Use of the Forehead as an Accepted Site for Clinical Temperature

Applies to: Caregiver Model Non-contact Clinical Thermometers

The purpose of this review is to examine the research evidence to determine the suitability of the forehead as a reliable site for the measurement of body temperature. The scope of the analysis is limited to measurements taken from the middle of the forehead and not from over the temporal arteries.

As early as 1964, scientists researching the circulation of the forehead have been able to show that the blood supply to the forehead originates in and responds to changes in the internal carotid artery (Heinz, Goldberg, & Taveras, 1964). Conrad and colleagues used thermistors to measure various non-temporal forehead temperatures with a high level of precision to identify compromised carotid circulation and concomitant altered forehead perfusion through comparison with normal values (Conrad, Toole, & Janeway, 1969). Subsequent studies centered mostly on perioperative temperature measurement with the forehead being of particular interest as a site that is readily accessible to the anesthesia team without having to rearrange surgical drapes.

The advent of liquid crystal phase-change forehead strips turned the attention of researchers from the characteristics and reliability of the forehead to the liquid crystal technology. The forehead continued to be found to track other sites quite well but about 4°F lower (Burgess, Cooper, Marino, & Peuler, 1978). The interest in forehead as a measurement site was also based on the need for continuous measurement during surgery and the liquid crystal strips were able to deliver that with reasonable precision (Lees, et al., 1978). Successive studies comparing forehead temperature with multiple sites continued to be confined to the perioperative area and the potential to measure clinical temperature extremes characteristic of the perioperative course (Tsuji, 1987; Tsuji, et al., 1984; Tsuji, Suma, et al., 1981; Tsuji, Tamura, Nemoto, & Togawa, 1981).

Two distinct aspects dominated this research:

- The forehead was an acceptable site for measuring body temperature and
- There was complete awareness that body temperature exists on a dynamic gradient and that measuring simultaneous temperatures at multiple sites will not yield identical measurements.

This awareness persisted until research moved out of the perioperative setting and into ordinary acute care at which point researchers began to consider the forehead strip inaccurate (Lewit, Marshall, & Salzer, 1982) when compared to glass mercury thermometers used orally and rectally when the readings did not match closely.

In order to summarize the trend in the use of the forehead as a temperature measurement site, we have assembled the most important studies characterizing the site and its clinical reliability and usefulness. It is our position that the forehead remains a highly reliable and appropriate site for measuring temperature and that infrared technology is ideal for taking advantage of its accessibility and reliability.

Author	Title	Subjects	Devices	Results	Conclusions	Recommendations
Conrad et al. (1969)	Thermistor recording of forehead skin temperature as an index of carotid artery disease.	Six normal and 35 adults with suspected cerebro-vascular disease	Thermistor probes taped to forehead around eyebrow and in orbit.	Consistent differences between forehead sites in normal. Higher above nasal area of brow. Marked decrease in that site when carotid flow compromised. Higher on non-affected side showing re-routing of blood flow.	Forehead temperature can be diagnostic of diminished carotid flow.	Normal values very stable and reliable.
Burgess et al., 1978	Continuous monitoring of skin temperature using a liquid-crystal thermometer during anesthesia.	20 adults undergoing coronary artery bypass surgery.	Liquid-crystal forehead strip, rectal, esophageal, axillary thermistors, readings every half hour and every few minutes during bypass.	Forehead temperature was ~4ºF lower than other measures but trended very closely even during rapid warming.	Strip closely parallels changes in body temperature.	LC strip performed well as trend indicator and may be a safe alternative means for routine temperature monitoring during anesthesia where exact core temperature is not critical.
Lees et al., 1978	An evaluation of liquid-crystal thermometry as a screening device for intraoperative hyperthermia	Six male adults undergoing whole-body hyperthermia (up to 41.8ºC) for cancer therapy.	Rectal, esophageal, and forehead skin thermistors with liquid crystal plastic forehead strip monitored every 5 to 10 minutes during 2 hour heating phase.	Forehead thermistor was highly correlated (r=0.88) with esophageal and thermistor with liquid crystal even more (r=0.94) and esophageal with Liquid crystal of r=0.97. Rectal was less well correlated as	Forehead temperatures reflect rising esophageal core temps in a highly linear manner with rapid response time. (Both thermistor and liquid crystal strips).	Liquid crystal devices are not as accurate as forehead thermistors but are useful as practical monitoring and screening devices during hyperthermic conditions. Favorite quote: “The rectum does

				expected.		not have thermal significance of its own…"
Lewit et al., 1982	An evaluation of a plastic strip thermometer.	613 observations on 553 ambulatory patients and 60 inpatients. Adults and children.	Oral, rectal mercury in glass, possibly pooled. Clinitemp forehead liquid crystal strips which are "pressed against the forehead for one minute".	Mean oral gm 37ºC mean rectal gm 37.8ºC gm. Mean LC strip 36.5ºC. Correlation to oral =0.53 and 0.78 to rectal. Dispersion said to be wide, but SD not given. Poor sensitivity and specificity.	Clinitemp found to be unacceptable as fever detector. Statistically significant difference by ambient temperature. Some gm temps were not simultaneously taken but came from patient's chart.	Recommends determination of consistency of relationship between body core temperature and skin temperature measured on forehead. Autors do not appear to be aware of this body of research.
Nemoto & Togawa, 1988	Improved probe for a deep body thermometer	Fortythree adults in ambient controlled room (20 and 25ºC) at 60% humidity.	Deep forehead, left and right TAI probe and oral electronic continuous readings	Mean differences were within ±0.1ºC of oral for all forehead sites and not statistically significant, except for the left TA.	Objective was to use an insulated probe to eliminate the effect of ambient.	Findings are consistent with other studies that show that the forehead compares closely with internal body sites such as rectal and blood (internal jugular).
Allen, Horrow & Rosenberg(Allen, Horrow, & Rosenberg, 1990)	Does forehead liquid crystal temperature accurately reflect "core" temperature?	24 adults undergoing CPB measured during rewarming.	Esophageal probe, mid-forehead LCT, axillary and rectal probes continuous readings.	No significant difference between esophageal and forehead curvature or regression coefficients. Curves were parallel with LCT trending ET with mean gradient of 3.3ºC. Rectal and axillary did not.	Forehead LCT reflects core temperature (ET) better than rectal or axillary.	Forehead accurately parallels core temperature during rapid rewarming, but should not replace invasive core temperature monitoring during cardiopulmonary bypass.
Ikeda et al., 1997(Ikeda, Sessler, Marder, & Xiong, 1997)	Influence of Thermoregulatory vasomotion and ambient variation on the accuracy of core-temperature estimates by cutaneous liquid-crystal thermometers	21 adult volunteers, 7 under anesthesia, 7 not anesthetized but in thermoregulatory vasomotion, 7 in ambient temperaturefrom 18 - 26ºC.	TM contact, center forehead and neck (carotid) thermocouple probes and LCTs.	Core to forehead difference varied depending on thermal manipulation, but averaged -0.1ºC ±0.3 in thermoneutral condition vs. 0.2ºC ±1.1 for core to carotid.	Core to forehead temperature difference was not significantly affected by redistribution of body heat during general anesthesia.	Forehead skin temperature may not be adequate for monitoring during anesthesia for detection of malignant hyperthermia, but may be fine for monitoring during regional anesthesia or when general anesthetic is not done with a triggering

						drug.
Matsukawa et al., 1997(Matsukawa, et al., 1997)	Comparison of distal oesophageal temperature with “deep”and tracheal temperatures.	20 adult females undergoing gynecological surgery.	Distal oesophageal, deep sternal, deep forehead, tracheal	Deep forehead bias from oesophageal was 0.2ºC ±0.3 with correlation of r = 0.69.	Both accuracy and precision of deep tissue at forehead and sternum are sufficient for clinical use.	Tracheal temperatures are not a suitable substitute.
Harioka et al., 2000(Harioka, et al., 2000)	“Deep-forehead” temperature correlates well with blood temperature.	41 adults undergoing abdominal or thoracic surgery >3 hours.	PA thermistor, Coretemp deep forehead sensor, rectal, TM, distal oesophageal thermocouples.	Bias vs. PA: Forehead 0.0ºC ±0.3; rectal 0.3ºC ±0.3; tympanic 0.0ºC ±0.2; esophageal 0.1ºC ±0.2	Deep forehead has excellent accuracy and precision sufficient for clinical use.	Deep forehead can be used for monitoring body temperature during anesthesia.
Suleman et al, 2002(Suleman, Doufas, Akca, Ducharme, & Sessler)	Insufficiency in a new temporal artery thermometer for adult and pediatric patients.	30 adults and 26 children who developed mild core ‘fever” (≥37.8ºC) after cardiopulmonary bypass.	SensorTouch (contact above eyebrow, then across forehead to top of ear), PA catheter in adults, bladder catheter in children to represent core.	Only patients who reached 37.8ºC were analyzed. Some sweaty forehead temps(3 of 4) were not usable, one was included in spite of large difference.	In children, mean diff was 0.3ºC ±0.5º, which was within the threshold set by authors, but they apparently changed their definition in midstream.	Available data fail to support use in infants and adults. Study had many limitations. Multiple temps per patient making sample dependent; bladder lags in warming, etc. Very small sample to draw conclusions and Bland Altman analysis was not interpreted correctly. Core measures were different in adults and children. Also, not mid-forehead and not non-contact.
Liu et al., 2004(Liu, Chang, & Chang, 2004)	Limitations of forehead infrared body temperature detection for fever screening for severe acute respiratory syndrome.	500 patients entering hospital for outpatient services. Shelter at hospital entrance.	Welch Allyn 9000 ear thermometer as reference, Thermofocus infrared for forehead and auditory meatus.	No bias or limits of agreement given, only % of readings within 0.37ºC of tympanic, sensitivity and specificity.	Auditory meatus is better than forehead.	Deeply flawed study with outdoor temperatures used, no specifics as to setting of reference thermometer, location of forehead target or technique used. Limitations not addressed.
Ng et al., 2005	A brief report in the normal	1000	3 factory new	3t HITs had	Normal range	Individual

(D. K.-k. Ng, et al., 2005)	range of forehead temperature as determined by noncontact, handheld, infrared thermometer.	apparently healthy subjects, equal male vs. female, >18 and <65 years of age excluding any with potential malady or fever.	ST8812 handheld infrared thermometers (HIT) (5 cm from mid-forehead)and GT131electronic thermometer. Waterbath-surface tested,	significantly different bias in the water bath and the bias trended upward with the increase of bath surface temperature. Best HIT (0.2ºC from actual bath) was used to determine normal range.	for forehead temperature wa 31.0ºC to 35.6ºC (mean ± 1.96 standard deviations) and apparently normally distributed. Male and female temps were not statistically different.	thermometers require offset determination/ calibration to find offset. IR (HIT) forehead temperature >35.6ºC (unadjusted?) is suggestive of fever. Cannot conclude this holds in younger than 18 or older than 65.
Ng et al., 2005b(Ng, Chan, Lee, & Leung, 2005)	Non-contact forehead thermometry temperature measurement for screening fever in children.	567 children in hospital >1 month to 18 years. No same-day repeated readings.	Standard ST8812 (5 cm from mid-forehead) (NIFT) vs FirstTemp Genius (left ear) in rectal equivalence. >38.0ºC was fever cut-off.	Mean bias 2.34ºC ±1.06, range 0.26 – 4.42ºC. Range of forehead readings 31.8 – 38.8ºC; Range of tympanic readings 36.0 – 41.5ºC	Recommended for mass screening ony and not for clinical monitoring. For SARS-type screening, need a very low false-negative rate, making the NIFT appropriate as NPV was 0.98	Recommend 35.1ºC as NIFT cut-off value for fever. NIFT has sensitivity and specificity similr to other forehead thermometers . Could not devise a constant conversion factor to approximate tympanic rectal.. Comment: Good case for a non-linear algorithm.
De Curtis et al. 2008(De Curtis, Calzolari, Marciano, Cardilli, & Barba, 2008)	Comparison between rectal and infrared skin temperature in the newborn	107 newborns some in heated environments.	3 minute Rectal glass mercury (2-3 cm depth); No Touch Sensor IR skin thermometer mid-forehead from 0.5 cm distance. Some by two operators for reliability assessment.	Mean bias was -0.038ºC±0.288 . Mean difference between two operators -0.017ºC±0.111	IR produces highly reproducible readings and avoids the techniques issues associated with ear thermometers	IR mid-forehead and rectal are not identical but differences are modest.
Williams et al., 2008(Williams, Heusch, & McCarthy, 2008)	Thermal screening of facial skin arterial hot spots using non-contact infrared radiometry.	169 healthy adults, only 54 had mid-forehead temps taken. (26 female, 28 male)	Ear (Braun Thermoscan proLT) IR forehead non-contact (Raynger MX) for TA behind ear and mid-forehead.	Ear 36.7ºC ±0.5 TA 34.2ºC±0.7 Beh. Ear 34.2ºC±0.9 Mid-forehead 34.0ºC±0.7. Bias not provided. No significant correlation between any sites except TA and beh. Ear. Male and femal forehead	Facial IR not a good substitute for ear temperature.	Individual sites need further study.

				temps significantly different.		
Duran et al., 2009(Duran, Vatansever, Acunas, & Sut, 2009)	Comparison of temporal artery, mid-forehead skin and axillary temperature recordings in pre-term infants <1500 g of birthweight.	34 pre-term infants >7 days of age and <1500g in incubators.	3 minute axillary glass-mercury, mid-forehead and TA PlusMed IR TA model pM 1-802 from 0.5 cm distance.	Axilla 36.71ºC±0.07; TA 36.81ºC±0.09; mid-forehead 36.72ºC±0.08. TA only was significantly different.	Mid-forehead and axillary not significantly different. TA significantly different. Nurses found difficulty aiming accurately at TA, but not mid-forehead.	Mid-forehead is best site for use in pre-term infants in incubators.
Becker et al.	Assessing the validity of devices that asses body temperature during outdoor exercise in the heat. Research poster.	25 active heat-acclimated adults during outdoor game activities (soccer, Frisbee, football etc.)	Rectal, ingestible thermistor, OTC oral, prof. oral, OTC axillary, prof. axillary, mid-forehead LC sticker, TA, TA alt method, tympanic.	Sticker tracked rectal well (bias not given, but graph seems to show ~0.5ºF difference on average.	All but ingestible and forehead sticker were significantly less than rectal.	Forehead sticker may be appropriate for measuring temperature in athletic setting. More research is needed.
Ganio et al., 2009(Ganio, et al., 2009)	Validity and reliability of devices that asses body temperature during indoor exercise in the heat.	15 male and 10 female adults during climate controlled indoor exercise.	Rectal thermistor at 10 cm depth, intestinal thermocouple, oral prof, oral OTC, TA Exergen, Sportstemp Forehead sticker, IR ear (Thermoscan Exactemp 4520), Axillary prof., and OTC.	Bias against rectal: Intestinal -0.02º±0.82 LOA; Forehead 0.29ºC±2.27 LOA etc. Repeatability for forehead 0.03ºC±0.35.	FST is likely more influenced by changes in skin temperature than rectal. Bias depended to extent on ambient. Not recommended in spite of low mean bias.	Telemetric pill is the only device recommended for prediction of rectal during indoor exercise.
Langham et al., 2009(Langham, et al., 2009)	Noninvasive temperature monitoring in postanesthesia care units	50 adults having laparoscopic surgery. Temp on PACU arrival, +30 and +60 minutes.	Bladder reference, oral, axillary, TA, forehead skin thermocouple, forehead liquid crystal, IR ear, deep forehead (Coretemp), deep chest.	Biases to bladder reference: Deep FH -0.50ºC±0.41 Forehead skin -0.46ºC±, forehead LC -1.09ºC±0.73	None of therms were within 0.5ºC of bladder, but oral, deep forehead and TA were better and agreed reasonably well.	Oral, deep forehead and TA appear suitable for clinical use and forehead thermocouple with a 2ºC offset performed at intermediate level.
Zeiner et al. 2010(Zeiner, et al., 2010)	Non-invasive continuous cerebral temperature monitoring in patients treated with mild therapeutic hypothermia: An observational pilot study.	19 adult patients with restoration of spontaneous circulation after cardiac arrest with therapeutic mild hypothermia.	Esophageal reference, deep forehead, bladder. Also in some: PA and contact tympanic.	Mean difference deep forehead: -0.12ºC ±-0.59 - +0.36ºC LOA. Bladder -0.01ºC±-0.54-0.52 LOA Concordance coefficient 0.98	Deep forehead probe provides a safer approach than invasive methods.	Not all patients had all methods used.
Edling et al., 2010(Edling, Carlsson, Magnuson, &	[Temperature measurement in the forehead or axilla are not reliable]. Swedish	52 adult patients, 364 measurements	IR skin thermometers: Thermofocus	Both IR skin devices showed excellent	Axillary thermometers should not b used.	More study is needed.

Holmberg, 2010)			and IR Forehead HV-T36 (Ketonic), rectal and axillary Terumo C402.	repeatability though one had several outliers.. Bias rel to rectal:Thermofocus -0.8 and IR Forehead -1.0ºC	Forehead IR have good repeatability but a single linear offset cannot be applied.	
Chiappini et al., 2011(Chiappini, et al., 2011)	Performance of non-contact infrared thermometer for detecting febrile children in hospital and ambulatory settings.	251 children aged 3 to 8.6 years.	Axillary glass reference (>38ºC=febrile), IR forehead skin (Thermofocus)	Thermofocus repeatability 0.108ºC±0.095 ; axillary repeatability 0.114ºCC±0.103. Mean axillary temp 37.18ºC Mean IR Forehead 37.30ºC. Bias 0.07ºC±0.76 -0.62 LOA. Bland Altman done incorrectly. Used only axillary on x-axis not mean .	Forehead skin IR has advantage over ear IR because technique is not an issue. Forehead skin IR performed well relative to axillary , is less cumbersome than both axillary and ear.	Forehead IR can be used in children > 1 month and is comfortable for children.
Teran et al., 2011	Clinical accuracy of a non-contact infrared skin thermometer in paediatric practice	434 children aged 1 – 48 months.	Rectal glass reference, temporal artery, forehead non-contact	Forehead non-contact 0.029 ± 0.01°C; temporal artery −0.20 ± 0.27°C	Forehead non-contact infrared thermometer is reliable and accurate.	More studies needed.

A variety of conditions are described in the articles reviewed. The majority of findings confirm the forehead as a viable measurement site with some conditions and reservations. The 'deep forehead' thermometer is based on the zero-heat-flow principle achieved by using heavy insulation of the probe where it contacts the skin, thus eliminating the effect of ambient. While this is not possible in the case of IR, the use of the site is no less valid as a temperature monitoring site on the body.

A number of articles were critical of the liquid crystal display technology, but the use of the forehead was not disputed. Infrared forehead skin thermometers were found to be highly repeatable which is essential when attempting to construct an algorithm for estimation of core temperature. Comparisons with other sites varied in their favorability, but were generally found to be preferable over IR tympanic because technique is not an issue.

Many of these studies were conducted in challenging circumstances such as rewarming from cardiopulmonary bypass or cardiac arrest, during indoor or outdoor exercise, in outdoor mass screening settings and in artificially heated environments. Overall, the forehead was an acceptable site, while the measurement technology was variably successful. Of particular note are the several studies that show the excellent performance of forehead skin IR in premature neonates, a challenging population in whom thermoregulation is of particular interest, but as little manipulation of the infant as possible is desired.

The clear message is that the mid-forehead is a clinically acceptable site and that its repeatability makes the construction of a curvilinear algorithm a real and highly promising possibility.

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