Contactfree Infrared Thermography for the Determining "Normal Skin Temperature" in 50 Healthy Probands

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Abstract — Definition of "normal temperature" is controversial in many text books on dermatology and physiology and depends on many factors. Thermographic imaging of the hands was performed in 50 healthy volunteers on four different days with an interval of 48-72 hours summing up to a total of 200 measurements. Infrared thermograms were gathered at defined points in each person after an acclimatization period of 30 minutes under standardized conditions according to the recommendations of the American Academy of Thermology. Despite of an acclimatization period of 30 minutes a decrease of temperature in the monitored area independent of gender could be observed. Initial surface temperature after the acclimatization period in these healthy probands ranged from 25.2 to 33.8°C (31.6 ± 2.1°C, median 32.2°C). Severe intra- and interindividual temperature differences could be detected despite standardized room conditions. Skin temperature varies greatly between and within individuals. Contactfree infrared thermography may improve detection of areas with altered perfusion if a symmetrical scan is performed. Nevertheless, screening patients on their general surface temperature does not provide any beneficial information in diagnosing or differentiating diseases unless a certain pathology is suspected in a particular area.
Keywords: skin temperature, infrared thermography, tool, detection, screening.

Resumo — Definição de "temperatura normal" é controversa em muitos livros de texto sobre dermatologia e fisiologia e depende de muitos fatores. Foram realizadas imagens térmicas das mãos em 50 voluntários saudáveis, em quatro dias diferentes, com um intervalo de 48-72 horas somando um total de 200 medições. Termogramas foram coletadas em pontos definidos depois de um período de aclimatação de 30 minutos, sob condições padronizadas de acordo com as recomendações da Academia Americana de Termologia. Apesar do período de aclimatação, uma diminuição da temperatura na área monitorada pode ser observada, independentemente de sexo. As temperaturas iniciais da superfície após o período de aclimatização variaram 25,2-33,8 ° C (31,6 ± 2,1 ° C, mediana 32,2 ° C). Grandes diferenças de temperatura intra e interindividuais puderam ser detectadas. A temperatura da pele varia muito inter e intra indivíduos. A termografia infravermelha pode melhorar a detecção de áreas com perfusão alterada se uma varredura simétrica é executada. No entanto, triagem de pacientes em sua temperatura de superfície geral não fornece qualquer informação útil no diagnóstico de doenças ou de diferenciação, a menos que se suspeite de uma determinada patologia em uma área em particular.
Palavras-chave: temperatura da pele, termografia infravermelha, ferramentas, detecção, triagem.

1. INTRODUCTION

In order to be able to use thermographic imaging in detecting normal and abnormal health states, it is inevitable to collect data on pathophysiology and alterations of skin temperature without as well as during medical treatment. Skin temperature varies between individuals and even within an individual depending on room temperature, humidity and sympathetic as well as hormonal activity and emotional state. In medical textbooks on dermatology or physiology "normal skin temperature" is usually defined to range from 32 to 34°C (1) (2).

As thermographic imaging has become a routine in our daily practice working with patients with intractable pain, we noticed that human beings as well may present with skin temperature less than 32°C or more than 34°C even if no pathology is present in the monitored area of skin. An acclimatization period of 15 minutes is recommended according to numerous authors in order to rule out temperature changes due to room conditions (3) (4).

2. METHODS

Changes in skin temperature were monitored by non-contact infrared thermography (ThermaCAM PM 390) during a 30 minute time-interval in 50 healthy persons to acquire information on the average skin temperature in humans and its variation during a defined period. Room conditions were standardized according to the American Association for Thermology with a room with laminar air flow, humidity of 50% at a room temperature of 23.5°C. The monitored humans were asked to wear standard clothing. Pictures of the hands up to the wrist were obtained at 0, 1, 2, 3, 4, 5, 10, 20 and 30 minutes after a 30 minute acclimatization period. They were analyzed with the aid of AGEMA REPORT 4.5.1.

Probands

Fifty healthy volunteers aged 31.5 ± 10.9 years (range 21-66 years, median 29 years, male/female: 21/29) were included after written informed consent was obtained. Participants were recruited with written announcements on the medical campus in Hamburg.

Assessment of temperature

Specific points on the hands in the thermographic images were analyzed. As temperature changes are most likely to be observed in the tips of the fingers, one point was chosen at the middle of the nail bed of each finger and another point at the middle of each metacarpal bone. This was performed in both hands separately for each proband. The median of these 20 values was taken and compared intra- and interindividually.

Statistical analysis

With the Friedman Repeated Measures Analysis of Variance on Ranks significant differences within the groups were calculated. A p-value of 0.01 was defined to be statistically significant. Significance testing was two-tailed: increase as well as decrease of surface temperature was analyzed.

3. RESULTS

Skin temperature ranged from 25.2 to 33.8°C (31.6 ± 2.1°C, median 32.2°C) despite of an acclimatization period of 30 minutes under above mentioned conditions. Imaging revealed changes in skin temperature for the following 30 minutes. This is especially important, as some authors only demand an acclimatization period of 15 minutes only, which might have an impact on judging the effects of Interventional Pain Management and classifying temperature to be normal or not when trying to find the correct diagnosis. Figures 1-9 show a 23 year old female after acclimatization as mentioned above and monitored skin temperature over 30 minutes. Here, it becomes obvious that temperature stays constant for about 5 minutes after acclimatization. Note that the tips of the fingers show a decrease of temperature at ten minutes (figure 7) already, that grows even more significant after 30 minutes (figure 9).

To classify the extension of temperature decrease we divided the subjects into groups. Figure 10 shows that 70% of the subjects had a temperature decrease (≤ 0°C). 12% had a minor increase of temperature between 0 and 0.5°C. In 8% of the monitored subjects temperature increased 0.5 to 1.0°C and 10% showed an increase between 1.0 and 1.5°C. We could not determine an increase exceeding 1.5°C.

Acquired data revealed a significant decrease in skin temperature at 30 minutes (median 31.73°C) as compared to the initial temperature (median 32.06°C). There also was a significant decrease in temperature at 30 minutes as compared to three (median 31.81°C), four (median 31.8°C) and five minutes (median

31.8°C) after imaging began. As figure 11 shows, there is a significant decrease in temperature ($p \leq 0.01$) over 30 minutes.

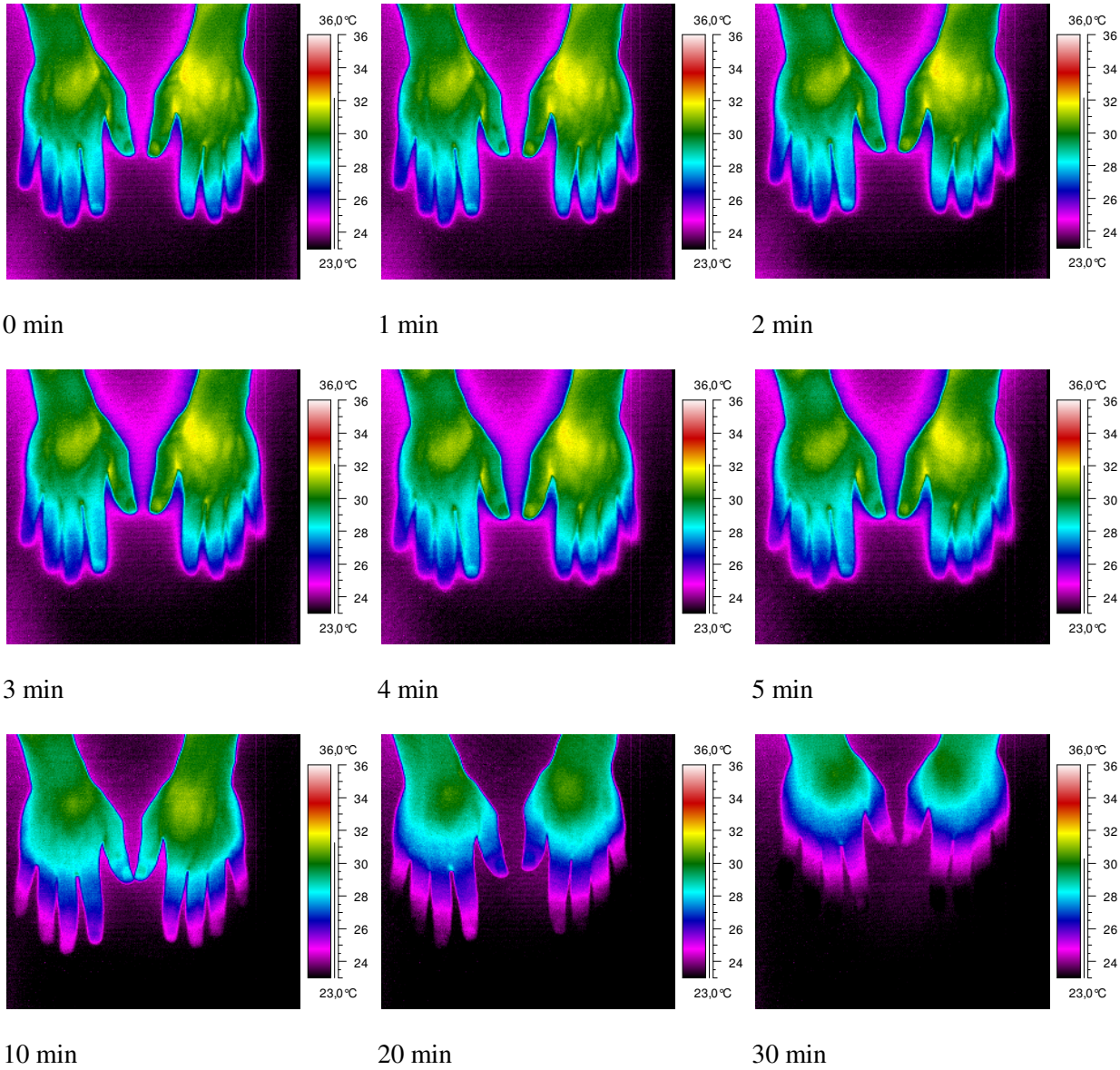

Figure 1-9. Thermographic imaging of hands in a healthy female over 30 minutes

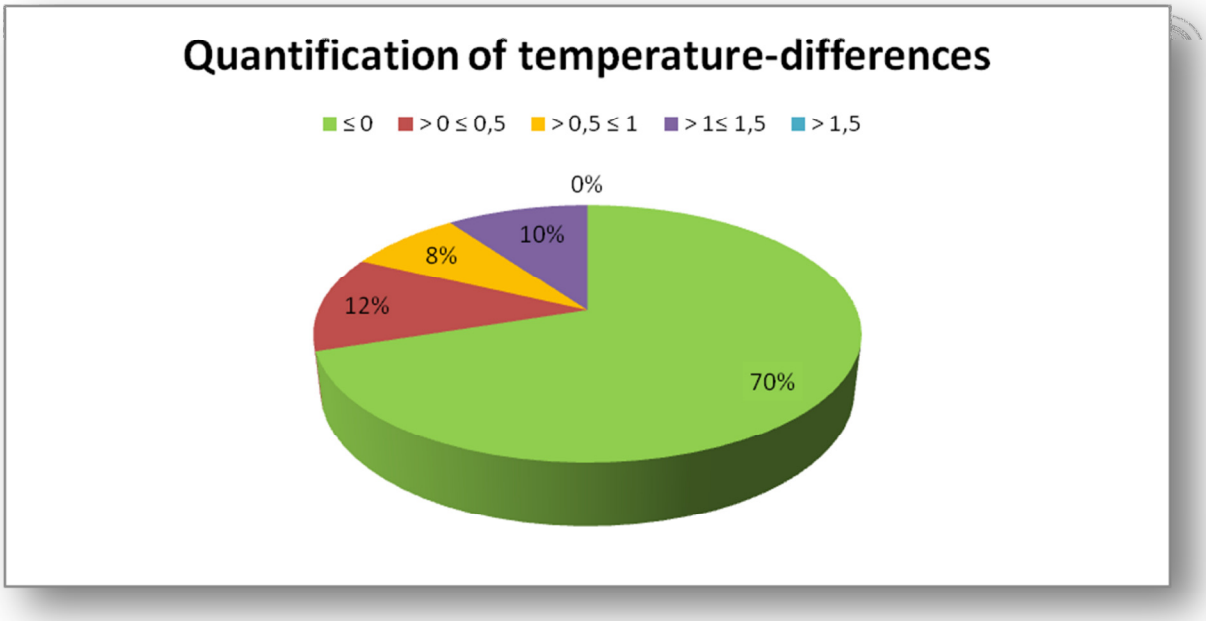

Figure 10. Quantification of temperature differences

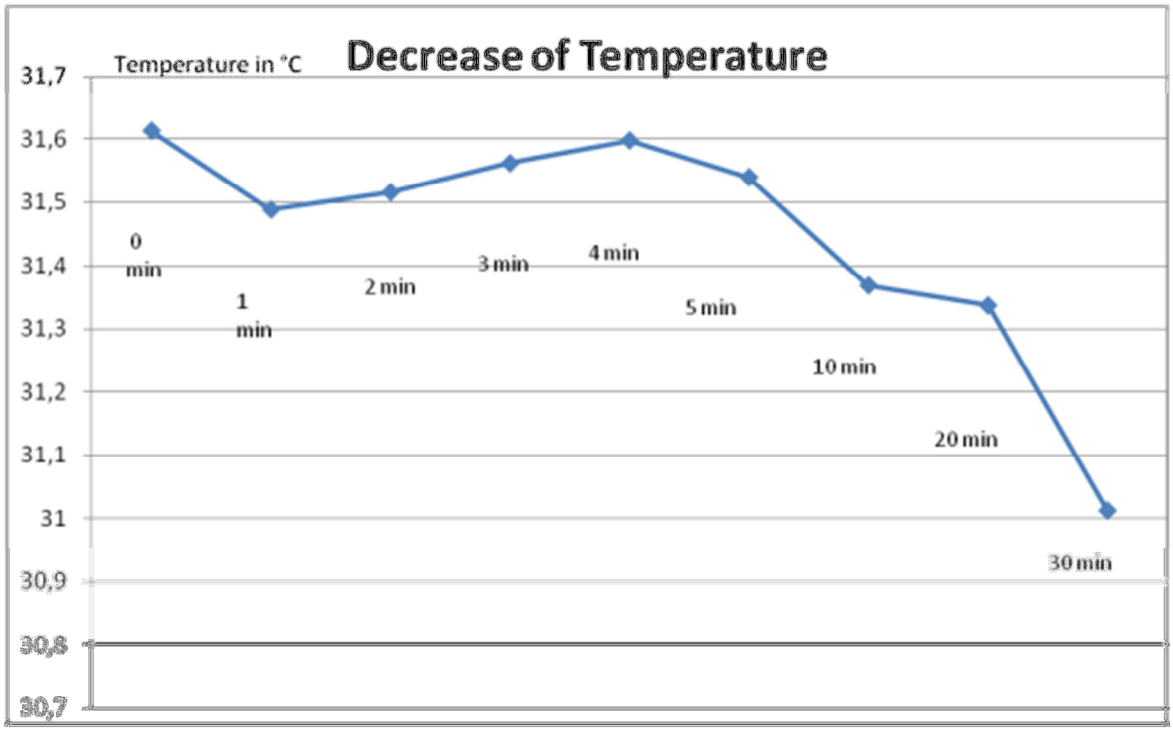

Figure 11. Decrease of surface temperature over 30 minutes after acclimatization for 30 minutes under standardized conditions.

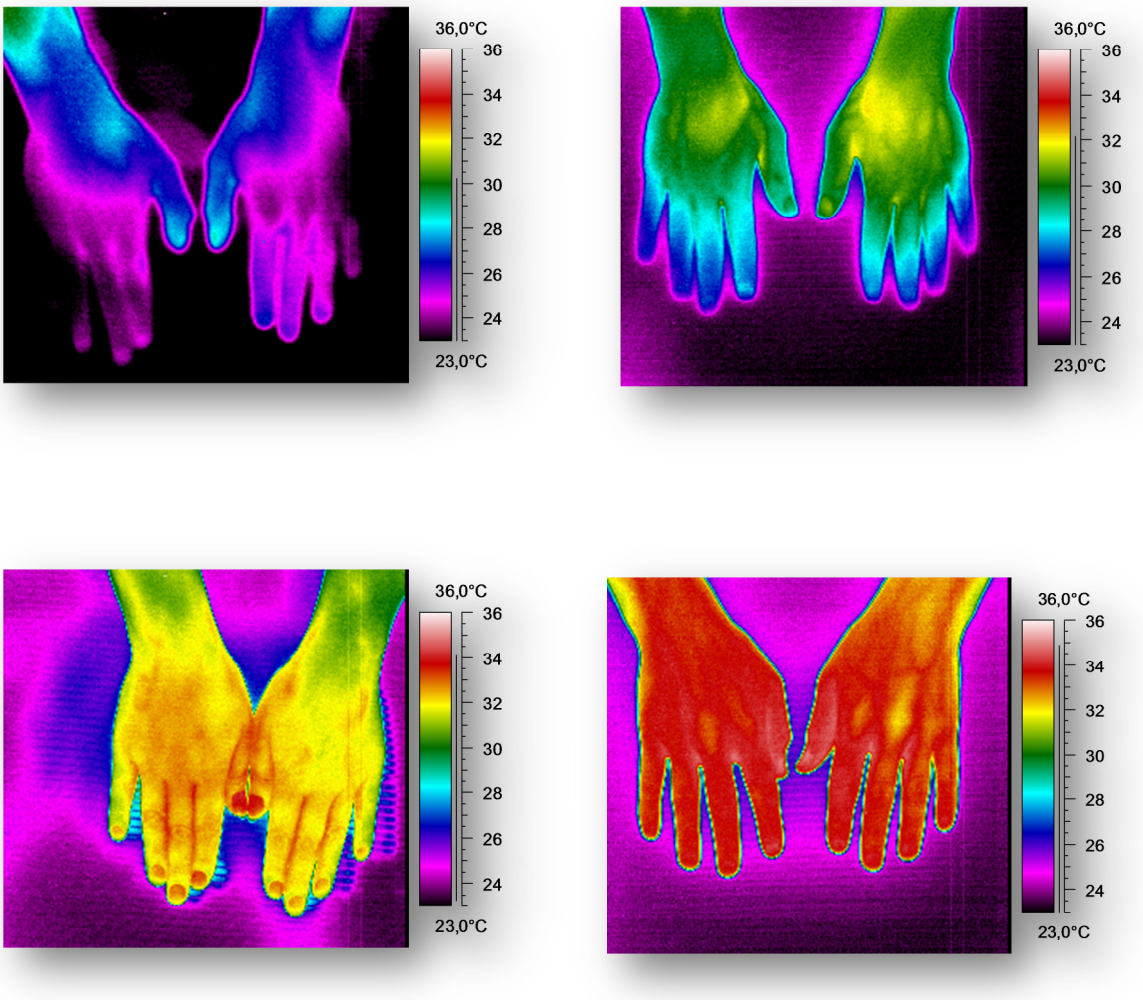

Figure 12-15. Initial thermograms of 4 healthy subjects after acclimatization over 30 minutes at standardized conditions.

Interindividual Differences

Our results show, that there are significant interindividual differences between the subjects. Despite acclimatization in the same environment, initial skin temperature ranged from 25.2°C to 33.8°C. Gender does not seem to have an influence on the acral body-temperature as we did not find significant differences between males and females. Since 49 of our 50 subjects were Caucasians no statement can be given on ethnic differences. This also applies to age-related differences as shown in table 1.

Table 1. Data on age of the probands

Group	Age	Number
1	20-29 years	33
2	30-39 years	8
3	40-49 years	3
4	50-59 years	4
5	60-69 years	2

4. DISCUSSION

Skin blood flow and surface temperature are linked to cutaneous microcirculation. Numerous techniques are available to detect ischemia of the

skin as angiography, laser or color Doppler imaging/ultrasonography, digital photoplethysmography, fingertip lacticemy test, magnetic resonance angiography, nail fold capillaroscopy and infrared thermal imaging (5).

According to previous studies room temperature less than 30°C results in a decrease of surface temperature of the skin. This phenomenon may continue for up to two hours, reaching its peak within the first 15 minutes (6) (7). Temperature changes affect primarily a persons' extremities whereas the influence on the surface temperature of the torso and the head is less. This could be sustained by our findings: Despite of an acclimatization period of 30 minutes a decrease of temperature in the monitored area appeared independent of gender. Surface temperature in these healthy probands ranged from 25.2 to 33.8°C (31.6 ± 2.1°C, median 32.2°C).

Nail bed temperature highly correlates with skin temperatures measured on the palmar surface of the hand under ambient conditions as well as after palmar hand cooling (8). Savastano et al. found higher fingernail bed temperature in obese subjects as compared to those with normal weight. In our study, we could sustain this finding, though none of the participants exceeded a body mass index of 25 kg/m2 or undercut 19 kg/m2. But even within the normal range we could find, that probands with a lower body mass index presented a lower surface temperature. This may be attributed to the fact, that the effect of the sympathetic nervous system on vasoconstriction/-dilation is much more likely to be observed in peripheral areas of the body as opposed to the trunk where body heat needs to be retained in order to sustain function of internal organs (9). This might account for the fact of reduced heat loss through a large amount of abdominal fat via the trunk with increased heat dissipation from the extremities.

Our probands were quite a homogenous group of healthy young adults of Caucasian origin, hence the results may be difficult to transfer to other races and age groups. It has been shown that skin temperature at thigh, forearm and hand during daytime were significantly higher in Vietnamese than in Japanese subjects in Vietnam in daytime than those at night. Also, for different body regions varying patterns in surface temperature were identified (10). Further investigation is required as body heat management and peripheral vasomotion may vary and temperature in different body regions may also differ. Vascular function allows the circulatory system to act in response to physiologic and pharmacologic stimuli that necessitate regulation of blood flow and modification of vessel tone as well as diameter (11). Sweat gland and sympathetic activity (12) may influence surface temperature just like the hormonal status (especially in fertile females and general circadian rhythm), comorbidities as well as emotional status as macro- and microvascular reactivity are controlled by numerous physiologic regulatory mechanisms and interceded by various biochemical agents, like adenosine, bradykinin, endothelium-derived hyperpolarizing factor (EDHF) (13), histamine, nitric oxide (NO) (14), prostaglandins, and many more bodily vasoactive substances. Vascular reactivity can be revealed at the macro- and micro-vascular level. The first mentioned ensues from reactive hyperemia, whereas the latter accounts for it. Next, endogenous opioid production may have an impact on blood flow in the hand as has been shown by Archer et al. (15). Finally, peripheral blood flow may be modified significantly by the thermal state of a person according to the level of activity, ambient climate/temperature as well as clothing.

Also, all our probands were instructed to refrain from smoking, consumption of alcohol or caffeine, exercise, sunbaths etc. as required by the American Association for Thermology (3) as these factors might affect infrared temperature assessment of the skin. Nevertheless, circadian rhythm and climate outside the room where probands had to acclimatize for 30 minutes were neglected while obtaining surface temperature as 50 healthy persons were examined on four different days.

Intra and interindividual temperature differences could be detected despite standardized room conditions. The cause for the strong differences in our study could not be identified. In our study "normal" skin temperature could not be defined as all probands were examined under the same room conditions but findings showed an extreme variation of the surface temperature. Contactfree infrared thermography may improve detection of areas with altered perfusion if a symmetrical scan is performed. Nevertheless, screening patients on their general surface temperature does not provide any beneficial information in diagnosing or differentiating diseases unless certain pathology is suspected in a particular area.

5. CONCLUSION

Thermographic imaging is a precious tool in medicine, if standardized conditions are established. “Normal skin temperature” might have to be reconsidered as intra- and interindividual differences exist despite acclimatization. The time slot for acclimatization should exceed 15 minutes as proposed by the American Association for Thermology. The most ideal period may vary and should be determined by thermography to choose an initial point as soon as a steady state is established.

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