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Thermal Imaging in Veterinary Medicine

Gender difference in hand rewarming

Conference Abstracts

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History and Research Review of Thermology in Veterinary Medicine At Auburn University

Ram C Purohit *

Professor Emeritus, Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, AL. USA.

* Based on a presentation at 10th European Congress of Medical Thermology, Zakopane, Poland, September 17, 2006

SUMMARY

Research of Thermology in Veterinary Medicine started at Auburn University in the 1970's induced by the Horse Protection Act resulting in several grants for thermographic studies in horses conducted by RC Purohit. Soon, research objectives encompassed a wide range of topics including determination of thermal patterns in healthy and diseased horses, thermographically assisted diagnosis, evaluation of drug effects in inflammatory disease, fertility of male animals and intestinal viability. Equipment representing the state of art at the time was applied for temperature measurement and thermal imaging. More full length manuscripts were published in refereed scientific journals in the period between 1970 to 1991 than from 1992 to 2006. In the last 15 years the relationship between published abstracts and full length papers was 10 to 1. Some basic information in veterinary thermology is still missing including a standard protocol for outdoor thermal imaging, determination of thermal patterns in other animals than horses, influence of hair coat or anaesthetics on temperature readings that all warrant further research in this field.

Key words: Thermography, veterinary medicine, thermal pattern, history

GESCHICHTE UND ÜBERBLICK ÜBER DIE VETERINÄRMEDIZINISCHE THERMOLOGISCHE FORSCHUNG AN DER UNIVERSITÄT AUBURN

Thermologische Forschung in der Veterinärmedizin begann an der Universität Auburn in den 1970iger Jahren und wurde durch das "Pferde-Schutz-Gesetz" gefördert in dessen Rahmen RC Purohit verschiedene Forschungsaufträge für thermographische Studien an Pferden durchführte. Bald umfassten diese Forschung einen weiten Themenbereich wie die Bestimmung von thermischen Mustern bei gesunden und kranken Pferden, thermographisch gestützte Diagnose,Überprüfung von Medikametenwirkungen bei entzündlichen Erkrankungen, Fertilität von männlichen Tieren und die Lebensfähigkeit des Darms nach Ileus. Für die Temperaturmessung und die Erfassung der Wärmenbilder wurde jeweils Geräte verwendet, die den höchsten Standard der Zeit entsprachen. Zwischen 1970 und 1991 wurden mehr Volltext-Manuskripte in begutachteten wissenschaftlichen Zeitschriften veröffentlicht als im Zeitraum zwischen 1992 und 2006. In den letzten 15 Jahren betrug das Verhältnis von publizierten Kurzfassungen zu Vollversionen 10 zu 1. Einige Grundlagen der veterinärmedizinischen Thermography fehlen nach wie vor wie zum Beispiel ein Standardprotokoll für die Thermographie im Freien, die Bestimmung von thermischen Mustern von anderen Tieren als Pferden, der Einfluss des Fells oder von Narkosemittel auf die abgelesenen Temperaturwerte. Alle diese Fragen begründen die Notwendigkeit weiterer Forschung in diesem Gebiet.

Schlüsselwörter Thermographue, Veterinärmedizin, Temperaturmuster, Geschichte

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Introduction

From mid 1960's to early 1970's several studies were published indicating the value of infrared thermography in veterinary medicine (1-5). These publications were mainly focused on the identification of inflammatory changes, particularly in horses.

In 1970 the Horse Protection Act was passed by the United State Congress to ban the use of chemical and mechanical means of "Soring" of horses. It was difficult to enforce the this act because of the difficulty in obtaining measurable and recordable proof of violations. This prompted the USDA-APHIS (United States Department of Agriculture and Animal Public Health Inspection Services) to fund research for the detection of "Soring". At that time, Nelson and Osheim had already performed initial research for the efficacy of thermography in the diagnosis of "Soring" (6).

Dr. Ram C Purohit, than Assistant Professor at the Department of Large Animal Surgery and Medicine, College of Veterinary Medicine, Auburn University, received several research grants to perform thermography studies in horses. He then established a protocol for thermal imaging in horses and other animal in the year 1977 (7).

The team in Auburn was also responsible for training personal for USDA- APHIS to enforce the ACT. This research resulted for him to present data to US Congress hearing for Horse Protection Act regulation in 1983. This was also followed by the implementation of the new guide line by the USDA-APHIS

Research in Veterinary Thermology at Auburn University

The thermal imaging studies by Purohit and his co-workers resulted in many refereed research publications from the year 1977 to 2006.

More than 150 Tennessee Walking Horses were examined. From 1976 to 1982. A field trial was done to thermograph horses before (pre-exercise) and after exercise at 15, 75, 135, and 255 minutes respectively, and trial was repeated for 5 to 6 days in each horse used. Heat increase due to exercise did not substantially alter the normal thermographic pattern. Many in-house studies and field studies were also conducted in Walking Horses and other breed of horses.

Another research topic was fertility in various species studied at Auburn since 1974 (9, 10, 11) including studies on the thermoregulation of scrotum and testes (12, 13). Thermal patterns of the male genitals have been reported for llamas (14), bulls, stallion and dogs (15). A clear relationship between the surface temperature of the scrotum and the quality of semen was also established (16).

Studies conducted at Auburn had various objectives.

Objective I. Normal thermal patterns

In horses, normal thermal patterns for both thoracic and pelvic limbs were established (17). Thermograms of various parts of the body were also obtained 30 minute before and after exercise for several horses. There was a high degree of symmetry between right and left and between front (dorsal) to rear (palmar, plantar) in the legs, distal to the carpus and the tarsus (17, 18, 19). The warmer areas of the thermogram tended to follow major vascular structures. The coronary band was the warmest area of the leg (17). Thermographic mapping of cervical dermatomes in the horse was achieved by performing spinal nerve blocks using mepivacaine (20, 21).

Objective II Thermal patterns in diseased animals

Thermal patterns of normal vs neurectomized legs were investigated to determine the prolonged effects of neurectomies. Surgical induction of Horner's syndrome was performed in four horses by isolation and transection of the vagosympathetic trunk (22). One clinical case and the surgically induced cases of Horner's syndrome were evaluated clinically. Thermographic findings of the clinical case were similar to the experimental cases.

Case reports reported temperature changes in dermatomes in other species such as bulls (23), cows (24) and dogs (Figure 1). Administration of tranquilizers such as acepromazine hydrochloride can be used as pharmacological challenge in horses to differentiate vascular from nerve injuries in thermal images (21).

Objective III. Thermographically assisted diagnosis

Diagnosis of subclinical osteoarthritis in Standardbred racehorses were also done (25). Thermographic and radiographic evaluations of the tarsus (hock) were performed on 20 Standardbred racehorses before and after exercise at three consecutive 6-week intervals. Normal thermographic patterns were established before and after exercise. These patterns corresponded to the underlying tarsal vasculature. Postexercise thermal patterns indicated a warming trend, and the increases were uniform. Abnormal thermal patterns were more localized and did not conform to the normal underlying vascular distribution. Five of the 20 horses trained successfully and competed professionally, with 1 of the 5 showing abnormal thermographic changes. Four horses were too slow to race, and all of these had abnormal thermographic changes of their tarsi. The medial aspect of the right tarsus was more commonly involved than the lateral in these horses. Only one horse was clinically lame and exhibited thermal increases, as well as radiographic changes in the right tarsus. The remaining horses were removed from training due to miscellaneous causes. It was believed that the four horses that failed to make minimum track times (for racing) suffered discomfort in their tarsi sufficient to impair performance. This problem was attributed to early subclinical inflammatory changes within the joints. Though difficult to recognize radiographically, these early changes were conspicuous as abnormal thermographic patterns typical of inflammation.

The diagnosis of podotrochlosis may be assisted by thermal imaging (26). Turner and coworkers investigated the distal forelimbs of 10 clinically normal horses with hair clipped on one limb thermographically before and after exercise. The thermal patterns, temperature distribution, and temperature changes after exercise were determined and compared with those of 8 horses with podotrochlosis. Clipping the hair did not cause changes in the thermal patterns, but the clipped limbs were warmer than the unclipped limbs. The temperature of the limbs of horses with podotrochlosis did not increase as much after exercise as did the limbs of normal horses. The failure of skin temperature increase correlated with the radiographic evidence of enlarged vascular foramina in the navicular bone. Because the failure to increase skin temperature after exercise is the result of low blood flow, the enlarged vascular foramen can be related to a state of low blood flow.

Thermography is as an aid to the clinical evaluation of lameness as this technique detects heat before it is perceptible during routine physical examination. Therefore, it is useful for early detection of laminitis, stress fractures, and tendonitis (27).

The "Limber Tail Syndrome" caused by injuries of the coccygeal muscles is clinically characterized by the temporary inability of (hunting) dogs to raise their tail (28). In thermal images, the tail appears hypothermic (figure 2)

Objective IV Evaluation of drug effects in inflammatory disease

Thermography was effective in quantitative and qualitative evaluation of anti-inflammatory compounds in the treatment of chemically induced inflammation (17), Thermal imaging was successfully applied for the evaluation of corticosteroid efficacy in amphotericin B induced arthritis in ponies. (29). The effects of phenylbutazone and flunixin meglumine on enhanced healing were shown by infrared imaging (17). Temperature changes due to DMSO alone or in combination with Gibson's linament were recorded . Application of silicon containing compounds and silver nitrate may mask acute inflammation, which can be shown by thermography.

Objective V: Determination of intestinal viability

Thermography was used to assess the intestinal viability in experiments with ponies undergoing intestinal strangulation (30, 31). The findings of other authors (32, 33) were confirmed stating that thermography is a valuable technique

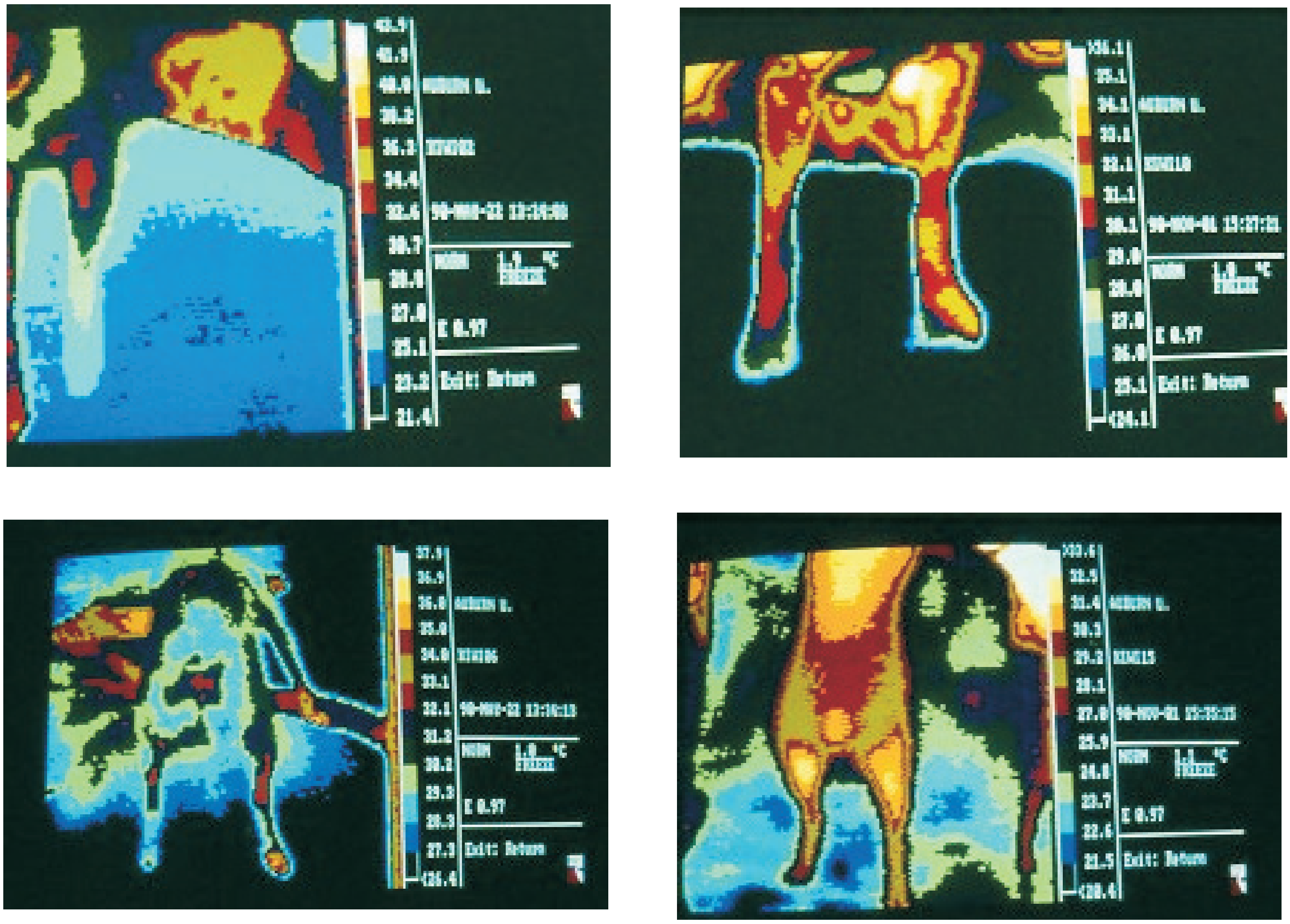

Figure 1
Case of a dog with atlantoaxial subluxiation
Left column: Thermal image before surgery right column: thermal image after surgery
The surgical intervention achieved thermal symmetry and normal temperature of the previously cold forelegs.

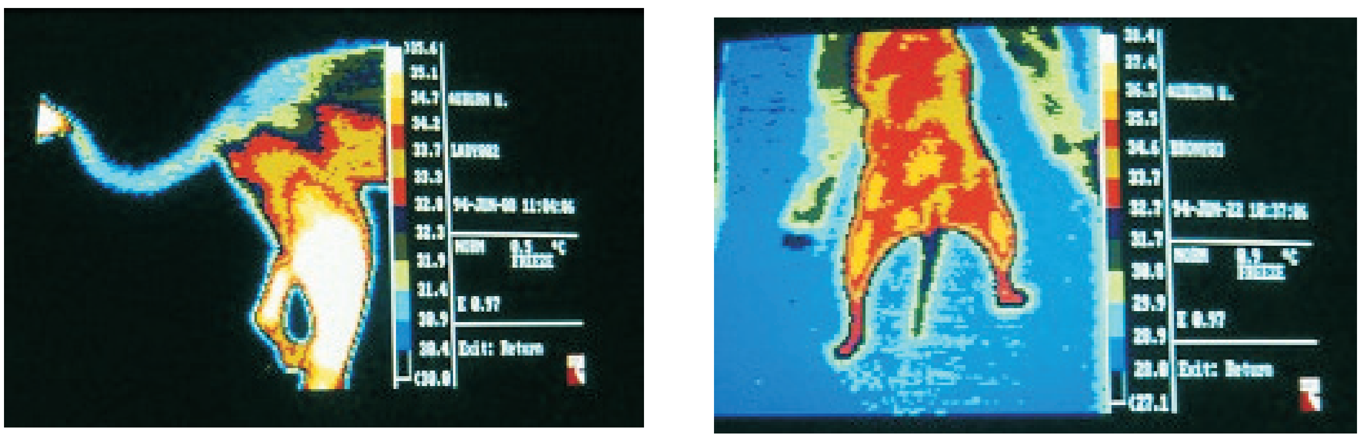

Figure 2
Thermograms of dogs suffering from "Limber Tail Syndrome" which is caused by injury of the coccygeal muscles


Figure 3


Figure 4 Contact Thermography Nova Therm


Figure 5
Inframetrics


Figure 6 Agema 780


Figure 7 Hand Held Infrared Temperature Reading Devices

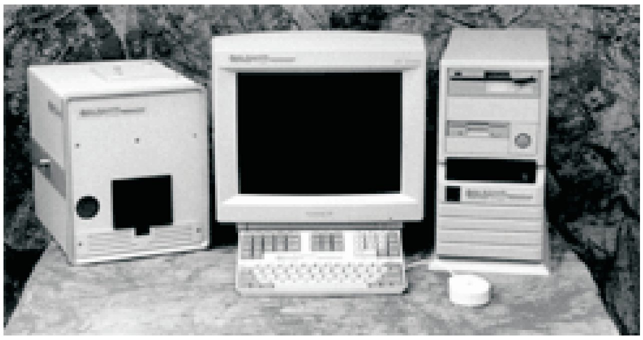
Figure 8 Bales Thermal Imaging Processor 50

Figure 9 Computerized Thermal Imaging

for the determination of intestinal viability in horses and other species.

Equipment used at Auburn

Various equipment was used since 1974 for temperature measurement and thermal imaging. The thermographic re-search started with a nitrogen cooled AGA 680 (figure 3),contact thermography using liquid crystal foils (figure 4). Temperature measurements in horses were also performed with hand held radiometers (34, figure 7). Later on the AGA 680 was exchanged with an AGEMA 780 (figure 6) and an Inframetrics (figure 5) was also used for thermal imaging. The cooperation with D. Pascoe from the Sports Science Department was partly based on the use Bales Camera (figure 8) and computerized infrared imaging (Figure 9).

Quantity of Publications in Veterinary Medicine

Even though a long list of clinical cases with various inflammatory conditions, along with neurovascular problems were diagnosed in equine, bovine, canines, and other animal species, the manuscript of full length publication in refereed research Journals dropped after 1986. Many of the published reports in 1990 to 2006 contain material collected from 1975 to 1990. Some research was done in 1990's.

From 1970 to 1991: More than 26 full length manuscripts were published in refereed scientific journals.

From 1992 to 2006: Last 15 years less than 10 full length manuscripts were published in refereed scientific journals.

During the last 15 years almost 10 times more abstracts or short notes were published compared to full length manuscripts

Discussion

It seems that in the last 10 years more abstracts than full length papers have been published in reference to veterinary thermology originating from research at Auburn University. Most of it seems to be old work and some of the so called new studies were done. It seems that lots of small projects were conducted but they lack data for full length manuscript to be published in referred research journal.

After 30 years of experience and use of thermology in veterinary medicine, this opportunity is taken to reflect upon the research questions that need further investigative studies. These studies must adhere to the highest standards of scientific inquiry, while meeting the scrutiny and requirements for publication in appropriate referred journals.

In addition to the already recognized, normal thermographic patterns in horses, we need to establish thermal patterns and dermatome patterns for various animal species. This will be a challenge due to the potential use of pharmacological agents that can alter thermal patterns. The thermal variation among animal species, as well as within different breeds of animals, would provide significant contributions to the field of thermology. We have not yet developed suitable standards for various animals. Indoor thermal imaging standards for environmental control are well known, but we lack meaningful guidelines and standards for outdoor imaging. However, standards for preparing horses for thermal imaging were recently debated (35,36)

Skin thickness and hair coat in some animal species has been an extensively debated issue (35) There are some parts of the body where meaningful diagnostic thermographic data can be obtained, where there is a lack of hair coat, such as scrotal and perineal areas. In other cases hair clipping may be desirable to obtain diagnostic thermograms.

Some animals are not calm and quite or easily controlled during clinical examination. This requires the use of sedatives and tranquilizers to make it easy to handle them. It is well known, that such tranquilizer and sedative may alter thermal patterns and temperature gradients. Thus, we need to research appropriate sedatives and tranquilizers which can be used to calm the animal but does not have adverse effects on diagnostic value of the thermograms. We know that exercise, heating, cooling, and the use of tranquilizers before and after thermal examination has been efficacious for diagnosis of various neurovascular and inflammatory conditions. What are the additional challenges of testing that we can use to enhance thermographic examination? In addition, as advanced portable equipment is now becoming available for use in veterinary medicine, do we have a need for standardization of this equipment, and if so, what can we do to make it easier for the practicing veterinarian to use them?

Acknowledgement

I wish to thank and acknowledge many of my friends who have helped in the past to enhance thermal imaging in veterinary medicine. It is difficult to list all the names who has contributed over the period of 30 years. The names of the many contributors appears as major author or co-authors on the publications used as for the basis of this review.

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Address for correspondence
Ram C Purohit, DVM, PhD, DACT
761 Kentwood Drive, Auburn, Alabama, 36830, USA
Email:rpurohit1336@charter.net

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Thermographic Evaluation of Metabolic Changes in Swine

Sophia Wilcox

Department of Animal Science, Purdue University, West Lafayette, IN 47906

SUMMARY

This study was done to evaluate infrared thermal imaging as a technique to assess change in metabolic rate due to prolonged feedd deprivation. Analysis of thermal images showed that the average skin temperature decreased relative to core body temperature, as feed-deprivation period increased. Analysis of infra-red thermal images of sows fed once daily show that the skin temperature relative to core body temperature follows the diurnal pattern established by the feeding schedule.

Key words:feed-deprivation, core temperature, skin temperature, swine, infrared thermal imaging

THERMOGRAPHISCHE BEURTEILUNG METABOLISCHER VERÄNDERUNGEN BEI SCHWEINEN

Diese Studie wurde durchgeführt, um die Infrarotthermographie als Technik zur Beurteilung metabolischer Veränderungen aufgrund von langdauerndem Futterentzug zu untersuchen. Die Analyse der Wärmebilder zeigte, dass die durchschnittliche Hauttemperatur relativ zur Kerntemperatur abnahm, je länger der Futterentzug dauerte. Die Auswertung der Infrarotbilder von Schweinen, die einmal täglich gefüttert worden waren, ergab, dass die Hauttemperatur relativ zur Kerntemperatur dem Tagesrhythmus folgte, der durch den Zeitplan der Fütterung induziert war.

Schlüsselwörter: Futterentzug, Kerntemperatur, Hauttemperatur, Schwein, Infrarotthermographie

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Introduction

Many swine-production facilities feed non-gestating sows limited portions of feed once a day (1). Hunger is one of the parameters used to assess animal well being (2). Thermal images map heat radiation from the skin surface. After six hours of feed-deprivation, the neuro-endocrine system decreases the blood flow to the skin surface as the metabolic priority is given to maintaining homeostasis and vital organ function (3, 4). The neurogenic responses should result in decreased skin surface temperature.

Thermography is a non-invasive, non-contact, technique that has been used to measure and map skin surface temperature of human (5, 6) and various animal species. (7, 8, 9, 10) This map reflects the skin-surface temperatures and abnormalities which may be associated with peripheral, systemic, environmental and/or physiological changes, which may occur (11).

This study was done to evaluate infrared thermography as a technique to measure skin surface thermal patterns and temperatures in swine's and to co- relate the skin surface temperature changes to assess change in metabolic rate due to prolonged food-deprivation.

Methods and Materials:

Sixteen market-weight sows were housed individually in a temperature-controlled building. The control animals were fed ad libitum, twice a day. After one hour, the feed was withdrawn and the pens cleaned. The treatment-sows were divided into four treatment-groups: 0, 12, 24 and 36 hours

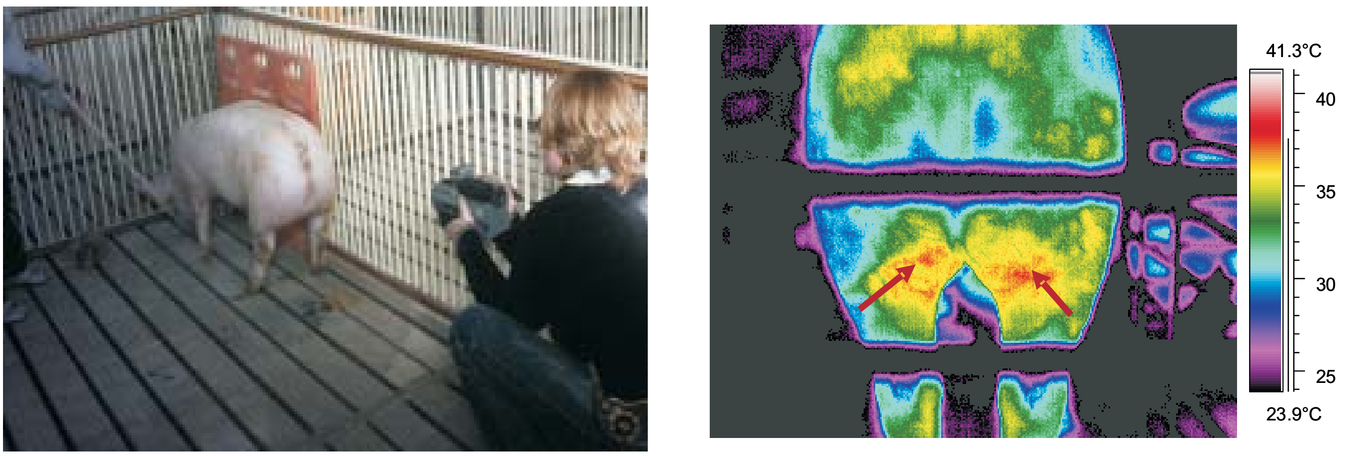

Figure 1
Method of capturing the caudocranial view and the resulting thermal image. Note the thermal signature of the saphanous vein as it surfaces. (arrows)

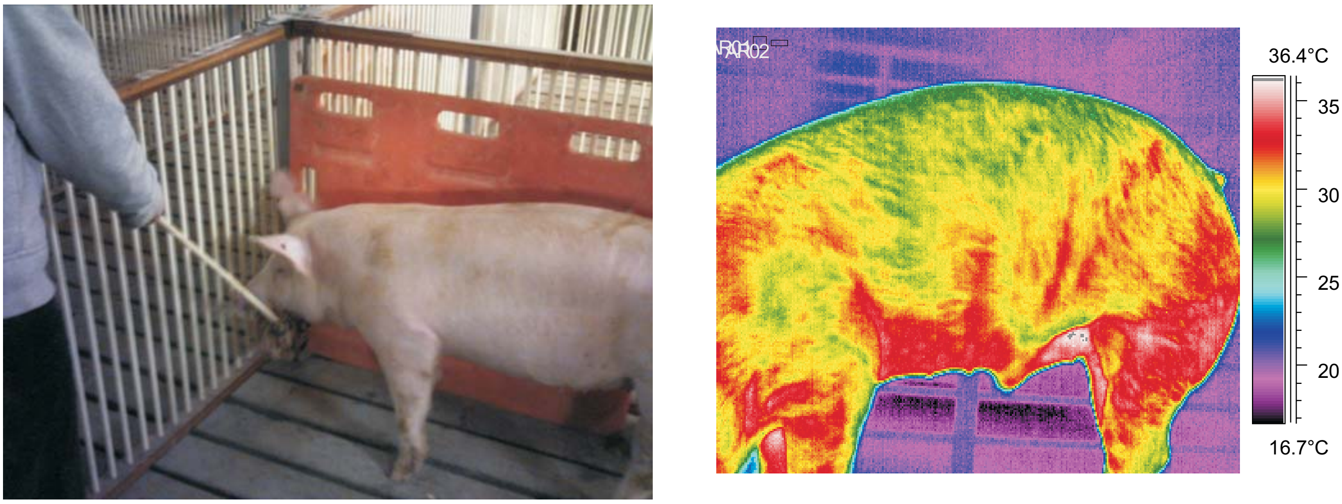

Figure 2
Method of capturing the lateral-medial view of the flank and the resulting thermal image.

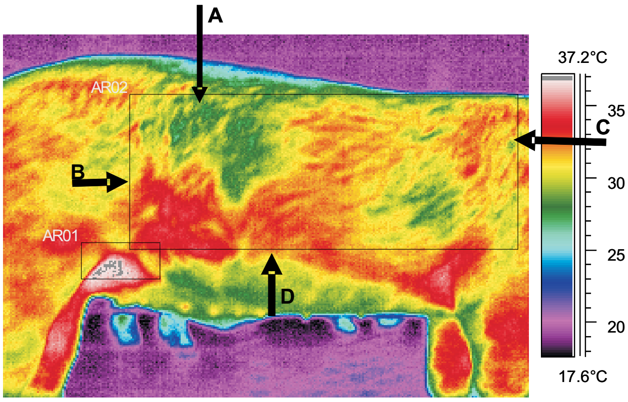

Figure 3
The area used to find average skin temperature was bounded by:
A, the dorsal midline;
B, the perpendicular to the midline proximal to the cavity formed by the distal limb;
C, perpendicular to the midline distal to the front limb;
D parallel to the midline dorsal to mammary structure.

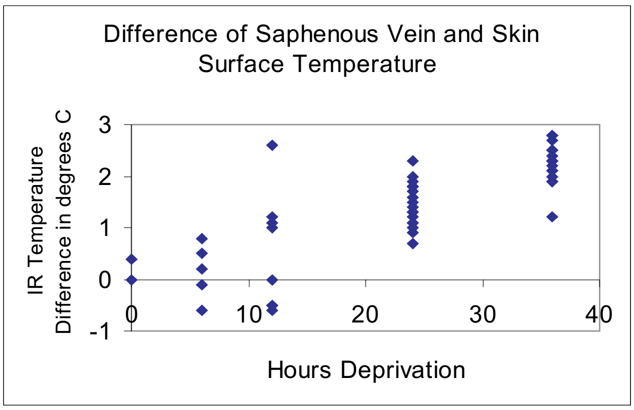

Figure 4
The difference between the maximum Saphenous vein-area temperatures and the average skin temperatures for each individual was calculated and plotted against the hours of feed deprivation. As the hours of feed deprivation increased, the temperature difference of these two areas increased, as recorded by an infrared-sensitive camera.

of food deprivation. Thermal images were taken using a FLIR ThermaCAM™ PM695. Thermographic view obtained were of the lateral-medial view of the flank and the caudocranial view of the stifle where the saphanous vein comes to the surface.

The images were taken in the dark, 2.3 meters from the animal's surface, accounting for the ambient temperature at each exposure and holding the thermal camera level with and perpendicular to the cranial-cortical line for the flank-view (Fig 2) and the dorsal–ventral line for the stifle-view (Fig 1). While the animals were still on regular feedings, a set of control-images was captured at 6-hour intervals to allow for circadian temperature-fluctuations.

After the specified feed-deprivation period, another set of images was captured under the same conditions prior to sacrificing the animal.

In the second study 25 sows housed in gestation-crates in a temperature-controlled barn were limit-fed once a day. A control group of 15 sows were feed ad lib Thermal images were taken at 7:00 am, 12 hours after feeding for the treatment group and 7:00 pm, 24 hours after feeding for the treatment group, for three days. Thermal images of the back and the eye of each sow were taken using a FLIR ThermaCAM™ PM695, accounting for ambient temperature at each data collection session. The camera was held 1.3 meters over the back of the animal perpendicular to the dorsal-ventral line for the dorsal view and 0.6 meters level with and perpendicular to the eye.

Results and Discussion

The maximum temperature from the saphenous vein-region of the stifle-image of each leg was found using Reporter 2000™ software (MMS). Reporter 2000™ software also calculated the average skin-surface temperature (AST) from a uniform rectangular area of the corresponding flank-image. The area analyzed by Reporter™ to find the AST was bounded by the dorsal midline, the perpendicular to the midline proximal to the cavity formed by the distal limb, parallel to the midline dorsal to the mammary structure, and perpendicular to the midline distal to the front limb (Fig 3).

The difference between the MMS (mean maximum temperature of the stifle joint) of the controls and the treatment-pigs (taken at the same time of day) was calculated for each deprivation-period. Since this difference was zero in each case, the MMS can be considered an indication of core-body temperature for that individual. (95% C.I for μ_6-$\mu_{control}$ (-0.848, 0.920), for μ_{12}-$\mu_{control}$ (-1.002,1.2), for μ_{24}-$\mu_{control}$ (-0.0727,1.003) and μ_{36}-$\mu_{control}$ (-0.964, 1.100).

The AST decreased as feed-deprivation increased. The calculated difference between the MMS and the AST for each individual was statistically significant increasing as feed-deprivation was prolonged (Paired t P value < .05) (Fig 4).

The variation in the AST within each block was larger than that in the stifle joint. (SD of MSS = 0.9112° C and SD of AST = 1.3001°C) Can this variation be due to the variation in curvature of the barrel of the flank?

The second study used the back of the pig, which is more nearly uniplanar.

Using Reporter 2000™, a rectangular area bounded by two laterals parallel to the caudocranial mid-line at either limit of the back, a perpendicular to the caudocranial mid line just cranial of the tail-head and a perpendicular to the caudocranial mid line just caudal to the shoulders was drawn on the dorsal images (Fig 5). The average skin temperature (AST) for each individual was calculated over the area of this rectangle. The homeostatic reference-temperatures were calculated from the maximum temperatures (MET) found at the tear-duct of the eye-images (Fig 6).

The difference between the maximum eye-temperature found from images taken12 and 24 hours after feeding was calculated for each individual and averaged over three days. In all cases, the 95% CI for (MET_{12}-MET_{24}) included zero, validating the maximum eye-temperature as a homeostatic reference-point. The difference between the maximum eye-temperature and the AST for each sow at each time-point was calculated and plotted (Fig 7). The graph of MET-AST values over time reveals a circadian rhythm

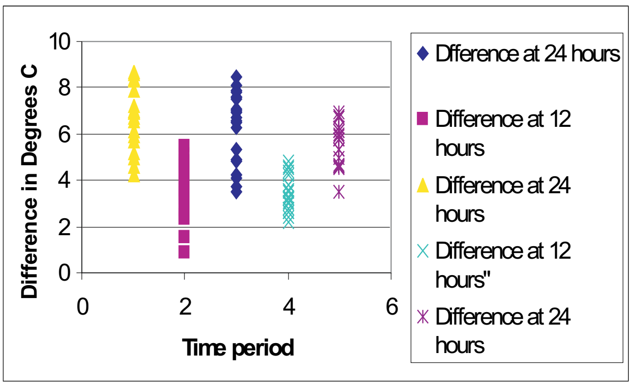

Figure 7
The temperature difference calculated from the maximum eye-temperature found on the thermal images of the sow-eye and the average skin temperature found from the corresponding thermal image of the dorsal view of the sow was plotted over time.

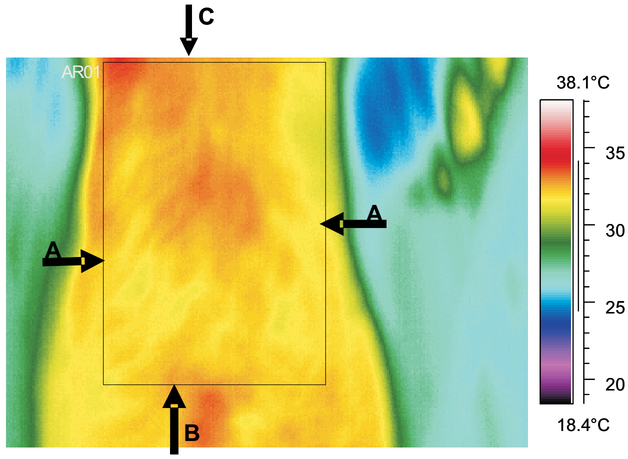

Figure 5
The average skin temperature was found in the rectangular area bounded by:
A; two laterals parallel to the caudocranial mid- line at either limit of the back;
B: a perpendicular to the caudocranial mid-line just cranial to the tail head and;
C: a perpendicular to the caudocranial mid line just caudal to the shoulders

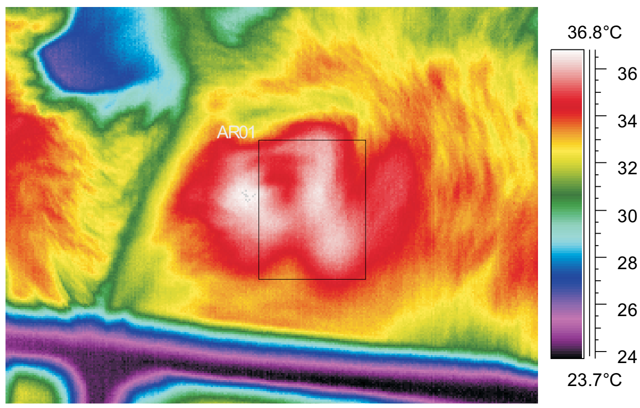

Figure 6
The homeostatic reference temperatures were calculated from the maximum temperatures found at the tear duct of the eye-images

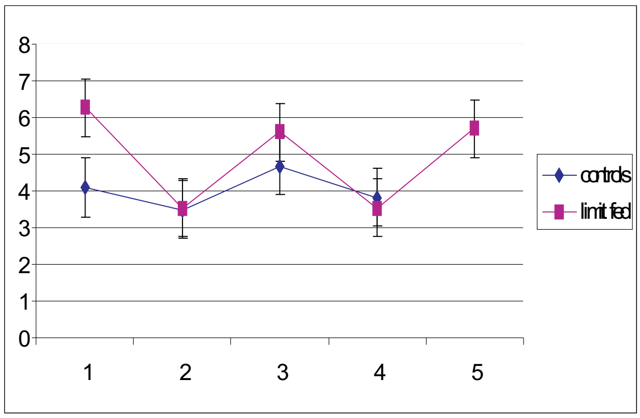

Figure 8
The mean temperature difference calculated from the maximum eye-temperature found on the thermal images of the sow-eye and the average skin temperature found from the corresponding thermal image of the dorsal view of the sow found over all individuals at each time point was plotted over time. A set of images was taken a 7:00am each day just before feeding and another set was taken at 7:00 pm.

corresponding to the 24-hour feeding schedule (Fig 8). The standard deviation for the AST values was 0.89.

The mean of MET-AST differences were tested for significance using the paired t test. (P value <.05).

Conclusions

In both studies, the thermal images show statistically significant increases in the difference between the homeostatic reference-temperature and average skin-surface temperature with increasing hours of feed deprivation. his is consistent with the expected homeostatic behavior of the autonomic response to feed deprivation. Therefore, thermal imaging is a non-invasive tool for assessing sow well-being.

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Address for Correspondence
Sophia Wilcox
Department of Animal Sciences, Purdue University,
West Lafayette, IN 47906, USA
Email: cswilcox@purdue.edu

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Peripheral Neurogenic Thermoregulation of the Bovine Scrotum

Ram C. Purohit, Robert L. Carson, M. Gatz Riddell, Jim Brendemuehl, Dwight F. Wolfe, Luisito S. Pablo

Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, Alabama, 36849

SUMMARY

To evaluate the role of peripheral neurogenic mechanisms of thermoregulation, unilateral neurectomies were performed in six bulls by surgical transection of the superficial perineal nerve and the caudal scrotal nerves under halothane general anesthesia. Thermographic and breeding soundness examinations were performed periodically for a duration of 8 months. Thermograms of the normal scrotum were characterized by right-to-left symmetrical patterns and an constant decrease in thermal gradient of 4 to 6 C from base to apex of the scrotum. There was a significant difference (P<0.05) in the temperature from base to apex of the scrotum (34.94 7 0.60 C versus 30.11 ± 0.91° C) in normal bulls. Unilateral neurectomies caused the loss of normal thermal gradient, thermal patterns and thermal symmetry of the scrotum on both neurectomized and nonneurectomized sides. The thermal pattern disruption and abnormal increases in scrotal temperature by 2.5 C to 4 C occurred on both sides of the scrotum. This increased heat due to loss of sympathetic tone resulted in testicular degeneration of greater than 3 months in all bulls. Readjustment of thermal patterns occurred in all bulls and their testicular function returned to normal in 5 to 8 months.

Key words: Scrotum. bull, thermal pattern, temperature gradient, neurectomie

PERIPHERE NEUROGENE THERMOREGULATION DES SCROTUMS BEIM RIND

Zur Erforschung des Beitrags peripherer neurgener Mechanismen zur Thermoregulation, wurden einseitige Neurektomien an 6 Stieren durchgeführt. indem der oberflächliche Perinealnerve und die caudalen Scrotalnerven in Halothan-Allgemeinnarkose chirurgisch durchtrennt wurden. Thermographischc und Untersuchungen zur Hodenfunktion wurden periodisch 8 Monate lang durchgeführt. Das thermische Bild eines gesunden Scrotum ist durch ein links-rechts symmetrisches Temperaturmuster und einen konstanten Temperaturgradienten von 4 bis 6° C von der Basis bis zum Scheitel des Scrotums gekennzeichnet. Bei gesunden Tieren fanden sich signifikant unterschiedliche Temperaturen (p<0.05) an der Basis und am Scheitel des Hodensacks (34.94 ± 0.60° C versus 30.11 ± 0.91° C) Eine unilaterale Neurektomies führte an der Seite mit Neurektonmie und auch an der Seite ohne chirurgische Intervention zum Verlust des normalen Temperaturgradienten, des typischen Temperaturmusters und der thermischen Symmetrie . Die Zerstörung des Temperaturmusters und ein abnormer Anstieg der Scrotaltemperatur von 2,5 C bis 4° C war an beiden Seiten des Hodensacks zu beobachten. Die durch Verminderung des sympathischen Nerventonus induzierte Erwärmung führte über 3 Monate bei allen Stieren zu einer Hodendegeneration. Bei allen Tieren kam es zu einer Wiederherstellung des Temperaturmusters und einer Normalisierung der Hodenfunktion nach 5 bis 8 Monaten.

Schlüsselwörter: Scrotum,. Stier, Temperaturmuster, Temperaturgredient, Neurektomie
Thermology international 2007, 17: 137-142

Introduction

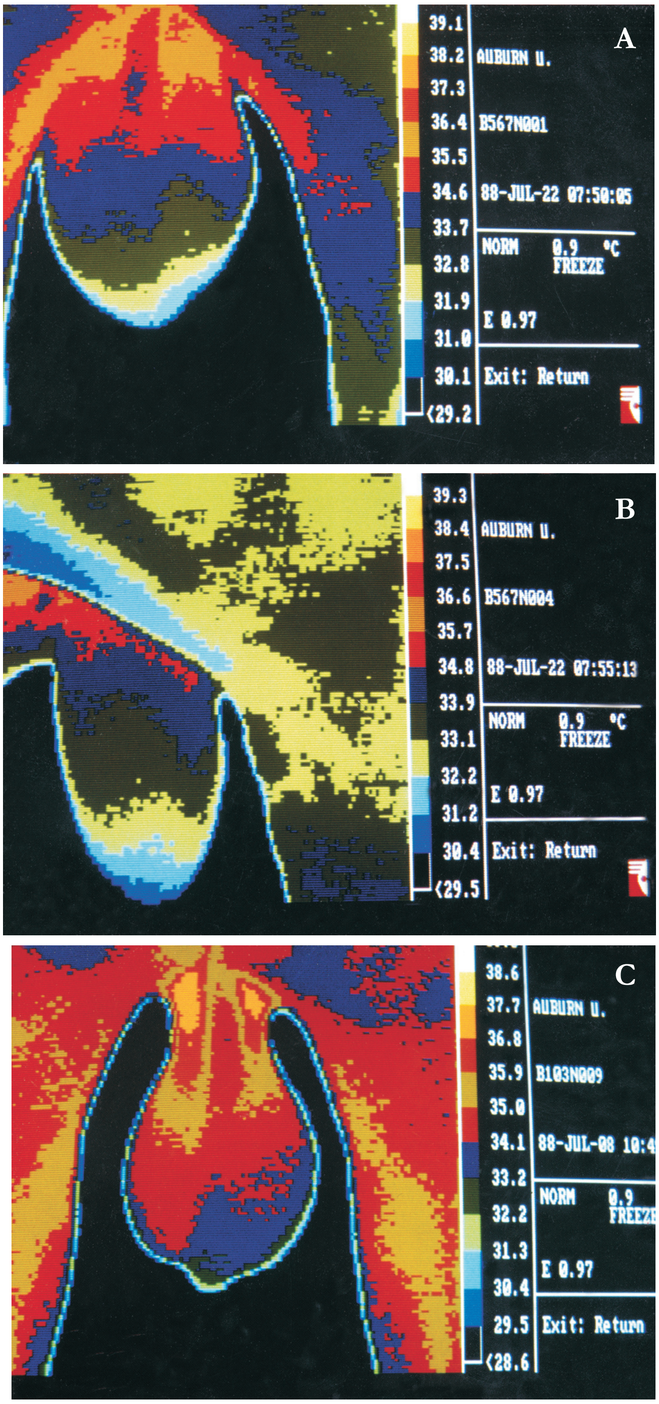
Historically, the relationship of temperature to infertility has been shown to be the effect of temperature differences on spermatogenesis. Studies have shown heat induced disruption of normal spermatogenesis and testicular degeneration in animals [1,2,3] , whereas very little work has been done to show that the disruption of neurogenic control may cause testicular degeneration [4]. Thus studies were done to evaluate the effects of unilateral scrotal neurectomies to evaluate the long term effects on testicular degeneration in the bull.

Material and Methods

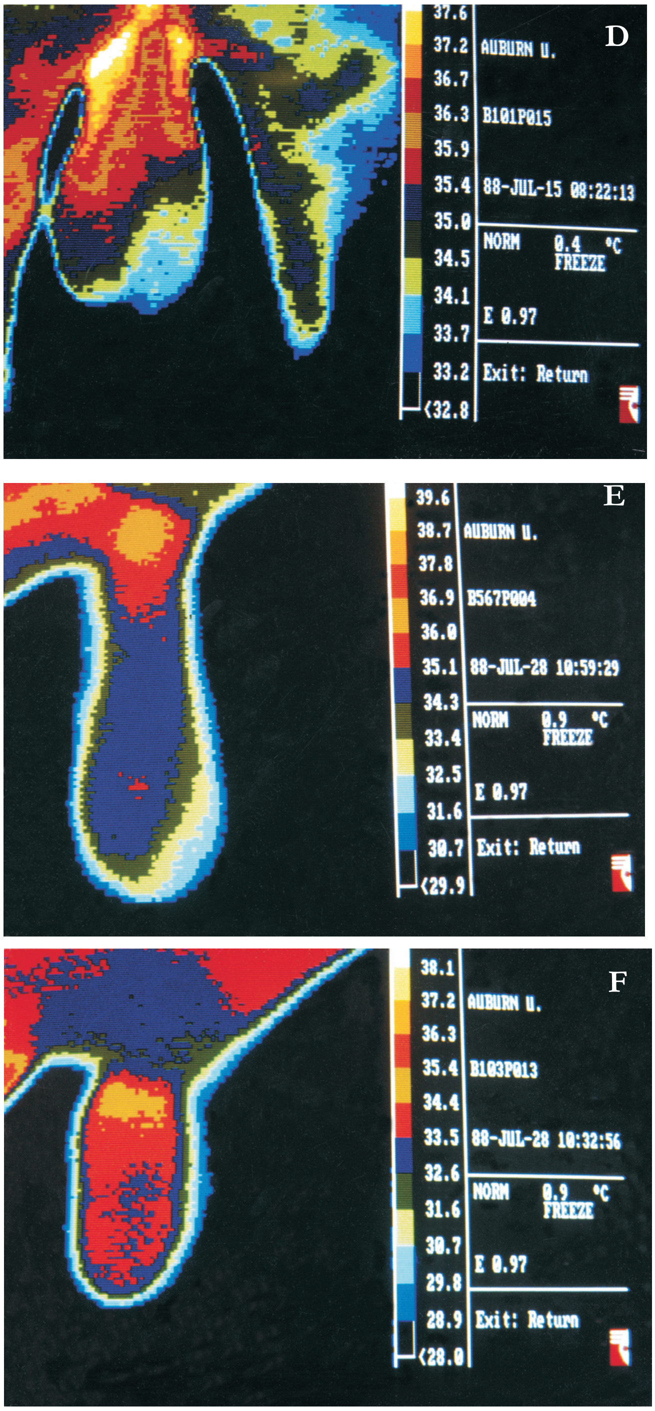
Six normal adult bulls as judged by physical examination were used in this study. All bulls were satisfactory potential breeder according to the standards of the Society for Theriogenology. Normal thermographic patterns of all four planes (cranial, caudal, left lateral and right lateral) of the testes were obtained as previously described. 1-3 The bulls were restrained on a surgical table in right lateral recumbency and anesthesia was induced with thiamyulal sodium and maintained with 2 to 3% halothane during surgery. The caudal scrotal nerves and the superficial perineal nerve were transacted either on the left side of the scrotum or the right side of the scrotum. In all cases, unilateral neurectomies were performed, so that the non- neurectomized side of the scrotum served as a control. Thermographic and breeding soundness examinations were performed periodically for 8 months.

The breeding soundness examination consisted of measurement of scrotal circumference, and semen evaluation to assess progressive sperm motility, and sperm morphology. AGEMA 870 thermography equipment was used to obtain thermograms. The thermographic isotherms (colors) used consisted of 9 colors plus white. There was a temperature difference of 1 C or 0.5 C between each isotherm. The isotherm mode used in this study recorded blue as coolest and white as warmest with 8 other colors distributed between. An analysis of variances of the temperature differences from the base to the apex of the scrotum was performed.

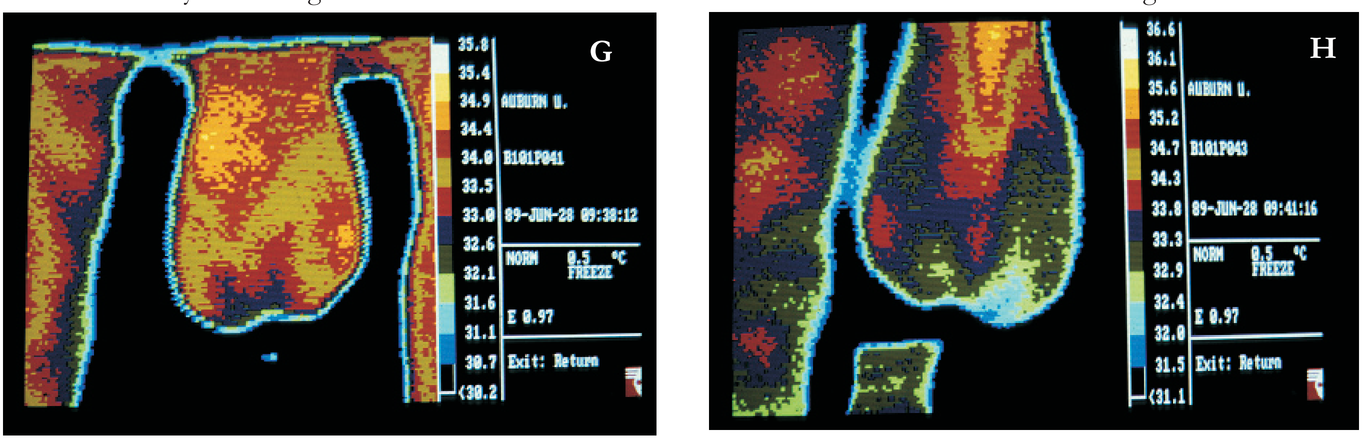
Normal Thermographic Patterns of the Bull Scrotum
Fig. A, B & C



Post-Neurectomy Pattern of the Bull Scrotum
Fig D, E & F



Post-Neurectomy: Returning To Normal Thermal Patterns and Gradient in about 8 to 10 Months. Fig. G & H



Results and Discussion

In the normal bull, the thermographic pattern of the scrotum was characterized by right to left symmetry and a constant decrease in the thermal gradient from the base to the apex (Fig A, B, C). A temperature gradient of 4 to 6 © from the base to apex was considered normal. A gradual decrease in temperature from the base to the apex of the scrotum was also demonstrated by concentric bands representing the temperature gradients. There was a significant difference ($P<0.05$) in the temperature from the base to the apex of the scrotum (34.94+/- 0.60 to 30.11 +/- 0.91 C) in normal bulls. All bulls in this study with normal thermographic patterns had satisfactory scores on breeding soundness examination.

Initially unilateral neurectomies caused increased heat in both neurectomized and non-neurectomized sides of the scrotum (Fig. D, E, and F). Thereafter, in some cases the non-neurectomized sides of the scrotum had earlier return to normal pattern than the neurectomized side. Neurectomies also caused the loss of normal thermal patterns and thermal symmetry of the scrotum on both sides. The thermal pattern disruption and abnormal increases in scrotal temperatures by 2.5 to 4 C occurred on both sides of the scrotum. This increased heat due to loss of sympathetic tone resulted in testicular degeneration of greater than 3 months in all bulls. Unsatisfactory breeding soundness scores were obtained in all bulls post neurectomies. Readjustment of thermal patterns began as early as 6 weeks after neurectomies. In some cases readjustment of thermo- regulation occurred on non-neurectomized side earlier then the neurectomized side of the scrotum (Fig. G & H). All bulls returned to normal testicular function 5 to 8 months, postoperatively.

Conclusion

Our previous studies and the present study provide the evidence that disruption of sensory-sympathetic tone causes thermal changes in the affected areas. This disruption may also cause severe functional impairment. For example, the loss of sympathetic tone causes excessive vasodilation and increased heat in the affected areas. This increased heat was responsible for testicular degeneration in these bulls. Thus we feel that spinal injuries, rear leg lameness, and scrotal injuries may cause extensive alteration in neurogenic thermoreg ulation, thus inducing testicular degeneration in bovine and other animal species. Clinically the extent and duration of testicular degeneration may depend on the severity of the injury involved.

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Address for Correspondence
Ram C Purohit, DVM, PhD, Dip. ACT
Professor Emeritus
Department of Clinical Sciences,
College of Veterinary Medicine
Auburn University, Alabama, 36849 USA
Email: rpurohit1336@charter.net

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Thermography as a Method for Assessing Disease State: Salmonella Challenge in Dairy Calves

Sophia Wilcox

Department of Animal Sciences, Purdue University, West Lafayette, IN 47906

SUMMARY

This study was done to evaluate infrared thermal imaging as a noninvasive technique to compare eye (orbital) temperature with those of the rectal temperatures obtained with digital rectal thermometer. Twenty one Holstein bull calves were used to collect data before and after induction of infection with *Salmonella Dublin*. In normal noninfected calves mean orbital temperatures were 35.58°C, SEM 0.14?C, which was slightly less then that of the rectal temperatures (38.54 °C). The ocular temperature correlated positively with rectal temperatures (82.8%). Correlation increased to 92% in the calves infected with Salmonella, due to increased body temperature. This study provided the evidence that a noncontact and non invasive technique can be used to evaluate febrile state of the animal by obtaining orbital temperatures with infrared imaging and, the rectal temperature with digital thermometer may not be required for initial state of evaluation of a group of animals.

Key words: infrared thermal imaging, orbital temperature, rectal temperature, fever

THERMOGRAPHISCHE BEURTEILUNG DES KRANKHEITSSTADIUMS: SALMONELLENINFEKTION BEI MILCHKÄLBERN

Diese Studie wurde durchgeführt, um die Infrarot-Thermographie als nicht invasive Methode zur Erfassung der Augen (Orbital)-Temperatur zu evaluieren und diese mit der Rektaltemperatur zu vergleichen, die mit einem digitalen Kontaktthermometer erhoben wurde. Bei einundzwanzig Holstein Stierkälber wurden vor und nach einer Infektion mit *Salmonella Dublin* Temperaturdaten erhoben. .Bei gesunden, nicht infizierten Kälbern betrug die mittlere Orbitaltemperatur 35.58°C, SEM 0.14°C, wobei diese gering unterhalb der Rektaltempertur von 38.54° C lag. Die Augentempertur koorrelierte positiv mit der Rektaltemperatur (82.8%). Die Korrelation eröhte sich bei mit Salmonellen infizierten Kälbern aufgund der erhöhten Körpertemperatur auf 92%. Diese Studie beweist, das die nicht invasive, kontaktfreie Infrarotthermographie mittels Bestimmung der Orbitaltemperatur Fieber bei Tieren entdecken kann, und dass die Bestimmung der rektalen Temperatur mit einem digitalen Thermomrzrt im Frühstadium der Untersuchung einer Gruppe von Tieren nicht notwendig ist.

Schlüsselwörter: Infrarotthermographie, Augentemperatur, Rektaltemperatur, Fieber

Thermology international 2007, 17 (4) 140-142

Introduction

Core-body temperature is an important physiologic measure of health and well being of an animal. It is used as an indicator of response to an immune challenge or disease. Rectal temperatures are accepted indicators of core body-temperature. Much of animal well-being research is based on the determination of stress caused by production-procedures and their results on animal health [1]. The collection of samples to measure physiologic indicators of stress is itself, stressful to the experimental animal, and can also be hazardous to the technician [2, 3]. Handling and restraint needed to collect blood, saliva and body temperature causes an increase in cortical steroid levels [4].

Thermography is a non-invasive, non-contact, technique that has been used to measure and map skin surface temperature of human and various animal species. [5,6,7,8] This map reflects thermal patterns and gradients on the skin surface and the temperatures associated with such as large blood vessels, skin circulatory plexus, as well as physiological changes caused by abnormalities which can alter core as well as peripheral temperatures [9,10]

This study was done to evaluate the eye (orbital) temperatures using thermography and to correlate the core body-temperature measured with digital thermometer.

Materials and Methods

Twenty one Holstein bull calves were divided into three treatment groups. Calves were infected with three different levels (high, medium and low) of Salmonella *Dublin* (10 ml). Oral administration in each calf was done according

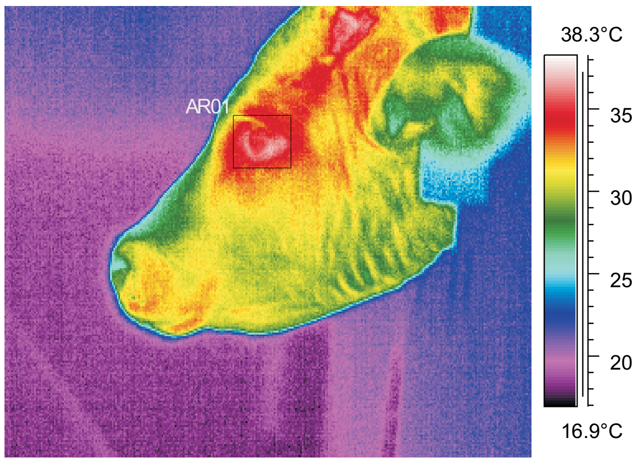

Figure 1
Using Reporter 2000™ software the tear duct was framed and the maximum temperature in that area was found.

to treatment group, with high 108, medium 107, and low106 CFU/ml. Thermal images of the calf-eye and rectal temperatures using a standard digital rectal thermometer, were taken simultaneously, hourly for eight hours prior to, and 72 hours after inoculation. Thermal images were taken with a FLIR®™ PM695 1.2 meters from the animal, holding the camera level to but 45° from the median line in an anterior-posterior view of the face. Both the ambient temperature and relative humidity were noted and the camera adjusted at each image-collection session.

Results and Discussion

Using Reporter 2000™ software, the tear-duct was framed and it was found to be the maximum temperature in that area of the eye [Fig 1]. The mean temperature of the eye in non infected calves was 35.58°C, SEM 0.14°C slightly less than that of the rectal temperatures 38.54°C, SEM 0.03°C. A regression scatter-plot was generated using the maximum orbital temperature found from the thermal image of the eye and the rectal temperature.

When analyzed by treatment group the correlation between the maximum orbital temperature and rectal temperature increased as the *Salmonella* dosage increased 0.52 to 0.92.for 10^6 CFU/ml and 10^8 CFU/ml dose respectively. The overall correlation coefficient was 82.8% (P-value was .001) for non infected calves (Fig 2). When analyzed by rectal temperature range the correlation (95%) and the R^2 value (0.89) was highest in the range of normal temperatures (37° to 39 °C). Earlier phase of the study increased rectal temperatures correlated well with eye temperatures.

As the calves became moribund, and body temperatures starts to drop, as indicated by extremely low rectal temperatures, their eyes were only partially open causing a decrease in the R^2 value.

This study indicates that the thermal camera is a valid method of monitoring fluctuations in body temperature in moderately acute immune reactions of dairy calves, especially when animal-handling must be kept to a minimum and the animal is serving as its own control.

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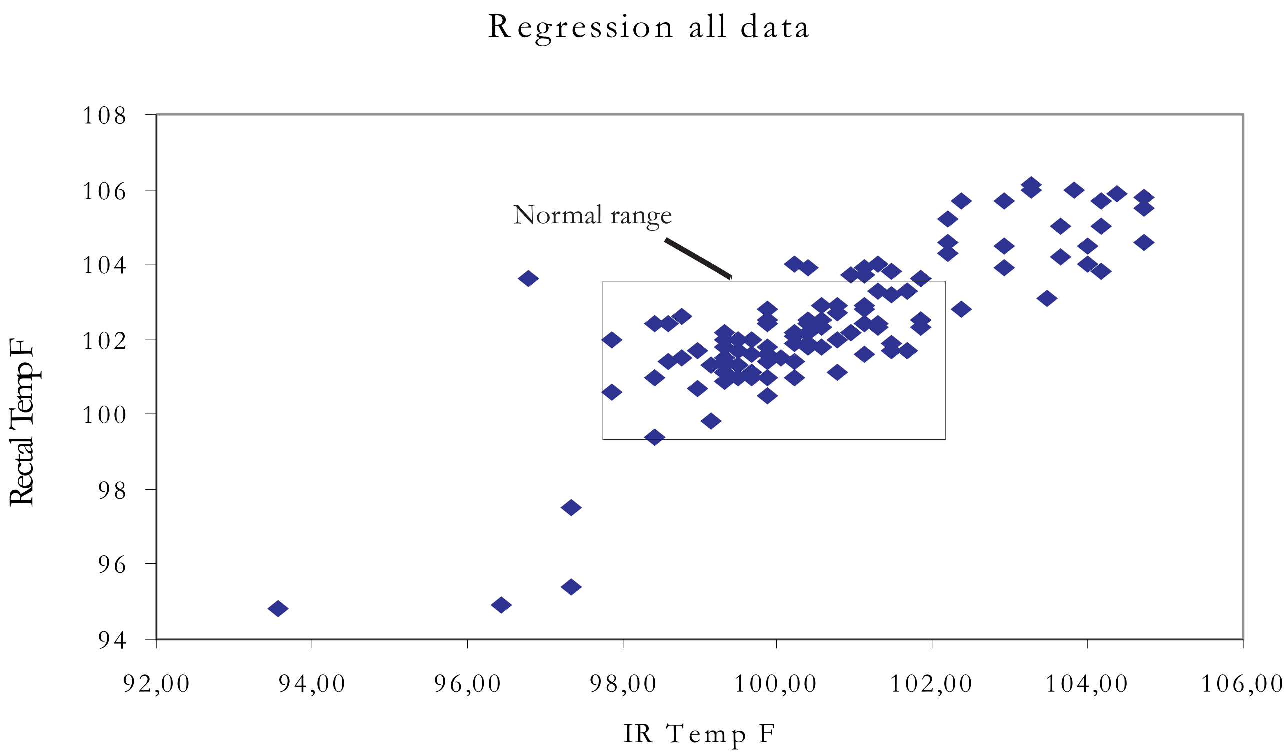

Figure 2
The maximum orbital temperatures found from the thermal image of the eye were plotted against the rectal temperatures found using a standard rectal thermometer. The correlation coefficient calculated was 82.8% (P value of .001).

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Address for Correspondence
Sophia Wilcox
Department of Animal Sciences, Purdue University,
West Lafayette, IN 47906, USA
Email: cswilcox@purdue.edu
(Manuscript received 24.10.2005, revision accepted 7.7.2007)

The use of Thermography to Screen for Sub-Clinical Bumblefoot in Poultry

Sophia Wilcox

Department of Animal Science, Purdue University, West Lafayette, IN 47906

SUMMARY

Pododermatits is responsible for significant economic losses in commercial poultry operations. It is also a significant concern for the well-being of captive avian in zoos and rescue centers. Thus studies were done to evaluate the use of thermography as a diagnostic tool for detecting sub clinical bumblefoot in poultry. In first phase of study 150 birds were evaluated by giving visual score and comparing visual score with that of thermal image in each bird. In this part of study the clinical signs and thermal observation provided a correlation of 83% (p <0 .001). In the second part of the study using Staphylococcus as a source of induced inflammation. In this phase of the study, the visual observation and thermal image correlation was 98% (p < .001). In cases of mild (sub-clinical) clinical category visual observation only picked the condition in 27% of the cases. Seventy three percent of the time the visual inspection missed incidence of bumblefoot found by thermal image analysis. Therefore thermography was more sensitive in early diagnosis of bumblefoot in the birds than visual observation.

Key words: Thermography, bumblefoot, Screening, poultry, Staphylococcus

THERMOGRAPHIE ALS SCREENINGINSTRUMENT FÜR DIE SUBKLINISCHE PODODERMATITIS BEIM GEFLÜGEL

Pododermatits ist einer der Gründe für bedeutende ökonomische Verluste in der kommerziellen Geflügelhaltung. Die Erkrankung hat auch für das Wohlbefinden gefangener Vögel im Zoo und für Tierrettungsstellen Bedeutung. Deswegen wurde eine Studie durchgeführt, um die Thermographie zur Diagnose der subklinischen Pododermatis beim Geflügel zu evaluieren. Im ersten Teil der Studie wurden 150 Vögel untersucht und der Score bei der visuellen Beurteilung mit den Ergebnissen der Thermographie verglichen . Zwischen den klinischen Zeichen und der thermischen Beobachtung fand sich eine Korrelation von 83% (p < 0.001). Im zweiten Teil der Studie wurde durch Staphylokokken eine Entzündung ausgelöst. In diesem Teil der Studie betrug die Korrelation zwischen klinischer Untersuchung und den Wärmebildern 98% (p < .001). Fälle, die klinisch als leicht (subklinisch) beurteilt worden waren, konnten durch die visuelle Beurteilung in nur in 27% der Fälle endeckt werden.Von den leichten Pododermatitis-Fällen, die alle in der Thermographie sichtbar waren, wurden 73% durch die klinische Untersuchung nicht endeckt. Die Thermographie besitzt für die Frühphase der Pododermatitis bei Vögeln eine höhere diagnostische Sensitivität als die klinische Beurteilung.

Schlüsselwörter: Thermographie, Pododermatitis, Screening, Geflügel, Staphylokokken

Thermology international 2007, 17, 142-146

Introduction

Bumble foot is chronic, debilitating, ulcerative ball like pododermatits. It occurs in captive avian species from raptors to penguins [1] as well as in domestic poultry. Bumblefoot is also one of the most frequent causes of clinical complications in birds of prey. Sea World reported that 64 % of the penguin population showed symptoms of bumble foot. This disorder adds 6% to the cost of operations in broiler- chicken- operations and causes one of every 200 chickens to be condemned at processing time.[2, 3] Incidence of bumblefoot is an animal well-being criterion, and is gaining recognition as a well-being indicator. It is painful, hinders perching, and walking, and limits access to food and water. If left untreated, bumble foot will compromise the mesoderm, tendons and bones causing osteo- my elitis, synovialitis and death [4].

Staphylococcus aureus has been cultured from 90% of the spontaneously occurring cases of bumblefoot, depending upon species and environment [4] Staphylococcus aureus is a ubiquitous gram-positive bacterium present in high concentrations in the dust of poultry houses, in animal feed, in gut contents and even on the skin of non-clinical animals [5, 6]. When the mucosal or skin barriers have been compromised due to trauma or stress, S. aureus can invade the mesoderm and cause a proliferative inflammation. Of course, the earlier the diagnosis and treatment, the smaller the chance that the bones and cartilage will be permanently damaged.

Thermographic cameras are able to detect radiation in the infra-red range of the electromagnetic spectrum and convert this into an image. The intensity of infra-red radiation emitted by an object increases with temperature according to Planck's law of black-body radiation. Thermal imaging has been used in many animal species to document inflammatory processes associated with skin surface temperature changes [7, 8, 9, and 10] and to determine the physiologic reactions of challenges to the sympathetic nervous system [11].

Because of the debilitating nature of this disease, and because of its significance as an indicator of animal well-being, this two part study was conducted to validate thermal imaging as a valuable diagnostic tool for detecting sub clinical bumble foot.

Methods and Materials

For the first part of the study 150 hens housed in pairs in standard battery cages were randomly selected from a peak-production population. Using a FLIR ThermaCAM®™ PM695, thermal images of the ventral view of the foot were taken at 0.91 meters from each selected hen. Each hen was held upside down by the hocks and the dorsal side of the feet pressed against the wall (Fig1). The Sony® NCV-FD83 digital still camera and the thermal camera, mounted on tripods, remained at a constant distance from the wall throughout the experiment.. After 14 days, the hens classified as suspect based upon the thermal images, were visually scored again for signs of clinical bumblefoot and digital photos of the feet were taken.

For the second part of the study 40, 15-month-old leghorn hens whose feet were determined to be free of lesions, were housed individually in standard battery cages and had un restricted access to commercial layers mash and water. From this group of 40 birds, 10 were used as control birds, and were given a 0.5 ml saline subcutaneous injection in each foot. Twenty nine were used to induce inflammatory reaction in the foot by subcutaneous injection of 0.5 ml, having 5.3 X 10^7 CFU/ml of *Staphylococcus aureus*. One bird was handled but given no injection in order to provide a double control.

Preparation of Staphylococcus inoculum.

Lyophilized *Staphylococcus aureus* (ATCC # 29506) was revived in .5 ml Bovine Yeast Peptone (BYP) broth (table 1) and incubated at 37ºC over night. The stock solution of bacteria was diluted with prepared peptone diluent (table 1) and the optical density measured with a spectrophoto-m eter. Each dilution was plated on blood agar (VWR #EM1.10328.0500), incubated at 37ºC overnight and colonies counted. The final inoculum had an optical density of 0.160. When plated this developed 264 colonies yielding 5.3 x 10^7 CFU/ml.

Every 24 hours a fresh tube of BYP broth was inoculated with *Staphylococcus aureus* from the original bacterial solution and incubated over night. Subsequent dilutions and plating was done from this fresh bacterial solution. The inoculation of the feet was timed to coincide with the mid stationary phase of bacterial growth.

Data Collection.

Thermal and digital images were collected simultaneously as above. Images were taken prior to inoculation, then at 24, 48, 72, 96 hours and 7 and 9 days post inoculation. Behavior was recorded beginning the day before inoculation for six hours each day using Panasonic® Ag-6540 time-lapse video- cassette recorders and Panasonic® BP390 cameras. Nine days after inoculating the hens with *Staphylococcus aureus* each foot was visually inspected then the hens were sacrificed and their feet collected and stored in formalin.

Image Analysis

The 150 thermal images of chicken feet taken in the first part of the study were analyzed and categorically classified as normal, suspect or positive. A normal thermal pattern for the ventral view shows a slight decrease in temperature from the metacarpal foot-pad to the digit-extremities (approximately 12 °C), (Fig 2). Normal images showed no unusual thermal patterns. Images in the suspect category

Table 1

<u>BYP Broth</u>
5 grams Beef Broth Extract (Difco Lab 0126-01-8)
5 grams Protoese Peptone No. 3 (Bactp 211693)
1.5 grams Yeast extract (Sigma Y-0500)
2.5 grams NaCL
500ml distilled water
<u>Peptone Diluent</u>
2.5 grams Peptone water (Difco 218071)
0.15 grams Potassiun Phosphate Monobasic Crystal

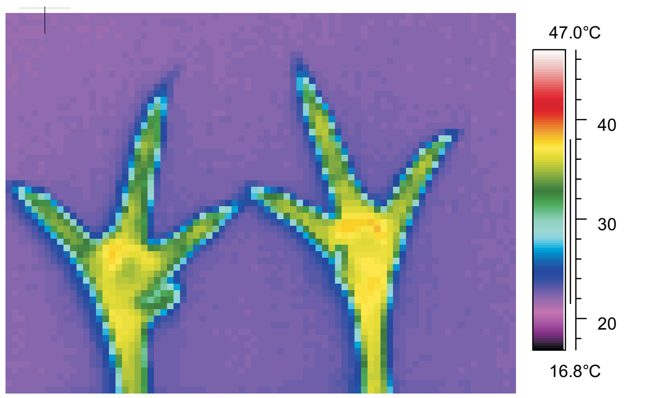

Figure 1
Using a FLIR ThermaCAM®™ PM695, thermal images of the ventral view of the foot were taken at 0.91 meters from each selected hen

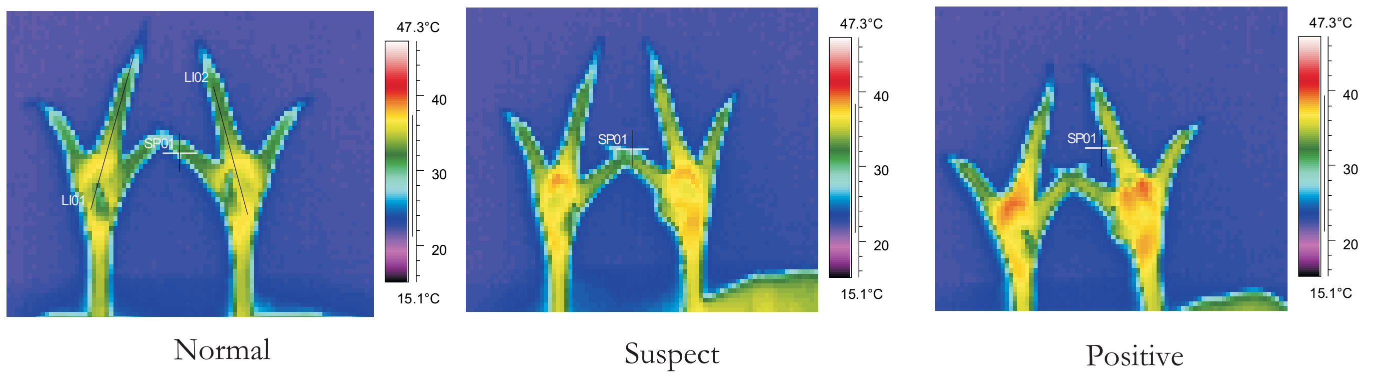

Figure 2
Images in the normal category were those that showed no unusual thermal patterns. Images in the suspect category showed small areas of unexpected heat patterns, and those in the positive category showed definite large areas of unexpected heat patterns(16°C to 17°C).

showed small areas of unusual heat patterns, and those in the positive category showed definite large areas of abnormal heat patterns (16° C to17°C).

These categorical differences were correlated to the visual clinical bumble foot-score for each of the 150 hens. A score of "Clinical" was given to any foot with pustules or swellings that were prominent or visible at first glance. A score of "mildly clinical" was given to any foot that looked red, slightly swollen, scabbed or caused the inspector to re-examine the foot. A "negative score "was given to any foot that presented no visible anomalies. (Fig 2)

Table 1
The classifications based upon the thermal images were correlated to visible clinical signs.

Classification	#	Clinical Signs at day 0
Positive	25	Yes
Suspect	43	No
Negative	77	No
No Classification	5	

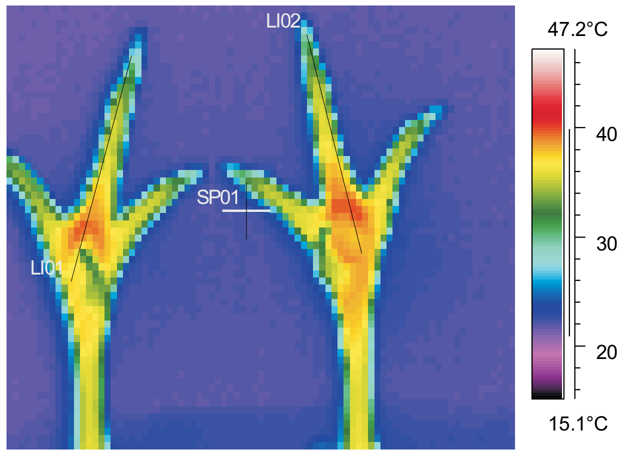

Figure 3
Thermal images of the ventral- dorsal view of chicken feet inoculated with *Staphylococcus aureus* were analyzed by finding the difference between the minimum and maximum temperatures along a line drawn from the middle toe across the metatarsal pad

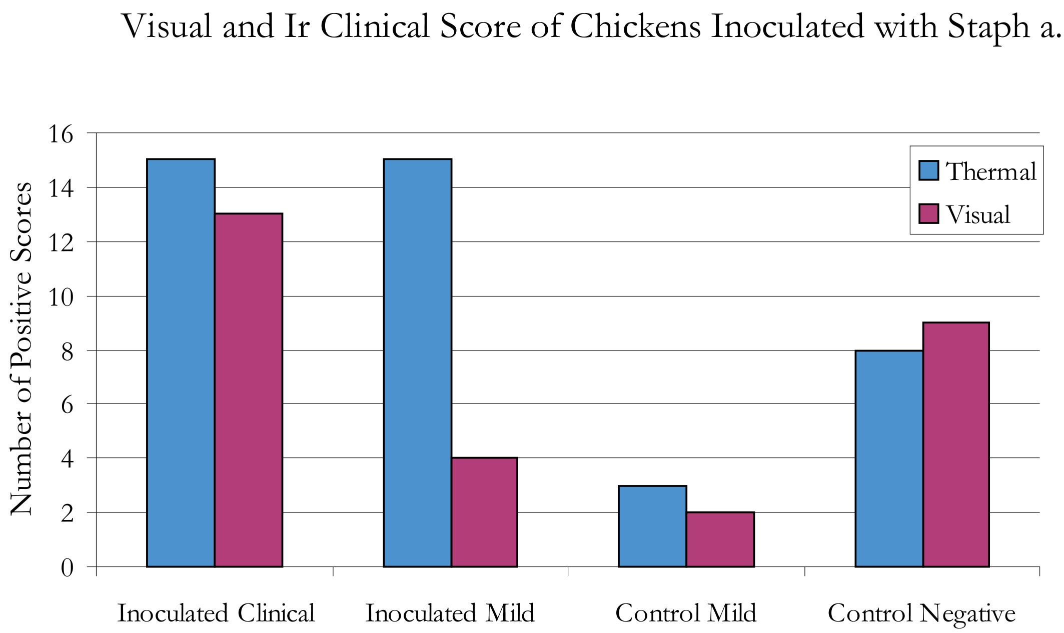

Figure 4
Chickens were inoculated with *Staphylococcus aureus*. Nine days later they were scored based upon analysis of infra-red images and visual inspection Correlation of the mildly clinical category was 27%

Based upon the thermal images, 25 of the 150 hens were positive, 43 were suspect and 77 were negative. Five were not classified because the images were ambiguous (Table 2).Of the 43 suspect birds, 36 scored "clinical" visual score, 14 days later. In the second part of the study clinical scores based upon visual inspection were given to each foot nine days after inoculation with the *Staphylococcus aureus*.

In the second part of the study thermal images were analyzed using the Reporter 2000™ software. A line was drawn from the middle toe across the metatarsal pad for each foot in each image (Fig 3). The difference between the maximum and minimum temperatures along that line was found (TD). The mean temperature difference (MTD) found for the control feet of the eleven chickens was 5.8°C +/- 1.9. Thus for the thermal images; a score of not clinical or negative was given to a foot with an temperature difference of (TD) of 7.7°C or less, a score of "mildly clinical" was given to any foot with an TD between 7.7°C and 9.2°C . and a score of "clinical" was given to any foot that with peaked TD was above 9.2°C.

Results and Discussion

The scores based upon visual inspection and infra-red thermal image analysis was correlated. For the fist part of the study the correlation between the image-category and the clinical signs of bumble foot was 83%. (P value < .001)

The average temperature difference (ATD) was calculated from the infra- red images taken for the second part of the study. A two-sample t test found that there was no significant difference between of the control feet, pre- inculcation and 24, or 48 hours post inoculation. (P value =0.384) but there was a significant difference for the treatment birds pre inoculation and 24 or 48 hours post inoculation. (P value <0.05). There was also a significant difference between groups classified as mildly clinical and clinical. (P value < .05).

The correlation for visual score and the thermal image interpretation based upon the ATD, as clinical was 98%. (P value < .001) However the correlation for the mildly clinical category was only 27% (Fig 4).

Fig 5 follows the average temperature difference of three groups of birds; controls, inoculated, active, and inoculated recovered. The 29 inoculated birds were assigned a group based upon the ATD nine days post inoculation. The inoculated recovered group had ATD on day nine close to control hens. Peek temperatures were significantly different from the control group but not as high as the inoculcated active group. This inoculated recovered group was classified as mildly clinical while the inoculated active group was classified as clinical.

Conclusions

In the second part of the study the correlation for the mildly clinical scores was 27%. Seventy three percent of the time the visual inspection missed incidences of bumblefoot. Fig 5 showed that infra red thermography has the

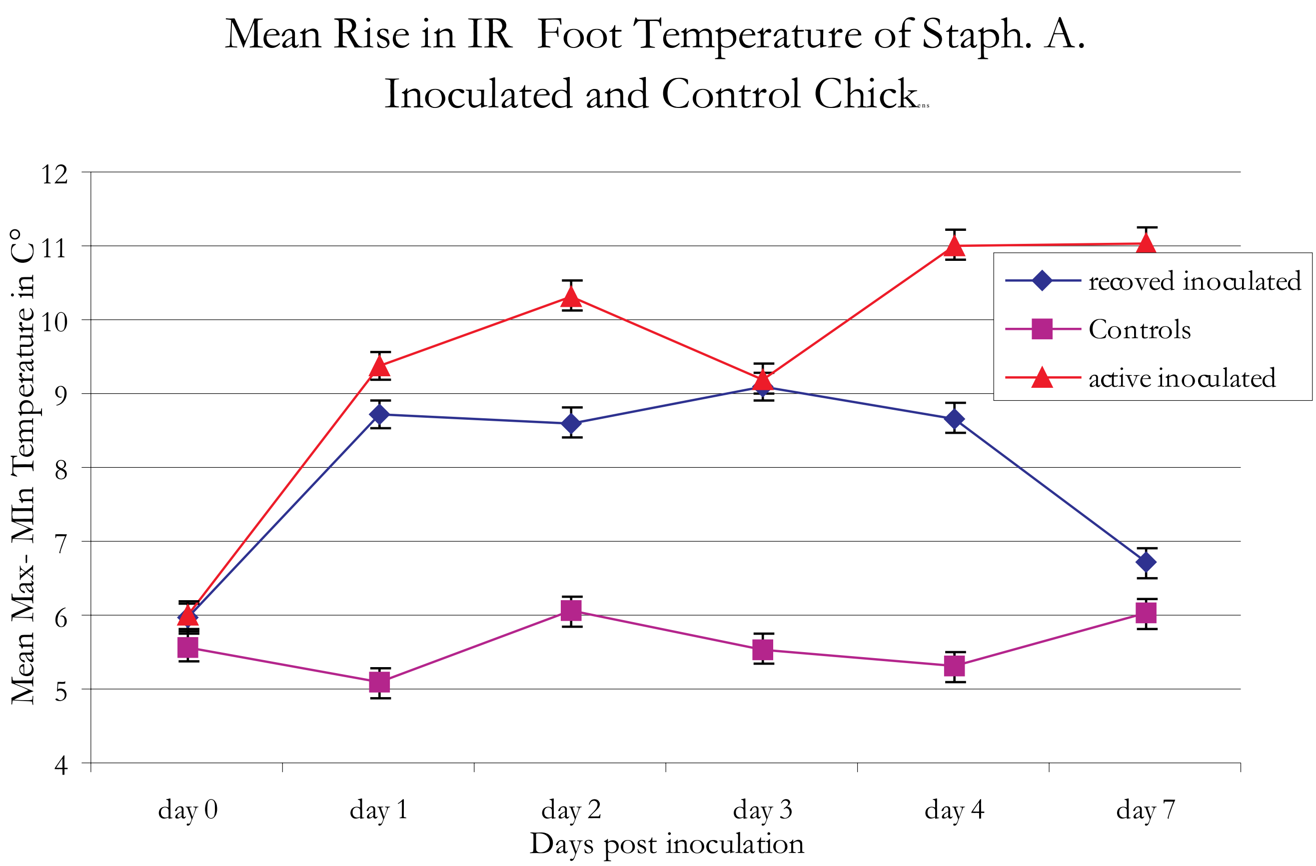

Figure 5
Chickens were inoculated with *Staphylococcus aureus*. Infra-red images were taken every day post inoculation for nine days. The groups of inoculated birds were divided based upon average temperature difference along a line which crosses the metatarsal pad.

ability to identify cases of sub-clinical bumble foot either as result of low-grade infection or recovery as well as clinical cases. Interpretation of infra-red images based upon thermal patterns also reveled incidences of subclinical bumblefoot. Infra-red imaging warrants further study as a technique for screening populations and detection of sub clinical cases in individuals for prompt treatment and better chances of recovery.

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Address for Correspondence

Sophia Wilcox

Department of Animal Sciences, Purdue University,
West Lafayette, IN 47906, USA

Email: cswilcox@purdue.edu

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Use of Infrared Imaging to Evaluate Sex Differences in Hand and Finger Rewarming Patterns Following Cold Water Immersion

François Haas[1], Rebecca Altschul[1], Alexis Kruczek[1], Alexander O. Haas[2], Laura Downing[1], Jeffrey M. Cohen[1], Mathew H.M. Lee[1]

[1] Kathryn Walter Stein Chronic Pain Laboratory, Department of Rehabilitation Medicine, New York University School of Medicine, New York, NY.
[2] Department of Aeronautics and Astronautics, Stanford University, Stanford, California

SUMMARY

We used Infra Red (IR) thermography to evaluate gender differences in local thermal regulation, assessing the response of 18 men and 16 women to a 30-second immersion of the dominant hand and digits in water maintained at 3–5º C. IR images—taken prior to immersion, immediately after withdrawal, at 15 second intervals for 5 minutes and 30-second intervals for the final 5 minutes —were analyzed to obtain surface temperature of the index finger and dorsum of the hand. Men had higher baseline temperatures than women in both hand and finger (P<0.01). Within sex, there were no hand–finger temperature differences. Immediately after withdrawal, temperatures showed that the finger had cooled more than the hand. The contralateral hand and finger showed a modest drop in temperature. After 10 minutes, men's and women's hands had rewarmed to 91.5 ± 1% and 86.5 ± 0.9% (m ± SE) of baseline, respectively (p<0.001). Men's fingers rewarmed to 89.5 ± 3.1%, while women's rewarmed to 77.0 ± 3% (p<0.008). Although our data showed a broad spectrum of rewarming patterns, particularly in fingers, we were able to divide them into *slow rewarmers* (<90% return to baseline: 12 women, 5 men) and *fast rewarmers* (>90% of baseline: 13 men, 4 women). Fast rewarmers demonstrated a vasodilation absent in slow rewarmers. As the contralateral side showed a similar pattern, our data suggest that local rewarming is partly mediated by a reflex mechanism that is more prevalent and/or effective in men than women, possibly helping explain the higher incidence of cold-induced vasospastic disorder in women.

Key words: thermogenesis Infrared thermography heat loss rewarming pattern

INFRAROT-THERMOGRAPHIE ZUM NACHWEIS VON GESCHLECHTSUNTERSCHIEDEN BEI DER WIEDERERWÄRMUNG DER FINGER NACH EINEM KALTWASSERBAD

Wir untersuchten mittels Infrarotthermographie Geschlechts abhängige Unterschiede der lokalen Thermoregulation an 18 Männern und 16 Frauen, nachdem sie die dominante Hand 30 Sekunden in ein Wasserbad von 3–5º C getaucht hatten. Infrarotbilder wurden vor, unmittelbar nach dem Tauchband und dann in 15 Sekundenabständen 5 Minuten lang und in 30 Sekunden Abständen in den folgenden 5 Minuten aufgenommen. Von den Wärembildern wurden die Oberflächentemperatur des Zeigefingers und des Handrückens bestimmt . Männer boten sowohl am Handrücken auch am Finger höhere Ausgangstemperaturen als Frauen (p<0.01). Innerhalb der Geschlechtsgruppen fand sich kein Temperaturunterschied zwischen Handrücken und Finger. Unmittelbar nach dem Bad fanden sich niedrigere Temperaturen am Finger als an der Hand. An der kontralateralen Hand zeigte sich ein mäßiger Temperaturabfall am Finger und Handrücken. Nach 10 Minutes, hatten sich die Handrücken der Männer zu 91.5 ± 1% des Ausgangswertes wieder erwärmt, Frauen erreichten 86.5 ± 0.9% (Mittel ± Standardfehler) des Startwertes (p<0.001). Die Fingertemperatur erreichte bei Männern 89.5 ± 3.1% und bei Frauen 77.0 ± 3% des Ausgangswertes (p<0.008). Obwohl wir einen großen Bereich von Wiedererwärmungsmustern besonders der Finger fanden, konnten wir *langsame Erwärmer* (<90% des Ausgangswertes, 12 Frauen, 5 Männer) und *schnelle Erwärmer* (>90% des Ausgangswertes, 13 Männer, 4 Frauen) unterscheiden. Schnelle Erwärmer boten eine Vasodilation, die bei langsamen Erwärmern fehlte. Da die kontralateral Seite ein ähnliches Verhalten bot, interpretieren wir unsere Daten dahin, dass die lokale Wiedererwärmung zum Teil über einen Reflexmechanismus vermittelt wird, der bei Männern häufiger oder effektiver vorkommt als bei Frauen. Das könnte die größere Häufigkeit von Kälte-induzierten vasospastischen Erkrankungen bei Frauen erklären.

Schlüsselwörter: Thermogenese Infrarot-Thermographie, Wärmeverlust, Wiedererwärmungsmuster

Thermology international 2007, 17(4): 147-153

Introduction

Thermoregulation is a complex system involving physical, chemical and behavioral processes that enable body temperatures to be maintained within a restricted range under conditions of variable internal or external heat loads (1) . Skin temperature reflects the sum total of these processes. Under conditions consonant with thermal comfort (roughly between 20–25°C), heat is carried via blood perfusion from central "warm" locations to the superficial skin layers where it is lost to the environment by radiation and convection. The skin's temperature can be measured by recording the natural infrared radiation (IR) emitted at the skin's surface using an infrared camera which produces an image that represents the temperature distribution over the imaged area (2).

There are substantial data indicating a spectrum of differences in peripheral vascular reactivity and thermoregulation that exists between healthy men and women when exposed to cooling (3, 4). These variations have focused on a number of variables including sympathetic neural reactivity (5,6,7), differences in anthropometric variables such as surface-to-mass ratio (3) , and the influence of hormones on vascular reactivity (8).

IR imaging may help to understand these sex differences in thermoregulation. We therefore used IR thermography to assess the response to localized cooling of the hand and digits in a group of self-selected, healthy men and women.

Methods

Subjects

Subjects were recruited by word of mouth. People with Raynaud's disease, peripheral vascular disease, coronary artery disease, uncontrolled hypertension, or diabetes were excluded from the study. Participating subjects first signed an IRB-approved informed consent. Eighteen men and 16 women ranging in age from 20–75 and 20–63, respectively, were recruited (Table 1).

Procedure

The temperature of the room in which the procedure was performed averaged 21.1 ± 1.4º C (m ± SD). Each subject's BMI, pulse, and blood pressure were taken. Index finger length and diameter were measured and used to calculate the finger's surface area, volume, and the ratio of surface area to volume. We did not measure the hand surface area-to-volume ratio because of the difficulty in calculating hand volume or surface area with accuracy. There is general agreement, however, that women have smaller hands then men.

Subjects were asked to sit quietly with both hands resting palm down on a foam pad. In accord with current guidelines (9) , a minimum equilibration period of 15 minutes preceded the baseline IR image. The dominant hand was then immersed for 30 seconds, to above the wrist in water cooled to 3–5º C. After withdrawal, the water was rapidly blotted and IR images taken of both the cooled and contralateral hand and finger at 15-second intervals for the first 2 minutes, then at 30-second intervals for the remaining 8 minutes. Images were analyzed to obtain average skin temperature of the index finger and dorsum of the hand (Figure 1).

Instrumentation

Images were obtained using the Thermal Image Processor System (Computerized Thermal Imaging Inc.; Ogden, UT), a computerized infrared imaging (CII) instrument. This three-component system comprises a high-resolution thermal imager withclosed cycle cooler The standard CII camera is sensitive to infrared radiation in the 8- to 12-micron range, with a resolution of 0.0125° C.

Finger temperature was evaluated within the oval area outlined on the dorsal surface of the index finger, within which each pixel is a record of the IR energy (temperature). The individual pixels were averaged to yield an average temperature for that circumscribed area. In the same way, the dorsum of the hand was evaluated within the outlined circle extending from the wrist to the middle knuckle (Figure 1).

Statistics

Data were evaluated with Student's t-test and two-way ANOVA. If the ANOVA resulted in statistical significance, a Bonferroni post-test was performed to identify the significant variable between columns. Fisher's exact test was used to assess nonparametric data. A level of $P<0.05$ was taken as statisitcally significant. Analyses were performed using Graphpad Prism 4 (GraphPad Software, Inc.; San Diego, CA).

Results

Population

There was no significant age difference between men and women. On average, men had significantly higher BMIs than women ($P < 0.01$). Women had significantly smaller finger dimensions and consequent higher surface- area-to-volume ratios ($P = 0.02$, Table 1).

Baseline levels

Data on hand and finger temperatures obtained before, immediately following, and 10 minutes after withdrawal from ice water are shown in Table 2. Both overall and within each sex, there were no significant differences in baseline temperatures between the hand and fingers of the immersed hand and fingers (Table 2). Within this normal range, however, men's hand and finger temperatures were significantly higher than women's ($P < 0.01$). This may in part be attributed to the smaller hand and finger dimensions and consequent higher surface-area-to-volume ratios for women resulting in greater heat loss.

Immersion/Recovery: Measurements done within 15 seconds of withdrawal from the water showed similarly lowered temperatures in men and women (Table 2). Temperature was significantly more reduced in finger skin than hand skin in both sexes (men: 14.1± 1.3° C and 12.1 ± 1.4° C, respectively; women: 12.9 ± 1.7° C and 11.7 ± 1.4° C, respectively (paired t-tests hands vs. fingers, $P < 0.020$ for both).

Table 1.
Population characteristics.

	age	height (cm)	weight (kg)	BMI	*finger SA/Vol (1/cm)*
MEN Mean ± SD	38.4 ± 18.3	177.3 ±6.35	78.8 ± 8.6	25.3 ± 2.9	1.76 ± 0.15
WOMEN Mean ± SD	30.4 ± 13.7	165.1 ± 5.1	59.8 ± 10.5	21.8 ± 3.8	1.91 ± 0.16
P<	NS	NS	NS	0.01	0.02

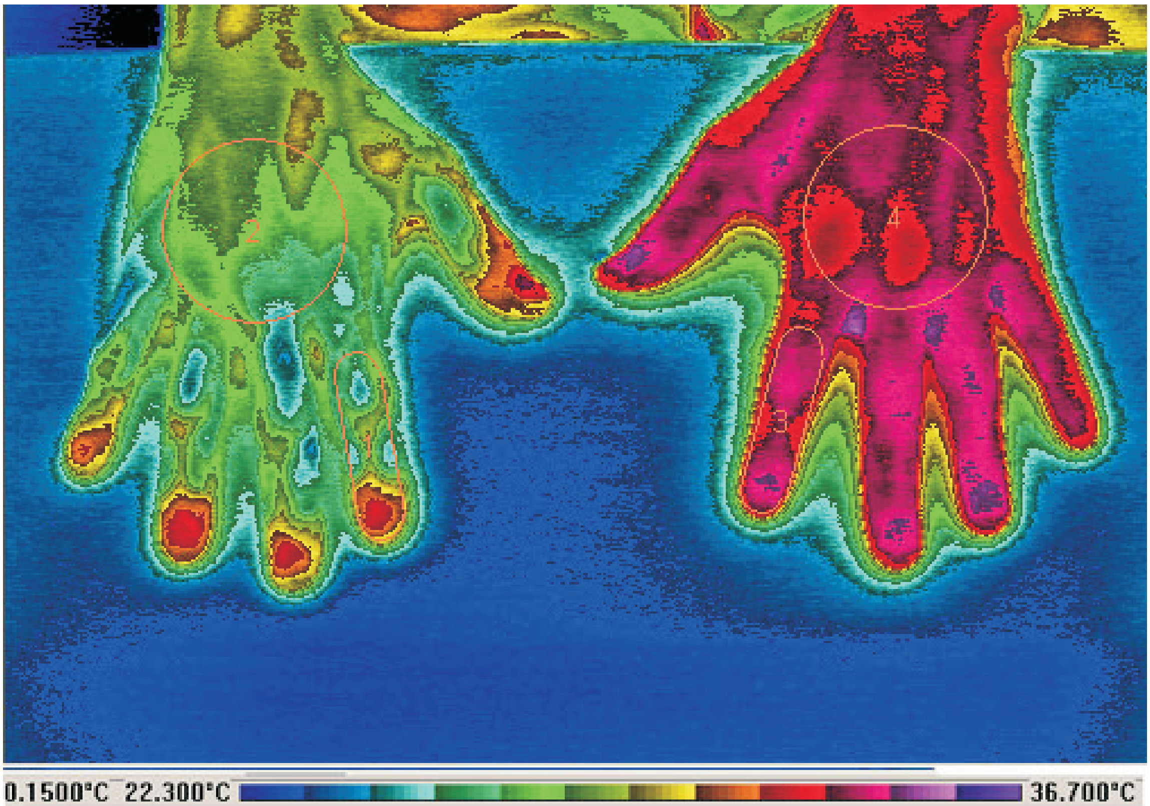

Figure 1:
Example of CII images. The dominant hand was immersed with the contralateral hand serving as control. This photo illustrates the immersed right hand 5 minutes post-immersion. The control left hand is shown for comparison. The average temperature obtained from the dorsum of each hand was calculated within the circumscribed circle. Similarly, the average finger temperature was obtained from within the circumscribed oval.

Table 2
Men's and women's average hand and finger baseline temperatures and temperatures within 15 seconds and 10 minutes after withdrawal of the hand from ice water (temperature in °C, mean ± SD)

	Hand Temperature			Finger Temperature		
	baseline	**15 sec post immersion**	**final**	**baseline**	**15 sec post immersion**	**final**
Men (Mean±SD)	32.6 ± 1.6	20.5 ± 2.0	29.9 ± 2. 7	32.9 ±1.9	18.7 ±2.0	29.6 ± 5.5
Women (Mean±SD)	30.8 ± 2.0	19.0 ± 1.7	26.55±1.9	30.5 ± 3.1	17.6 ± 1.7	24.1±4.8

Statistical significance was determined using a two-way ANOVA followed by the Bonferroni post-hoc to determine significance between cells. The null hypothesis is that there is no difference within the hand or finger temperatures between Men and Women or between baseline, 15sec post immersion or final temperatures
Men's baseline hand and finger temperatures were higher than in women (P <0.001). Hand and finger temperatures cooled significantly (P<0.02) and equally in both sexes Fingers cooled more than hands in both sexes, (P <0.001).
Men's final hand and finger temperatures were higher than women's (P<0.01).

Table 3
Slow and **fast** rewarmers' average hand and finger baseline temperatures and temperatures within 15 seconds and 10 minutes after withdrawal of from ice water (temperature in °!C, mean ± S.D.)

	Hand Temperature			Finger Temperature		
	baseline	**15sec >immersion**	**final**	**baseline**	**15sec >immersion**	**final**
slow (Mean±SD)	30.5 ±1.8	18.9 ± 1.7	26.0 ± 1.3	29.8 ± 2.7	17.2 ± 1.8	21.7 ± 2.9
fast) (Mean±SD)	33.0 ±1.3	20.8 ± 1.8	30.6 ± 2.0	33.6 ± 0.9	19.2 ± 1.5	32.3 ± 1.5

Statistical significance was determined using a two-way ANOVA followed by the Bonferroni post-hoc to determine significance between cells.
Fast group's baseline hand and finger temperatures were higher than slow group (P <0.001). Hand and finger temperatures cooled equally in both groups relative to baseline (P<0.02) Fingers cooled more than hands in both groups (P <0.001).
Final hand and finger temperatures were higher in the fast group (P<0.01).

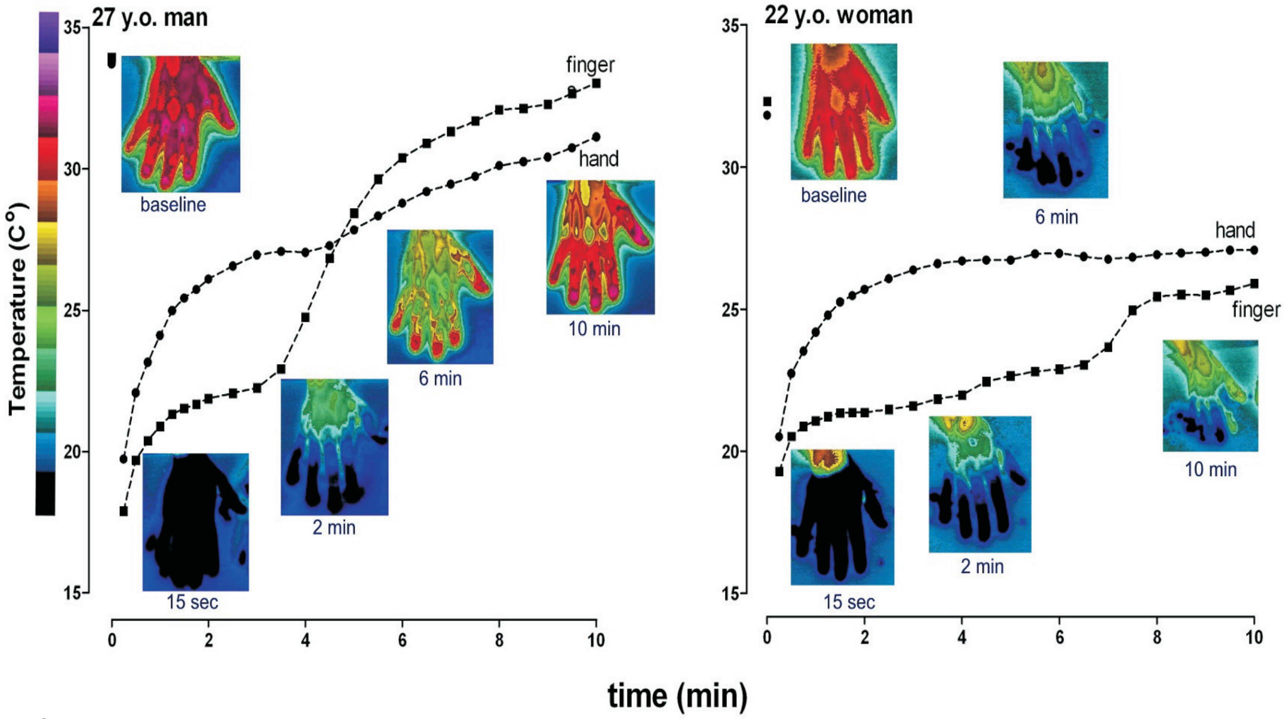

Figure 2.
Typical responses of the hand and fingers of a man and a woman following a 30-second immersion in ice water.

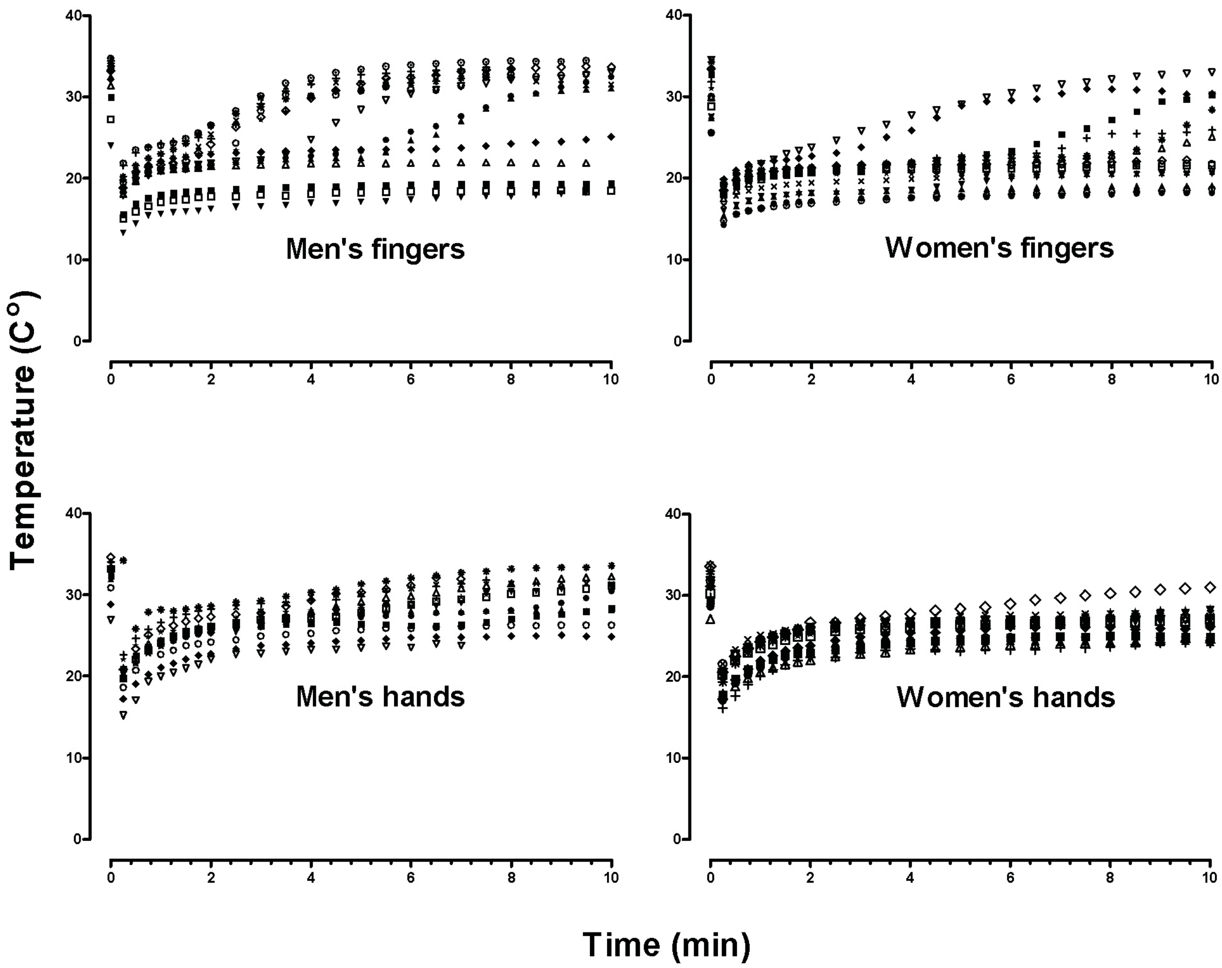

Figure 3.
Differences in finger and hand rewarming patterns observed in men and women following a 30-second hand immersion in ice water.

After a 10-minute recovery period, men's hands had rewarmed to 91.5 ± 1% (m ± SEM) of baseline, significantly more than the 86.5 ± 0.9% observed in women ($P < 0.01$). Men's rewarmed fingers also returned closer to baseline than women's did, 89.5 ± 3.1% and 77 ± 3%, respectively ($P < 0.01$). Figure 2 illustrates the typical rewarming patterns observed in men and women.

The rewarming patterns shown in Figure 3 indicate that significantly more men (13/18 or 72%) than women (4/16 or 25%) rewarmed to within 90% of baseline during the 10 minutes following withdrawal from the ice water (Fisher's exact test, $P = 0.015$). We subsequently regrouped our subjects based on the rewarming level attained. The **slow** group included those whose fingers rewarmed to less than 90%, and the **fast** group contained those whose fingers rewarmed to 90% or more of baseline (Table 3).

Figure 4 illustrate the rewarming patterns for fast and slow rewarmers. The **fast** group had significantly warmer fingers even at baseline, and then rewarmed to within 10% or less of their baseline level (Table 3). The **slow** group had cooler fingers at baseline and cooled to a lower temperature than the fast group ($P < 0.01$), The **fast** group had significantly warmer fingers and hands at baseline, and did not cool to the same extent as the slow group (Table 3).

We analyzed the individual rewarming patterns using the rewarming index (RWI) defined as the percentage of baseline temperature as a function of time. By 10 minutes the RWI averaged 96.6 ± 3.5% (mean ± SEM) and 73 ± 6.2%, fast and slow groups, respectively (Figure 4). Typically, the average finger rewarming occurred in 2 phases in both groups. showing similar exponential increases in the RWI for the about 2 minutes. Subsequently there was a step increase in RWI with the fast fingers reheating to a higher level. The rewarming patterns of the hands were similar but not as pronounced as the fingers, RWI was 92.8 ± 3% and 85.6 ± 2.92%, fast and slow groups respectively (Figure 4).

Contralateral Side: Both overall and within each sex, there were no significant differences in baseline temperatures between the hand and fingers to be immersed and the contralateral hand and fingers. Immediately post-immersion , the skin temperature of both the contralateral hand and finger had cooled significantly ($P < 0.001$) in both men (hand by -0.31 ± 0.25° C, finger by -0.96 ± 37° C, mean ± SD) and women (hand by -0.37 ± 42° C, finger by -0.8 ± 0.5° C), with fingers cooling significantly more than hands ($P < 0.001$) in both sexes

When the contralateral hand and finger were analyzed by **fast** and **slow** groups, distinct patterns again emerged (Figure 5). Although the contralateral temperature immediately following withdrawal from ice water was significantly lower in each group, the *fast* group's average contralateral hand and finger temperatures reached their nadir significantly faster ($P < 0.01$) than the average time of decline in the *slow* group's contralateral hand and finger temperatures(Figure 5) . During the 10-minute rewarming period, the *fast* group returned to baseline temperature whereas the *slow* group's did not reach pre-challenge levels (Figure 5).

Discussion

Thermoregulation is a complex system involving physical, chemical and behavioral processes that enable body temperatures to be maintained within a restricted range under conditions of variable internal or external heat loads (1) .

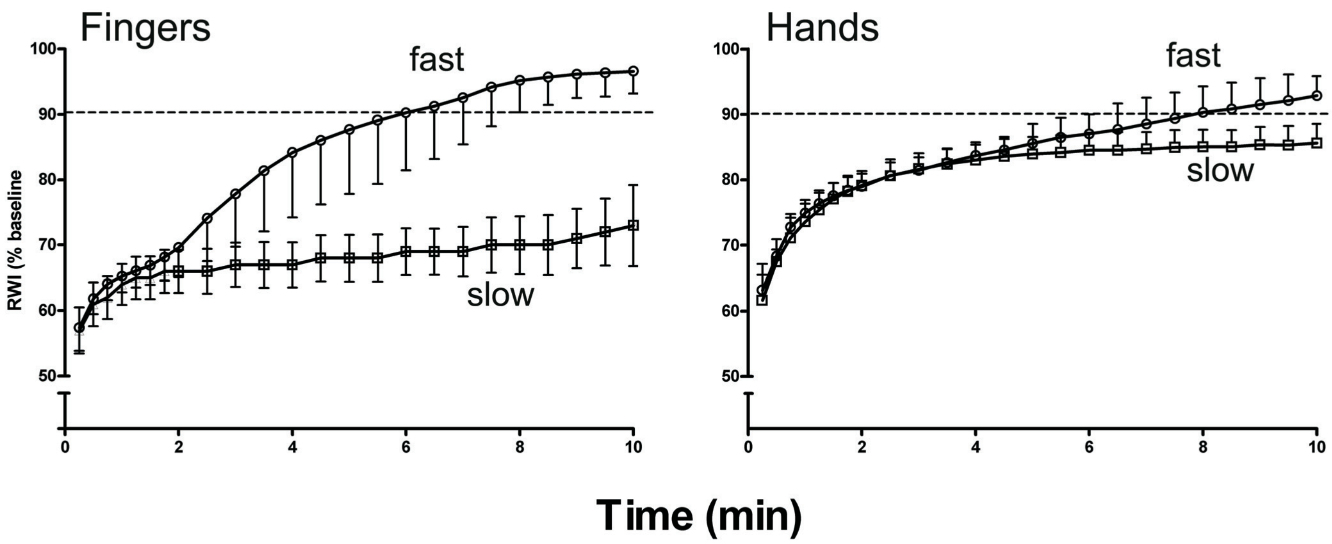

Figure 4.
Average **hand** and **finger** rewarming pattern (mean ± SEM) in subjects who rewarmed to = 90% of baseline (**fast** rewarmers) and those who didn't (**slow** rewarmers). The two equations describing the **Fast** group's **finger** rewarming were:
$RWI = 51.6 + 16.7 (1-e^{-1.77})$, and $RWI=51.6 + 16.7(1-e^{-1.77}) + 31.0(1-e^{-0.3(t-1.75)})$. The **Slow** group's **finger** equation were: $RWI = 51.7 + 15.0 (1-e^{-1.89})$ and $RWI = 51.7 + 15.0 (1-e^{-1.89}) + 0.017(t-2)^3-0.14(t-2)^2+ 0.86(t-2)$.
For the **hands**, the **Fast** group's equations were $RWI =54.8 + 25.1(1-e^{-1.62t})$ and $RWI=54.8+25.1(1-e^{-1.62})+34.1(1-e^{-0.05(t-2)})$. The **Slow** group's **hand** equations are $RWI = 56.1 +26.8(1-e^{-1.03t})$ followed by $RWI = 56.1 =26.8(1-e^{-1.03t})+2.5(1-e^{-0.49(t-4)})$.

Skin temperature reflects the sum total of these processes. Under conditions consonant with thermal comfort, heat is carried via blood perfusion from central “warm” locations to the superficial skin layers where it is lost to the environment by radiation and convection. Under these conditions, skin temperature of the hand and fingers ranges between 30–33° C (10, 11). Temperatures for our group fell within the expected range, and are similar to published data using a variety of temperature measuring instruments (12,13).

The sex differences we observed are consistent with published studies (14) and reflect a variety of differences between men and women that result in greater heat loss in women’s hands and fingers. One factor—supported by our data—is the higher surface-area-to-volume ratios for women which has been shown to result in greater heat loss (14) . The difference in surface-area-to-volume ratio within each group, however, did not correlate to rewarming patterns observed.

We were unable to properly evaluate two other factor that have been proposed to explain sex temperature differences. We were unable to measure sex differences in sympathetic tone or sex hormone levels. Sympathetic tone has been postulated as resulting in observed sex difference in cutaneous circulation (15, 16). Skin blood flow, and consequently temperature, may also vary with sex hormone levels (3,4,8,12,16) . Basal flow (and thus temperatures) is lowest during the luteal phase, which is the time of greatest cold-induced vasoconstriction and lowest recovery, and basal temperatures are highest in the pre-ovulatory phase (12,17). However, the majority of the women we tested were either on birth control pills or post menopausal and the remainder was not large enough to yield sufficient statistical power. We cannot, therefore rule out a possible hormonal influence in blood flow regulation and consequent rewarming pattern. Published data, however, indicate that, regardless of a statistically significant hormone-associated

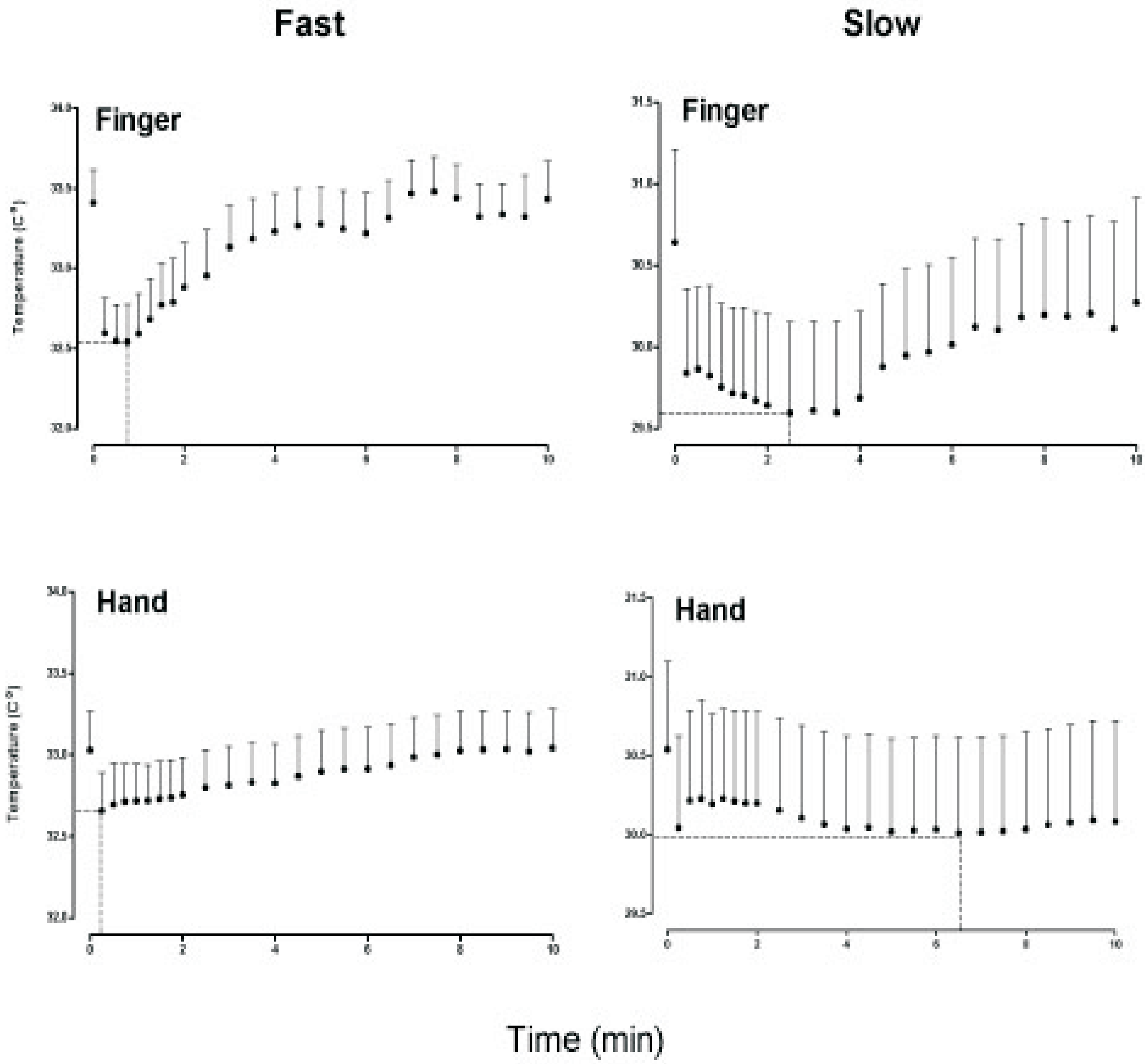

Figure 5
Contralateral hands and fingers rewarming pattern in the Slow and Fast rewarming groups. Each data point represents the group mean at that time ± SEM. Dotted line indicates the lowest temperature achieved.

difference in response to local cooling, women on average have blunted rewarming patterns compared to men (17).

The observed drop in surface temperature has been attributed to a marked vasoconstriction mediated by an increased contractile response of blood vessel walls to noreinephrine mediated by the α_2-adrenergic receptor in vessel walls (5) . Most previous data on local cooling, however, used controlled water baths, plethysmographs, or blocks of various metals cooled to different temperatures (12, 17,18). Published temperatures varied from -20°C to 16°C, with the higher temperatures used in evaluating vasospastic conditions such as Raynaud's disease. We chose immersion in a water bath containing ice cubes because it did not require any controlling elements to maintain a constant temperature (3-5°C). Because local cooling at these temperatures results in marked vasoconstriction that is capable of reducing blood flow to nearly zero, skin temperatures in our subjects immediately after immersion were somewhat lower than those previously reported (12,17,18).

The temperature drop in the immersed hand has been attributed to marked vasoconstriction. The temporal coincidences, first between the fall in contralateral temperature following im- mersion, and the increase in temperature in the 2nd phase of the rewarming pattern in the fast rewarmers fingers mirrored in the warming in their contralateral finger suggests that rewarming may, in part, be controlled by centrally mediated vasomotor reflexes. This is supported by Cankar et al's (14) demonstration that cooling resulted in significant reduction in contralateral finger blood flow, which they attributed to vasoconstriction triggered by increased sym pathetic tone via a neural reflex initiated from the immersed hand.

Conclusion

Our data indicate a broad spectrum of hand skin and finger skin temporal rewarming patterns that may be determined, in part, by the intensity of a central neural reflex initiated in the immersed hand. Although many more women than men exhibited a slower rewarming pattern, the fact that roughly 25% of the male subjects were **slow** rewarmers and 25% of the female subjects were ***f*ast** rewarmers, makes it apparent that the *slow–fast* difference is not solely attributable to sex.

This overall distribution of rewarming patterns may help explain the higher prevalence of vasospastic syndromes from exposure to cold, such as Raynaud's phenomenon, in women than in men (16, 19, 20).

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Address for Correspondence

François Haas, Ph.D.

New York University Medical Center

400 east 34th Street, New York, NY 10016

Phone: 1212-263-6127, Fax:1212-263-7980

Email:francois.haas@med.nyu.edu

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20th Thermological Symposium of the Austrian Society of Thermology

What is the place of thermal imaging in medicine ?

17th November 2007, Rosa Saal, Belle Etage, SAS Hotel, Vienna, Parkring 16

Programme

Chair: K Ammer (Austria), Anna Jung (Poland)

9.00 O. Rathkolb (Austria)
Welcome address

9.05 K Ammer, T. Schartelmüller, (Austria)
The value of thermal imaging for the diagnosis of Thoracic Outlet Syndrome
9.25 Discussion

9.30 Jan Hendrik Demmink (Norway)
The Net Temperature Increase In the Context of Ultrasound-Induced Heat.
9.50 Discussion

9.55 E.F.J,Ring A Jung , J.Zuber, P.Rutkowski , B.Kalicki , U.Bajwa (UK/Poland)
Thermometry, Radiometry and Thermal Imaging for Fever Detection in Children.
10.25 Discussion

10.30 J.B. Mercer (Norway)
Dynamic Thermal Imaging and Its Role In Medicine
10.55 Discussion

11.00 Coffee Break

Chair: H.Mayr (Austria), F.Ring (UK)

11.30 K. Ammer (Austria)
Three methods of evaluation of thermal images from patients with suspected Raynaud's phenomenon
11.50 Discussion

11.55 J.R.Harding (UK)
Raynaud's Phenomenon: Cold Hands = Warm Heart, But What About Cold Noses
12.15 Discussion

12.20 E,Stikbakke J.B. Mercer (Norway)
An Infrared Thermal Imaging and Laser Doppler Flowmetric Investigation of Skin Thermal Inertia in the Forearm and Hands Following A Short Period of Vascular Stasis
12.35 Discussion

12.40 R.Vardasca, U. Bajwa (Portugal/Pakistan)
Extracting Outlines Of Hands From Thermal Images
12.55 Discussion

13.00 R Berz (Germany)
Breast thermal imaging: The challenge of the BI-RADS classification
13.20 Discussion

13.25 R.C. Purohit (USA)
The Future of Thermology in Veterinary Medicine
13.55 Discussion

14.00 Close

Abstracts

20th THERMOLOGIOCAL SYMPOSIUM. WELCOME ADDRESS

O.Rathkolb

Austrian Society of Thermology, Vienna

The first Thermological Symposium was organised in Oktober 1988 by the Ludwig Boltzmann Research Institute for Physical Diagnostics (LBF Phys Diag), 9 months before the Austrian Society of Thermology was founded. However, the collaboration between this two institutions lasted until the LBF Phys Diag, ceased all research activities in 2005. Speakers at this first symposium were Prof Ring, who should participate in most of the following Austrian Symposia up to date, Prof Ammer, founding member and president of the Austrian Society of Thermology and Prof Partsch, one of pioneer of thermal imaging in Austria for clinical use in dermatology. The venue was the SAS Palais Hotel which was found to be approriate for other symposia organised by the LBF Phys Diag in the future. Proceedings with all lectures of this symposium were published., being the basement from which the journal Thermologie Österreich derived.

Up to date 19 other symposia followed, four of them included in international conferences (1997 7th European Congress of Thermology, Vienna, 2001 5th International Congress of Thermology, Vienna, 2003 9th European Congress of Thermology, Krakow, 2006 10th European Congress of Thermology, Zakopane). In total, 152 papers were presented at the previous 19 meetings, Authors from 14 different countries (Austria, Belgium, Brazil. Germany, Italy, Norway, Romania, Poland, South Korea, Slovakia, UK, USA,Yugoslavia) all around the world attended. Full length versions of the lectures of the 1st and 3rd Symposium have been published in proceedings, the abstracts of the second symposum appeared in ThermoMed, the abstracts of all other symposia in Thermologie Österreich, European Journal of Thermology or Thermology international.

THE VALUE OF THERMAL IMAGING FOR THE DIAGNOSIS OF THORACIC OUTLET SYNDROME

K Ammer [2,3], T. Schartelmüller [1,3] (Austria)

[1] Institute for Physical Medicine and Rehabilitation, Privatklinik Döbling, Vienna,
[2] Institute for Physical Medicine and Rehabilitation, Hanuschkrankenhaus, Vienna
[3] Austrian Society of Thermology, Vienna

In 1993 Schartelmüller and Ammer (1) established a protocol for thermal imaging in patients suspected of Thoracic Outlet Syndrome (TOS). With some modification(2) this protocol is routinely used since 1994 for the thermographically assisted diagnosis of Thoracic Outlet Syndrome. Temperature measurements were also applied as outcome measure in a clinical trial on the effectiveness of exercise therapy in patients with thoracic outlet syndrome (3). Temperature readings from thermal images recorded from patients with thoracic outlet syndrome showed a high degree of inter- and intra-rater repeatability (4).

About 1000 subjects underwent routinely this investigation, since thermal imaging was included in the diagnostic pathway for TOS. A temperature difference of 0.5 or more degrees between index and little finger in at least two provocative arm positions is regarded to be diagnostic. However, the definition of regions of interest may be time consuming, especially in cases when the contrast between cold finger tips and the image background is low. An alternative method based on the mean temperature value of a line over the finger of interest obtained high degree of agreement with the estabilished way of analysis (5). However, the new method is less time consuming and more robust in images with low contrast between fingers and background**.**

The thermal images of 210 cases (156 females, 64 males) were quantitatively re-evaluated. In 115 image series did not show pathological findings and have been classified as normal (55 on the left hand side, 60 on the right hand side). Definite TOS affecting the little finger was detected in 49 left hands and 44 right hands, a definite cold index finger was observed in 6 hands (3 right and 3 left hand side) only. 102 image series showed temperature changes that indicated a probable TOS on the little finger (48 left hand, 54 right hand). A possible TOS (little finger) was seen in 80 hands (42 left hand, 38 right hand). The remaining cases were 9 times classified as probably TOS (index) and as possible TOS (index) in 15 other cases. There was no significant difference in age between the different classes of TOS, with the exception that patients with probable or definite cold index finger at the right hand side had a higher age as subjects without symptoms or with TOS symptoms at the little finger. At the right hand, males had also less definite and probable TOS symptoms at the little fingers than females.

Thermal imaging is the only method that provides pictorial information of functional changes caused by compression of the brachial plexus. It is a complementary diagnostic test and can be used as outcome measure in clinical trials with patients suffering from Thoracic Outlet Syndrome

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THERMOMETRY, RADIOMETRY AND THERMAL IMAGING FOR FEVER DETECTION IN CHILDREN

EFJ Ring [1], A Jung [2], J Zuber [2], P Rutkowski [3] , B Kalicki [2], U Bajwa [1]

University of Glamorgan UK, Military Institute of Medicine, Warsaw, Flir Systems Poland.

[1] Medical Imaging Research Group, Faculty of Advanced Technology, University of Glamorgan, Pontypridd, UK
2 Pediatric, Nephrology & Allergology Clinic, WIM, Warsaw Poland
3 Flir Systems AB Warsaw ,Poland

Recent interest in fever detection for airport screening of passengers has shown the lack of data, outside conventional clinical thermometry. Increasing use is now being made of simple ear radiometers for routine clinical temperature measurement. These devices are known to have limitations, and the technique and the variability of the human auditory canal add to the uncertainty of results.

This study has been conducted at the Paediatric Department of a major Hospital in Poland. The aim of this study is to investigate the possibilities of thermal imaging of the face being used as a reliable indicator of fever in children. In the screening context, thermal imaging has many advantages over other methods, given the need for rapid and objective evidence to exclude a travelling passenger with a raised temperature from increasing the risk of spread of infectious disease (such as H5N1 or similar viruses). In earlier reports on the SARS outbreak temperatures over 38^{0}C were classified as febrile, and made to undergo a simple clinical examination and have temperatures confirmed by thermometry.

To date, 106 children aged from 3 months to 16 years have been tested in the clinical using a clinical thermometer in the axillary, under arm position, and thermal imaging of the anterior face. The ambient temperature has been maintained at 22 – 23^{0}C. The subjects were seated before the camera, and in front of a cloth screen. Thermal images were recorded, and regions of interest around the eyes and centre forehead were used. Mean and maximum temperatures from these regions of interest were determined.

RESULTS: In total, 96 of 106 subjects recorded temperatures in the normal range (defined as <37.5^{0}C) axillary, and had no direct disease or clinical problem affecting their temperature. Ten children had raised temperatures >37.5 with 3 being 38°C and over. Forehead temperatures were consistently lower in value than the inner canthi of the eyes.

AFEBRILE CHILDREN			FEBRILE
Anat.site, n=96	Mean temp °C	S D	Temp. Range n=10
Forehead	34.9	0.51	36.3 – 37.2
Inner Canthi	36.4	0.52	37.3 – 38.6
Axilla	35.9	0.81	37.5 – 39.0

A moderate correlation was found between the canthus eye temperatures and the forehead temperatures from the analysis of the frontal face thermograms. r=0.66

Thermal Imaging of the face in children is an efficient means of identifying the presence of fever. Potential artefacts caused by sinus infection, even prolonged crying in children, and may elevate the maximum temperatures recorded over the inner canthi of the eyes. However, the use of a carefully placed clinical thermometer (oral or axillary site) is sufficient to exclude the presence of clinical fever. Further data is being collected on healthy and febrile children. Thermal imaging for screening of travelling passengers may prove to be a suitable and rapid tool, with the inner canthi being the measurement site of choice

THE NET TEMPERATURE INCREASE IN THE CONTEXT OF ULTRASOUND-INDUCED HEAT.

Jan Hendrik Demmink

Bergen University College, Faculty of Health and Social Sciences, Department of Physiotherapy. Norway

PURPOSE: Dosage is the energy supplied to the patient's tissue during a session. Ultrasound power is measured and expressed in watt (W) and the energy in watt-minutes (Wmin). The dosage can equally well be stated in Wmin/cm2. The main purpose of the application is to produce a specific temperature in the depth of the tissues. This study tried to show the connection between the energy output of ultrasound and the temperature inside the tissue.

RELEVANCE: The study relates the energy output of ultrasound with the temperature, in proportion to the depth, inside the tissue.

PARTICIPANTS: The study used a fresh pig cadaver hind leg, fixed by stainless steel nails to a wooden shelf. The camera was positioned at the end of the shelf to keep a distance of 40 cm to the tissue face. The tissue was equilibrated to 15°C in saline and recorded in a temperature-regulated environment.

METHODS: A ThermaCAM S65HS thermal imaging system of Flir Systems AB was used. Comparisons were made between the net temperature increases using 3MHz continuous ultrasound with 2W min/cm^2, 1W min/cm^2, 0.5W min/cm^2, 0.25W min/cm^2, 0.07Wmin/cm^2 and 0.05Wmin/cm^2 spatial average intensities, respectively. The treatment time was set at five minutes. All thermal images after five minutes were compared with the reference image, being the starting image without insonation.

ANALYSIS: During the actual computerized comparison, every temperature data point from the reference image is "subtracted" from the thermal image. In this way, it is possible to create patterns of relative heating. The temperature difference was measured for every millimeter on a perpendicular line based at the location of the center of the ultrasound applicator.

RESULTS: The study found a maximum temperature difference of 17°C with 2Wmin/cm2 at 0.5 cm depth and that the mean temperature at more then 1 cm in depth of the tissue was 1°C.

CONCLUSIONS: We found that ultrasound induced heat therapy only can insist if the intensity of ultrasound was set to 1Wmin/cm2 or more. It may be questioned whether ultrasound induced heat can bring about the desired temperature increases in the target tissue in order to achieve a beneficial thermal effect.

IMPLICATIONS: Using thermal outcome measurements in clinical trials with ultrasound therapy means that the intensity has to be set at 1Wmin/cm2 or higher with continuous ultrasound.

DYNAMIC THERMAL IMAGING AND ITS ROLE IN MEDICINE

J. Mercer

Department of Medical Physiology, Faculty of Medicine, University of Tromsoe & Departmet of Radiology, University Hospital of North Norway, Tromsoe, Norway

Infrared thermal imaging in medicine is based on analysis of skin surface temperatures as a reflection of normal or abnormal human physiology using specialized IR-cameras. In a fraction of a second, a large surface area of the human body can be imaged to an accuracy of less than 0.1°C. There are many situations where skin surface temperature can clearly be directly correlated to skin blood perfusion. This undisputable fact forms the basis for the use of thermal imaging in medicine. Asymmetric images may also provide valuable information, with diagnostic value. There are, however, situations where it is difficult to obtain adequate information on the dynamics of skin perfusion, for example from static thermal images. These difficulties can often be overcome with dynamic infrared thermal imaging. The technique of dynamic infrared thermal imaging is based on the relationship between dermal perfusion and the pattern and response of skin surface temperature following the application of a transient local thermal challenges. Rapid physiological changes can be readily registered with the new generation of infrared cameras. The information can be easily analysed using infrared cameras that employ, for example, fire-wire technology. This new development allows real time analysis of radiometric images. Having access to this technology provides an enormous advantage in the use of infrared thermal imaging. This is especially important since being able to measure rapidly changing skin temperatures opens up a whole new field of possibilities for this technique. Examples of the use of dynamic thermal imaging will be presented in both research and routine clinical situations.

THREE METHODS OF EVALUATION OF THERMAL IMAGES FROM PATIENTS WITH SUSPECTED RAYNAUD'S PHENOMENON

Kurt Ammer

[1] Institute for Physical Medicine and Rehabilitation, Hanuschkrankenhaus, Vienna
[2] Austrian Society of Thermology, Vienna

Diagnosis of Raynaud´s phenomenon may be assisted by the results of temperature changes after immersion of hands in water of 20°C. However, a standard for evaluation of temperature changes is not yet established. Francis Ring has proposed a Thermal Index by combining the temperature gradients from the dorsum to the fingers prior and past the cold challenge. Others determined the gradient of single fingers or used the slope of the rewarming curve.

Three methods of evaluation of temperature readings from thermal images were compared in hands of 26 subjects after cold challenge. The cold stress test- tool of the software package C-Therm was used for the calculation of Ring's Thermal-Index. Alternatively areas over single fingers were defined and gradients of single fingers were calculated by substracting the mean temperature of the dorsum from the mean temperature of finger areas (FG1=finger gradient 1) Temperature gradients for single fingers were also determined in the following way: Spot temperatures were measured on the tip and over the mid of metacarpal bone of each finger. Gradients were calculated by subtracting the metacarpal temperature from the temperature of the finger tip (FG2=finger gradient 2). The mean value of the temperature gradients of all fingers of the right and the left hand were calculated.

The difference of both mean temperature gradients of fingers prior, 10 or 20 minutes past cold challenge were compared with the findings of the Thermal Index for the same periods.

Comparison of the thermal index 10 minutes and 20 minutes past cold challenge, obtained a mean decrease of the Thermal Index of 0.32 ± 1,0 at the later measurement. The absolute values of the mean FG1 were 0,93 to 1,28 greater than the related Thermal Index. The differences between FG2 and the thermal index were 0.1 to 1. However, analyzing all thermal indices with non parametric tests obtained no significant differences between the indices. Single measure interclass correlations revealed values between 0.74 and 0.82.

Using a threshold of –4.0 for a diagnostic thermal index, the highest number of cases with Raynaud's phenomenon were identified with TG2, followed by TG1 and the C-Therm derived Thermal Index

In conclusion, after cold challenge a high correlation was found between the Thermal Index determined by the dedicated tool of the software package C-Therm and an alternatively calculated Thermal Index based on the temperature gradient of single fingers. However, the Thermal Index derived from the temperature gradients of single fingers may by more sensitive for diagnosis than the Thermal Index generated by the C-Therm software package.

RAYNAUD'S PHENOMENON: COLD HANDS = WARM HEART, BUT WHAT ABOUT COLD NOSES?

Harding JR

St. Woolos & Royal Gwent Hospitals, Newport, South Wales, NP20 4SZ, UK.

Infra-Red Imaging of the hands and wrists is the accepted gold standard test for confirming or excluding Raynaud's Phenomenon, and is one of the most widely performed investigations in medical thermology. It can help differentiate between primary Raynaud's Disease and Raynaud's Phenomenon associated with connective tissue disorders such as systemic lupus erythematosis (SLE), scleroderma, Sjogren's syndrome and rheumatoid arthritis etc.

A fresh approach to the investigation of Raynaud's Phenomenon will be described and discussed.

In addition to the standard thermal imaging of the hands & wrists, images of the face were obtained at baseline following temperature equilibration, & skin temperature of the nose & forehead compared subjectively & objectively in 55 Patients attending for thermological assessment of clinically suspected Raynaud's Phenomenon. It was found that:

- Patients with no evidence of Raynaud's Phenomenon usually have a normal nose temperature.
- There is a very strong association of symmetrical Raynaud's Phenomenon with a cold nose.
- There is a less strong association of asymmetrical Raynaud's Phenomenon with a cold nose.
- Comparison of nose & forehead temperature may be a useful adjunct to conventional assessment of Raynaud's phenomenon.

AN INFRARED THERMAL IMAGING AND LASER DOPPLER FLOWMETRIC INVESTIGATION OF SKIN THERMAL INERTIA IN THE FOREARM AND HANDS FOLLOWING A SHORT PERIOD OF VASCULAR STASIS

Stikbakke E, Mercer JB.

Department of Medical Physiology, Faculty of Medicine, University of Tromsoe, Norway

Infrared thermal imaging examinations of patients suffering from cold extremities are well described. In many cases the starting point is warm extremities that are subjected to a cold thermal challenge. The thermal pattern and rate of recovery is then used for aiding the diagnosis. In many cases the patients arrive at the examination room with cold extremities and it may take some time to induce a vasodilatory state, often involving a variety of heating regimes, before the examination can commence. We wished to investigate the possibility of using reactive hyperemia as a test method for examining the circulatory status in patients with cold hands. In this pilot study seven healthy students of both sexes have so far been tested. The Regional Ethical Committee approved the experimental protocol.

During the experiments, which were carried out at room temperature, the normally clothed subjects sat in a comfortable stool while resting their hands (palm down) on a thin grid made of nylon netting placed 3 cm above an electric heating plate maintained at ca 39°C. Following a 15 minute control period to establish base line values a conventional blood pressure cuff, which was placed over the right upper arm, was inflated to 230 mmHg for a period of 3 minutes. The resulting changes in skin surface temperature of the lower arms and hands following cuff release (skin flushing) were continually recorded for a post-ischemic period of 5 minute by an infrared camera (Flir Therma CAM S65HS, Flir Systems, USA). In addition, skin perfusion was continually measured using 2 laser Doppler flow probes, one located dorsally near the centre of the right lower arm and the other located close to the dorsal tip of the 2nd right finger. In each subject the responses to the 3-minute ischemic period were tested 3 times. Preliminary results showed a good correlation between changes in fingertip temperature measured thermographically and changes in skin perfusion measured with the laser Doppler probe. However, on the underarm there were many situations when an increase in skin blood flow following the ischemic insult was evident from the laser Doppler measurements (reactive hyperemia) without a concomitant change in skin surface temperature. In one subject with cold hands it was not possible to induce a clear hyperaemic response indicating that our approach may have limited clinical value.

The results, furthermore, indicate that caution must be taken when using infrared thermal imaging to measure temperature changes associated with skin flushing in the proximal extremities

EXTRACTING OUTLINES OF HANDS FROM THERMAL IMAGES

Ricardo Vardasca*, Usama Bajwa**

* Medical Imaging Research Unit, Department of Computing and Mathematical Sciences, Faculty of Advanced Technology, University of Glamorgan, Pontypridd, Mid Glamorgan, CF37 1DL, UK
** Department of Computer Engineering, Center for Advanced Studies in Engineering, 19-Attaturk Avenue, G-5/1, Islamabad, Pakistan

Extracting object outlines in thermal images is a difficult task because of the frequently "shapeless" nature of objects when their temperature is in parts close to that of the background. Although a human operator can in many cases produce a reasonable manual segmentation this can be difficult and very time consuming when complex objects such as hands are analysed. Hands are physiologically those parts of the body (together with the feet) where body heat loss is highest, which makes it likely that they assume the temperature of the environment and are thus difficult to identify in the infrared domain. From all parts of the body hands are most difficult to segment. As a correct outline is needed for studying certain diseases such as arthritis, neuro-musculoskeletal injuries or circulatory pathology, exact segmentation, however, is required.

It is the aim of this study to investigate which of the many edge detection algorithms known from literature produce the best performance in these images. In order to study the effect pixel noise can have on this process a homomorphic filter was used prior to edge detection. This filter is suitable as it allows pixel noise produced by the imaging system to be modelled as an additive term to the original image.

From our existing database of 35 volunteers thermal images of 5 hands with the lowest hand/background contrast were selected to test 10 different edge detection algorithms. Images were processed by an application scripted in Matlab software, both with and without prior noise filtering.

For the extracted edges both a visual (subjective) and a quantitative (objective) analysis were performed. Both assessment methods concluded that the best outlining results are achieved when using a probabilistic based (Canny and Shen-Castan) edge detector together with homomorphic noise filter pre-processing.

BREAST THERMAL IMAGING: THE CHALLENGE OF THE BI-RADS CLASSIFICATION

Reinhold Berz

InfraMedic AG, Burgrieden-Rot,Germany

There is widespread use of infrared thermography examination devices for medical purposes in several European countries, going back to the 1970s. Recent generations of infrared cameras, representing a significant part of these devices, are now able to measure temperatures with a suitable geometrical and thermal resolution and with sufficient stability and reproducibility.

All medical devices with measurement functions are class one devices according to the European Medical Devices Directive (MDD) and the national legislation (e.g. in Germany Medizinproduktegesetz). In addition, every user of medical equipment has to ensure that medical devices are CE certified (in Germany Medizinprodukte-Betreiberverordnung). Class one devices have to comply with this directive and legislation and therefore have to CE certified as a medical device. This is much more than just to have a CE sign fixed to any IR camera (which of course every IR camera has). A medically valid CE certification is characterized by a CE sign followed by the code of the national certifying body.

As long as there was no infrared examination device in Europe meeting these criteria, a lot of physicians and clinics used infrared technology for medical purposes, not bothered by legislation. But now the situation has changed: In August 2007 the first medical infrared examination systems have been fully CE certified according to the medical devices directive.

InfraMedic (Germany) presented its infrared examination equipment MammoVision™, ReguVision™ and FlexiVision two years ago at the Vienna Thermological Conference. These systems now are CE certified meeting the MDD criteria. Mammo-Vision™ is dedicated to breast examinations, but it does not compete, rather it complements traditional breast imaging methods. MammoVision has high specificity in detecting women with extremely low risk of bearing or actually developing breast cancer through measurements from the breast surface temperature. MammoVision uses a sophisticated area definition (patented grid), semi-automated evaluation and the BI-RADS analogue assessment system BIRAS (Breast InfraRed Assessment System) to calculate the extent of enhanced breast metabolism as an indicator for benign or malignant breast conditions, completed by a detailed breast vascularity rating.

Now that there is a CE certified medical infrared examination system available, physicians and clinics using not CE certified infrared equipment are in danger of conflicting with European and national legislation. They will have to demand that their infrared equipment supplier achieves medically valid CE certification for their systems. Equipment bought not too long ago could have to be taken back by suppliers failing to get medical CE certification.

THE FUTURE OF THERMOLOGY IN VETERINARY MEDICINE

Ram C Purohit

Professor Emeritus,. Department of Clinical Sciences,
College of Veterinary Medicine, Auburn University, Alabama, USA

Infrared thermology has been used in veterinary medicine since the early 1960's. In early 1970's and 1980's significant scientific advances were made in both human and veterinary medicine. Lack of portable equipment limited its use in universities and teaching hospitals in veterinary medicine. Availability of advanced portable equipment in 1990's provided a valuable asset for advancement of thermology in the field practice of veterinary medicine. At the same time lack of acceptable standards for the use of equipment in medical practice created mistrust for the use of infrared imaging in veterinary medicine. To resolve this issue, would require the help of qualified medical and veterinary thermology scientists to institute following future practices for its use, are:

1. Standards for equipment to be used in medical and veterinary practice.

2. Training courses for veterinary professionals by qualified thermology scientists.

3. Guide lines for use of new equipments applicable in veterinary and medical practice.

4. Converting the old high quality thermology data, to be transported in the new usable format, so as not to duplicate the animal studies which have already been done.

5. Efficacy of its early detection of impending problem will allow veterinary and medical personal to enhance their diagnostic capabilities.

In conclusion, the future use of this technology will require qualified medical and veterinary professional to provide quality education and continuing education courses to bring recent advances in thermology in the field of practice.This may also require offering and teaching of continuing education courses to medical and veterinary professional personal.

Meetings

2007

8th December 2007

The 4th National Symposium of the Romanian Society of Thermology in Campina, Romania

Theme: The Investigation of Diabetic Leg

Conference President : Prof.Dr. Adriana Sarah Nica

Information: www. Srt.ro/english-index.htm

2008

16th-20th March 2008

Infrared Technology and Applications XXXIV (DS28) Part of the SPIE International Defense and Security Symposium

Venue Orlando World Center Marriott Resort and Convention Center • Orlando, FL USA

Conference Chairs: Bjørn F. Andresen, Elbit Systems Electro-Optics ElOp Ltd. (Israel);

Gabor F. Fulop, Maxtech International, Inc.;

Paul R. Norton, U.S. Army Night Vision & Electronic Sensors Directorate

Information: Bjørn F. Andresen, andresen@netvision.net.il
Gabor F. Fulop, gfulop@maxtech-intl.com
Paul R. Norton; p.norton@verizon.net

2nd -5th July 2008

QIRT 2008 - 9th International Conference on Quantitative InfraRed Thermography at the AGH University of Science and Technology, Krakow, Poland

Conference Organiser:Institute of Electronics
Faculty of Electrical, Electronic, Computer and Control Engineering of the Technical University of Lodz, Poland
and
Faculty of Mining Surveying and Environmental Engineering AGH University of Science and Technology, Krakow, Poland

The Quantitative Infrared Thermography (QIRT) conference is an international forum, which brings together specialists from industry and academia, who share an active interest in the latest developments of science, experimental practices and instrumentation, related to infrared thermography.

Following conferences in Paris (1992), Sorrento (1994), Stuttgart (1996), Lodz (1998), Reims (2000), Dubrovnik (2002), Brussels (2004), and Padova (2006), the 9th Quantitative InfraRed Thermography conference, QIRT2008, will take place on July 2-5, 2008 at the AGH University of Science and Technology, Krakow, Poland

CONFERENCE FEE

Regular participants:

The conference fee is € 300 (before May 15, 2008) and € 400 (after May 15, 2008).

The fee covers Conference Procedings, welcome reception and conference dinner, lunches and coffee break facilities, but not the accomodation.

Students:

The conference fee is € 150 (before May 15, 2008) and € 200 (after May 15, 2008). Without Conference Procedings, welcome reception and conference dinner, but including lunches and coffee break facilities.

Accompanying persons: The conference fee is € 100. The price includes welcome reception and conference dinner.

Pre-conference course

Preceding the conference, the following courses will be organised:

A - Basic Thermography,

B - Application to Fluids,

C - Application to Solids,

D - Medical Applications.

The Courses are scheduled on Wednesday, July 2, 2008.

The tuition is € 100 for one or more courses. Two courses will be presented in parallel, in the morning (A and B) and afternoon (C and D).

Concerning the QIRT, please consult the QIRT website.

QIRT Journal page: http://qirt.revuesonline.com.

QIRT 2006 page: http://qirt2006.pd.cnr.it.

CONTACT:

Please address inquiries to qirt@p.lodz.pl.

Secretary of QIRT2008
Technical Univesity of Lodz (TUL),
Institute of Electronics, Wolczanska 211/215,
PL 90-924 Lodz, Poland

Phone (+48) 42 631 2656, 2657, 2637
Fax (+48) 42 636 2238.

2009

24th-26th June, 2009

16th International Conference on Thermal Engineering and Thermogrammetry (THERMO), Budapest, Hungary

Information

Application Forms and abstracts/papers should be sent to:

Dr. Imre BENKÖ,
MATE Secretariat, House of Technology, III. 318.

H-1372 Budapest, POB. 451., Hungary

Fax: +361-353-1406, Phone: +361-332-9571.,
E-mail: mate@mtesz.hu

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Dr. Kurt Ammer
Österreichische Gesellschaft für Thermologie

Hernalser Hauptstr.209/14
A-1170 Wien
Österreich

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