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SAFE PRACTICES *in Patient Care*

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Physicians have recognized fever as a sign of illness since several thousand years before Christ. In the late nineteenth century, bacteria and other microorganisms were identified as able to induce fever, but how they did so was unknown. Clinical thermometry became an accepted clinical diagnostic resource when Carl Wunderlich published research findings of body temperature and established a range of normal temperature. A recent focus on patient safety standards by JCAHO has prompted clinicians to evaluate the safety of thermometry in their clinical environment. The hazards of clinical thermometry continue to change as technology and patient acuity become more complex. In her article, Dr. Holtzclaw explains while thermometer breakage and displacement have been the primary concerns for safety, however more attention should be focused on factors that affect the correct interpretation of thermometer readings.

Measurement of body temperature is a crucial clinical assessment in the care of acutely ill neonates, infants, and children. Acutely ill children require frequent and repeated temperature measurement, and accuracy and safety are paramount considerations. In their article, Ms. Kline and Martin discuss the safety issues in neonatal and pediatric thermometry.

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This issue's commentary:
Safeguarding Patients Through Certification
by Jan Foster PhD, RN, CNS, CCRN

Monitoring Body Temperature in Critical and Acute-care Settings

By Barbara J. Holtzclaw, PhD, RN, FAAN

Safe surveillance of body temperature in seriously ill patients requires a level of caution that is often underestimated. The hazards of clinical thermometry continue to change as technology and patient acuity become more complex.

Historically, thermometer breakage and displacement have been the primary concerns for safety, while less attention has been focused on factors that affect the correct interpretation of thermometer readings. Confusion and false expectations have surrounded the use of newer temperature-measuring devices, affecting their interpretation, and care decisions related to temperature change are often inconsistent or faulty.

A review of current practices and literature related to temperature monitoring shows safety concerns in the following areas:

- injury or infection hazards posed by patient/thermometer contact
- thermometers as a source of iatrogenic infection
- incomplete understanding and false expectations of device capabilities
- inconsistent calibration and reliability checks of measuring devices
- few training and guideline sources for correct technique, interpretation, or troubleshooting of thermometric devices
- underuse of research on dynamics of temperature change in the critically ill

This article presents these problems within the context of accident and incident prevention. It discusses resources and suggestions for reducing risk factors in clinical situations.

> Safe surveillance of body temperature in seriously ill patients requires a level of caution that is often underestimated.

Hazards of patient/thermometer contact

Glass thermometers

Most intrusive thermometric devices are placed in body orifices with fragile mucous membranes, which increases the potential for tissue injury. Indeed, the injury of glass breakage and risk of mercury toxicity to patients and caregivers are among the main reasons that traditional mercury-containing thermometers are no longer used in most clinical settings.

Safety concerns have launched a growing movement to ban the use of glass thermometers in the USA and other countries.[1,2] The small size and smooth handling end of glass thermometers makes it difficult for caregivers to maintain a firm grasp. These thermometers can be easily lost in the rectum, vagina, or urethra. Accidental breakage, swallowing, or migration of glass thermometers constitutes a medical emergency, requiring surgical or therapeutic intervention to treat mercury toxicity, repair lacerations, or extract a device lodged in an organ wall. Exposure to mercury vapors after a thermometer breaks requires evaluation by site-support personnel to assure that caregivers and patients have not been affected.

Risk of tissue injury

Risk of injury to the patient's skin or delicate mucous membranes remains a concern when caregivers insert any thermometric

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Hazards in Neonatal and Pediatric Thermometry

By Andrea M. Kline, RN, MS, PCCNP, CPNP, CCRN, and Sarah A. Martin, RN, MS, PCCNP, CPNP, CCRN

Measurement of body temperature is a crucial clinical assessment in the care of acutely ill neonates, infants, and children. Temperature measurement is one important indicator of an alteration in the child's clinical status. The presence of fever may warrant additional laboratory and diagnostic testing or changes in the child's treatment plan.

A recent focus on patient safety standards by the Joint Commission on Hospital Accreditation of Healthcare Organizations (JCAHO) has prompted clinicians to evaluate the safety of thermometry in their clinical environment. Acutely ill children require frequent and repeated temperature measurement, and accuracy and safety are paramount considerations. This paper focuses on the safety of neonatal and pediatric thermometry.

Thermoregulation

Variations in the temperature of blood bathing the preoptic area of the hypothalamus, the body's temperature-control center, determine the physiological response in maintaining homeostasis.[2,3] This natural process is known as thermoregulation.

Almost 40 years ago, researchers measured numerous body sites with calorimetry and sensitive thermocouples to show that the hypothalamus controls sweating and peripheral vasodilation in response to warm stress.[3] Cold stress responses, such as increased heat production and peripheral vasoconstriction, are mediated by peripheral and central thermoreceptors.[3]

Since it is impractical to measure temperature at the hypothalamus, body sites that most closely approximate temperature changes in the hypothalamus or "core" provide the most accurate readings.[3]

Fever

Fever is an abnormal elevation of temperature in response to a number of pathologic conditions. There are many accepted definitions of fever; in pediatrics, there is a lack of consensus of what constitutes normothermia versus fever. Reference values for rectal temperature measurements in children are 37.0 to 37.3 degrees Celsius(°C). The suggested reference values for normothermia in the neonate are 36.5-37.5°C for the term baby and 36.3-36.9°C for the preterm baby.

A variety of biologic processes cause fever in the pediatric population. Some are infectious; others, non-infectious. Non-infectious etiologies can be as life-endangering as infectious ones. Non-infectious etiologies include adrenal insufficiency, thyroid storm, heat stroke, exercise, neurologic pathology, environmental exposure (e.g., heat lamps, air mattresses), medication administration, and malignant hyperthermia.[4] Neonates, however, tend to become hypothermic when assaulted with biologic processes.

> The tympanic membrane is unaffected by ambient air temperature, mouth breathing, oral intake, or insulation by stool.

Fever pathology

Cytokine release in the body, particularly interleukin (IL)-1, IL-6, and tumor necrosis factor (TNF)-alpha, play a central role in fever formation.[5] These cytokines bind to their unique receptors, located near the anterior hypothalamus, promoting the release of prostaglandin E.[2] Ultimately, this small lipid mediator crosses the blood-brain barrier, provoking responses that decrease heat loss and increase heat production.

A small population of acutely ill patients may experience increased sympathetic activity and heat production, resulting in hyperthermia.[5]

Routes of administration

Body temperature has traditionally been measured by different routes. Pulmonary artery temperature assessment has been described as the gold standard; however, it is impractical in children, as pulmonary artery monitoring is rarely done in this group of patients. Some temperature measurements, including esophageal, bladder, tracheal, and nasopharyngeal, are reserved for patients in the operating room (OR) or intensive care unit (ICU) due to their invasive nature.

In children, body temperature is usually assessed by rectal, sublingual, axillary, tympanic, or skin routes. The axilla and skin temperature routes are used in neonates. Each route has hazards and the risk of inaccuracy.

Oral

The oral route is common and generally well-accepted for older children. Oral thermometers have limited use in infants and young children due to issues of cooperation and appropriate mouth seal. Inaccurate placement, drinking, eating, and smoking within 15 minutes of measurement may alter the oral temperature value. Results may take several minutes and accuracy depends on the mouth being closed – a challenge for infants and young children.

Oral measurement may reflect changes in blood flow to the lingual or external carotid arteries and not the child's core temperature. Oral temperature values may vary up to 0.6°C in various sublingual regions, unless the thermometer is placed accurately in the posterior sublingual pocket.[3]

Axillary

The main advantage of this route is ease of access.

The axilla is not located near a major artery; therefore, fluctuations in core temperature may not be accurately assessed. Axillary measurements may be more than 1°C lower than core temperature.[6] It may take several minutes to obtain an accurate reading.

This route can be useful to track temperature trends in infants and children. Toddlers are more accepting of the axillary route than the tympanic-membrane route.[8] Mercury-containing glass, digital, infrared, or dot matrix thermometers can be used to obtain axillary temperature.

Rectal

The rectal route is the gold standard for noninvasive temperature assessment in children.

While widely accepted, this route has drawbacks. Inaccuracies in rectal temperature readings may be related to site of measurement within the rectum, presence of stool, and blood flow to the abdominal region. Rectal temperatures are slow to change, as compared to blood temperatures.[3,6,7,9] Even at steady state, rectal temperatures differ significantly from pulmonary artery temperatures.[9] Parental perceptions of abuse, embarrassment, and discomfort are associated with rectal-temperature measurement. Due to the short length of the rectum and the increased risk of perforation, this route is not recommended for use in the neonate.

Tympanic

Tympanic thermometry measures infrared radiation emitted from the tympanic membrane. This membrane is well-perfused and located merely 3.5 mm from the hypothalamus, the body's temperature regulator. This location may be ideal for measuring body temperature.[3,6,8,9]

This route is preferred by some parents and is more accepted by some pediatric patients.[6,8] The tympanic membrane is unaffected by ambient air temperature, mouth breathing, oral intake, or insulation by stool. Temperature-measuring time is less than 2 seconds with most devices, making it quick and convenient, even for uncooperative children.

Some evidence suggests that this route may not be accurate in infants less than 3 months of age due to their short ear canal.

The thermometer has disposable covers, reducing concerns of infection transmission. It is designed to prevent deep penetration in the ear canal to minimize the risk for perforation.[6] Wax in the ear canal, presence of myringotomy tubes, acute otitis media, and otitis media with effusion do not appear to affect temperature assessment.[3,6,7] Purulent aural discharge is a contraindication to using this method of thermometry.[6] The thermometer does not come into contact with mucus membranes.

Temporal artery

Two devices that can be used for this route of temperature assessment are the infrared scanner and dot-matrix or liquid-crystal strip (see below). This route is rapid, delivering data in seconds, and is well tolerated in infants and children. It may be more accurate in children than adults, who have a thicker layer of skin over the temporal artery, which has an impact on temperature results.[9,10]

Physiological states that involve vasoconstriction, which occur in post-cardiac surgery patients, or high levels of catecholamine release may falsify data, causing lower readings.[10]

Types of thermometers

Infrared scanners

A noninvasive infrared scanner detects the highest temperature by scanning, presumably over the temporal artery.[10] This new technology has received mixed reviews in the limited research. Its disadvantages include the inability to obtain a reading at all and the potential for error when the child perspires on the forehead.[10]

Dot matrix thermometers

These single-use, disposable devices are available for several routes, including oral, axillary, and temporal artery. Each dot is filled with a chemical mixture that is formulated to melt and change color at a certain temperature.

These devices may limit the risk of cross contamination between children. However, some evidence suggests that, even with disposable devices, there is a risk of cross contamination due to contact with caregivers' gloves or hands.

Limited research has documented the accuracy of dot-matrix thermometry. Infants and children who are crying are not candidates for oral dot-matrix devices, as they are unable to seal their mouths around the thermometer. It takes 60 seconds for an oral reading and 3 minutes for an axillary reading.

When these thermometers are exposed to temperatures of 86° Fahrenheit or 30°C , the dots turn blue and the thermometers must be reset. They must be placed in a freezer for one hour, then remain at room temperature for one day before reuse. Accuracy is not affected by this procedure.

Single-use thermometers are not as cost-effective as reusable ones.

Safety issues

Mercury-containing thermometers: Do risks outweigh benefits?

The use of mercury-containing glass thermometers, despite alternate means of thermometry, is still the standard for obtaining temperatures in many healthcare settings.[11] These thermometers have a 25% error rate after a use or shelf life of 8 months.[12]

The main concern with these devices is the possibility of mercury exposure and poisoning on breakage. Recently proposed federal legislation, Bill S.616, calls for banning the sale of mercury-containing glass thermometers, except by prescription, and for provision of federal monies for state and local exchange programs. This bill calls for a plan for long-term management of mercury, including long-term storage and sequestration, and for minimizing the use of mercury-containing products.

In a recent position statement, the American Academy of Pediatrics (AAP) has raised the public's awareness of the danger of mercury exposure.[13] The AAP recommends eradicating mercury in waste by eliminating mercury-containing medical devices, including sphygmomanometers and thermometers, from medical facilities. The AAP encourages parents not to use mercury-containing thermometers at home.

In a number of cases, the use of a mercury-containing glass thermometer has caused injury.[14, 15, 16] Potential risks include breakage within a bodily orifice, rectal perforation, peritonitis, diarrhea, and acrodynia after breakage.[12,17] In one account a mercury-containing glass thermometer became imbedded in the floor of a child's mouth after the toddler jumped on the bed during temperature measurement.[14] The toddler experienced significant bleeding, which was brought under control with ice cubes. Surgery was needed to remove the device. Mercury exposure was clinically insignificant.

FILAC™/FasTemp™

Mercury levels in a two-year old who sustained a facial impalement with a mercury-containing thermometer were elevated; however, the child did not show any signs of mercury poisoning and, at one year post-intervention, blood levels were negligible.[16]

Although cases of rectal perforation are reported, one author contends that it occurs in less than one in two million measurements.[18] Caregivers should use caution when obtaining rectal measurements, particularly in neonates and infants, as this rare event can be associated with serious sequelae.[19] Due to the risk, in many neonatal units, axillary temperature measurement is the preferred route.

Caregivers should consider obtaining mercury levels in children with known mercury exposure or symptoms of mercury toxicity after breakage of a mercury-containing glass thermometer. Acrodynia or pink disease is diagnosed in young children with chronic mercury exposure. Symptoms include lethargy, poor memory, and pink discoloration of fingers and palms.[20] With disease progression, desquamation, pruritus, and pain can occur.[20]

Risk of infection

Hospital-acquired infection has been linked to contaminated temperature-measuring equipment.[21-25] In a position statement on infection control in physicians' offices, the AAP recommends the disinfection of temperature-measuring equipment and the use of disposable equipment, e.g., plastic sleeves, shields etc., whenever feasible.[26] Infection-control issues and cross contamination can be avoided by disinfecting any soiled thermometer and avoiding the contamination of storage boxes, which can be cleaned with either soap and water or alcohol.[26]

A number of reports have documented the transmission of hospital-acquired infection via thermometry.[21-24] Several cases of nosocomial infection in neonatal units have been tracked back to temperature-measuring devices.[23,24] In one neonatal intensive care unit (NICU), an outbreak of *Enterobacter cloacae* was isolated from a single cap of an electronic digital thermometer.[24] Interestingly, the authors reported that the cap design prohibited proper disinfection. Isolation of colonized patients and elimination of the suspect device did not prevent the spread of infection to other neonates. The unit was eventually closed; control of the outbreak occurred after the adequate disinfection of thermometers.[25]

Certain devices, such as the FILAC FasTemp (Tyco Healthcare), have incorporated technology that use digital animation to tell the operator when to "place probe cover on" when the thermometer probe is removed from the probe well to reduce the incidence of cross contamination. Integrated into the FILAC FasTemp are color-coded isolation chambers, which house the thermometer. If using this thermometer for rectal measurements, the isolation chamber is red; if for oral use, the isolation chamber is blue. Completely separate color-coded isolation chambers with individual probes, probe wells, and probe covers may help to ameliorate infectious breakouts due to cross contamination.

In an outbreak of a multiply resistant strain of *Klebsiella pneumoniae*, an NICU was closed to control further colonization and infection.[23] Contaminated breast milk, electronic thermometers, and oxygen-saturation probes were contaminated with one strain of *Klebsiella pneumoniae*. The electronic thermometers were personal equipment carried by nurses in plastic cases that were macroscopically dirty. Their use was discontinued in favor of single-use items, bringing the outbreak under control.

Other accounts of hospital-acquired infection in adults and children include the transmission of Clostridium difficile and vancomycin-resistant Enterococcus.[21]

One institution, which stopped using disposable devices, due to the fear of cross contamination from caregivers' gloves, changed to tympanic thermometers. Another institution reduced the incidence of *Clostridium-difficile* diarrhea by changing from electronic to disposable devices.[22]

Different institutions have different solutions for this same problem. What is your unit's routine for disinfecting temperature-measuring devices?

Conclusion

Temperature assessment is a task performed by nurses on a routine basis. A variety of thermometers can determine body temperature in neonates and children. Selection of the appropriate device is influenced by the child's developmental stage as well as accuracy and safety considerations.

Routine involvement of biomedical engineering in calibrating thermometers is imperative. The disinfection of shared measuring devices and soiled equipment before reuse is part of routine care. When purchasing new equipment, it is imperative that caregivers consider devices that use technology which does not involve bodily fluids or has features to prevent cross contamination in pediatric patients, e.g., Tyco's FILAC FasTemp thermometer.

Nurses must obtain accurate temperature information, while protecting our patients from the risks of mercury toxicity, rectal perforation, cross contamination, and other hazards of thermometry. Cross contamination lengthens hospital stay, drives up hospital costs, and causes unnecessary morbidity.

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Monitoring Body Temperature in Critical and Acute-care Settings — Continued

device into a body orifice. The most potentially dangerous injuries are those that cause perforation of the intestinal wall, esophagus, bladder, or tympanic membrane.[4-7] Infants and small children, restless and unconscious people, and patients with indwelling temperature probes are at greatest risk for perforation. When an indwelling thermistor is left in place, e.g., during surgery, induced hypothermia, or in emergency-care units, it is necessary to tether its lead to the patient's skin and mark the reference point where the probe enters the body orifice.

Source of iatrogenic infection

Any time that an instrument or medical device must be shared among patients, the hazard of cross-contamination exists. The advent of disposable probe covers for oral and rectal thermometers and hand-held tympanic membrane™ thermometers may lead to complacency among caregivers, because the contact

Singapore General Hospital using a TM thermometer (GENIUS® Tyco Healthcare) for SARS screening.

point of these devices is covered. However, evidence emphasizes the need to continue decontamination procedures between usages.[8] When plastic sheaths were tested for their efficacy in protecting oral mercury-containing glass thermometers from contamination, 80% of thermometers were found to be contaminated after use, because patients' teeth had perforated the plastic coverings. Plastic probe covers or sleeves that contain latex should not be used as a precaution against latex allergy.

Even when covered by protective sleeves, the handling of these devices can transmit pathogens between patients. Examples of hospital-acquired infections are found in studies of hospital outbreaks of vancomycin-resistant *Enterococcus faecium*.[9,10] In one case, the organism was isolated repeatedly from rectal probe handles on three electronic thermometers that were used only on nonisolated patients in the intensive care unit.[9] More recently, the spread of E. faecium among seven patients in one ward was linked to a clonal strain of the same organism, which was found on the handle of a shared electronic ear-probe thermometer.[10] Cross contamination has occurred between two geographically separate units on a hospital ward that shared equipment but not personnel.

When patients are isolated because of highly infectious disease, a thermometric device should be assigned to each individual and subjected to organism-specific disinfecting procedures before it is used on another person. Probe covers are disposed of as hazardous waste.

Preventing cross contamination from thermometers during highly contagious epidemics, such as a severe acute respiratory syndrome (SARS) outbreak, is a challenge. Thermometers are used to screen hundreds of people to detect new cases. Proper disinfection or disposal of traditional thermometers may be neither feasible nor affordable.

The thermometer was dubbed as "the single most important tool in bringing SARS under control" by the World Health Organization (WHO),[11] because of its usefulness in screening and early detection. At the same time, the likelihood that thermometers could be vectors of SARS cross contamination led manufacturers to market one-time use, disposable thermometers for "SARS kits." Examples include the 3M TempaDot Thermometer.™ The disposable thermometer may save time, because the used thermometer can be thrown away.

Tympanic membrane thermometers appear to take less time in mass screening situations because of their rapid display. To avoid cross contamination, the handle should be cleaned between patients.

Thermometer capabilities

What do thermometers measure?

Body temperature, a thermodynamic property, defies direct measurement and must be estimated by measuring the heat content of a specific substance such as body tissue. Temperatures vary throughout the human body because the heat content of various tissues and organs varies. Body temperatures are strongly influenced by the circulation of warm blood and insulation provided by fat and superficial tissues. Skin and superficial tissues are generally cooled by the environment. The ability of vasomotor activity to change blood flow to the skin or organs contributes to rapid changes in regional body temperatures, which occur during dynamic conditions, e.g., shock, hypothermia, or fever.

Because hemodynamic and thermoregulatory alterations can cause dramatic changes in circulation to the skin, mouth, and gut, the patient's condition should dictate the site where body temperature is measured. Furthermore, the pattern of temperature change and gradients between sites can give the astute critical care nurse clues to the patient's overall condition.

Accuracy

Thermometers cannot be accurate unless they are reliable, but the converse is not true. A thermometer may provide stable, reliable measurements over time, but unless it is calibrated for accuracy, these readings will not reflect the actual temperature being measured. When available, the pulmonary artery (PA) thermometer provides the most accurate reflection of central temperature, but when unavailable, TM thermometry, using a reliable instrument and procedural skill, is a realistic alternative.

Linearity of a thermometer is important, particularly in patients with hypothermia, hyperthermia, or fever. For example, laboratory water-bath testing of eight TM thermometers from well-established manufacturers showed their accuracy in the range of 36.7° to 38.9°C (98 to 102°F). This means that temperatures above or below this level may not be accurate. In this study, three thermometers had enough accuracy, linearity, and reliability to be used in clinical studies: The GENIUS 3000A, and FIRSTEMP 2000, (Tyco Healthcare)and THERMOSCAN (Pro-1, Braun).

None of the TM manufacturers guaranteed accuracy at temperature levels commonly seen in febrile states (>39°C) and all were found to underestimate extremely high and low (<36°C) temperatures.[12] The brands of TM thermometers deemed unacceptable for clinical studies varied in linearity along the range of 36.7° to 38.9°C.

Using Thermometers and Temperature Probes

- Placement of any thermometric device requires gentle insertion.
- Never force entry; gently withdraw, rotate, and guide the instrument into a path without resistance.
- Choose an alternative to oral temperature measurement when patients have oral lesions or irritated oral mucosa.
- Rough handling of tympanic membrane thermometers during placement can be painful and injure the auditory canal.
- When lubrication is indicated (e.g., for rectal or vaginal insertion), use a water-soluble, non-greasy, non-irritating lubricant, such as K-Y Jelly™.
- Rough or broken edges on plastic casings, wrinkles on plastic sheaths, or simply a lack of sufficient lubrication can traumatize the anus during rectal thermometer insertion.
- Rectal, vaginal, esophageal, or urinary bladder thermistors must be taped or attached to an external site to prevent misplacement and migration.
- An untethered thermometer, inserted in any body orifice, should never be left unattended.
- Leads, attachments, and placement of indwelling thermistors should be checked every time that a caregiver repositions a patient.

What's the right temperature?

There is no single body temperature and no ideal site for measuring body temperature for every assessment. In critical care, the primary concern has been to keep the brain and central nervous system within a safe and optimal temperature range to prevent injury and maintain vital function. Because brain temperature cannot be measured clinically, unless indwelling thermistors are in place, other "core" temperatures are measured from deep within the body.

It is erroneous to assume that there is a single core temperature and that it can be accurately estimated from readings extrapolated at another site. Each region of the body has its own temperature, which varies as cellular metabolism, tissue friction, and circulation affect heat content.

A common misconception is that there are reliable temperature differentials of about 1° F (0.2° C) between oral, rectal, and axillary measurements. This belief leads to the faulty assumption that temperature readings from one site can estimate body temperature at another by mathematical algorithm (a predetermined formula to add or subtract an expected estimated gradient).

This assumption guides the use of offsets in TM thermometers. Algorithms are programmed into settings, so a calculation can convert TM temperature readings into rectal or core readings. This assumption is flawed. Differences or gradients between body regions are easily affected by changes in circulation or vasomotor responses. During vasodilation, the gradient between skin and core temperatures are less than during vasoconstriction. Physiological shunting of blood away from the body surface during hemorrhage, hypothermia, or in stressful situations, widens the gradients considerably.

The offset feature is not reading the actual temperature from the rectum or body core. For that reason, caregivers are often confused about what they are reading and reporting. When an abnormal temperature, based on an estimated value, is reported to a physician, unwarranted treatment may follow. When the site, type of thermometer, and any offset or code settings are reported, the physician may request a secondary temperature source or additional assessment before instituting treatment.

Predictive electronic thermometers use another type of offset estimate, which is programmed into the thermometer during manufacture.[13] These thermometers display an estimated rather than actual temperature value, while waiting for the actual temperature to equilibrate. The predicted values are determined by clinical studies during product development. Beginning with the patient's own temperature, the electronic circuitry tracks the rise of temperature in the thermistor probe and uses the slope of rise to add the offset. The final temperature is plotted as an estimate before the actual reading is reached. Accepting the speed of an estimated prediction over the accuracy of a final reading in thermometers that require a lengthy wait before achieving a steady state is the trade-off. More controlled clinical studies are required to validate the accuracy of predictive thermometers.[13]

Some important points to remember about the practice of estimating temperatures at various body sites are:

- Comparable clinical differences between temperature sites are only fair estimations, even when measured in a resting, afebrile person in a homeostatic state.
- In dynamic states, temperatures at various sites often do not even track together; core temperatures may rise, while temperatures in peripheral regions fall.
- In critical care, conditions that mandate continuous temperature monitoring are often dynamic. Rectal temperatures lag behind central temperatures during circulatory instability or hypothermic rewarming.
- Comparing temperatures from several sites may give helpful insights about heat distribution during dynamic states, such as rewarming or stabilizing circulation.
- Measurements from one site cannot provide the gold standard for testing the accuracy of others. This practice is risky, because all body temperatures are only estimates of existing temperatures.

Measuring central temperatures

Increasingly, central temperature is used to determine which temperatures affect the heart and brain. Indwelling TM thermometers estimate central temperatures well. When probes touch the TM, they have been shown to approximate the hypothalamus in animals and pulmonary artery in humans.[14] Unfortunately, these devices are hard to keep in place in active or restless patients and cases of perforated tympanic membrane make them less desirable for monitoring temperature in critical-care settings.[4,5]

Hand-held TM thermometers, which use infrared light-reflectance technology to detect heat radiated as infrared energy from the tympanic membrane, are a reliable measure of core temperature when dependable equipment is used by trained personnel. Introduced in the late 1980s, the ear thermometer has evolved to a more streamlined hand-held device.

While the hand-held TM thermometer lacks the advantage of continuous measurement, this instrument is convenient and comfortable for patients. It is handled like an otoscope. A disposable probe tip is inserted into the ear canal and aimed at the tympanic membrane. This is where training in the use of these devices becomes crucial. Unless the infrared beam has a perfect view of the tympanum (which in one study only occurred 5% of the time),[15] it is incapable of providing a reliable measurement of TM temperature (Figure 1). When staff are trained in otoscope use, they become more aware of the positioning necessary to view the eardrum. Training should include interrater reliability checks to assure competency.

Important Characteristics of Thermometers

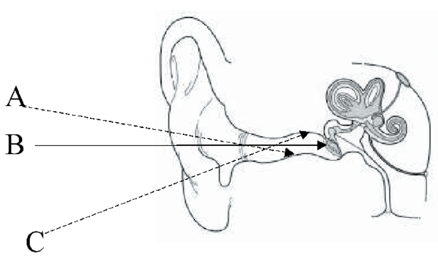
Accuracy:	ability to measure a true temperature value
Reliability:	stability and reproducibility over time
Linearity:	ability to measure accurately throughout the full range of specified temperatures
Precision:	ability to detect small changes reliably in repeated measures

Esophageal temperatures are considered central temperatures because of their close proximity to the heart and large central vasculature. This site is commonly used during surgery and anesthesia.[16] There is some risk of nasopharyngeal trauma, and prolonged use has been associated with tracheoesophageal fistula.[17] Accuracy of esophageal temperature can be affected by cold or warm inhaled gases or gastric contents. Temperatures tend to increase with depth of esophageal insertion. Optimal location for probe placement is at 15 to 20 cm.[16]

Pulmonary artery temperature is the gold standard for central temperature measurement in critical-care settings. Thermistor-tipped pulmonary artery catheters that are part of advanced hemodynamic monitoring systems provide the most accurate and informative central temperature information. However, certain precautions are necessary to maintain temperature accuracy:

- Accuracy of central temperatures from the pulmonary artery depends in part on factory calibration of the monitoring system and careful handling of thermistors to prevent breakage.
- Problems with cardiac output computers contribute to faulty readings. Testing by hospital bioengineers is required at least every 6 months.

Angle of Infrared Reflection Influences Accuracy of TM Measurement



A = Elevating handle of TM probe reflects on and measures external auditory canal temperature

B = Perfect view of TM allows infrared light to reflect TM temperature

C = Lowering handle of TM probe reflects on and measures external auditory canal temperature

Figure 1

Calibration and reliability checks

Large, well-serviced institutions generally rely on a department of bioengineering to calibrate thermometric devices on a regular basis. Smaller hospitals or emergency-care centers may rely entirely on contracting out for calibration and repair. All electronic thermometers have a battery life, are sensitive to vibration, falls, and electrical interference. For this reason, these devices need a maintenance plan.

Few guidelines exist for the correct use and maintenance for thermometric equipment to ensure reliable readings. Information on how to insert and maintain indwelling thermometer probes should appear on packaging. Standards of practice, giving explicit instructions for depth of placement, lubrication, and methods of securing probes are required for consistent, safe practice. For example:

- Variations in the placement of oral thermometers affect the accuracy of readings.[21,22]
- While electronic thermometers usually signal the observer when the temperature has registered, mercury-containing glass thermometers require a waiting time of at least 3 minutes.
- Instruction in use of TM thermometers can improve the reliability and accuracy of this type of thermometry.[12] The nurse should be familiar with each type of thermometer, read the accompanying literature or instruction manuals, and follow these basic principles for troubleshooting electronic devices:
- Arrange calibration checks by a bioengineer at regular periods; enter maintenance dates on the device label.
- Use desktop calibrators when available. Keep records of calibration trends.
- Observe battery warnings and keep a record of recharging activity, as an inability to hold a charge or an erratic display may indicate the need to replace the battery.
- Remove from service any device with a hard-to-read display, cracked case, frayed or broken lead, or erratic readings.
- Do not attempt to open, adjust with a screwdriver, or otherwise fix the device.

Dynamics of temperature change

The understanding of what these changes mean are crucial to protecting critically ill patients from temperature extremes. Studies show that the site of temperature measurement becomes an important decision during unstable dynamic events. Usual temperature gradients between sites can vary widely during shock or thermal events. For example, bladder and rectal temperatures tend to underestimate brain temperature in hyperthermic or hypothermic states.[23] To prevent temperature drift or instability during hypothermia, the temperature nearest the brain becomes more relevant. Likewise, during fever or hyperthermia, the range of temperature of critical importance is that of the brain and central nervous system.

Research shows that accurate prediction of core temperature in critically ill people cannot be achieved by measuring skin temperature with axillary or chemical dot thermometers.[24] Nurses are advised to avoid drastic gradients between skin and core temperatures that can evoke shivering.[25-27]

The following evidence-based principles of care have been developed:

- Site-specific temperature readings near the brain are most helpful in determining the threat of temperature elevation to the central nervous system.[28]
- Brain temperatures are estimated from TM and PA measurements when intraventricular thermometers are not possible.
- When wide gradients exist between brain and peripheral temperatures, maintaining a safe brain temperature is the goal.
- Peripheral temperature gradients are most helpful in determining changes in the heat distribution of patients in rewarming or hypothermic states.

Conclusion

Nurses who remain current with emerging research learn about new findings that lead to safe clinical practices. Clinical nurses should be actively involved in searching the evidence base for new information on safe and accurate temperature measurement.

There is a need to remain equally well informed about and involved with new devices. Ideally, nurses should serve on quality-assurance boards that evaluate and make purchasing decisions about these devices. Recognition of the scope, dimensions, and importance of temperature measurement is a major step toward these goals.

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This continuing education activity was approved by the Vermont State Nurses Association, Inc., an accredited approver by the American Nurses Credentialing Center's Commission on Accreditation (ANCC).

Upon completion of this offering the learner will be able to:

1. Identify injury hazards posed by thermometry devices in contact with the patient.
2. Discuss how thermometers can be a source of iatrogenic infections.
3. Compare and contrast direct temperature measurement with estimated or algorithm-derived measurements.
4. Describe four common temperature assessment routes used in neonates and children.
5. Describe three potential routes of cross contamination when using thermometry devices.
6. List three ways to decrease the risk of cross contamination in neonatal and pediatric thermometry.

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1. **Where is the body's temperature control center?**
   a. Right atrium
   b. Hypothalmus
   c. Brain stem
   d. Carotid artery

2. **Which of the following chemicals historically used in thermometry measurement may be banned from sales?**
   a. Mercury
   b. Lead
   c. Titanium
   d. Chromium

3. **Which of the following is a reason why oral thermometry devices are often not effective in neonates or infants?**
   a. Underdeveloped sublingual vessels
   b. Anatomically relative short distance to reach sublingual pocket
   c. Unable to create a seal with mouth around thermometry device
   d. Risk of aspiration

4. **Which of the following can affect tympanic membrane thermometry measurements?**
   a. Acute otitis media
   b. Serous otitis media
   c. Improper placement of probe
   d. Wax in ear canal

5. **All of the following are ways to decrease risk of cross contamination in thermometry between patients, EXCEPT:**
   a. Use disposable probe covers
   b. Use color coded chambers: red for rectal, blue for oral
   c. Wash hands frequently
   d. Disinfect thermometer device each day

6. **Transmission of which of the following bacteria has been reportedly linked to thermometer related cross contamination in hospitalized patients?**
   a. *Pseudomonas aeruginosa*
   b. *Streptococcus pneumoniae*
   c. *Haemophilus influenzae*
   d. *Enterobacter cloacae*

7. **Benefits to axillary temperature measurements include which of the following?**
   a. Less than two seconds required to obtain accurate reading
   b. Close to hypothalamus
   c. Often widely accepted route of measurement in toddlers and young children
   d. Appropriate axillary thermometer placement occurs > 95% of the time

8. **Mercury-in-glass thermometers are:**
   a. the gold standard for accuracy in clinical thermometers.
   b. no longer used in any US clinical facility.
   c. potential sources of injury through breakage and toxicity of mercury.
   d. easier to read than digital thermometers.

9. **Plastic sheaths used on oral thermometers:**
   a. have eliminated cross-contamination between patients.
   b. make it unnecessary for the caregiver to wash hands between patients while taking vital signs.
   c. are rigid enough to guard against perforation and contamination.
   d. do not eliminate need for decontamination procedures between thermometer usage.

10. **Temperature is which of the following?**
    a. an actual entity that can be measured directly by the right thermometer
    b. a thermodynamic property of something that cannot be measured directly
    c. a conceptual model of desired warmth or coolness
    d. a characteristic that depends on sensory ability

11. **Which of the following is most influential in influencing the body temperature measured at a particular site?**
    a. Regional circulation of blood
    b. Relative of the patient
    c. pH of the urine
    d. State of the patient's consciousness

12. **Why is it important to know a thermometer's linearity with regard to its accuracy limits?**
    a. This guarantees the readings from a thermometer will stay in line during indwelling temperature measurement
    b. Lack of linearity at either end of guaranteed accuracy limits cautions the user that temperatures above or below this level may not be accurate.
    c. This characteristic tells what substances the thermometer is made of.
    d. Linearity helps to predict how often a temperature should be measured.

13. **Which of the following is correct with regard to estimating temperatures in one site from measurements taken in another?**
    a. The algorithms in tympanic membrane thermometers can estimate core or rectal temperatures with precision and accuracy.
    b. Since there is just one "core" temperature," measurements from one body cavity can be estimated from another.
    c. Temperature differentials of about 1° F (0.2° C) between oral, rectal, and axillary measurement sites are stable so estimations in algorithms are extremely reliable.
    d. Temperature differentials are unreliable in hemodynamically unstable conditions or during thermodynamic changes such as fever, hypothermia, or heat-illnesses.

14. **Under what circumstances do peripheral temperatures provide important information for planning safe patient care?**
    a. Gradients between peripheral and core temperatures are most helpful in determining changes in heat distribution of patients in rewarming or hypothermic states.
    b. Peripheral temperatures are as reliable as core temperatures to detect dangerously low hypothermic temperatures.
    c. Peripheral temperatures are of no use clinically.
    d. Peripheral temperatures from skin or axillary thermometer measurements can reliably monitor the patient during heat related illnesses, such as heat stroke.

What is the highest degree you have earned (circle one) ? 1. Diploma 2. Associate 3. Bachelor's 4. Master's 5. Doctorate

Indicate to what degree you met the objectives for this program: Using 1 = Strongly disagree to 6 = strongly agree rating scale, please circle the number that best reflects the extent of your agreement to each statement.

	Strongly Disagree					Strongly Agree
1. Identify injury hazards posed by thermometry devices in contact with the patient.	1	2	3	4	5	6
2. Discuss how thermometers can be a source of iatrogenic infections.	1	2	3	4	5	6
3. Compare and contrast direct temperature measurement with estimated or algorithm-derived measurements.	1	2	3	4	5	6
4. Describe four common temperature assessment routes used in neonates and children.	1	2	3	4	5	6
5. Describe three potential routes of cross contamination when using thermometry devices.	1	2	3	4	5	6
6. List three ways to decrease the risk of cross contamination in neonatal and pediatric thermometry.	1	2	3	4	5	6

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2	☐	☐	☐	☐	10	☐	☐	☐	☐
3	☐	☐	☐	☐	11	☐	☐	☐	☐
4	☐	☐	☐	☐	12	☐	☐	☐	☐
5	☐	☐	☐	☐	13	☐	☐	☐	☐
6	☐	☐	☐	☐	14	☐	☐	☐	☐
7	☐	☐	☐	☐	15	☐	☐	☐	☐
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