsistency in the temperature measurement procedure itself both within and between subjects are recognized as possible sources of error. Although every effort was made to ensure that recording of data was accurate, and the procedure consistent, the absence of intrarater reliability testing and a second investigator to verify measurements recorded are limitations. Further errors also could have occurred as data was being entered into the computer. To decrease the chance of the latter, meticulous data cleaning and verification by a second person of data entered into the computer was done.

The possible effects of transient changes in clothing and/or bedding may have altered temperature measurements. With the exception of electric heating or cooling blankets, these were not controlled for and will remain a limitation of the study.

The effect of fecal material on rectal temperature

measurements is unknown. Since bowel preparation orders were inconsistent between subjects before surgery, the taking of rectal temperatures prior to any bowel preparation was deemed the best alternative but remains a limitation of the study.

Finally, the 10 minutes allowed for stabilization of mouth temperatures following removal of oral prostheses in non intubated subjects may have been insufficient. Although this allowed for control of dentition between non intubated and intubated subjects, the absence of research to support this stabilization time may have resulted in erroneous non intubated oral temperature measurements for the subjects with these prosthetic devices. The use of repeated measurements, although decreasing reliance on a single measurement and reducing this threat, may not have eliminated it.

Finally, the results of this study pertain to the immediate eight hour phase in ICU following admission after cardiac surgery and therefore generalization is limited to this time period. However, it has been documented that the most significant and rapid changes in temperature occur within this time period. This would suggest that if a site was suitable during this period of dynamic thermal change, it likely would be suitable at other time periods when temperature changes are not as dramatic.

Implications for Nursing Practice, Education, and Research

There are several implications for nursing practice as a

result of this study. It has long been considered by nurses that the oral site is not suitable for body temperature measurements when patients are orally intubated and that an alternative site should be used. The alternative site frequently chosen has been the rectum. Results of this study, however, support the use of the oral site for temperature measurements in patients with an ETT in place and who are mechanically ventilated.

Since oral temperature measurements still remain a common practice outside of ICU, use of this same site for patients who are in ICU and who are intubated will allow for better observation of temperature trends. The oral site also may be used to verify PA catheter temperatures or to take core temperature measurements should a PA catheter not be in situ.

Results of this investigation also have implications for the use of the rectal site for body temperature measurement. Findings from this study concur with other investigations that have demonstrated instability in rectal temperature measurements during rapid thermal changes. Therefore, it is recommended that temperature measurements from this site should not be relied upon by nursing or medical staff at these times.

Further implications of this study relate to the use of electronic thermometers and PA catheter thermistors. This study supports research by other investigators who concluded that the electronic thermometer and the Swan-Ganz catheter are

valid instruments for temperature monitoring and that nurses may rely on these tools for temperature measurements. However, the caution put forth by Gotchall and colleagues (1989) that sole reliance on one temperature monitoring device or on one site needs to be heeded. Temperatures obtained from only one site that are falsely elevated or depressed may have a deleterious effect on the clinical management of patients in ICU. Drug therapy may be given, withheld, or changed, and unnecessary procedures undertaken such as laboratory studies or the application of warming or cooling blankets. Because of the consistently close agreement between oral and PA temperatures as demonstrated by the results of this study, it is recommended that oral temperature measurements be used to verify PA temperature measurements.

Although results from this study cannot be generalized to other intubated surgical intensive care patients, the use of subjects in this study who underwent surgery with both normothermia and hypothermia suggest that it may be useful for subjects undergoing other surgeries where either of these are used and who return to ICU with an oral ETT in place.

The findings from this study also have implications for nursing education. Although nurses are aware of the importance of temperature measurements as indicated by the reliance placed on these and the frequency with which they are taken, education as to the various modes of an electronic thermometer and the uses of each are needed. Awareness that

only oral and rectal sites may be used for temperature measurement using the predictive mode, and that the monitor mode should be used for other sites such as axilla, needs to be reinforced.

Education, as well, is needed in the area of rectal temperature measurements. That rectal temperature measurements do not accurately reflect thermal changes when temperatures are changing quickly must be taught to both nursing students and nursing staff. During slower temperature changes this site may be used.

The literature review undertaken in preparation for this study revealed that continued research into many of the variables that may affect temperature measurement are needed. More conclusive data is needed to determine effect of dentition on oral temperature measurements. Few studies have been undertaken to specifically investigate this area. Research also is required in the area of the effect, and duration of effect, of bowel preparation on rectal temperature measurements. No studies could be located that investigated this area. Similarly, studies to determine the effect of oral airways and orogastric tubes on temperature measurements are required.

Additional studies investigating the accuracy of oral temperature measurements in medical or other surgical groups when patients are intubated is recommended. This may be particularly important in intubated neurosurgical patients

where head dressings or drainage from the ear would prohibit the use of the tympanic site.

A study similar to this but over a longer duration of time, up to and including extubation, would further identify if oral temperature measurements of intubated patients remained accurate as time following surgery lengthened and temperatures normalized.

A further suggestion for nursing research is in the area of PA and oral temperature measurements of patients with no respiratory assistant devices. This would provide a clearer determination of the normal PA-oral temperature difference. Few studies could be located that specifically investigated this area, and the small sample size in these is a severe limitation.

Lastly, with the increased use of the tympanic thermometer to measure temperatures at the tympanic site, it is suggested that further studies comparing temperatures at this site with oral and PA temperatures of critical care intubated patients be undertaken. Although Konopad (1990) noted no significant difference in tympanic temperature measurements of intubated and non intubated medical ICU patients ready for extubation, the poor showing of the tympanic membrane thermometer in the study undertaken by Heidenreich et al. (1992) when intubated post cardiac surgery patients were undergoing rapid temperature changes, led them to conclude that further investigations are needed in this

area.

CONCLUSIONS

According to Smith (1984) "The practice of nursing depends on research to provide valid courses of action for and with the recipients of nursing care." (p.43) Schubert (1980) also reports that the end of "practical" research is decision and action that are situationally specific. The purpose of this study was to determine if oral temperature measurements are accurate in orally intubated patients. In order to be considered accurate, temperature measurements at the sublingual site would have to demonstrate that they not only accurately, but consistently, reflected core temperature. The findings from this study suggest that during times of dynamic thermal changes, oral temperature measurements can be relied upon to accurately reflect core (PA) temperatures for intubated open heart surgery patients. This conclusion is supported by not only the high correlations of oral temperature measurements with PA temperature measurements, but also the non significant difference, statistically and clinically, between PA and oral temperature measurements of intubated subjects in the eight hours following admission to ICU. The findings of this study support those of other investigators who concluded oral temperatures were accurate in intubated patients.

A secondary finding of this study is that rectal temperatures are unstable during times of rapid thermal changes and should not be relied upon. Oral, not rectal temperature measurements, are recommended in intubated post cardiac surgery when PA catheter thermistors need to be verified or a PA catheter is not in situ. Oral temperature measurements require less nursing time, less equipment, and less energy expenditure by both the nurse and the patient compared with rectal temperature measurements. In addition they are more easily obtained and less psychologically distressing to patients. For patients in the critical care area who are already under considerable stress, these are particularly important considerations.

Although the findings cannot be generalized to non adult populations, other surgical groups, or other time periods further investigations using medical or other surgical ICU patients with an ETT in place are recommended in order to determine the appropriateness of oral measurements in these intubated populations.

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APPENDICES

Appendix A

Surgeon's Consent For Conduction Of Research

Wendy Fallis, a graduate student in the Master of Nursing program at the University of Manitoba has my permission to obtain research information from patients about to undergo open heart surgery and who are under my care. This research is being undertaken to determine if the discrepancy between oral and rectal temperatures in non orally intubated adult patients is significantly different from that of orally intubated adult patients.

This study will be conducted during the spring of 1992 or until a sample size of 40 has been obtained. Informed consent will be obtained from each subject the day prior to surgery. Subjects agreeing to participate and who have signed a written consent will have oral and rectal temperatures measured with an IVAC 2080A electronic thermometer twice preoperatively (the evening before surgery at one half hour interval) and three times postoperatively (at one, four and eight hours following admission to the Intensive Care Unit). Pulmonary artery temperatures and endotracheal tube temperatures also will be obtained postoperatively.

All data will be collected by Wendy Fallis. Each subject will be given a number and will be identified by subject number only on all data collection forms, thereby ensuring her/his anonymity. Access to data will be limited to Wendy Fallis' thesis committee members and a statistician from the Manitoba Nursing Research Institute, thereby ensuring confidentiality.

If I would like a copy of the abstract mailed to me at the completion of the study, I will advise Wendy Fallis of this.

Signed:_____ Date:_____

Appendix B

Sample Dialogue With Potential Participants

Hello, Mr(s)_____, I'm Wendy Fallis, a registered nurse and a student in the Master of Nursing program at the University of Manitoba. Would you mind if I talked to you for a few minutes about a study I am doing? (If patient agrees, I will continue, if patient is not in agreement, I will thank him/her and leave.)

Mr(s) _____ I understand that you will be going for open heart surgery tomorrow. I am doing a study related to body temperature and am trying to determine if temperatures taken in the mouth are accurate in patients who have a breathing tube in their windpipe. I am approaching you to participate in this study because I know that during and following your surgery you will have a breathing tube in place.

Mr(s) _____, if you did decide to participate, I would need to measure mouth and rectal temperatures twice this evening, about a half hour apart, when there is no tube in place, and three times tomorrow, at one hour, four hours, and eight hours after your surgery, when the breathing tube is in place. In addition, I would need to measure the temperature of the breathing tube and the room temperature. Each set of measurements would take a total of approximately five to seven minutes.

Prior to the measurements, it would be necessary to lie quietly in bed for 30 minutes; you could still read or watch TV. You also would be requested not to eat or drink, rinse your mouth, chew gum, smoke, or bathe during that time. If you have a denture or a partial plate you would be asked to remove this 10 minutes before I took your temperature. No further time commitment would be required of you. Lastly, I would need your permission to look at your hospital chart to gather information related to your surgery.

There may not be any particular benefit to you at this time as a result of participating in this study, however, the results may benefit other patients in future.

Participation in this study is voluntary. If you decide to participate, you are free to drop out of the study at any time. Whatever your decision is, the quality of your care will not be affected in any way.

The information collected relating to your personal record will be shared only with my thesis committee and a

Appendix B continued

statistician. Your personal identity will not be disclosed. The overall study results may be published at a later date. Do you have any questions? (Any questions posed will be answered by the investigator.)

Mr(s)_____ would you be willing to participate in this study? (If patient verbally or non verbally indicates that he/she is not willing to participate, I will thank them and leave. Patients indicating that they are willing to participate, and who meet the selection criteria will be asked to read and sign a consent form. Patients unwilling to sign a consent form will not be included in the study.)

(For patients agreeing to participate): Mr(s)_____, thank you for agreeing to participate. I will give you a copy of the consent form to keep with a phone number that you may call in order to reach me or my advisor should you have any questions about the study.

If you would like a copy of the results of the study mailed to you after the study is completed, there is a place on the second page which you can complete.

Thanks again for agreeing to participate Mr(s)_____, I will see you later this evening after visiting hours to take your first and second set of temperatures and I will go over the instructions again with you at that time.

Appendix C

Consent Form

I _____, voluntarily agree to participate in the study relating to the accuracy of oral temperatures in patients with an oral endotracheal tube in place. This study is being conducted by Wendy Fallis, RN, B.Sc.N, Master of Nursing candidate, in partial fulfilment of her thesis.

I agree to have my oral and rectal temperatures measured on five occasions, twice the evening before my surgery and three times following my surgery. The room temperature and the temperature of my breathing tube also will be measured. Each set of measurements will take a total of approximately five to seven minutes. Prior to each set of measurements I will be asked to lie quietly and to not eat, drink, rinse my mouth, chew gum, bathe, or smoke for 30 minutes. If I have a denture or a partial plate in my mouth I will be asked to remove this 10 minutes prior to my temperature being taken. No further time commitment will be required of me.

I have been advised that there may not be any particular benefit to me at this time by participating in this study. However, my participation may benefit other patients in the future should it be shown that oral temperatures in patients with breathing tubes are no different from those without breathing tubes. Participation in this study exposes me to no added risks.

Participation in this study is voluntary and I understand that I am free to drop out at any time. I further understand that if I do not participate in the study or if I desire to drop out at any time, the quality of my care will not be affected.

I also give permission to Wendy Fallis to look at my hospital chart in order to obtain information relating to my surgery.

I have been assured that my personal records will be kept confidential and that no information will be released or printed that will disclose my personal identity. Only Wendy Fallis, the members of her thesis committee, and a statistician will have access to the gathered data. The results of the study may be published at a later date.

I agree to participate in this study of temperature monitoring and have received a copy of the consent form. Any questions that I have regarding the study have been answered.

Appendix C continued

Should I desire a copy of the study results I will advise Wendy Fallis of this and complete the information below.

If I have any questions about this study, I may contact Wendy Fallis at 261-8061 or her advisor Professor Annette Gupton, Faculty of Nursing, University of Manitoba at 474-6220

Date:_____ Signature:_____

I would like a copy of the study results.
Please send them to:

Name: _____
Address: _____
_____
_____

Appendix D

Instructions To Subjects Preoperatively

FOR THE NEXT 30 MINUTES YOU ARE REQUESTED TO:

* Lie quietly in your bed. (You may read or watch television if you like.)

IN ADDITION, YOU ARE ASKED NOT TO

* Eat or drink
* Brush your teeth or rinse your mouth
* Apply hot or cold cloths to your face/neck
* Shower or bathe
* Chew gum
* Smoke
* Immerse any extremity in water

AT THE END OF THIS THIRTY MINUTE PERIOD YOUR ORAL AND RECTAL TEMPERATURES WILL BE TAKEN

Appendix E

Subject Data 2A Subject #_____

Time of Day		Room Temp. (^{O}F)	Temperatures ^{O}C O=oral R=rectal ETT=endotracheal PA=pulmonary artery			
	1	_____	_____	O_____	R_____	
T	2	_____	_____	R_____	O_____	
I						
			POST-OPERATIVE/INTUBATED			
M	3	_____	_____	ETT____ O_____	PA_____	R____
E	4	_____	_____	R_____ PA_____	O_____	ETT____
	5	_____	_____	ETT____ O_____	PA_____	R____

Extraneous Variables Controlled for Pre-operatively:Times 1 & 2

1	2		1	2	
__	__	no food/fluids X 30 min.	__	__	no gum chewing X 30 min.
__	__	no mouthwash X 30 min	__	__	no bathing X 30 min.
__	__	no smoking X 30 min.	__	__	no extremity immersed
__	__	no cold IV infusions	__	__	supine X 30 min.
__	__	dentition as for surgery	__	__	no hot/cold applications to face or neck

Extraneous Variables Controlled for Post-operatively:Times 3, 4, & 5

3	4	5		3	4	5	
__	__	__	no extremity immersed	__	__	__	no hot/cold applications to face or neck
__	__	__	no mouthcare X 30 min.				
__	__	__	no bathing X 30 min	__	__	__	no refrigerated blood or fluid challenge infusing
__	__	__	NG tube in place (Y/N)				
__	__	__	minimal occlusive seal ETT	__	__	__	no oral suctioning X 15 min.

Appendix F

Subject Data 2B Subject # _____

		Time of Day	Room Temp. (°F)	Temperatures (°C) O=oral R=rectal ETT=endotracheal PA=pulmonary artery			
				PRE-OPERATIVE/NON INTUBATED			
	1	_____	_____		R_____	O_____	
T	2	_____	_____		O_____	R_____	
I				POST-OPERATIVE/INTUBATED			
M	3	_____	_____	R_____	PA_____	O_____	ETT____
E	4	_____	_____	ETT____	O_____	PA____	R_____
	5	_____	_____	R_____	PA_____	O_____	ETT____

Extraneous Variables Controlled for Pre-operatively:Times 1 & 2

1	2	
__	__	no food/fluids X 30 min.
__	__	no mouthwash X 30 min
__	__	no smoking X 30 min.
__	__	no cold IV infusions
__	__	dentition as for surgery

1	2	
__	__	no gum chewing X 30 min.
__	__	no bathing X 30 min.
__	__	no extremity immersed
__	__	supine X 30 min.
__	__	no hot/cold applications to face or neck

Extraneous Variables Controlled for Post-operatively:Times 3, 4, & 5

3	4	5	
__	__	__	no extremity immersed
__	__	__	no mouthcare X 30 min.
__	__	__	no bathing X 30 min
__	__	__	NG tube in place (Y/N)
__	__	__	minimal occlusive seal ETT

3	4	5	
__	__	__	no hot/cold applications to face or neck
__	__	__	no refrigerated blood or fluid challenge infusing
__	__	__	no oral suctioning X 15 min.

Appendix G

Demographic Data 1

SUBJECT NUMBER _____

Gender _____M _____F
Age at last birthday _____ Yrs.
Height_____cm.
Weight_____kg.
B.S.A._____m^2
Surgical Procedure_____
Duration of Surgery: started_____ ended_____
total hours_____ min_____
Cardioplegia: warm_____ cold_____
temp_____°C temp_____°C
Time on Bypass_____min.
Time of Admission to ICS_____hrs.
Temperature (PA) on Admission____°C

MEDICATIONS: (within 8 hours prior to measurements)

Prior to Surgery	During Surgery	Post Surgery

TRANSFUSION OF BLOOD/BLOOD PRODUCTS (FFP, PC, Platelets)

Prior to Surgery	During Surgery	Post Surgery / Time
_____/_____	_____/_____	_____/_____
_____/_____	_____/_____	_____/_____
_____/_____	_____/_____	_____/_____
_____/_____	_____/_____	_____/_____

TIME OF TEMPERATURE MEASUREMENTS:

Prior to Surgery: (1 _____hrs.
(2) _____hrs.

Post Surgery: (3) _____hrs.
(4) _____hrs.
(5) _____hrs.

Miscellaneous information:_____

Appendix H

Temperatures (°C) Measured by the Standard Mercury and IVAC 2080A Thermometers Pre and Post Data Collection

Standard	IVAC 2080A			
	Pre Data Collection		Post Data Collection	
	Oral	Rectal	Oral	Rectal
28.0	28.1	28.1	28.0	28.0
28.5	28.6	28.6	28.6	28.6
29.0	29.1	29.1	29.0	29.0
29.5	29.6	29.6	29.5	29.5
30.0	30.1	30.1	30.1	30.1
30.5	30.6	30.6	30.5	30.5
31.0	31.1	31.1	31.1	31.1
31.5	31.6	31.6	31.5	31.5
32.0	32.1	32.1	32.0	32.0
32.5	32.6	32.6	32.6	32.6
33.0	33.1	33.1	33.0	33.0
33.5	33.6	33.6	33.6	33.5
34.0	34.1	34.1	34.1	34.1
34.5	34.6	34.6	34.5	34.5
35.0	35.1	35.1	35.1	35.1
35.5	35.6	35.6	35.6	35.6
36.0	36.1	36.1	36.1	36.1
36.5	36.6	36.6	36.6	36.6
37.0	37.1	37.1	37.1	37.1
37.5	37.6	37.6	37.6	37.6
38.0	38.1	38.1	38.1	38.1
38.5	38.6	38.6	38.6	38.6
39.0	39.1	39.1	39.1	39.1
39.5	39.6	39.6	39.6	39.6
40.0	40.1	40.1	40.1	40.1
40.5	40.6	40.6	40.6	40.6
41.0	41.1	41.1	41.1	41.1
41.5	41.6	41.6	41.6	41.6
42.0	42.0	42.0	42.1	42.1

Appendix I

Testing of IVAC 2080A Thermometer For Accuracy With and Without Probe Covers

Prior to Data collection

Probe Cover	Standard Thermometer Temperature (°C)					
	35.0		37.0		39.0	
	With	Without	With	Without	With	Without
1	35.1	35.1	37.1	37.1	39.1	39.1
2	35.1	35.1	37.1	37.1	39.1	39.1
3	35.1	35.1	37.1	37.1	39.1	39.1
4	35.1	35.1	37.1	37.1	39.1	39.1
5	35.1	35.1	37.1	37.1	39.1	39.1
6	35.1	35.1	37.1	37.1	39.1	39.1
7	35.1	35.1	37.1	37.1	39.1	39.1
8	35.1	35.1	37.1	37.1	39.1	39.1
9	35.1	35.1	37.1	37.1	39.1	39.1
10	35.1	35.1	37.1	37.1	39.1	39.1

Following Data Collection

	With	Without	With	Without	With	Without
1	35.1	35.1	37.1	37.1	39.1	39.1
2	35.1	35.1	37.1	37.1	39.1	39.1
3	35.1	35.1	37.1	37.1	39.1	39.1
4	35.1	35.1	37.1	37.1	39.1	39.1
5	35.1	35.1	37.1	37.1	39.1	39.1
6	35.1	35.1	37.1	37.1	39.1	39.1
7	35.1	35.1	37.1	37.1	39.1	39.1
8	35.1	35.1	37.1	37.1	39.1	39.1
9	35.1	35.1	37.1	37.1	39.1	39.1
10	35.1	35.1	37.1	37.1	39.1	39.1

Appendix J

Reliability Testing of IVAC 2080A Thermometer

Pre and Post Data Collection

Oral and Rectal Probes Inserted Ten Times Each

(Temperatures in °C)

Time	Standard	Pre		Post	
	Thermometer	Oral	Rectal	Oral	Rectal
1.	36.0	36.1	36.1	36.1	36.1
2.	36.0	36.1	36.1	36.1	36.1
3.	36.0	36.1	36.1	36.1	36.1
4.	36.1	36.1	36.1	36.1	36.1
5.	36.0	36.1	36.1	36.1	36.1
6.	36.0	36.1	36.1	36.1	36.1
7.	36.0	36.1	36.1	36.1	36.1
8.	36.0	36.1	36.1	36.1	36.1
9.	36.0	36.1	36.1	36.1	36.1
10.	36.0	36.1	36.1	36.1	36.1
1.	38.0	38.1	38.1	38.1	38.1
2.	38.0	38.1	38.1	38.1	38.1
3.	38.0	38.1	38.1	38.1	38.1
4.	38.0	38.1	38.1	38.1	38.1
5.	38.0	38.1	38.1	38.1	38.1
6.	38.0	38.1	38.1	38.1	38.1
7.	38.0	38.1	38.1	38.1	38.1
8.	38.0	38.1	38.1	38.1	38.1
9.	38.0	38.1	38.1	38.1	38.1
10.	38.0	38.1	38.1	38.1	38.1

Appendix K

Testing of Swan-Ganz Thermodilution Paceport Catheter Thermistors for Accuracy (N = 33)

Post Data Collection

Catheter Number	Standard Thermometer Temperature (°C) 30.0	35.0	40.0
1	29.9	35.0	40.1
2	30.0	35.1	40.1
3	29.9	35.0	40.0
4	29.9	35.0	40.1
5	30.0	35.1	40.1
6	30.0	35.0	40.1
7	30.1	35.1	40.0
9	30.0	35.1	40.1
11	30.0	35.0	40.0
13	30.1	35.1	40.0
14	30.0	35.0	40.1
15a	30.0	35.0	40.1
15b	29.9	35.0	40.0
16	29.9	35.0	40.1
17	30.0	35.0	40.1
18	30.1	35.1	40.1
19	30.0	34.9	40.0
20	30.1	35.0	40.1
21	30.1	35.0	40.1
23	30.0	35.0	40.1
24	30.0	34.9	40.0
25	30.1	35.0	40.1
27	30.1	35.1	40.1
28	30.1	35.1	40.1
29	30.1	35.1	40.1
30	30.0	35.1	40.0
32	29.9	34.9	40.0
33	30.0	34.9	40.1
34	30.0	35.0	40.0
35	30.1	35.0	40.1
36	29.9	34.9	40.0
37	29.9	34.9	40.0
38	29.9	35.0	40.1
39	29.9	34.9	40.0

Note. Catheter number = subject number.

Appendix L

Conversion Chart

To convert Fahrenheit to Celsius

(Temperature in °F - 32) X 5/9 = Temperature in °C

To convert Celsius to Fahrenheit

(Temperature in °C X 9/5) + 32 = Temperature in °F

Appendix M

Medications Received by Subjects Within Eight Hours Prior to or During Temperature Measurements (N=33)

Medication	Subjects Receiving
Preoperative Phase	
Ativan	1, 17, 18, 23, 34
Atrovent	5
Beclovent	33
Cefazolin	1, 3, 5, 7, 17, 18, 19, 33, 34
Digoxin	11
Dilantin	37
Diltiazem	3, 7, 9, 14, 15, 17, 18, 23, 27, 30, 36, 38
Furosemide	25, 35
Heparin	11, 14, 19, 29, 30, 34, 39
Hydralazine	25, 33
Insulin Regular	16, 19
Isosorbide	7, 9, 15, 23, 24, 28, 35
Metoprolol	23
Morphine	2, 3, 5, 7, 9, 11, 16, 19, 33
Nadalol	2
Nicardipine	25
Nifedipine	28
Nitroglycerine	2, 3, 4, 6, 13, 14, 20, 25, 30, 34, 36, 38, 39
Pentoxifylline	16
Questran	23
Ranitidine	1, 9, 11, 16
Scopolamine	2, 3, 5, 7, 9, 11, 16, 19, 33
Serax	30
Slow K	11
Sulcrate	21
Tylenol Plain	20, 21
Valium	30
Vancomycin	9, 16
Ventolin	3, 5, 9, 33

Appendix M continued

Intraoperative Phase

Adrenalin	1, 6, 15, 19, 28, 29
Amicar	36, 39
Amrinone	2, 5, 11, 28, 29, 32, 33
Atropine	6, 19, 27, 33
Betaloc	9
Cefazolin	1, 2, 3, 4, 5, 6, 7, 13, 15, 17, 18 19, 20, 21, 23, 24, 25, 27, 28, 29, 30, 32, 33, 34, 35, 36, 37, 38
DDAVP	27, 36
Diaxotide	4
Furosemide	1
Glycopyralate	3
Heparin[a]	
Hydralazine	25
Insulin (regular)	15, 16
Isoflurane	2, 6, 11, 13, 14, 16, 17, 19, 20, 21, 23, 25, 27, 30, 37, 39
K Chloride[a]	
Levophed	36
Lidocaine	1, 3, 9, 14, 25, 27, 28, 29, 32
Mannitol	13, 25
Metoclopromanide	9
Met/Panc[b]	1, 2, 3, 4, 5, 6, 7, 9, 11, 13, 14, 15, 16, 18, 19, 20, 21, 24, 25, 27, 29, 30, 32, 33, 34, 35, 36, 37, 38, 39
Magnesium Sulfate	11, 19, 39
Midazolam	1, 2, 3, 4, 7, 9, 13, 14, 15, 16, 19, 20, 21, 23, 24, 25, 27, 28, 29, 30, 34, 35, 36, 37, 38, 39
Neostigmine	9
Neosynephrine	1, 2, 3, 4, 5, 6, 7, 9, 11, 13, 14, 15, 16, 18, 19, 20, 21, 23, 24, 25, 27, 28, 29, 30, 32, 33, 34, 36, 37, 38
Nifedipine	39
Nitroglycerine	6, 7, 13, 14, 15, 19, 20, 21, 25, 28, 32, 34, 36, 38, 39
Propanalol	25, 29
Protamine[a]	
Reglan	9
Sodium Thiopental	1, 5, 11, 15, 33
Solumedrol	9
Succinocholine	9, 16, 21, 33
Sufentanyl[a]	
Trasylol	17, 21
Vancomycin	9, 16, 39
Vecuronium	17, 18, 20, 23, 24, 28, 34, 38

Appendix M continued

Postoperative Phase

Adrenalin	6, 14, 19, 28, 32
Amicar	19
Amrinone	11, 29, 33
Cefazolin	1, 2, 3, 4, 5, 6, 7, 11, 14, 15, 19, 21, 23, 25, 27, 28, 29, 30, 32, 34, 35, 36, 37, 38
Demerol	2, 3, 4, 5, 6, 7, 17, 18, 19, 20, 23, 28, 32, 34, 35
Dilantin	37
Dobutamine	13, 14, 32, 33, 36, 38, 39
Dopamine	2, 32, 36
Furosemide	4, 25, 28
Gravol	7
Insulin (regular)	15, 16, 19
K Chloride	1, 11, 13, 15, 23, 32
K Phosphate	3, 4, 5, 6, 7, 9, 11, 14, 16, 17, 18, 19, 23, 32, 34, 35, 39
Levophed	25, 28, 34
Lidocaine	1, 11, 13, 20, 21, 32, 38
Maalox	5, 34, 36
Mannitol	3
Magnesium Sulfate	1, 3, 7, 11, 14, 16, 21, 23, 30, 32, 38
Midazolam	21
Morphine	1, 2, 4, 5, 6, 7, 9, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 25, 27, 28, 29, 30, 32, 33, 34, 35, 36, 37, 38, 39
Neosynephrine	1, 2, 3, 5, 6, 11, 16, 17, 18, 19, 21, 23, 24, 27, 28, 29, 32, 34, 37
Nifedipine	39
Nitroglycerine	7, 20, 30, 36
Nitroprusside	4, 6, 7, 13, 14, 17, 18, 21, 24, 25, 27, 29, 33, 38
Propanolol	20, 21, 23, 38
Ranitidine	11
Sodium Bicarbonate	36
Sodium Phosphate	16, 21, 27, 33, 37
Solucortef	35
Solumedrol	9
Sulcrate	1, 3, 14, 15, 21, 37
Tylenol	28
Valium	1, 2, 3, 4, 5, 6, 7, 9, 14, 17, 18, 19, 21, 23, 24, 25, 27, 28, 29, 30, 33, 34, 35, 37, 38, 39
Vancomycin	39
Ventolin	2, 3, 6, 14

Note. [a]Medication received by all subjects. [b]Metubine Iodide/Pancuronium Bromide (Pavulon)

Appendix N

Refrigerated Blood or Blood Products Received by Subjects Within Eight Hours Prior to Temperature Measurements

Time	Blood or Blood Product		
	Frozen Plasma	Packed Cells or Whole Blood	Platelets
Prior to Surgery			
During Surgery	1, 13, 18, 19, 27	2, 4, 13, 14, 18, 19, 20, 24, 27, 30, 32, 33, 38	19
Post Surgery	4, 5, 6, 29, 30, 36	4, 6, 13, 14, 27, 28, 32, 38	

Appendix O

	ORALTC1	ORALTC2	ORALTC3	ORALTC4	ORALTC5	RECTTC1	RECTTC2	RECTTC3	RECTTC4	RECTTC5	PATC3	PATC4	PATC5
1	37.1	37.0	37.1	39.0	38.7	37.7	37.5	37.7	39.6	39.1	37.5	38.9	38.5
2	37.5	37.4	36.5	38.5	38.2	38.0	37.9	35.9	39.0	38.2	36.4	38.9	38.1
3	36.7	36.7	36.1	37.7	37.7	37.4	37.2	36.6	37.7	38.5	36.0	37.4	37.6
4	37.0	36.8	35.7	37.2	37.9	37.2	37.2	36.1	37.2	38.1	36.0	37.1	37.7
5	37.4	37.5	36.2	38.3	39.2	37.9	37.7	36.4	38.8	39.4	36.4	38.3	38.8
6	37.1	37.0	36.3	37.5	38.4	37.5	37.3	36.8	37.5	38.3	36.4	37.8	38.1
7	36.6	36.6	35.1	37.3	38.0	37.2	37.2	35.4	37.0	37.9	35.0	37.3	37.6
8	37.0	37.0	36.7	36.8	37.1	37.6	37.6	36.9	37.1	37.6	36.3	36.5	37.1
9	37.1	37.0	36.8	38.0	37.7	37.8	37.6	37.5	37.9	38.3	37.2	37.5	37.6
10	36.9	36.4	33.2	35.3	37.5	37.4	37.1	33.9	34.5	37.7	33.6	35.2	37.5
11	36.3	36.9	35.7	36.9	37.5	37.1	37.0	36.0	37.3	37.6	36.2	37.1	37.4
12	36.9	37.6	36.1	37.6	38.0	37.7	37.6	35.8	37.7	37.9	36.5	37.8	37.7
13	37.0	36.8	37.1	37.3	38.2	37.2	37.3	37.2	37.7	38.2	36.8	37.7	38.0
14	36.4	37.0	36.5	38.3	38.5	37.2	37.2	36.4	38.2	39.0	36.5	38.4	38.4
15	37.4	36.9	35.8	38.3	38.1	37.7	37.5	35.5	38.2	38.2	35.5	38.2	38.0
16	37.1	37.1	35.7	36.9	37.8	37.3	37.1	36.2	37.5	37.7	35.8	37.2	37.5
17	37.2	37.2	37.1	37.4	38.0	37.6	37.1	37.5	38.2	37.7	37.7	37.8	37.7
18	37.1	37.0	35.8	37.9	38.6	37.7	37.6	35.9	38.7	39.2	35.8	38.5	38.8
19	36.8	36.5	35.8	38.2	38.1	37.2	37.0	35.8	38.2	38.0	36.2	38.1	37.7
20	37.1	37.0	36.1	37.5	38.1	37.2	37.1	36.1	37.5	38.0	35.9	37.4	37.9
21	37.5	37.2	36.2	36.7	37.0	37.6	37.7	36.4	36.9	37.1	36.1	36.6	36.7
22	36.8	36.9	36.3	37.5	38.5	37.2	37.2	36.0	37.9	38.6	36.2	37.9	38.3
23	37.1	37.0	36.6	38.6	39.0	37.5	37.5	35.9	39.2	39.4	36.9	38.9	38.9
24	37.3	36.8	36.4	37.5	37.8	37.5	37.1	37.0	38.0	38.2	36.7	37.6	37.7
25	36.7	36.4	34.4	37.0	37.8	37.1	37.0	34.8	36.7	38.0	34.6	36.7	37.7
26	37.0	37.1	34.8	35.9	36.9	37.5	37.5	35.4	36.2	37.6	35.5	36.2	37.6
27	36.7	36.9	34.6	35.8	37.1	37.7	37.5	35.5	36.0	37.5	35.5	35.8	37.1
28	36.9	36.9	35.8	36.7	38.1	37.3	37.4	35.9	36.7	37.9	35.7	36.7	37.7
29	36.6	36.8	36.8	37.5	37.3	37.2	37.1	36.4	37.9	37.7	36.7	37.2	37.2
30	36.8	36.6	36.5	37.5	38.0	37.5	37.3	37.1	37.6	38.6	36.5	37.4	38.1
31	36.6	36.4	36.8	37.1	37.2	36.9	36.8	37.2	37.4	37.5	36.8	36.9	37.0
32	37.0	36.9	35.6	36.2	37.7	37.6	37.5	35.8	36.1	37.7	35.6	35.8	37.8
33	36.7	36.7	34.8	36.3	37.9	37.5	37.2	35.2	36.3	38.0	35.0	36.2	37.6