Relationship Between Corneal Temperature and Finger Temperature

François Girardin, MD; Selim Orgül, MD; Carl Erb, MD; Josef Flammer, MD

Background: Because the temperature of the body surface depends largely on local blood flow, temperature measurements might provide information on the latter.

Objective: To evaluate the relationship between corneal temperature and finger temperature.

Methods: Corneal, finger, and body core temperatures were measured in a relatively unselected population of 266 white persons. Excluded were persons taking topical eye medication or with corneal inflammatory signs. Corneal and finger temperatures were measured on 1 randomly selected side of the body by means of a noncontact infrared thermometer. As a measure of body temperature, the tympanic temperature was measured by means of a noncontact infrared ear thermometer. A total of 124 females and 142 males were examined.

Results: A correlation analysis in a least squares regression model was highly significant ($R = 0.67; P < .001$), with corneal temperature as the dependent variable and environmental, tympanic, and finger temperatures and age and sex as predicting variables. All variables contributed significantly to prediction of the corneal temperature. The corrected mean corneal temperature after adjusting for environmental, tympanic, and finger temperatures and for age of participants was $0.16^\circ C$ higher in male participants ($P = .002$).

Conclusions: Corneal temperature correlates with finger temperature even after adjusting for environmental and tympanic temperatures and for the age and sex of participants. A possible cause for these findings are some parallelisms in blood-flow regulation in the finger and the eye.


The observation of parallel changes in peripheral blood flow (fingers) and visual field in vasospastic patients led to the definition of an entity called “presumed ocular vasospastic syndrome,” implying that the regulation of blood flow of various regions of the body surface might show some parallelisms.1 Indeed, in this study, the changes in visual field have been suggested to be caused by changes in choroidal blood flow.2 Consequently, the correlation between corneal and finger blood flow is of interest.

Because the temperature of the body surface depends largely on local blood flow, temperature measurements might provide information on the latter. Temperature measurements have been applied to previous evaluation of blood flow.3 Heat sources to a tissue are (1) locally produced metabolic heat, (2) heat transported via the vascular system, and (3) environmental heat—from adjacent tissue or from the environment external to the body. Temperature measurement of the anterior segment of the eye is of potential importance in a variety of research applications, including corneal inflammation, tear film, and photorefractive surgery.4-9 It has been established that body core temperature, external environment, and blinking affect corneal temperature in humans.5-1213 In addition, using infrared thermometry, a significant decrease in the temperature of the cornea with increasing age has been demonstrated.13 A correlation between conjunctival hyperemia and conjunctival temperature,7 and the observation of reduced corneal temperature in the ipsilateral eye of patients with angiographically proven internal carotid stenosis,8 emphasize a link between corneal perfusion—or, more correctly, the convected heat of the perfusing blood—and anterior segment temperature. Furthermore, vasodilatation and vasoconstriction after local application of vasoactive substances have shown an increase or a decrease in corneal temperature, respectively.14

From the University Eye Clinic Basel, Basel, Switzerland. None of the authors has any proprietary interest in the THI-500 infrared thermometer or the Braun Thermoscan infrared ear thermometer.

©1999 American Medical Association. All rights reserved.
PARTICIPANTS AND METHODS

Healthy persons between 16 and 87 years of age were recruited for this study. Informed consent was obtained from each participant. Excluded were persons with any long-term topical medication use or any inflammatory signs on slitlamp biomicroscopy and funduscopy. Neither a history of systemic or cardiovascular diseases nor a history of treatment of hypertension or hypotension was a criterion for inclusion or exclusion. Tympanic, corneal, and finger temperatures were measured on 1 randomly selected side (either right ear, right eye, and right hand or left ear, left eye, and left hand) in 266 white persons. A total of 124 females and 142 males were examined. The mean ± SD age of participants was 54.0 ± 16.1 years.

A noncontact infrared thermometer (THI-500, Tasco Japan, Osaka, Japan) was used to measure corneal temperature. The reliability coefficient (1 - intraclass correlation) of repeated measurements of corneal temperature, based on 5 measurements with this instrument within 45 minutes in 10 participants, is above 97% (I. Koc¸ak, MD, S.O. and J.F. unpublished data, 1996). The THI-300 noncontact infrared thermometer can evaluate temperatures between 0°C and 300°C with a resolution of 0.1°C, and the range of measured wavelengths is 8 to 16 µm (information provided by the manufacturer). Infrared detection was used because it is noninvasive, does not require the use of anesthetic drops, and provides practically instantaneous readings. The application of infrared thermometry for temperature measurements at the cornea was pioneered by Zeiss and elaborated on by Mapstone. In such thermometry, surface temperature is measured by detecting electromagnetic radiation emitted from the surface. With changing temperature, the spectrum of emitted radiation from an object's surface varies. Consequently, the temperature of an object can be calculated if its emissivity is known and the radiation emitted can be measured. Emissivity is the ratio of radiation emitted by a surface to radiation emitted by a black body at the same temperature. Mapstone provided the first detailed analysis of corneal temperature, and established that corneal emissivity is 0.97 to 1.00. Furthermore, because corneal transmission in the infrared area is strongly reduced and above a wavelength of 3 mm no longer occurs, it has been argued that radiation emitted from deeper corneal tissues adds little to the spectrum emitted by the cornea. Consequently, it has been suggested that the cornea can be regarded as a black body radiator.

A noncontact infrared ear thermometer (Braun Thermoscan, Alphamed, St Ingbert, Germany) was used to measure body temperature. Within 1 second, the Braun Thermoscan noncontact infrared ear thermometer measures tympanic temperature, which represents body core temperature. This device can evaluate temperatures between 20°C and 42.2°C and works basically by detecting infrared energy emitted from the deep auditory canal and tympanic membrane. Infrared ear thermometry findings have been suggested to be reproducible and to provide a relatively close estimate of pulmonary artery core temperature.

Participants were seated for 15 minutes before any temperature measurement. The environmental temperature was not controlled and was recorded immediately before any examination (mean ± SD, 22.5°C ± 1.4°C; range, 20°C-23°C). The tympanic temperature was recorded first by means of the infrared ear thermometer. The probe was inserted in the ear of the sitting participants, and an instantaneous temperature reading was obtained. For corneal temperature measurement, participants were seated at a conventional slitlamp chin rest to stabilize the head. The infrared thermometer was mounted horizontally on a vertical support and coupled to a slitlamp joystick for ease of alignment. The aiming beam of the infrared thermometer was centered slightly inferotemporally to the geometric center of the cornea. The measuring distance from the cornea was defined as the distance at which the aiming beam formed a sharp pattern of small concentric rings on the iris of the participants (central spot diameter, 2.5 mm). After proper alignment was achieved, participants were asked to briefly blink, and a temperature measurement was obtained 1 to 2 seconds after the eyes reopened. Corneal temperature was measured before stabilization of the temperature readings to avoid desiccation and an ensuing blink reflex. For corneal temperature measurements, an emissivity of 0.98 was assumed.

Finger temperature was measured with the THI-500 noncontact infrared thermometer as well. For that purpose, the infrared thermometer was disconnected from the joystick of the slitlamp and was mounted vertically on a table. The infrared aiming beam was directed toward the table. The holder allowed vertical adjustment of the distance of the measuring device to the table. For finger temperature measurement, participants put the palms of their hands on the table beneath the infrared thermometer, and the vertical position of the measuring device was adjusted to obtain a sharp pattern of concentric rings on the skin of the annular, immediately proximal to the nailfold. Participants were asked to apply no pressure on the table, and once the temperature reading stabilized, the finger temperature was recorded. For skin temperature measurements, an emissivity equal to that of the cornea (0.98, value provided by the manufacturer) was assumed.

The relationship between environmental, tympanic, corneal, and finger temperatures and age of the participants was analyzed by the Pearson linear correlation factor and by partial correlations in a least squares regression model (multiple regression) with corneal temperature as the dependent variable. Partial correlation represents the unique (remaining) contribution of each predicting variable to the estimate of the dependent variable. Because the hormonal cycle may affect body temperature in females, the sex of participants was included as a “dummy” variable in the latter model. In addition, differences between male and female participants were evaluated by an analysis of covariance. Differences were considered statistically significant at P<.05.
The mean ± SD age of participants was 54.6 ± 16.1 years (range, 16-87 years). The mean ± SD values for age and the temperature at various locations are given in Table 1. The differences between male and female participants for these variables were not significant except for a minimal difference in tympanic temperature (Student t test for independent variables: \( t = 2.60; P = .01 \)). The observed differences between the sexes in tympanic and corneal temperatures were significant after correcting for environmental temperature and age in an analysis of covariance (F = 5.73; \( P = .02 \) and \( F = 4.06; P = .04 \), respectively). The correlation matrix for age and the temperature at various locations is given in Table 2. Corneal temperature correlated with environmental, tympanic, and finger temperatures and age of the participants (Table 2). In addition, finger temperature correlated with tympanic temperature. The correlation of environmental temperature with tympanic or finger temperature did not reach statistical significance. The multiple regression model, with corneal temperature as the dependent variable and environmental, tympanic, and finger temperatures and age and sex as predicting variables, was highly significant (\( R = 0.67; P < .001 \)) (Figure). The correlation coefficients of the partial correlations and their \( P \) values are listed in Table 3. Table 3 demonstrates that all analyzed variables contribute significantly to prediction of the corneal temperature. The corrected mean corneal temperature, after adjusting for environmental, tympanic, and finger temperatures and for the age of participants was 0.16°C higher in male participants (\( P = .002 \)).

**COMMENT**

In the present study, corneal, finger, and tympanic temperatures were measured in 266 participants of a relatively unselected population. Excluded were only persons taking topical eye medication or with corneal inflammatory signs. Because persons with cardiovascular diseases were not excluded, some participants might have had vascular diseases altering corneal blood flow and, thus, corneal temperature. The inclusion of such persons might have altered the correlation between corneal and finger temperatures. The strong correlation observed in the present study, however, suggests that such persons may not have been numerous in our sample. A regression analysis disclosed a significant relationship between corneal temperature and environmental, tympanic, and finger temperatures and the age and sex of participants. All analyzed variables contributed significantly to prediction of the corneal temperature. After adjusting for environmental, tympanic, and finger temperatures and for the age of participants, females showed a slightly lower corneal temperature.

The effect of environmental and body temperatures on corneal temperature has been described by others.3,10-12 A decrease in corneal temperature with increasing age also has been reported previously.14 The present results confirm these findings in a large population. However, the finding of a significant correlation of corneal temperature with the temperature of other peripheral body sites, such as the fingers, is, to the best of our knowledge, new.

Even after correcting for confounding variables, corneal and finger temperatures were significantly corre-
lated. Heat sources to a tissue are locally produced metabolic heat, blood flow, environmental effect, and temperature from adjacent tissue. Temperature readings were corrected for environmental temperature. An effect of eyelid temperature was not evaluated in the present study and therefore cannot be excluded. A likely cause for the observed correlation between finger and corneal temperatures is the effect of local blood flow. Indeed, it has been argued that peripheral blood flow may show parallel changes with blood flow variation in the eye. In several patients with unexplained visual field defects, peripheral vasospasms were observed. Such visual field defects worsened in some of these patients after cold provocation, and peripheral vasospasms and visual field defects often improved after calcium channel blocker treatment. Because peripheral temperature depends largely on local blood flow, the correlation of corneal and finger temperatures might indicate that a similar correlation could occur between corneal and peripheral blood flow. For definite confirmation of such a relationship, the correlations tested in the present study need to be evaluated under extremes of ambient temperature.

Female participants showed a slightly lower corneal temperature after correcting the measured value for environmental, tympanic, and finger temperatures and for age. The cause for a slightly lower corneal temperature in females despite a higher body temperature is not clear. Such a difference has not been reported previously. A potential cause for such a finding is a difference between females and males regarding blood flow regulation, possibly caused by hormonal effects. The latter finding is in contrast to results published by Ruprecht. However, in the latter study, male participants were, on average, older than female participants. Because no age correction was performed, this may have affected the results. Furthermore, the difference in corneal temperature between males and females was not significant in a 2-sided t test. Therefore, our results cannot be compared with these previous findings. Nevertheless, the difference in corneal temperature between males and females in the present study should not be overinterpreted because it is barely higher than the resolution of our instrument. Consequently, the clinical relevance of such a finding is not clear and is mentioned here only for sake of complements.

In conclusion, corneal temperature correlates with finger temperature, even after adjusting for many confounding variables. A possible cause for these findings are some parallelisms in blood flow regulation in the finger and the eye. This, however, cannot be proven with the present results and needs to be investigated in a further study. Such a correlation would explain some clinical observations in vasospastic patients.

Accepted for publication October 6, 1998.

Reprints: Selim Orgül, MD, University Eye Clinic Basel, Mittlere Strasse 91, PO Box CH-4012 Basel, Switzerland (e-mail: ORGUEL@uabclu.unibas.ch).

REFERENCES


Call for Papers

JAMA and the ARCHIVES journals will be participating in the 1999 global theme issue, “Impact of New Technologies in Medicine.” We invite all investigators to submit their best research addressing issues concerning new technologies in ophthalmology such as confocal laser microscopy, nerve fiber polarimetry, OCT, ICG, MRI/MRV, functional MRI, FDP, SWAP, and SITA for consideration for the November issue. Manuscripts received by May 1, 1999, have the best chance for acceptance for the global theme issue. Manuscripts not accepted for the theme issue may be considered for other issues of the ARCHIVES. All manuscripts are subject to our usual peer review. Please note in the cover letter that the submission is for the November “new technologies” issue.