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Infrared Thermal Imaging As A Tool In Pain Management - An 11 Year Study Part II: Clinical Applications

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Summary

ITI is a neurophysiological tool providing diagnostic and therapeutic information in patients suffering from neuropathic pain with neurovascular involvement. This information cannot be obtained from anatomical tests (e.g.,MRI or CT).

Bales Scientific Thermal Processor (Bales Scientific, Walnut Creek, CA)(762 patients) and Agema Cameras (Flir)(2,503 patients) were used for this study of 3,265 successive patients. A review of our experience with Infrared thermal imaging (ITI) and its role in pain management was conducted, and compared with the recent medical literature. The study was limited to the role of ITI in the management of complex chronic pain syndrome.

ITI is helpful in proper localization of hyperthermic foci due to iatrogenic permanent damage to thermosensory nerves, such as seen after repetitive sympathetic ganglion blocks; or due to sympathectomy or prolotherapy. As the result, the physician stays out of harms way by not causing further permanent damage. In addition, ITI identifies the spread of CRPS, pointing to the need for treatment of such spread. It helps differentiate migraine from neuropathic occipital neuralgia - two diseases requiring to contrasting treatments.

ITI has not been proven useful in evaluation of cervical and lumbar radiculopathies, stroke, and transient ischemic attacks. ITI can differentiate cervicogenic headaches from migraine - each requiring opposite forms of treatment. ITI is a useful prognosticator for diabetic foot pain, sparing some patients from amputation. ITI can spare patients from unnecessary carpal tunnel, spinal disc, and TMJ surgeries by identifying the original source of neuropathic pain. If ITI shows diffuse hyperthermia in the extremity already treated with repeated sympathetic ganglion blocks (virtual sympathectomy), such patients should be spared from undergoing further ganglion blocks. The hypothermic extremity after sympathectomy proves the futility of this and other ablative treatments such as chemical sympathectomy, or neurolytic blocks.

Key Words - CRPS, Headache, Sympathectomy ,Thermography.

Infrarothermographie als Hilfsmittel im Schmerzmangement-in 11 Jahres Studie, 2.Teil:Der klinische Einsatz der Infarrotthermographie

Die Infrarotthermographie liefert als neurophysiologische Untersuchungsmethode diagnostische und therapeutische Informationen über Patienten, die an neuropathischem Schmerz mit neurovaskulärer Begleitsymptomatik leiden. Diese Information kann durch keinen anatomischen Test (z.B.NMRI, Ct) zur Verfügung gestellt werden.

Ein Bales Scientific Thermal Processor (Bales Scientific, Walnut Creek, CA)(762 Patienten) und Agema (Flir)Kameras (2,503 Patienten) wurden in dieser Untersuchung an 3265 aufeionander folgenden Patienten verendet. Ein Überblick über unsere Erfahrungen mit der Infrarrotthermographie wird gegeben und der rezenten medizinischen Literatur zu diesem Thema gegenüber gestellt. Die Untersuchung wurde auf die Bedeutung der Infrarotthermographie im Management von Schmerzpatienten beschränkt.Die Infrarotthermographie hilft in der Entdeckung hyperthermer Zonen, die durch wiederholte iatrogene Schädigung der thermosensiblen Nervenfasern entstehen und die bei wiederholten Sympathikusblockaden, Sympathektomie oder therapeutischer Gewebe-Sklerosierung vorkommen.Durch solche Veränderungen

gewarnt,kann der Arzt weitere Schädigungen vereiden. Die Infrarotthermographie kann die weitere Ausbreitung Schädigungen vermeiden. Die Infrarotthermographie kann die weitere Ausbreitung eines komplexen chronischen Schmerzsyndroms (CRPS) anzeigen und auf eine notwendige Therapie dieser Ausbreitung hinweisen. Die Infrarot-Technik kann auch für die Differenzierung zwischen Migräne und neuropathischerOkzipitalneuralgie hilfreich sein, zumal diese Krankheitsbilder völlig unterschiedliche Behandlungen benötigen.

Die Infrarorthermographie ist wenig brauchbar in der Beurteilung von zervikalen oder lumbalen Radikulopathien, von Schlaganfall oder transitorischen ischämischen Attacken. Man kann aber mit ihrer Hilfe cervikogenen Kopschmerz von der Migräne unterscheiden. Die Infrarotthermographie hat prognostische Bedeutung bei Fussschmerzen von Diabetikern,und hat so manchen Patienten eine Amputation erspart. Ebenso können auf Grund von Infrarotbildern nicht notwendige Operationen wegen eines Karpaltunnelsyndroms, einer Bandscheibe oder chirurgische Eingriffe im Kieferbereich vermieden werden, da die Ursache eine neuropathischen Schmerzgeschehens eindeutig gefunden werden kann. Wenn die Infrarotthermographieeine diffuse Hyperthermie bei Patienten nach wiederholten Sympathikusblockaden zeigt, sind weitere Blockaden nicht mehr angezeigt. Eine hypotherme Extremität nach Sympathektomie beweist die Entbehrlich keit dieser und anderer destruierender Behandlungen wie z.B. die chemische Sympathektomie oder Nervenblockaden.

Schlüsselwörter - CRPS, Kopfschmerze, Sympathektomie ,Thermographie

The Role Of ITI In Selection of Nerve Blocks

ITI provides indispensable information which guides the physician to stay out of harms way, and to prevent iatrogenic trauma. One example is the role of ITI in selection of proper nerve block modality. Traditionally, the nerve block of choice in CRPS has been stellate ganglion nerve blocks. After more than a dozen stellate, or lumbar ganglion nerve blocks, the repetitive needle insertion traumatizes the ganglion enough to result in permanent hyperthermia in the extremity ("Virtual Sympathectomy") (1). In such patients, ITI of the extremity shows permanent hyperthermia in face of no pain relief. Kozin, in his review of 500 patients treated with sympathetic ganglion blocks, reported "the majority of patients have transient or no significant pain relief" (2). Another meta-analysis of retrospective and prospective randomized controlled trials of 1144 patients revealed the local anaesthetic sympathetic blockade was as ineffective as placebo in treatment of CRPS(3).

Outcome: ITI identified the "virtual sympathectomy" phenomenon, and spared the patients from further damage by canceling the procedure (1) (Table 1). Repetitive ganglion nerve blocks are routinely applied for diagnosis (4) and treatment of neuropathic pain such as complex regional pain syndrome (CRPS). However, Hogan et al (5), have reported only 27% of stellate ganglion block achieved the goal of ipsilateral warming to exceed the contralateral skin temperature. This 27% success is not worth the traumatic complications of ganglion blockade. Moreover, they noted (5) that cervical paratracheal blocks frequently failed to produce evidence of sympathetic interruption to the arm. The sympathetic ganglion blockade done in peripheral occlusive vascular disease or CRPS maybe potentially dangerous and harmful1 (1,2,3,6).

Sympathectomy

The sympathectomy results in partial hyperthermia, with compensatory contralateral extremity hypothermia, this result in the spread of pain in the contralateral extremity. Out of desperation, sympathectomy has been applied for treatment of causalgia since 1916 (7). The literature review of sympathectomy literature for treatment of CRPS shows high rates of failure. Welch et al (8) showed 13% successful results of sympathectomy in 8.4 years of long term follow-up. In contrast, Jebara and Saade, on their short -term sympathectomy ollow-up of 26-60 days among teenage soldiers showed very good results (9). Obviously, ablation surgery provides temporary palliative relief. The rest of the literature review shows random follow-ups and results (10). The high percentage group has been wartime soldiers which have been diagnosed early , undergone surgery within a few days , and sent home to be lost to follow-up (10-31). Realizing that children and teenagers (such as soldiers), show a strong plasticity and healing power as compared to adults (32,33), and realizing that early diagnosis and treatment is more successful (34,35),

Table 1.
The influence of treatment on CRPS stages during 2 years or longer follow-up in 824 patients. Amputation or sympathectomy deteriorate the disease from stage I to stage III.

Characteristics of treatment (824 patients)	**Stage I **** number of patients**	**Stage II number of patients**	**Stage III number of patients**
History of Amputation * 11 Patients (1.3%)	0 (0%)	2 (19%)	9 (81%) (P=0.025)
Chemical Sympathectomy 13 Patients (1.5%)	0 (0%)	2 (15.4%)	11(84.6%)
Surgical Sympathectomy 22 Patients (2.6%)	0 (0%)	3 (13.6%)	19 (86.4%)
Surgical Treatment ** 295 Patients (36%)	24 (8%)	106(36%)	165 (56%) (P<0.001)

(*) Many patients had more than one treatment modality which change the total percentage.
(**) Sympathectomy; rotator cuff; thoracic out syndrome; compression neuropathy; exploration; etc.
(***) Stage I = Dysfunction; Stage II= Dystrophy; Stage III= Atrophy.
(****) According to the type of treatment stage III may reverse to stage I and vice-versa.

Table 1A. Surgical and Non-Surgical Group

Group Type	**Stage I**	**Stage II**	**Stage III**
Surgical Group 320 Patients	24.7% 79 Patients	33.13% 106 Patients	59.8%***** 135 Patients
Non - Surgical Group 528 Patients	31% 164 Patients	36% 190 Patients	33% 174 Patients

***** Note high percentage of stage III in the surgical group

explain the beneficial, albeit temporary, results of wartime sympathectomy. In contrast, the sympathectomy done in stage III CRPS*(table 1A) has been reported to show zero percent relief (36). Usually, by the time the physician resorts to the sympathectomy procedure, the patient is in advanced stages of the disease. In such late stages, the nervous system has lost its plasticity and cannot respond properly to surgical sympathectomy (37,38). More over, the disease spreads (1,37,39-44) to other parts of the body; hence a regional sympathectomy will not be of any benefit to the patient.

Outcome: ITI showed failure of sympathectomy to relieve the vascular dysfunction. Thermal imaging done in patients who underwent surgical or chemical sympathectomy showed a high percentage of surgical failure(45,46).

Prolotherapy and Articular Facet Blocks

Articular facet joint blocks and prolotherapy (injection of sclerotic agents to ligament surrounding the joints) act as new sources of trauma and pain originating from the injured vertebral facet joint. In contrast, spinal epidural and paravertebral blocks do not cause chemical (sclerotic) damage due to injection of hypertonic glucose or phenol as in the case with prolotherapy. These blocks should not be mistaken for articular facet injections. The facet injections should be avoided to prevent harmful facet joint damage. According to Cheema (47)

Table 2.
Stages of CRPS

Stage I:
Dysfunction: with thermal changes, neuroinflammation, neurovascular instability, neuropathic pain, vasomotor and flexion spasm.
Stage II:
Dystrophy: hair, nail, and skin trophic changes; bouts of hair loss, alopecia, skin rash, spontaneous subcutaneous bleeding, ulcerative lesions, edema, and entrapment neuropathy.
Stage III:
Atrophy: as well as fluctuating vital signs, visceral neuroinflammation, chest pain, neurovascular instability.

paravertebral nerve block provides effective pain relief for both sympathetically maintained pain and sympathetically independent pain. This is in contrast to articular facet (zygoapophyseal) blocks which are fraught with painful joint injuries (due to needle traumatizing the joint). Bogduk et al (48) have reported only 40% pain relief from radiofrequency treatment of the facet joints. The same applies to prolotherapy which is done by injection of

Table 3.
Neurophysiologic tests for neuropathic pain and somatic pain.

Tests	Somatic	Sympathetic	Para-Sympathetic	Nerve Fiber Type	Clinical application	Limitations	Advantages
EMG; NCV	+	-	-	Somatic, myelinated nerves	Study of efferent spinothalamic nerves	It cannot study the thermoreceptor or vasomotor function	Neuromuscular and myelinated somatic nerve study
Infrared Thermal Imaging (ITI)	-	+	-	Microvascular and C-thermoreceptors	Sympathetic function	Shows old and new pathlogies indiscriminately	A total body regional study
Laser Evoked Potential (LEP)	-	+	-	Poorly myelinated C- fibres; Aδ	Study of peripheral and central neuropathic pain	Mainly research	Study of C, Aß, and Aδ fibres
Microneurography (MCNG)	-	+	-	Post ganglionic sympathetic efferent C-fibres	Research on sympathetic efferents	Invasive, time taking, and painful	A research tool
Quantitative Sensory Test (QST)	-	+	-	C- thermoreceptors vs spinothalamic tactile nerves	Accurate test for thermoreceptors vs tactile somatoSensory nerves	Studies a limited area	Sensitive study of C-thermoreceptors vs somatic fibres
Quantitative Sudomotor Axon Reflex Test (QSART)	-	-	+	Parasympathetic; cholinergic, sudomotor nerves	Sweat function	Studies a limited area. It cannot study the thermal function	Sudomotor function
Somato-sensory Evoked Potential (SSEP)	+	-	-	Somato_ sensory nerve fibres	Identifies sensory nerve tracks	Not an autonomic test	Harmless

sclerosing agents (such as phenol) into the ligaments surrounding articular facet joints.

Outcome: Thirty-six patients had undergone Prolotherapy before they were referred to our Clinic. ITI showed focal hyperthermia in the area of Prolotherapy. None had effective long-term relief from this prolotherapy.

Distal Extremity Needle Insertion

In the area of original nerve damage, the hyperthermia points to damage and paralysis of vasoconstrictive function of sympathetic system (1). The hyperthermia area surrounded by hypothermia usually points to the apex of damaged thermosensory nerve resulting in heat leakage, as well as accumulation of substance P (49-51), and nitric oxide(52,53). This is an important therapeutic clue to help avoiding further trauma. Traumatic procedures such as surgical exploration, nerve blocks, botulinum toxin injection, capsaicin, or EMG needle insertion should not be applied to the damaged hyperthermic area in the extremity which may lead to further damage and aggravation of the condition (54-56).

Amputation

If at all possible, amputation should be avoided (57). All 11 painful amputee patients in our series (Table 1) who were referred to us after they had undergone amputation showed marked deterioration post-op. The surgical stump was the source of multiple neuromas with severe causalgic and ephaptic (11) CRPS II type of intractable pain. Amputation changed the CRPS from type I to type II by forming innumerable neuromas and nerve impingements in the surgical stump. Amputation should be avoided by all means due to its side effects of aggravation of pain and tendency for spread of CRPS. Dielissen et al (58) reported the results of amputation in 28 RSD patients who had undergone 34 amputations in 31 limbs. Only 2 of 28 patients reported partial pain relief. In 26 of 28 patients, stump involvement with RSD made it impossible to wear a prosthesis (57). ITI can identify the proper level of the extremity undergoing amputation (59). This spares the patient from losing any excess tissue in the amputee stump (59).

Outcome: ITI provided information that prevented amputation in 5 of 6 patients referred to us for evaluation and for consideration of amputation. Of the 5 patients, 4 showed enough warmth and intact circulation to prevent amputation. The 5th patient was found to suffer from diabetic neuropathy with multiple pathologic right foot fractures aggravated by 2 years of non-weight bearing. Under proper analgesia, the patient was instructed to start weight bearing. After 3 months, the fractures healed enough to avoid the necessity for amputation.

Neck And Back Pain

The 1970's and 1980's literature reflects confusing reports on diagnostic value of ITI in cervical and lumbar radiculopathies, back pain, disc herniation, and sciatica (54,56,60-66). More recent literature has reported that ITI has no consistent diagnostic value for the neck and back injuries (67-71). One reason may be the inconsistent delta-T measured by liquid crystal contact thermography (72) making it difficult to arrive at accurate "normal" values.

In the present study, the ITI done in patients suffering from failed spine, neck or back pain, and pain in the extremities revealed conflicting results - especially when compared with the thermal imaging tests done on the same patients in other laboratories. The confusion has its roots in technical limitations, and improper clinical applications of the test(67,68). Harper (73) and Chafetz (74) have successively reported 56% and 40% abnormal ITI of spine in the "normal" controls. In our daily lives, the spine undergoes minor injuries. Such preexisting minor injuries may show persistent minor abnormalities on ITI, contaminating the control studies. Lack of a consistent control standard handicaps the value of ITI in diagnosis of spine pathology. There have been repeated attempts to compare the physiological test of ITI with anatomical tests such as MRI and CT (75). This is an illogical comparison. ITI cannot be expected to diagnose disc herniation because disc bulging and herniation cannot be clearly represented on ITI. Conversely, MRI cannot be expected to identify micro neurosensory pathology.

Outcome: In the present study, the ITI done in patients suffering from failed spine, neck or back pain, and pain in the extremities revealed conflicting results - especially when compared with the thermal imaging tests done on the same patients in other laboratories. The confusion has its roots in technical limitations, and improper clinical applications of the test (67, 68).

Complex Regional Pain Syndrome (CRPS, RSD)

ITI can facilitate early diagnosis of Complex Regional Pain Syndrome (CRPS) (76), and can achieve a higher recovery rate among CRPS patients (10,11,34,77) by virtue of early diagnosis of the disease. CRPS cannot be accurately diagnosed by a single test. CRPS is a clinical diagnosis when the following four principles are met:

1. Neuropathic, hyperpathic, or causalgic pain;

2. Vasomotor disturbance, flexor spasm, or tremor;

3. Inflammation at some point in the course of the disease; and

4. Limbic system dysfunction in form of insomnia, agitation, depression, and poor memory (37,78).

Tests such as ITI are mainly helpful to obtain information regarding the nature and extent of the disease, and to guide the clinician in proper management of pain (11). ITI has the advantage of providing a comprehensive picture of the entire body temperature (79). In acute stage, the epicenter of the damaged area is usually hyperthermic (11,80). After a few weeks, the hyperthermic area shrinks. In some cases (80) the hyperthermia persists due to permanent damage to sympathetic nerve fibers (1). This is a harbinger of poor prognosis. The hypothermic area surrounding the hyperthermic epicenter of the damaged nerve reflects up-regulation and supersensitivity of sensory nerves to norepinephrine (81-84).

In chronic stages (85), the disease is manifested by a dysfunctional rather than an up-regulated sympathetic system (11,86-90). The neurovascular instability contributes to confusion and misunderstanding of ITI changes in CRPS. For example, spread of vasoconstriction to other extremities maybe mistaken for other diseases such as Raynaud's Phenomenon (90). The ITI, like any other test, cannot be expected to show 100% diagnostic sensitivity. Even with the cold water stress ITI testing (76,89), it is sensitive in 93 % of the patients, specific in 89 %, positive predictive value (PPV) of 90%, and negative predictive value (NPV) of 94% (76). Recently, Herrick et al (90), have found cold stress ITI useful to diagnose patients suffering from fracture who are at risk for CRPS.

Other diagnostic tests in CRPS

Lee and Weeks (91), in their meta-analysis of scintigraphic bone scan (SBS) (91)showed this test to be positive in no more than 55% of CRPS patients (71,91). EMG and NCV (92,93), or CT and MRI cannot be expected to detect the microscopic perivascular nerve dysfunction in CRPS. Even if a coincidental disc bulging is seen on MRI, surgical procedure in the inflamed region is apt to severely aggravate the CRPS (94-97). Quantitative sudomotor axon reflex test (QSART) (98) (Table 3) studies the post- ganglionic cholinergic sudomotor function of the sympathetic system (94,95,99,100), not the thermoregulatory function. Laser evoked potential (LEP) (Table 3) is a sensitive test for the study of capillary circulation (44, 101-103). It studies a small area of the body thereby limiting its overall extent of information. Quantitative thermal sensory evoked response test (QST) (44, 104,105) (Table 3) is sensitive and useful in studying the functions of c-thermoreceptors and A-beta mechanoreceptors in CRPS (104). This test identifies the threshold of somatic (spinothalamic)cold or heat touch sensation - versus neuropathic (sympathetic) cold or heat pain sensation.

Bilateral temperature changes in CRPS

The temperature difference between the two extremities (delta-T) should not normally exceed more than 0.4 -0.6º C (54,56). In early stages of CRPS, the ITI shows more than 0.50º C difference. In later stages, the temperature difference gradually disappears. The delta T between the two extremities is not statistically significant in CRPS patients. In contrast, comparing the same CRPS patients with non-CRPS group, the CRPS extremities were significantly colder than the control group (106). The cut off line to discriminate the patient from the control group was 0.61º C for accurate predictability of CRPS diagnosis (106). The equalization of function is due to symmetrical representation of autonomic changes at hypothalamic and spinal cord levels (107). Other pathologic changes such as asymmetrical foci of hyperthermia identify the site of the injury. These hyperthermic foci are usually a sign of damage to the nerve fibres causing hyperthermic ephaptic (in contrast to synaptic)(108) electrical discharges between the adjacent sensory nerve fibres. Frequently, the injured side may show a hyperthermic focus, compensated by

the contralateral normal side undergoing moderate hypothermia(109).

ITI Findings In CRPS Spread

In approximately 1/3 of CRPS patients, the complex regional pain and inflammation spreads to other extremities manifested on ITI test (98,110-114).The spread through paravertebral chain of sympathetic ganglia may be vertical, horizontal, or both (110,111,115,116).

Cryotherapy for CRPS

Repetitive ice application may result in chilblains (or perniosis) due to inflammatory areas of hyperthermia secondary to long term frost bite type of nerve damage by application of ice. The ITI helps diagnose this condition to discontinue the destructive cryotherapy. Basbaum (117), and others (118-121) have demonstrated lesions affecting large myelinated axons secondary to ice exposure. These lesions are in the form of Valerian degeneration and segmental demyelination (117,118,121). The cryotherapy causes iatrogenic hypothermia with islands of permanent hyperthermia due to frostbite nerve damage mentioned above.

Outcome: ITI was helpful in identifying the areas of thermosensory nerve damage, and as well as diagnosing the phenomenon of CRPS spread.

Diabetic Neuropathy and Diabetic Foot

In advanced stages of diabetic neuropathy, the disease is complicated by neuroinflammatory changes, fractures (Charcot's foot), and by foot ulcers (122-125). The ITI changes in these patients are the prototypical examples of nerve damage causing irreversible hyperthermia in different degrees. Armstrong et al (122) have utilized ITI as the predictor of early sign of deterioration of ulcers and trophic fracture. They have used the high delta-T of 2º C between the involved and contralateral extremities to initiate therapeutic intervention.

Outcome: In our studies, in all 11 diabetic foot patients hyperthermic foci were observed. These 11 patients were referred to us for a second opinion before amputation. None of these patient ended up with amputation. ITI played a pivotal role in sparing these patients' extremities. The recognition of neuroinflammatory phenomenon (101) in these patients led us to treat them with weight-bearing, mobilization, nerve blocks, I.V. Mannitol, physical therapy, etc., sparing these patients from amputation as well as relieving neuroinflammation and pain with nerve blocks and I.V. Mannitol (100gm/500cc D5W treatment)(126,127).

Tennis Elbow

Outcome: ITI is useful in diagnosing Traumatic lateral epicondylitis (128,129), or tennis elbow. The ITI showed a focalized hyperthermia at the lateral epicondyle in 53 of 56 patients (95%)(128). Similar finding of hyperthermia is also noted in tarsal tunnel entrapment neuropathy. These areas of hyperthermia should not be aggravated by needle insertion. Any trigger point injection or nerve block should be performed proximal to the hyperthermic area. Injections aimed at the foot, ankle, hand, or wrist causes further trauma and up-regulation of the sympathetic system leading to a source of pain, and further thermal dysfunction (37).

Thoracic Outlet Syndrome(TOS)

Outcome: Another frequently over-diagnosed and over- treated syndrome in neuropathic pain is Thoracic Outlet Syndrome (TOS)(130). Due to the inflammatory nature of neuropathic pain, especially in CRPS in upper extremities, brachial plexitis is frequently mistaken for TOS and is improperly managed by surgery. The surgical procedure becomes a new source of neuropathetic pain, further deteriorating the condition (130,131). ITI has been instrumental in identifying the nature of pathology in distal portion of the extremity in form of ephaptic hyperthermia- pointing to the original source of pathology rather than the secondary inflammation of brachial plexitis. ITI spared such patients from surgery for TOS in 14 of 824 CRPS patients with presumptive diagnosis of TOS (37).

Cervicogenic Headaches

ITI can help diagnose and differentiate cervicogenic headaches from migraine. The cervicogenic headache shows areas of hyper - and hypothermia in the distribution of posterior sensory nerve branches of C2 through C4 nerve roots, and occipital nerves. Nerve blocks in these areas provide excellent relief (11,37). On the other hand, radiofrequency damage to articular facet (48,132,133), or rhizotomy (134) generates a new source of algogenic pathology, hyperthermia and more severe pain. Stimulation of the peripheral ends of the cut dorsal roots dilates cutaneus blood vessels (135). The retrograde activation of cutaneous sensory nerves leads to focal vascular changes causing neuro-

genic inflammation (136,137) due to the release of pro-inflammatory chemicals (50-53, 116, 138-159).

This vasodilation and inflammation explains the hyperthermia in the area of nerve injury. The trigeminal vascular sympathetic function is influenced by many factors including, but not limited to, chemical changes in the blood (160), craniovascular circulatory changes (161,162), and stimulation of trigeminal nucleus by referred pain originating from the posterior nerve branches of the C1 to C4 nerve roots (163).

Outcome: ITI helps identify the craniocervical hyperthermic areas, and differentiate this headache from migraine. Where as in migraine headaches thermal fluctuations are quite unstable, in cervicogenic headaches the hyperthermia is present in the occipital nerve region and the craniocervical junction (11). These two types of headaches require two opposite forms of treatment. Sumatriptan aggravates cervicogenic headaches; conversely nerve blocks do not usually relieve the true migraine headaches.

Migraine Headaches

Unfortunately the term migraine has been relatively loosely applied to any type of neurovascular headache, migraine or otherwise. This results in contamination of studies done on this subject. The ITI has been reported as having no value for evaluation of true, generic migraine headaches (160,164) excluding cervicogenic, TMJ, and Trigeminal nerve injury headaches. The migraine headaches cause craniofacial thermal fluctuations which are unstable and change in different stages of the migraine attack (115). Hypothermia over the ophthalmic branch of the trigeminal nerve has been reported on ITI of migraine patients (160). It is seen mainly during the acute attack as a transient phenomenon. Mathew et al (165), have reported thermal symmetry in 78% of headache - free volunteers. However, this symmetry can also be present in a high percentage of migrainous patients as well.

Outcome: More studies are needed regarding the role of ITI in true migraine.

Temporomandibular Dysfunction (TMD)

ITI sheds more light on the complex subject of temporomandibular dysfunction (TMD): In painful, clicking type of TMD, McBeth et al, showed ITI to have a diagnostic sensitivity of 87% (166). This was in contrast with normal controls showing normal specificity of 86% (166). ITI and liquid crystal thermographies were usually normal in between flare ups of trigeminal neuralgia or trigeminovascular facial pains (167). During the symptomatic attacks ITI showed hot or cold spots in over 80 % of patients (84,167). The hot spots are more likely due to TMJ pathology (168,169) or facial sinusitis (169).

Thirty-three patients who had undergone TMJ surgery followed by persistence and spread of neuropathic pain were referred to us for diagnosis and treatment in the past six years. Two main factors - careful history taking and ITI - solved the puzzle, and explained the reason for poor recovery.

Outcome: The ITI revealed an abnormal sympathetic dysfunction in the cervical (16 patients), lumbar (9 patients), and thoracic spine regions (7 patients). Only one patient had shown no spinal involvement - instead the patient was found to suffer from maxillary bone osteonecrosis and abnormal thermal changes in the Trigeminal nerve distribution.

Conclusion

A properly performed ITI, provides diagnostic therapeutic information not obtained by EMG, NCV, CT, or MRI. This information is indispensable in helping to arrive at an accurate diagnosis, and in identifying the pathologic areas. It helps the physician to avoid further invasive blocks or surgical procedures.

Lack of such information leads to misdiagnosis, and to labeling the patients for being a malingerer, or as suffering from conversion reaction.

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Magnetic Heating as a Therapeutic Tool

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Rationale and Obectives: In preliminary investigations a method called "magnetic thermoablation" was proposed for the localized elimination of tumors by heating. Therapeutic heating is generated by the application of a magnetic material at the target and the exposure to an alternating magnetic field. The present study deals with the *in vitro* estimation of critical heating dosages (°C x min) for a reliable killing of tumor cells and the elucidation of the practicability of an application of correspondent dosages by magnetic thermoablation using a in vivo experimental tumor model.

Methods: Human adenocarinoma cells (BT-20) were exposed to 37 to 62 °C (water bath) for 4 min and incubated for 24, 48 and 72 h before colorimetrical cell viability determinations. The cells were implanted into 5 immunodeficient mice. 12 ± 3 mg magnetite per 300 mm³ tumor tissue was inserted into the tumor. Animals were exposed to an AC magnetic field (amplitude: 6.5 kA/m, frequency: 400 kHz) for 4 min and temperature measurements were performed at the tumor periphery and the rectum. The deposited heat dosages (DHD) were defined as the area between the time-dependent temperature curves during treatments and the temperature level without heating.

Results: The critical DHD lethal for tumor cells varied from 47 ± 2 °C x min (temperature setting of 51 °C) and 61 ± 2 °C x min (temperature setting of 55 °C) due to decreasing cell survival rates with increasing incubation time after treatments. The heat dosages deposited in tumors by magnetic thermoablation ranged between 197 ± 29 °C x min and 106 ± 4 °C x min (mean temperatures at the end of treatments: 84 ± 3 °C and 59 ± 0 °C) for the distal and proximal tumor periphery, respectively. The rectal temperatures increased by about 3 °C during treatments.

Conclusions: The comparison of the DHD from *in vitro* and *in vivo* investigations in tumor bearing mice demonstrates that a reliable cell killing is possible by the proposed method.

Key words: magnetic thermoablation, cancer therapy, heating, critical temperatures, iron oxides

Magnetisch induzierte Wärme als Therapiemittel

Zielsetzung: In vorangegangenen Untersuchungen wurde eine Methode, die sogenannte „magnetische Thermoablation", zur Beseitigung von Tumoren durch Wärme vorgeschlagen. Die therapeutische Wärme wird mittels der Applikation eines magnetischen Materials und der anschließenden Exposition in einem magnetischen Wechselfeld generiert. Die vorliegende Studie befaßt sich mit der *In-vitro*-Abschätzung der kritischen Hitzedosis (°C x min) für eine zuverlässige Zerstörung von Tumorzellen sowie mit der Applizierbarkeit von entsprechenden Hitze-Dosen durch die magnetische Thermoablation in einem in vivo experimentellen Tumormodell.

Methoden: Humane Adenokarzinomezellen (BT-20) wurden auf Temperaturen zwischen 37 und 62 °C (Wasserbad) für 4 min exponiert und weitere 24, 48 und 72 Stunden vor der kolorimetrischen Zellvitalitätsbestimmung inkubiert. BT-20 Zellen wurden in 5 immundefizienten Mäusen implantiert. 12 ± 3 mg Magnetit per 300 mm³ Tumorgewebe wurden appliziert und die Tiere in einem magnetischen Wechselfeld (Amplitude: 6.5 kA/m, Frequenz: 400 kHz) für 4 min ausgesetzt. Dabei erfolgten Temperaturmessungen im Rektum und in der Tumorperipherie. Die Fläche zwischen der zeitabhängigen Temperaturkurve und des nativen Temperaturspiegels (ohne Wärmebehandlung) wurde als die applizierte Hitzedosis (DHD) definiert.

Ergebnisse: Die kritische DHD für die Inaktivierung von Tumorzellen lag zwischen 47 ± 2 °C x min (51 °C) und 61 ± 2 °C x min (55 °C) und ist auf die abnehmende Zellvitalität mit zunehmender Inkubationszeit nach der Wärmebehandlung zurückzuführen. Die in Tumoren applizierte Hitzedosis reichte von 197 ± 29 °C x min und 106 ± 4 °C x min (mittlere Temperaturen am Ende der Wärmebehandlung: 84 ± 3 °C und 59 ± 0 °C) für die distale und proximale Tumorperipherie. Die rektalen Temperaturen stiegen um etwa 3 °C während der Wärmebehandlung an.

Schlussfolgerungen:. Der Vergleich der DHD aus den In-Vitro- und In-Vivo-tierexperimentellen Untersuchungen verdeutlichen die Möglichkeit für eine zuverlässige Zerstörung von Tumorzellen mittels der vorgeschlagenen Methode.

Schlüsselwörter: magnetische Thermoablation, Krebstherapie, Erwärmung, kritische Temperatur, Eisenoxid

Introduction

During the last decade therapeutic heating – preferentially cancer therapy - has become of increasing interest resulting in two basic techniques called "hyperthermia" and "thermoablation". Hyperthermia has been used as an adjuvant modality to classical oncological procedures, since it was shown to intensify the efficacy of radiation and/or chemotherapy. In this technique temperatures between 40 and 45 ° C are applied at the target for time periods between 30 and 60 min (1) that induces almost reversible cell damage. On the contrary, thermoablation procedures operate with temperatures higher than 50 °C, resulting in tissue necrosis, coagulation or carbonization - depending on the used temperature.

For both techniques internal or external heating sources have been applied. But one of the major associated problems was the selective focussing and control of the heat deposited in the tissues. Therefore, basing on the experiments of Gilchrist et al. (2) a method called "magnetic thermoablation" was proposed. The procedure consists of a selective accumulation of magnetic material (iron oxide, i.e. magnetite) within the target and the exposure of the tumor containing organ to an alternating magnetic field. I this way, the magnetic materials absorb energy from the magnetic field and convert it into heat, that is used to eliminate the tumor. In particular, tumors in organs with a good accessibility to magnetic fields, like the breast, head, neck and limbs, could be preferentially treated.

Previous investigations demonstrated the basic feasibility of the proposed minimal-invasive method (3;4) and that the exposure of parts of the body with a diameter up to 15 cm, may be tolerable, particularly if using short exposure times (several minutes) to AC magnetic fields with a frequency of 400 kHz and an amplitude of 6.5 kA/m.

When maintaining the duration of treatment as short as possible, the adaptation of heating to adequate temperatures is the major goal to be attained. Even though the necessary time-dependent temperature dosages to be applied for hyperthermic treatments of tumors have been widely investigated, in the thermo- abative treatments of tumors a critical temperature for cell destruction of 56 °C is assumed, but no systematic data are available. To our knowledge, only one investigation showed that acute lethal damages can be induced in cells by the aid of heating to temperatures between 50 and 60 °C (5) for a few minutes. Other investigations deal with the chemical processes of thermal injury (6,7, 8). Nevertheless, in view of a refined regulation of the heat focus at the target, the relatively wide critical temperature range has to be further characterized by consideration of dynamic cytotoxic effects of heating.

Furthermore, with respect to the proposed method, there is also lack of detailed information on whether ethal heating dosages could be magnetically deposited at the target using short exposure times to the magnetic field (4 min).

Therefore, in the present study the critical heating dosages for a reliable tumor cell destruction were investigated *in vitro* and compared with those dosages that were induced by magnetic thermoablation in tumor bearing mice. In order to quantify the temperature treatments with respect to time, we introduced the expression "deposited heat dosage" (DHD) being the area under the time-dependent temperature curves during treatments.

Materials and Methods

Water bath heating of tumor cells in culture

Asynchronically growing human breast adenocarcinoma cell lines (BT-20, Deutsches Krebsforschungszentrum: Heidelberg, Germany) were cultivated in exponential monolayer growth by the use of MEM containing 10 % (v/v) fetal calf serum (Life Technologies: Karlsruhe, Germany) and 1 mM sodium pyruvate (Gibco-BRL: Karlsruhe, Germany). All cultures were routinely checked for mycoplasma contamination.

Cell suspensions (1 x 10^5 cells in 1 ml DMEM) were adapted to 37 °C for 5 min using a water bath (water bath "a"). The water-bath heating treatments *per se* were performed by the introduction of samples for 4 min in an additional water bath "b" controlled by a precision thermostat kept at 37, 47, 51, 55, 57 and 62 °C. The temperatures within the cell suspension were recorded using thermocouples as already described (4).

Heated and non-heated (control) cells were seeded on micro well dishes (1000 or 2000 cells per 0.36 cm^2). After 24, 48 and 72 h of incubation under standard conditions, the cell viability was determined photometrically by the production of a colored formazan product in metabolically active (living) cells (9). Survival rates (v) were calculated by the formula:

$$v\ [\%] = (t \times 100\ [\%]) : k\ ,$$

where *t* means the absorbance at 450 nm of heated and *k* of non-heated control cells. All numerical data were expressed as mean ± standard error of the mean.

Magnetic heating of tumors in mice

5 female immunodeficient (SCID) mice (Institut für Versuchstierkunde des Klinikums der F.S.U. Jena, Germany) weighing approximately 23 g were group-housed in solid floored caging (Ehret: Berlin, Germany). Sawdust (Altromin Tierlabor Service: Lage, Germany) was used as bedding. Room temperature was controlled at 21 ± 2°C. A 10h:14h light-dark cycle was maintained. Animals received a commercial pelleted diet (Altromin Tierlabor Service: Lage, Germany) and water ad libitum.

A bilateral tumor implantation (lateral abdomen) was performed using 0.35 ml MEM containing 2 x 10^6 cells. Approximately 6 weeks

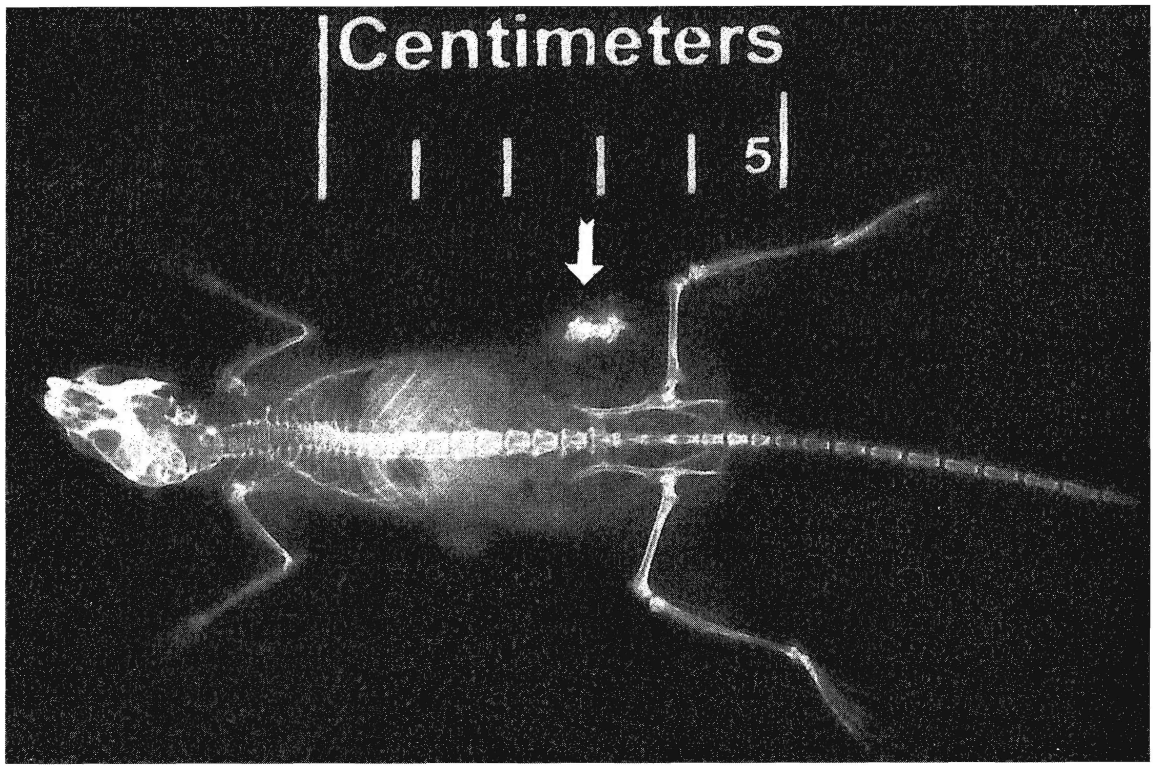

Figure 1.
Radiography of a SCID mouse with bilaterally implanted tumors (BT-20 cells) in the lateral abdomen. The upper tumor was centrally loaded with iron oxide particles (arrow)

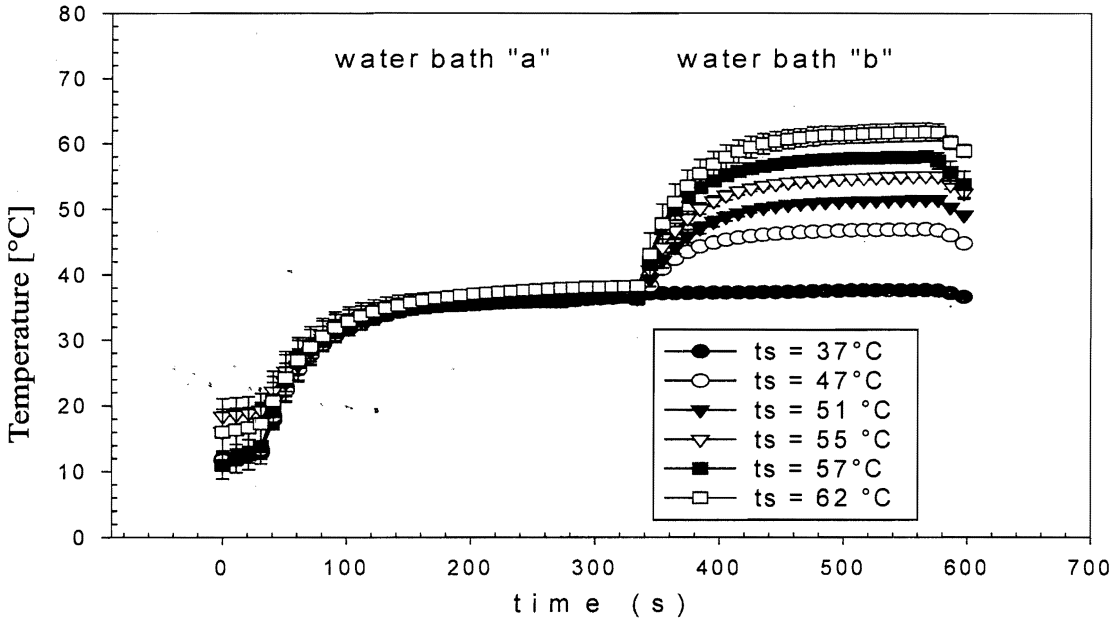

Figure 2.
Time-dependent temperature courses during water bath treatment of cells. The temperature of cell suspensions was adjusted to 37 °C (water bath "a"). Temperature treatments were carried out introducing the samples for 4 min into water bath "b" with temperature settings (ts) controlled by a precision thermostat.

after the tumor implantation the experiments were started. Tumor volumes were calculated to be of 1005 ± 331 mm^3 as determined using the formula V = π/6x(product of 3 principal diameters) according to Steel (10). All experimentation had been performed according to the regulations of the European Community.

Prior to experiments animals received anesthesia (per kg body weight: 0.5 mg medetomidin, 5 mg midazolam and 0.05 mg fentanyl). Approximately 50 microL of a magnetic fluid sample (coloidal suspension of magnetite particles; Ferrofluidics, Nürtingen, Germany) was intratumorally injected into the tumor center

Table 1
Mean survival rates (%) in dependence on time after heating cells in a water bath with temperature settings ontroled by a precisionthermostat. DHD: deposited head dosage as estimated by the area between the time dependent temperature curves and the temperature level of 37°C between beginning and ending of treatment.

Water bath temperatures [°C] and DHD [°C x min]	Mean survival rates (%) of BT-20 cell population		
	24 h	48 h	72 h
	of incubation after heating treatments		
37 ± 0 / 0 ± 0	113 ± 5	101 ± 4	110 ± 7
47 ± 0 / 32 ± 2	79 ± 5	50 ± 8	57 ± 9
51 ± 0 / 47 ± 2	50 ± 7	16 ± 3	12 ± 8
55 ± 0 / 61 ± 2	14 ± 4	0 ± 0	0 ± 0
57 ± 1 / 71 ± 2	0 ± 0	0 ± 0	0 ± 0
62 ± 1 / 85 ± 7	0 ± 0	0 ± 0	0 ± 0

(Figure 1). The amount of magnetite per 300 mm^3 tumor tissue was of 12 ± 3 mg.

Mice were placed in the center of a magnetic field applicator consisting of a circular coil (diameter: 9 cm). The exposure to the AC magnetic field (amplitude: 6.5 kA/m; frequency: 400 kHz) lasted for 4 min and simultaneously rectal temperatures as well as temperatures of the distal and proximal tumor periphery were measured using thermocouples.

The intratumoral magnetite deposition and the position of the thermocouples were monitored by radiography.

Calculation of deposited heat doses (DHD)

The deposited heat dosage at the target were calculated by estimating the area A between the time-dependent temperature curves and the temperature level without heating.

Results

The time-dependent temperature courses during the water bath treatments of cells show a good temperature alignment to 37 °C during exposure in water bath "a" and distinctive temperature increases until 40 s after exposure in water bath "b". With ongoing treatment time the temperature saturates (Figure 2).

Depending on the water bath "b" temperature settings the deposited heat doses ranged form 32 ± 2 °C x min (temperature setting of 47°C) and 85 ± 7 °C x min (temperature setting of 62 °C).

The cell survival rates were dependent on the incubation time after heating (Tab. 1) revealed stable values after exposure to temperatures of 37 °C. There was a tendency for cell viability recuperation when heating at 47 °C and decreasing rates after incubation at 51 and 55 °C. Particularly, after 24 h of incubation, critical survival rates were observed after heating between 55 and 57 °C; longer incubation times (48 h and 72 h) lead to critical survival rates at temperatures between 51 and 55 °C. No survival rates were observed after heating of cells at temperatures higher than 57 °C.

Radiography showed a clear deposition of magnetite particles in the tumor center (Figure 1). The measured temperature curves in mice tumors were averaged over the 5 tumor bearing mice to give the curve (dots) in Figure 3 with the spread represented by the error bars. Starting with an intratumoral temperature of 23 °C the temperature courses at the tumor periphery were similar when compared to those of water bath heating at higher temperatures. For the distal and proximal tumor periphery, a mean

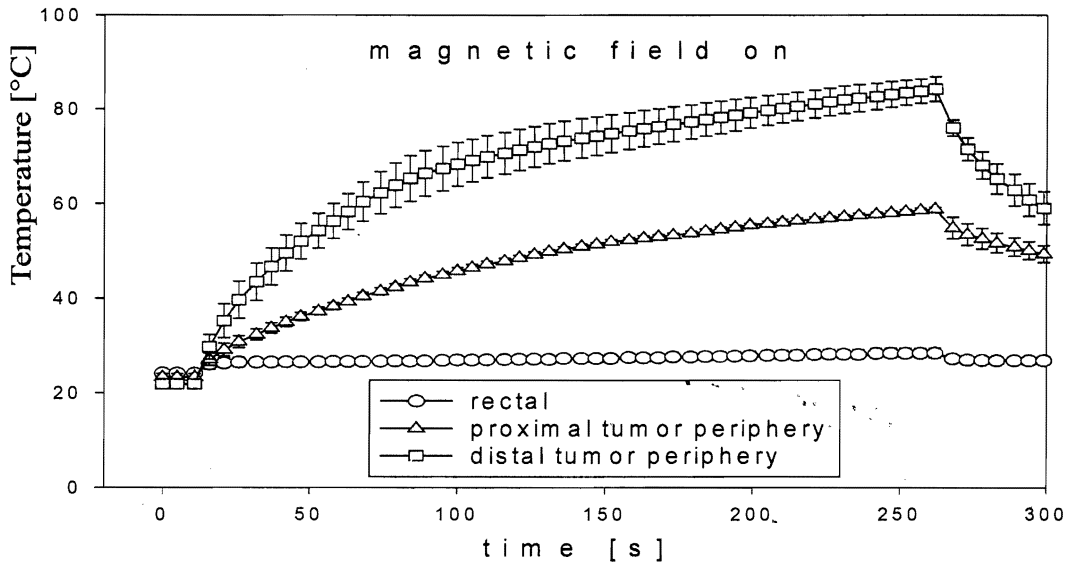

Figure 3.
Temperature courses at the distal and proximal tumor periphery and the rectum during exposure of 5 tumor bearing mice to an alternating magnetic field (frequency: 400 kHz; amplitude: 6.5 kA/m) for 242 s. Tumors were previously loaded with 12 ± 3 mg magnetite per 300 mm^3 tissue. The error bars indicate the interindividual differences after tumor treatment in 5 mice

temperature of 84 ± 3 °C and 59 ± 0 °C, respectively, was measured at the end of tumor treatments. The corresponding DHDs were estimated to be of 197 ± 29 and 106 ± 4 °C x min, respectively.

The rectal temperatures increased from 24 ± 1 °C at the beginning to 27 ± 0 °C at the end of treatments.

Discussion

The in vitro data revealed a significant correlation between the DHD and the cell survival rates. The heat doses induced by magnetic thermoablation in experimental tumors were fairly higher when compared to those generated by water bath exposure of cells.

According to the results concerning the heat-dose and time-dependent survival rates of water bath treated cells, the critical lethal heat dose to be deposited ranges between 47 ± 2 °C x min (temperature setting of 51 °C) and 61 ± 2 °C x min (temperature setting of 55 °C). The fact that the cytotoxic heating effect was intensified with continuing culture time after treatments could be explained by cell death through apoptosis, which is known to be a time-dependent cellular self-destruction program. In comparison, Heisterkamp et al. (5) found a critical temperature range between 50 and 60 °C (treatment time: 3 min) for tissue coagulation and cell death in tumor tissue samples. Their experimental conditions were similar to those in the present study. Nevertheless, the relatively broad temperature range can be explained by the fact that cell viability was determined *immediately* after heating.

In the question of the thermal injury, a detailed research on protein breakdown was performed (e.g. (6)), indicating a large variability for the temperature dependent coagulation of different cellular proteins (temperature range between 48 and 90 °C) (7, 8). Therefore, the current data suggest that cell viability is strongly related to the thermostability of several vital proteins.

One of the reasons for using the mitochondrial dehydrogenase activity as a criterion for measuring cell viability was that the widely known dye exclusion tests (e.g. trypan blue or eosin) are not suitable for measuring survival after application of high dosage thermotherapy, since interferences of membrane functions are can occur.. On the other hand, the mitochondrial dehydrogenase is a basic metabolic enzyme for maintenance of vital cell functioning. From the pathologic point of view, mitochondria are the first organelles reacting to lethal heating by swelling and crystolysis; the disintegration of polyribosomes and nuclear chromatin aggregation are later events (11).

The heat doses deposited into experimental tumors were significantly higher than the critical doses determined from in vitro investigations. The fact of different starting starting temperatures before heating should be kept in mind in comparing thesetwo experiments. The area between 23 °C (animal experiments) and 37 °C (water bath experiments), respectively, and the time period of about 250 s leads to a heat dosage of about 60 °C x min. Distinctive magnetically induced heat spots could be generated in the tumor. The data suggest that similar tumor cell survival rates after heating could be obtained as observed *in vitro*. Therefore, by using the proposed procedure, sufficient heat could be deposited at the target in order to destroy tumor cells. For ethical reasons, it was not possible to study the tumor remission after treatments in living animals, since – in relation to the total animal body volume - the large heat spots induced on the lateral abdomen could also have damaged vital organs impairing the animal's quality of life.

Based on the central deposition of the magnetic material within the tumor, a bell shaped curve with a peak at the tumor center and decreasing temperatures towards the periphery can be expected. Therefore, the threshold heat doses (temperatures) should be applied at the tumor periphery in order to achieve a reliable tumor destruction.

In tumors in the breast, which is a low vascularized organ and mainly composed of insulating fat, a risk of fat necrosis is conceivable. This is known from other cancer ablation procedures, such as radiofrequency laser therapy. Such problems should not arise during magnetic thermoablative methods when considering the possibility of regulating the heat doses by a refined selection of iron oxide masses and magnetic field parameters (3, 4).

The observed differences between the deposited heat dosages at the distal and proximal tumor periphery result from differences of the

tumor surrounding media. The distal tumor periphery was surrounded by air having higher insulation features than the biological tissue at the proximal one. Furthermore, blood flow in the surroundings might have had additional influences on this relationship. Similar situations are possible if tumors are situated in the vicinity of large vessels leading to a shift of the intratumoral, bell shaped temperature curves as a result of blood flow induced thermal clearance.

The low basal tumor temperatures in animals before the beginning of treatments were recorded and ascribed to anaesthetic effects. Anesthesia was necessary during tumor treatments due to the fact that unpredictable traumatic side effects could occur on vitally organs underlying the subcutaneously implanted tumors. Therefore, it is possible that hypothermia could have influenced to some extend the intra-tumor temperature measurements. These relationships could have led to higher temperatures in the tumor during ablation than would be possible if animals were perfusing normally with rapidly circulating blood acting to reduce peak temperatures.

The cause of the pronounced inter-individual variations of the temperature data (error bars in Fig. 3) is thought to be the result of inter-individual variations of the magnetite deposition morphology at the tumor center being influenced by the diverging texture of the tumor itself.

It should be noticed that the findings are based on one tumor model. It is very likely that other experimental models will exert similar heating effects, since the cytotoxic potential of heat at higher temperatures (over 50 °C) is not confined to tumor cells.

In summary, the present study demonstrated that the critical lethal heat dose for a reliable destruction of tumor cells ranges between 47 ± 2 °C x min (temperature setting of 51 °C, heating time: 4 min) and 61 ± 2 °C x min (temperature setting of 55 °C, heating time: 4 min) and that magnetic thermoablation is an effective and potent method for the localized application of therapeutic heat.

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29 th Annual Meeting of the American Academy of Thermology in Auburn, June 11-24, 2001: Abstracts

INTERPRETATION OF THERMOGRAMS DURING INVESTIGATIONS OF THERMAL PHYSIOLOGY

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Infrared (IR) thermography provides both medical clinicians and physiologists with a valid means of measuring regional skin temperature differences. However, varying the settings of a thermal processor can dramatically alter a thermogram's appearance.

The purposes of this presentation are to discuss issues related to the testing environment, patient or subject, and thermal processor settings that can influence the appearance and subsequent interpretation of a thermogram in chinical and physiological research settings. In particular, one must account for the measurement accuracy & range of temperatures represented in an image to properly interpret a thermogram.

When accounting for these factors, one must consider that increased measurement accuracy does not necessarily equate to increased clinical or research-based signiflcance. Also, environmental factors such as radiant heat, humidity and wind can affect imaging. Further, vasoactive factors such as nicontine and caffeine use by subects can alter thermal images.

In addition to accounting for thermography System settings, one must control for the effects of environmental and vasoactive factors and ensure adequate subject equilibration prior to imaging to ensure valid and reliable JR thermographic imaging.

THE INFLUENCE OF PROTECTIVE BARRIER CLOTHING ON THERMAL SKIN RESPONSES

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The purpose of this investigation was to determine the influence of protective barrier suits (PBS) and cooled vests on the skin/core temperatures of subjects during recovery after exercise. Subjects were recreationally fit males (19-50 years old) who performed randomized work trials (PBS or PBS w/vest).

Hydroweave vest (Aquatex ™) was saturated with water (24 °C). Rectal core and skin temperatures were measured during 30 minutes of walking on a motorized treadmill (3.5 mph, 6% grade) and 15 minutes of passive recovery (no PBS or vest). Exercise was performed in a controlled work environment (30°C, 50-55% relative humidity). Recovery was measured in a cooler recovery temperature (25 °C, 35-40% relative humidity). Thermal images (Bales TIP 50) were taken of the chest and head prior to exercise, immediately following the exercise, and at 5, 10, and 15 minutes postexercise without vest or PBS. Environmental conditions inside the suit were recorded throughout the trial.

Skin temperature was cooler during PBS-vest trials for the first 15 minutes of exercise. Thereafter no difference in skin temperature was observed for vest and no vest trials. Core temperature was significantly reduced during the last 10 minutes of the exercise bout. During recovery, skin temperature was increased and core temperature was lower during the trials where subects had worn the cooling vest compared to no-vest recovery.

The increase in skin temperature during recovery demonstrates greater vasodilation in the skin, thereby allowing for greater heat dissipation from the core temperature to skin and skin to environment.

INFRARED DETECTION OF HUMAN REGIONAL SKIN TEMPERATURES AT VARYING ENVIRONMENTAL CONDITIONS

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The purpose of this investigation was to determine the variance in regional skin temperatures at 20°, 30°, and 40°C environmental conditions using non-invasive, non-contact infrared thermography. Thirty college-aged participants (15 male, 15 female), wearing minimal clothing, passively stood in an environmental chamber for 15 minutes for equilibration prior to obtaining frontal and posterior infrared thermal images (Bales TipSO).

TheRe trials were performed at the same hour of differing days to ehiminate any variance due a previous trial or thermal changes due to circadian rhythms. Subects were pre-screened for contraindicated medical conditions. One hour prior to testing the subects refrained from food consumption, exercise, smoking, and caffeine use. The torso regions were defined as: right scapula, left upper chest, left lower back, and right abdomen. Peri- pheral regions were defined as: forehead. Lower occiput, right upper arm, heft lower arm, left hand, right anterior thigh, left posterior thigh, right anterior leg, left posterior leg. These sites are commonly used in physiological studies to determine mean skin temperatures from mean-weighted formulas.

The high, mean, and low temperatures from all regions were statistically different for all environmental conditions. The range of temperatures within each region was significantly greater at 20°C when compared to 30° or 40° C. However, the ranges in skin temperatures for the peripheral regions (not torso) were significantly greater during the 30° and 40° C environmental trials.

Unlike thermal probes that measure only one location, non-contact JR thermography can accurately assess multiple thermal skin responses from heterogenous distributions of skin temperatures within body regions.

THERMOGRAPHY IN WORKERS' COMPENSATION

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The office of the president of the American Academy of Thermology contacted the Workers' Compensation Commissioners of each state regarding approval for the use of Thermography in the management of patients with RSD/CRPS. The following States replied indicating that thermography was accepted in the workup of the patient: Florida, Iowa,Maryland, Massachusetts, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Jersey, Oklahoma, Oregon, and Wisconsin.

CPT codes mentioned were 93760 Cephalic and 93762 Peripheral. Set rates for Massachusetts are $260.00 each. Approval was based on medical necessity, choice of the treating physician or referred by specialist, not singularly useful and on case by case basis, should be appropriate and necessary, may be used adjunct to physical exam and not reimbursed separately from the office visit, at the recommendation of medical providers, Individual Judge to decide based on evidence submitted by modern science, Judge to decide if in dispute, subject to contest by the opposing physician, person performing the procedure must be practicing with in the scope of his/her license and must be adequately trained.

Thermography has acceptance at this time in patients with RSD/CRPS. American Academy of Thermology members who are Certified by the American Board of Thermology have the opportunity to work with their state workers' Compensation commissioners to try to implement use of this technobogy for diagnosis ofRSD/CRPS, in the follow up oftreatment and correlate with prognosis.

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COMPUTER ANALYSIS OF THERMOGRAMS OF THE VERTEBRAL COLUMN

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The thermographic examination was done with the camera AGEMA 470 in a chamber with standard conditions of humidity (60%) and temperature (20 to 22°C). Air stream convection in the chamber was restricted and the influence of any heat source was eliminated.

The camera was placed in about 1 meter distance from the patient, who was standing with his back in front of the camera. The thermograms obtained after examination were analyzed using the Real Time Work- shop and Image Processing computer programs, both included in the Matlab environment.

The program enables:

- To deect in a manual or automatic way the spinal shape on X ray picture.
- To locate the shape of the spine on a thermogram
- To calculate the average temperatures distribution on both sides of a certain region of the back..

On the basis of data mentioned above, the diagrams of paravertebral regions temperatures (thermograms) were obtained. The analysis of these diagrams allowed finding some interesting relationships between the temperature and the deformation angle (measured by the Coob's method) in children with idiopathic scoliosis.

MONITORING THE ANAESTHETIC NEURAL BLOCKADE: A CASE REPORT

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Iatrogenic neuropathies are frequently correlated with surgical treatment.The primary cause of chronic pain induced by surgeiy is direct or indirect nerve injury, either acute (caused by section or ischemia) or delayed (for adhesion and entrapment). Spinal and supraspinal mechanisms are secondary involved.

A 56 years old man came to our out-patient clinic complaining about pain in the left hand. The pain began after palmar aponeurotomy for Dupuytren syndrome of the ring finger. Three months later, the patient had to be operated again (adhesiothomy and neurolysis of the fouth interdigital nerve of the left hand) because of persisting pain.

The symptomatology was characterized by spontaneous burning pain in the little and ring finger with , touch evoked allodynia in the scar area, cold sensation in the fifth finger and disturbed sleep. Neurological evaluation detected hyposthesia and hypoalgesia of the fifth finger and of the ulnar side of the ring finger, motor impairment of the little finger. Neurophysiologic data were compatible with neuropathy of nervi digitales nervi ulnaris.

Thermographyc pattems showed hypothermia of the left hand ulnar area. The anaesthetic blockade oft the ulnar nerve a the wrist was monitored with thermography. During the blockade the hypothenar area and the ring finger became warmer while the little finger remained cold. The pain disappeared totally. Anaesthetic neural blockade determined a warm area due to sympathetic patways block. The cold area found in the patient is probably due to complete nerve lesion and denervation hypersensitivity. Monitoring temperature variations during anaesthetic blockade can be useful to understand which kind of fibers are affected by the lesion.

COMPLEX REGIONAL PAIN SYNDROME

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Complex regional pain syndrome (CRPS) is of two types, 1 and 2. (1) CRPS 1 is a pain syndrome that usually develops after an initiating noxious event, is not himited to the distribution of a single peripheral nerve, and is apparently disproportional to the inciting event. It is associated at some point with evidence of edema, changes in skin bbood flow, abnormal sudomotor activity in the region of the pain, ahlodynia, or hyperalgesia. The site is usuahly the distal aspect of an affected extremity, or has a distal to proximal gradient. CRPS II replaces the term causalgia and requires demonstrable peripheral nerve injury (2).

Thermography observations on neuropathic pain indicate the rohe of neural impulse activity on microcirculation and arteriovenous anatamoses (AVAs) (3). Blair et al. found CGRP to be increased in CRPS (4). Vasoactive peptides from a remote site can also induce prolonged changes in vasomotion of the AVAs5 .Regional blood flow abnormahities are found in CRPS (6).There is impairment of oxygen/ metabolism during progression of CRPS(7). Birklein et al documented increase in skin lactate in CRPS (8)..

In the diagnosis of CRPS /RSD (9 ,10) baseline temperature asymmetry or stress infrared telethermography has been documented to be useful. Mufson 1 stated that the effect of sympathetic block is on the arteriovenous anatamoses". Thermography images neuropeptide sensitive regional microcirculation /arteriov enous anatomoses and is helpful in the diagnosis and monitoring the effect of treatment in patients with CRPS (12).

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THE ANALYSIS OF THERMOGRAMS IN CHILDREN WITH IDIOPATHIC SCOLIOSIS

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The study was conducted in apopulation of 403 children divided into 2 groups:

1.The control group of 164 healthy subjects

II.Re experimental group of 239 subjects with idiopathic scoliosis

The experimental group included 2 subgroups of subjects in dependence of the spinal deformation and 4 subgroups with different levels of deformation (measured by Cobb's method). Other division was made in respect to the treatment options (with surgery or without surgery).

In the control group, soley the basic orthopedic examination and thermal imaging of the spine was performed. In the experimental group a radiological examination (X-ray imagere) was also performed.

Conclusions:

1.In the control group, the left and right paravertebral regions presented with a significant symmetry of temperature distributions.

2.In scoliotic children the level of the spinal deformation is correlated with temperature changes in destinct paravertebral area.

3.Thermal imaging is useful for evaluation of the efficacy of surgical treatment for scoliosis .

4. .Thermography may be a valuable method in screening for spinal deformation in children and adolescents.

THE THERAPEUTIC ROLE OF THERMOGRAPHY IN THE MANAGEMENT OF PAIN

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Thermography has been used mainly as a diagnostic tool. The therapeutic utilization of this test is even more useful in clinical practice. Whereas standard diagnostic tools such as EMG, NCV, MRI, or CT provide information regarding somatic (non sympathetic) nervous system, thermography provides therapeutic information regarding sympathetic nervous system dysfunction. This exclusive information is due to the fact that thermography measures the function of thermosensory C Fibers in the wall of the blood vessels, which cannot be measured by standard tests mentioned above.

Thermography guides the clinician to diagnose and treat CRPS, electrical injury, and repetitive strain inury (RSI). In addition, thermography helps to rule out fibromyalgia, myofacial syndrome, carpal tunnel and tarsel tunnel syndrome sparing the patient of unnecessary surgery.

OBTAINING GOOD IMAGES IN LESS THAN OPTIMAL CONDITIONS

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When the optimal facility or conditions are not available for doing infrared thermal imaging, the practitioner is faced with only two choices:
1.) forgetting the use of infrared imaging on the case; or 2.) using infrared in less than optimal conditions but nonetheless, acquiring useful images that provide reliable information.

Less than optimal conditions can be defined as:
1.) a compromised physical facility;
2.) less than optimal ambient temperatures;
3.) less than optimal help;
4.) difficult behavior of the patient;
5.) less than optimal preparation of the patient.

There are preparations that the practitioner can. recommend to make getting good images possible under these conditions.

Many of these problems can be avoided by proper planning and client education. Repeat clients are easy to work with because their previous experience using infrared imaging, helps them understand what is needed to get good images. To help new clients provide the best possible situation in which too work, proper questions should be asked the prospective client, and they should be instructed to make any necessary changes ahead of time. Taking the patient to a better facility, that the practitioner has used previously, is a good alternative if it appears that adequate changes cannot be made. Other problem factors can be handled by such actions as varying the time of day that images are taken, covering offending windows or doorways, taking along help trained by the practition er, or other optimizing and preplanned approaches.

One of the most important things that should be remembered in these situations is to keep the less than optimal conditions in mmd when interpreting the images. We do not want to overlook or misinterpret important artifacts that may have been created by any of these compromised imaging conditions.

NORMAL AND ABNORMA.L PATTERNS OF THE EQUINE FOOT

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In order to use infrared thermography as a diagnostic tool in equine medicine, we must first be able to recognize both normal and abnormal patterns of the

various anatomical areas of the horse's body. This paper addresses those patterns as found in the equine foot. The material was gathered from horses belonging to several breeds of performance horses, two breeds of racehorses, 3 breeds of draft horses, and individuals from a number of different breeds that were used only for non-athletic purposes.

My experience indicates that the best data can be obtained when 1 take a total of 12 specifically different images of the lower legs and feet. These 12 images are represented by *1* anterior image, 1 posterior image, 3 left side images, 3 right side images and 4 images of the soles of the 4 individual hooves. The anterior and posterior images are particularly helpful in evaluating the individual animal's preference of legs for weight bearing; this is quite helpful in determining which legs are involved in the pathological problems being sought by the infrared diagnostics being employed.

The paper presents normal examples of these 12 preferred images. It also presents abnormal examples of the anterior and posterior images as related to weight bearing and its significance in diagnosis. The paper concludes with images of individual pathological conditions such as those commonly recognized as sole bruises, subsolar abcesses, navicular bursa inflammation, navicular disease, acute and chronic laminitis, ringbone, and sidebone.

THERMOGRAPHY STANDARDS FOR THERMAL IMAGING IN VETERINARY MEDICINE: QUALITY CONTROL

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In most mammalian species, the body temperature is normally weil controlled by its own metabolic state. The skin temperature is normally lower than that of internal tissues and depends not only on the metaboiic state of the animai, but also various factors such as thermal conduction from heat sources within the body's vascular activity and just beneath the surface, heat losses due to evaporation, convection by air currents, or exchange of infrared radiation energy to the surroundings. Heat lost from the body by the exchanges of IR radiation with the surrounding is the basis of thermography. For this to occur there must be a temperature gradient. Thus, to obtain a reliable and meaningful diagnosis from a thermogram, one should consider the following:

1.The environmental factors which interfere with the quality of thermography should be minimized. The room temperature should be maintained between 21 to 260 C. Slight variations in some cases may be acceptable, but room temperature should always be cooler than body temperature and free from air drafts.

2.Thermograms obtained outdoors under conditions of direct air drafts, sunlight, and extreme variations in temperatures provide unreliable thermograms in which thermal pattems are altered. Such observations are meaningless.

3.When an animal is brought into a temperature controlled room, it should be equilibrated at least 20 minutes or more, depending on the external temperature from which the animal was transported. Animals transported from extreme hot or cold environments may require up to 60 minutes of equilibration time.

4.Other factors effecting the quality of thermograms are hair coat, exercise, sweating, body position and angle, body covering, systemic to topical medications, regional and local blocks, sedatives, tranquilizers, and anesthetics, vasoactive drugs, skin lesions, such as scars, surgically altered areas, etc.

The value of thermography is its extreme sensitivity to changes in heat and its ability to detect changes. Therefore, it is important to have weil documented normal thermai patterns and gradients in a species prior to making any claims or detecting pathological condition.

THERMOGRAPHY STANDARDS FOR THERMAL IMAGING IN VETERINARY MEDICINE: CHALLENGE TESTING

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Three changes in the peripheral vascular system has significant effect on the skin surface temperature. Therefore, the use of thermography to evaluate skin surface thermal patterns and gradient changes require an understanding of the dynamic changes which occur in blood flow at systemic, peripheral, regional, and local levels. To enhance the diagnostic value of thermography, various conditions require challenge testing such as obtaining thermograms before and after exercise, response to heating and cooling of the skin surface, and response to various medications. Thermograms obtained before and after exercise provides evidence of reduced or enhanced inflammatory reaction, failure to enhance blood flow in some selective areas after exercise, etc. Similarly, obtaining thermograms after nerve blocks helps to evaluate neurovascular injuries.

The use of hot and/or cold treatment will enhance diagnostic value for vascular impairment. Therefore, a meaningful test protocol should be used in understanding the pathophysiological mechanisms for evaluation of skin surface temperature.

A COMPARISON BETWEEN VISUAL AND REFLECTANCE SPECTROMETRIC ASSESSMENT OF ERYTHEMA AND THERMOGRAPHY IN THE ELUCIDATION OF DOSE-RESPONSE OF SKIN TO ULTRAVIOLET IRRADIATION IN PHOTO (CHEMO) THERAPY

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Photoresponsive dermatoses such as psoriasis and eczema are often treated with uitraviolet therapy, either UV-A Q—360nm) with topical or systemic psoralen skin sensitisation (PUVA) or with UV-B (31 2nm) alone (UVB). Before each course of therapy, the patients' skin is tested for sensitivity by applying to separate small patches of skin an increasing series of 6 (PUVA) or 8 (UVB) UV doses, waiting for delayed erthema to develop then visually assessing the dose which elicits the first sign of faint erythema (the Minimal Erythema Dose, MED, for UVB or Minimal Phototoxic Dose, MPD, for PUVA). This dose determines the therapeutic dose regimen.

We studied the time course of evolution of erythema and the dose-response of skin in 11 UVB and 5 PUVA patients. We compared visual assessment of redness, single-pigment indices of erythema and melanin pigmentation and measurement of skin surface temperature using the AGA Thermovision 782 thermal camera with Btherm software.

No increase in pigmentation occurred. The erythema-meter and visual assessment showed peak erythema occurred 72 hours post-irradiation for PUVA and UVB. Thermology did not show clear progressive changes in skin temperature. Both visual assessment and erythema meter demonstrated linear dose- responses. Thermology also showed a dose-response curve for group average skin temperature, but large inter-individual variability masked this. Small increases in skin erythema are detectable using the reflectance meter before they are visible.

Although thermology can show a dose-response of skin temperature to UV irradiation, the effects of underlying tissues and of day-to-day variation in individual body temperature cause poor contrast and excessive variability in measured skin surface temperature.

HYPOTHENAR HAMMER SYNDROME

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Hypothenar hammer syndrome, or ulnar artely thrombosis of the hand, due to repetitive injury to the ulnar artery was first described in the late 1800's. Frequently, the earliest symptoms may be intermittent numbness and/or tingling with no objective signs of any arterial involvement. Eventually, a thrombus is formed, and emboli can then be responsible for comparative vascular compromise, even necrosis of the fingers. Early diagnosis of the problem, before a large thrombus forms, may permit non-operative treatment, but complete recovery usually requires surgical reconstruction.

Causative factors include repetitive use of the ulnar aspect of the palm of the hand during various occupations and athletic endeavors. Previously, definitive diagnosis has always been obtained by arteriography; therefore, a non-invasive methodology, independent of significant operator dependence, i.e. ultrasonography, and/or considerable expense, i.e. MRI or MRA, would be extremely beneficial.

Herein presented is the ist reported, documented case of hypothenar hammer syndrome utilizing thermographic findings, preoperatively (before surgical reconstruction) and sequential thermographic findings postoperatively. This study demonstrates the utility of thermography as a noninvasive accurate methodology for assisting in the diagnosis, as weil as, providing a visually graphic objective display ofthe normalization of circulatory and neurological function postoperatively.

EXTRACRANIAL CBF IMAGING CLINICAL IMPLICATIONS

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To review literature and the methodology to image extracranial perfusion/ CBF (Cerebral Blood Flow) with potential clinical application. In order to understand the mechanisms and the predisposition to migraine, the differences in the vascular responses between extracranial and intracranial arteries were studied with regard to histamine receptors (1), blood flow (2), vascular reactivity (3), and extracranial blood flow index (4).

Moskowitz (5) reported the relationship between neurotransmitters, the fifth cranial nerve, intra/extra cranial blood vessels and migraine headache. Drummond and Lance used thermography to image and investigate extracranial vascular changes and the source of pain in migraine headache and recommended further studies to determine the degree of extracranial vascular involvement during migraine (6). The release of vasoactive peptide of trigeminal origin in the extracerebral circulation during migraine headache has been reported by Goadsby (7, 8). Clinical case studies also indicate differences in the vasoreactive properties of the extemal carotid artery in humans (9). Thermography images Extracranial perfusion/CBF.

Thermography criteria for extracranial CBF measurement, Criteria for extracranial CBF measurement and the Methodology have been published

(10-12). Recent update on cold patch(13), a biological marker for migraine indicates thermography images extracranial AVAs and has clinical / research applications in imaging the effect of anti-migraine drugs (14) and in monitoring microcirculation/AVAs in neurosurgical intensive care unit (15).

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AN INTRASPECIES REVIEW OF EXTREME THERMAL RESPONSES

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Our research has demonstrated the importance of recognizing both individual species and regional differences in thermal pattems among animals that result from environmental stressors.

Some animal species will increase the thickness of their hair coats during colder months, and decrease the thickness during warmer months. In alpacas (lama), the ventral and perineal regions ofthe body are covered with a thinner hair coat than that on the dorsal surface. The thicker hair coat on the dorsal surface may increase the alpacas' risks of heat-related problems due to their reduced heat dissipation capabilities in hot humid climates. Thus, shearing the hair coats of alpacas may improve their thermoregulation responses in hot humid climates. We have demonstrated that shearing the dorsal region of the alpaca results in decreased right medial thigh temperatures (0.90° C cooler in the morning and 1.60° C cooler in the afternoon). Additionally, the scrotal and rectal ternperatures were significantly lower in the sheared than in the non-sheared alpaca.

In most breeds of horses, hair coat is thin. In our studies, hair clipping did not cause any significant change in thermal patterns or gradients. It is important to note that all animals equilibrated for at least 30 minutes in a room with a controlled temperature of 21 to 26° C. However, skin surface temperatures increased (2.0 to 2.5 °C) due to increased emissivity. This does not affect the diagnostic value of the thermogram.

The clinical condition of anhydrosis (non-sweating syndrome) increases the body temperatures of many animal species and human subjects when exposed to hot humid conditions. Therefore, thermographic studies of these subj ects may provide different skin surface temperatures and thermal pattems when compared to those of normal subjects.

In conclusion, one must account for the effects of environmental stressors when performing thermographic studies under different climatic conditions. One must also account for the effects of anhydrosis when performing studies in hot humid environments.

REPRODUCIBILITY OF THE HOT SPOT COUNT IN PATIENTS WITH FIBROMYALGIA: AN INTRA- AND INTER-OBSERVER COMPARISON

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A high number of hot spots in thermograms of patients with fibromyalgia were reported previously. However, the inter- and intra-observer reproducibility of visually identified hot spots is unknown.

Series of thermal images (9 images in each) of 20 patients diagnosed as fibromyalgia according to the ACR criteria were evaluated by two independent readers and the number of hot spots was deter-

mined. One investigator repeated the hot spot count a week after the first test. A hot spot was defined as a small area at least 0.5 degrees warmer than the surroundings. Only hot spots located nearby the sites typically checked for tenderness were accepted. The number and the location of hot spots in all three assessments were analyzed statistically.

The intra-rater reproducibility was moderate to fair (first run; number of hot spots: median 8.5, 5th percentile: 4.0, 95th percentile: 12.0; second run: median number: 7.5, 5th percentile:3.1; 95th percentile: 12.0, Wilcoxon-test: 2-tailed p=0.53, correlation coefficient= 0.67), the inter-rater reproducibility was poor (number of hot spots: median: 10.0, 5th percentile: 7.0, 95th percentile: 13.0; Wilcoxon-test with first run: 2-tailed p=0.001, Wilcoxon-test with second run : 2-tailed p=0.0041; correlation coefficient with first run=0.29, with second run=0.21). The sites with the highest rate of disagreement were the occiput (intra-rater) and the anterior cervical spine (inter-rater), the highest agreement was found at the trapeze muscle (intra-rater) and the lateral epicondyle (inter-rater).

Improvement of the reliability of hot spot identification is needed and might be achieved by software assisted determination of hot spots.

TREATMENT OF MYOFASCIAL PAIN SYNDROME AND FIBROMYALGIA, AND RELATED NEUROPATHIC PAIN: A NOVEL METHOD

Fred F. Hafezi

P.O. Box 4429, Whittier, California 90607-4429;

Penetrating Radiation Via Photonic Stimulator

The use of high intensity low frequency photonic infrared stimulation, a new state-of-the-art treatment of myofascial pain syndrome, (which is related to reflex sympathetic dystrophy), has been revolutionary in modulating, ablating or relieving the patient's neuropathic symptoms of edema, hot or cold sensations, erythema, hyperemia, dysesthesia, numbness localized or generalized muscle spasms, crouching posture and also increasing the tange ofjoint motion abong the spine.

This response has been observed in ninety percent of my private patients treated, personally, in the last two years.

This favorable response occurs almost immediately in association with rapid mood change from depressive, agitated alarm state to a cheerful, more normal attitude which happens, in my experience, in the majority of cases, within five or ten minutes of such treatment, if properly applied. My patients also report a progressive relief of insomnia after each treatment.

The effect of treatment may last one day to one week, but is cumulative on repeated applications, twice a week for twelve maximum treatments. Each treatment takes 15-30 minutes for effective relief.

Indications:

1.Chronic pain.

2.Acute pain.

3.Diabetic peripheral neuritis.

4.Arthrofibrosis ofknee.

5. Soft tissue work related trauma, or neuro- muscular injuries after car accidents.

6.Obvious florid reflex syrnpathetic dystrophy.

7.Post lumbar decompression laminectomy for periodic, severe, clonic musclespasms.

8.Indolent infections.

9.Post stroke patients with pain and rigid joints.

10.Multiple sclerosis with painful extremities.

11..Effective relief has been noted for applications of photonic stimulators for various symptoms aggravating or mimicking 1) carpal tunnel syndrome, 2) tarsal tunnel syndrome, 3) thoracic outlet syndrome, 4)interosseous nerve entrapment syndrome, *5)* tardy ulnar nerve palsy, 6) sciatica and brachialgia, and 7)Tic de la Rue have responded effectively in the majority of cases.

Contraindications of Photonic Stimulator:

1.Never use around the eyes or look directly into it.

2.Metastatic cancer.

3.Over-treatment.

Mechanism of Action:

Blocks unmyelinated nocioceptor C-fibers of the sympathetic sensory nervous system.

The photonic wand is moved by the operator along the sclerotomes, neural pathways, muscle groups, and arterial pathways from the tips of the digits all the way up to the axial spine, in a slow painting fashion.

However, the patient is told to let the operator know whenever the subect feels tingling, buming or pins and needles sensation as the wand passes over the area of the skin. At times, dysesthesia may be so surprisingly severe that the patient may even jump, thus the reasoning for use of the lower Megahertz reading on the machine initially.

Once dysesthesia is encountered by the infrared probe, the probe is mi abong the area of:dysesthesia in a paunting action sbowly until it "erases" the paresthesia over that part of the skin. (You' must be continually reminding the patient to inform you as the paresthesia disappears). Then you move on to the next area where paresthesia is encountered, until all the dysesthesia and pins and needles tingling sensation, or sometimes tingling and numbness throughout the extremity or trunk, is eradicated over that 15-20 minute period of treatment. Sometimes even longer time is required for resistant cases, up to 30 minutes per session. This procedure is done until the whole area of paresthesia and

dysesthesia is either mitigated in severe cases, or totally eradicated if it is found to be patchy.

The procedure is labor intensive and will take a minimum of twenty minutes and a maximum of thirty minutes per session. If the patient, by this method, does not feel a gradual relaxation of rigid muscles, the examiner passively tries to move the patient's neck or back into flexion, extension or lateral movement, while the photonic wand is applied to the contralateral muscle groups that are under tension.

This method of treatment is not independent of neuropathic medications such as anticonvulsants, muscle relaxants such as Skelaxin, Baclofen, Neurentin and Trileptol, but is used in conjunction with these same medications, and adjunctive medications are always helpful, whether they be for vasomotor instability, burning, tingling neuropathic dysesthesias, muscle spasm or cbonic muscle spasms.

A CLINICAL EVALUATION OF DITI AND NEUROMETER FOR THE DIAGNOSIS OF COLD HYPERSENSITIVITY

Kyung-sub Lee, Yong-suk Kim

Kangnam Korean Hospital, Kyung Hee University
#994-5 Taechi2-dong, Kangnam-ku 135-289, Seoul, Korea.

Cold hypersensitivity is considered as excessive cold sensation, particularly at limbs, even in a normal temperature. This study was designed to make more precise diagnostic standard for cold hypersensitivity by the DITI and neurometer.

30 female patients with cold hypersensitivity at limbs were chosen for this study, from the outpatients of the women's clinic at the Kangnam Korean Hospital, Kyung Hee University, Seoul, Korea, from October to December 2000. Using Dorex DITI, themographic measurements were performed on two areas of each upper and lower limb. Average thermal deviations were 1 .35°C on upper extremity, 4.58°C on lower extremity. ($p<0.05$) The neurometer was used to provide objective measure of subjective sensation for assessing neuropathy by measuring current perception threshold (CPT). This data showed 84.8% with cold hypersensitivity were abnormal on CPT in this study ($p<0.05$).

lt is assumed that cold hypersensitivity is associated with dysfunction of peripheral sensory nerve. Detection of cold hypersensitivity by DITI and neurometer permits earlier therapeutic intervention, thereby improving the prognosis, with the potential of limiting more severe damage and reducing the cost of care. However, additional studies are needed to gain a better profile and explore potential treatment modalities.

DETERMINATION OF MEAN TEMPERATURES OF NORMAL WHOLE BREAST AND BREAST QUADRANTS BY INFRARED IMAGING AND IMAGE ANALYSIS

Jonathan F. Head, Charles A. Lipari, Robert L. Elliott,

Mastology Research Institute, Baton Rouge, LA, USA 70806 and Arizona State University East, Mesa, AZ, USA 85212.

In clinical testing it is standard to determine the normal range, and then to determine if a test can differentiate normal from diseased patients. Now with the advent of uncooled staring array digital infrared imaging systems (Prism 2000; Bioyear Group, Houston, TX) and image analysis, numerical results (mean temperatures of the whole breast and quadrants ofthe breast) can be used to determine the normal range and cut-off temperatures for risk assessment and detection ofbreast cancer.

In this study we determined mean temperatures of whole breast and breast quadrants of women being screened for breast cancer. Re rnean temperatures for the right breast, left breast, right upper outer quadrant (UOQ), left UOQ, right upper inner quadrant (UIQ), left UIQ, right lower outer quadrant (LOQ), Ieft LOQ, right lower inner quadrant (LIQ), and left LIQ were 32.79, 32.65, 32.60, 32.46, 32.91, 32.69, 32.28, 32.12, 33.29,and 33.00 °C, respectively. Temperature differences were calculated between the right and left breasts and quadrants, and temperature differences greater than 0.5°C for whole breasts and 1.0°C for breast quadrants were considered asynimetric and abnormal. This resulted in 4 (17%) patients with differences in whole breast ternperatures and 3 (13%) patients with quadrant differences from the 23-screened patients. Rese results are consistent with our previous results with both objective image analysis and subjective visual analysis (15% of screened patients have asymmetric breast infrared patterns).

Further objective infrared measurements in breast cancer patients are needed to determine the sensitivity and specificity of this objective metbod for risk assessment and detection ofbreast cancer.

POTENTIAL LOCALIZATION OF BREAST CANCER BY OBJECTIVE FFT AMPLITUDE ANALYSIS OF DYNAMIC INFRARED IMAGING DATA

Michael Anbar

Department of Physiology & Biophysics, School of Medicine and Biomedical Sciences, University ofBuffalo (SUNY)

Ihe principles of dynamic infrared imaging, or dynamic area telethermometry (DAT) and its potential use in breast cancer detection have been previously described (IEEE EMBS Magazine 19 (3): 58-62, 2000). In a recent paper (Thermology international 11(1): 11-18, 2001), we described new de-

velopments converting subjective qualitative visual analysis to a quantitative obective method.

Visual examination of images that present the spatial distribution of FF1 amplitudes over the breast at a certain frequency or range of frequencies have limited diagnostic value, as it calls for human expertise. This has been the main limitation of classical static thermal imaging. On the other hand, objective computerized evaluation can produce a single diagnostic parameter that allows physicians to classify an examined breast as cancerous or benign and at the same time determine the reliability of the classification. This quantitative approach is based on extracting from the FFT amplitude data parameters that differentiate cancerous from non-cancerous breasts and determine their mean values in cancerous and non-cancerous populations, respectively at each FFT frequency. Doing so, one can identify frequencies that best differentiate between those groups and derive from them the value of the diagnostic parameter for known cancerous and non-cancerous breasts, respectively. Once this has been established, one can take the values of breasts of unknown clinical status and classify them on a quantitative scale between cancerous and ioncancerous breasts, not unlike determining the likelihood of prostate cancer by the level of PSA.

In the later paper we used FFT amplitude parameters that evaluate the whole breast and showed quite effective diagnostic differentiation between breasts with invasive cancer, breasts with ductal carcinoma in situ, and breasts with benign lesions.

More recently we employed FFT parameters that measure the localization of the effect of a suspected lesion on the thermal behavior of breast surface. Using those parameters we did not only get better differentiation between cancerous and non-cancerous breasts, but demonstrates in group statistics that frontal views of breasts are far more indicative of the presence of invasive cancer than medial or lateral views. These findings suggest that our objective diagnostic approach may not only correctly classify a breast as having cancer or not, but might also help in rough localization ofthe lesion.

BREAST CANCER: NEW PARADIGMS 21ST CENTURY INFRARED IMAGING + ANTIANGIOGENESIS THERAPY

William Hobbins

Holistic Health Center, 5510 Medical Circle, Suite B, Madison, WI *35719.*

In the last 25 years, the total incidence of breast cancer has gone from 140 to 198,000 cases and accounts for one-fourth of all the cancers found in females. The deaths from cancer in the same 25 years has not decreased but has increased from 43,000 to 48,000. The increased incidence of breast cancer parallels the 1960 onset of birth control puls and this may be a major factor.

Breast cancer is one cell, which has undergone 26 doublings, 160 days per doubling, to create a 1-cm lesion in 8 years.

Mammography finds indications of a presence of a cancer one year before being able to feel it whereas thermography will show an increased thermal response in the breast 6-12 months before any sign on an x-ray.

Parallel to the early detection has been the discovery as to a methodology for stopping breast cancer from growing, which was initially pointed out by Jean of Mellen-Camege University in 1978. Further work in 1988 by Judith Folkman, a Harvard University researcher, that solid cancers can be prevented, regressed and destroyed by antiangiogensis was discovered. These substances, which are natural, nontoxic and weh tolerated, are in their final stage of trial before release from the FDA for the therapy of cancer and especially breast cancer.

The ultimate use of thermography as the earliest sign of the possibility of the presence ot cancer will be the primary method of screening patients cheaply and noninvasively. When a hyperthermic change in a breast occurs in a follow-up thermogram, the institution of this therapy with the antiangiogenesis factors will be started. When the thermal signal is turned off, the discretion of stopping the antiangiogenesis factor will have to be considered.

The availability of a detection of increased vascularity secondary to the angiogenesis factor of cancer followed by the proper therapy with the tum-off of the angiogenesis and the vascular signal on the breast will wipe out breast cancer in the 21st century.

EAT General Assembly, April 27, 2001, in Vienna, SAS Palais Hotel

K. Ammer, E.F. Ring

European Association of Thermology

The General Assembly of the national EAT Delegates took place in the evening preceding the 7th European Congress of Thermology. The following list of Agenda was distributed to the participants in due course.

Agenda

1. President's Report

2 Secretary's Report + Financial statement

3. Election of officers and members of the committee.

4. Nominations:

President: Prof. Dr. Francis Ring, U.K.

Vice-president: Prof. Dr.Anna Jung; Poland

General secretary and Treasurer:
DDr. Kurt Ammer; Austria

Members of the committee:

Prof. Dr. I. Benkö, Hungary

Prof. Dr. R. Berz, Germany

Dr. G. Dalla Volta, Italy

Dr. M. Engel, Germany

Dr. J. R. Harding, United Kingdom

Prof. Dr. B.Wiecek Poland

Dr. H. Mayr, Austria

Prof. Dr. H.Tauchmannova, Slovakia

The president, Prof. Francis Ring opened the meeting at 19.40.

Dr: Ammer, Prof. Dr. I. Benkö, Prof. Dr. R. Berz, Dr. G. Dalla Volta, Dr. J. R. Harding, Prof. Dr. B.Wiecek and Dr. H. Mayr participated in the meeting, Prof. Dr.Anna Jung, Prof. Dr. H.Tauchmannova, Dr. M. Engel and Dr: D.Rusch have sent apologies for absence.

Presidents Report

Since the last meeting held in Bath UK three years ago (April 1998) a number of significant events have taken place for the Association.

During the year 2000 four special meetings were held.

In February, the first ever meeting on medical uses of Infrared Imaging was held in **Copenhagen**. There was an excellent audience for a programme of papers organised by Dr Pors Nielsen of Hillerod. It is hoped that further meetings will be arranged in .the future as the technology becomes more available to clinicians in Denmark.

In March a conference was held in Bath United Kingdom, to commemorate 200 years from the discovery of infrared radiation by Sir William Herschel in 1800. This was the first conference of the newly merged British Society of Thermology and the **UK Thermographic Association**. Dr Harding (Newport) is the secretary of the medical section. The programme closed with the Annual Public Lecture of The William Herschel Society, attended by some 230 delegates and Society members. R.R.Wessen of the NASA Jet propulsion laboratory gave an illustrated lecture on infrared imaging in space.

The Deutsche Gesellschaft für Thermologie celebrated their 20th anniversary with a special conference in Celle in August. This was the place where the Society held its inaugural meeting in 1980. Dr Gunter Bergmann the local

physician became the Hon Treasurer for the Society. Sadly he was not alive to participate in this successful and enjoyable meeting. After the scientific sessions the evening programme was held at the delightful home of Mrs Bergmann and Dr Jost Bergmann. The occasion was marked by the attendance of Redwings Jazz band led by Dr D.Rusch, the Society Secretary. (Redwings also performed on the river boat in Bath in 1994).

A residential course and conference was held by the Polish Society of Thermology in Djerba Tunisia in October. This was very succesful, well attended by many Polish physicians and some other European members. The venue was outstanding, on the N. African coast, just a few meters from the beach! Despite the glorious weather, a record number of participants completed the course. Some deserved a second certificate for undertaking a jeep safari to the Sahara desert! Our congratulations to Prof. Anna Jung and the officers of the Society for the growth and success of this Society.

The year 2000 was also the time for our **European Congress of Thermology** held in Italy, close to Lake Garda. Dr Georgio Dalla Volta organised a splendid conference in a memorable setting. A Ducal palace set on the hills above the lake provided the special setting for a full and varied scientific programme of papers. Our special thanks to Dr Dalla Volta are due for this important meeting. There ahd been problems with the original venue, which became unexpectedly cancelled at short notice. The changed arrangements were therefore added responsibility to our host!

The Austrian Society of Thermology and the Hungarian Thermographic Society continue to hold regular meetings that attract scientists and physicians from other countries. Members of the EAT have been able to attend and present papers at a number of International meetings including Japan and the USA. The IEEE medical meetings held each year have had a growing number of papers devoted to clinical IR imaging, and this will continue during 2001 in Turkey. The last meeting held in Bath UK was a joint programme with the Royal Photographic Society (Imaging Science) and the European Federation for the Scientific Image. EFSI also arranged a special 3 day conference at Photokina, Köln during 2000, which is the largest Imaging exhibition in Europe. The president was invited to overview the progress in medical thermography at this important meeting.

The European Journal of Thermology has now undergone a second change of title, to become **Thermology International**. We would all like to express our thanks and support for the Editor in Chief, Dr Kurt Ammer for his consistent hard work to get the journal established. The flow of papers, and increased numbers of subscribers are essential for the future stability of this journal. We have the ability to speak with one voice in many countries of the world. As the circulation increases, hopefully in the future, we hope to bring the journal to the stage where it will be cited in the major reference indeces throughout the world.

Our conference timing, originally constituted for once every four years was modified to three, in order to slot in with the frequency of the International College Conference programme. For this reason we are today hosting this International Meeting in Europe, and look forward to the next European Congress in 2003, with the International Congress next due in 2004.

Secretarys Report

Dr.Ammer, General Secretary and Treasurer, reported the financial status of the EAT. The main reason for spending the money of the EAT is the production of the Journal "Thermology international". However, this publication is still dependent on the important financial support of the Ludwig Boltzmann Research Institute for Physical Diagnostics, without this support only 2 instead of 4 issues/year would be produced. This means the number of actual subscribers is still to small to allow a financially independent production of the journal.

The secretary suggested also a new regulation for membership fees. The actual procedure of subscription to the EAT favours big societies which pay a smaller sum per member than small societies. For example, the smallest subscription fee at the moment is 350ATS for societies up to 10 members. This means a sum of 35 ATS /year/ member in case of 10 members, but 70 ATS in case of 5 members. The same relationship is true for all the other steps of this subscription scheme. Dr Ammer proposed to change the subscription fee, which was established at the meeting in Cesena in 1990, towards a new regulation based on the actual

numbers of members within a national society. A sum of 3 EURO per member was discussed and the delegates agreed to follow this new scheme from the year 2002 on. This very moderate increase of membership fee per member (approximately 41 ATS instead of 35 ATS) provides a higher rate of fairness, but will not increase the total income of the EAT.

Election of officers and members of the committee

The delegates accepted the nominations for officers and members of the Committee and elected them unanimously.

Prof Francis Ring will continue as President and Dr. Kurt Ammer remains as General Secretary and Treasurer. The new Vice-President is Prof Dr. Anna Jung from Poland. Hopefully, this position will strengthen the very active Polish Society of Thermology, which hopes to organize the next, 9th European Congress of Thermology in Poland. Prof. R.Clark, M.L Calcina-Goff, Dr.Rusch and Prof L.Thibault de Boesinghe have now left the Committee and Dr. J-M.Engel, and Prof.B.Wiecek have become new members of the Committee. All elected committee members and officers accepted their appointments in the EAT.

Finally, Prof. Ring closed the general assembly at 21.30.

Newsletter

Course and Workshop on Thermal Imaging in Medicine at the University of Glamorgan

The Medical Imaging Group at the School of Computing,University of Glamorgan, has continued in the effort to become a center of excellence for thermal imaging. After hosting the Annual Conference of the Medical Thermology Group of UKTA in March, a 3 day course on Thermal Imaging in Medicine together with a workshop on Advances in Medical Thermography took place on July 3-6, 2001. The course was acknowledged and participants were certified by the University of Glamorgan.

Prof Bryan Jones gave a short introduction in the basic physics of thermal imaging. Prof Francis Ring reviewed the history of temperature measurement in medicine with a special focus on thermal imaging. He showed the enormous technical progress of the equipment used for this technique. Dr. Peter Plassmann reviewed the needs and the facilities of available computer software to evaluate thermal images quantitatively.

Dr. Kurt Ammer talked about the principles of thermal physiology. He included information on other physiological systems such as circulation and autonomic nerve system in his lecture, because these systems are related or partly involved in the process of temperature regulation of the human body.

The second day started with Dr. Richard Harding´s talk on clinical applications of thermal imaging in vascular disorders. He summarized his personal experience in this field covering the topics of deep venous thrombosis, diabetic foot ulcers and vasospastic disease. Prof Ring continued with an overview on provocation tests used in medical thermal imaging with a special focus on cold water challenge. Dr.Ammer described provocation tests using mechanical challenges such as positioning, exercise applied in body parts of interest or performing special tasks including type writing. A practical demonstration of the cold water challenge , closed the mor ning session.

After lunch Dr.Ammer presented examples of causes of temperature increase and temperature decrease respectively. He stated that knowing the temperature measured in the region of interest is not enough information to interpret the cause of this distinct temperature. Pitfalls in interpretation were shown and the difficulty of interpretation was discussed.

Dr. Plassman lectured on the principles of electronic image capturing and gave a introduction in the software programme CTHERM, which is based on a programme used for the evaluation of thermal images at the Department of Clinical Measurements of the Royal National Hospital for Rheumatic Diseases, and that was further developed by Dr.Plassmann.

This programme was used for the practice session in the Thermal Physiology Lab, when each participant practiced image capturing according to recently modified standard views. Defining regions of interest on provided thermal images of the knees and the upper arm was another task to learn. Comparison of the mean values of regions of interest defined by the participants showed a high degree of agreement both within and between observers.

A short lecture on producing a thermographic report given by Dr.Ammer closed this practice session.

Dr Plassmann demonstrated the use of the Archive CD of thermographic papers, which was together with the book entitled "Thermal Imaging in Medicine and Biology" included in the registration fee of this course. He also opened the closing session which was dedicated to future developments of thermal imaging in medicine :with a talk on recent and future developments in digital cameras and image processing. Prof. Ring discussed the problem

of integration of thermal imaging into digital imaging information systems in hospitals. He focused the DICOM systems which seems to become the main image information system in british hospitals. A short overview on facilities of medical education, journals and conferences for applications of temperature in medicine closed the course.

A workshop on **Advances in Medical Thermography** followed the course on July 6. Rod Thomas, phycist from Swansea, presented an interested overview on recent developments in infrared detectors and discussed advantages and disadvantages of the focal plane array technology. In his second talk heat generation due to surgical infrared lasers was shown. A model of heat exchange in this condition was presented and not yet answered questions of heat distribution in the superficial skin layers were raised.

D.Gibbs reviewed reasons for reconsideration of thermal imaging as a screening tool for breast cancer. Richard Harding presented a pilot study using a hand-hold radiometer for bedside diagnosis of Raynaud's phenomenon. Kurt Ammer showed that the change of temperature of finger tips during computer keyboard operation is related to the duration of typing. In a second talk he asked for computer assisted identification of hot spots on thermal images, as the inter-and also the intra-observer repeatability of visually detected hot spots from thermal images of fibromyalgia patients was unsatisfactory low.

Prof Ring presented proposals for standardising a protocol for medical thermal imaging. Most of these proposal has been successfully applied in the course organized in the day before this workshop. He reported also the project of the Thermal Physiology Lab to build a reference database of normal thermal images of healthy subjects. Definition of health and generation of easily reproducible standard views and repeatable positioning of regions of interest on thermal images being the most difficult tasks of this project.

Prof. Anna Jung, vice-president of the European Association of Thermology, from Warsaw, Poland, presented temperature changes on the back, which have been seen in patients suffering from obstructive pulmonary disease. The level of temperature changed after pharmacological induced relaxation of the smooth bronchial muscles. Thermal phenomena on the body surface might be caused by increased activity of skeletal muscles engaged in the breathing mechanism due to high resistance in the air flow.

All papers raised interesting discussion with the audience. It is hoped, that the activity of the University in promotion of thermal imaging will continue. The next course for Thermal Imaging in Medicine will take place in November, and a number of people have already expressed their intrest in participation.

4th Congress of the Polish Society of Thermology

The Polish Society of Thermology, that hold its Annual Conference last year in Djerba, returns this year to Zakopane on September 28-30, 2001, for the 4th Polish Thermology congress. As last year a certified course on Practical application of thermography in medical diagnostics is combined with the meeting. New results of research on thermal imaging from Poland, Germany and United Kingdom will be presented at this meeting. Abstracts of the conference will appear in the next issue of this journal.

For further information contact
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00-909 Warsaw, Szaserow str. 128, Poland.

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Announcement for the Guenter Bergmann Award 2001

The Guenter Bergmann Award is announced for the second time according to the conditions of the award

The Award will be given in a 2 years cycle for outstanding work in the field of clinical application or clinical research of thermal imaging. Papers in German or English from around Europe are welcomed.

Manuscripts should meet the standard of scientific papers and be consistent with the instructions for authors of the journal "Thermology international". A thesis will not be accepted. Members of the committee of the German Society of Thermology are not eligible for the Award.

The award winning paper will be published in the journal "Thermology international". Other sub mitted papers will be also sent the journal "Thermology international" for possible publication.

The Award Committee will consist of

A committee member of the GermanSociety of Thermology

A member of the Bergmann family

A known personality as chairman of the committee.

The jury is allowed to consult external experts for reviewing papers. Deadline for submission (original manuscript and 2 copies) is August 31, 2001.

Address for submissions is

The President of the German Society of Thermology

Dr Joachim-Michael Engel M.D.

marked PERSONAL

Rheumaklinik Bad Liebenwerda

Dresdener Straße 9

D-04924 Bad Liebenwerda,

Germany

Veranstaltungen (MEETINGS)

29.-30.September 2001
4th Congress of the Polish Society of Thermology in Zakopane

Conference Venue:

"HYRNY" guest house

Zakopane, Pilsudkiego str 20

Course schedule

Practical application of thermography in medical diagnostics

Friday 28.9.2001 19.00- 20.30

Saturday 29.09.2001 12.40-13.45

Sunday 30.09.2001 16.30-17.30

Sunday 30.09.2001

Ship excursion on Pieniny Reservoir visiting Niedzica Castle

Conference schedule

Saturday 29.09.2001 9.00-12.30

15.30-18.00

Sunday 30.09.2001 15.00-16.30

Information

Prof.Dr.A.Jung

Pediatric and Nephrology Clinic,
Central Clinical Hospital, Military University,
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email: ajung@cskwam.mil.pl

November 2001
Course on Thermal Imaging in Medicine at the University of Glamorgan

Speakers: Dr K Ammer (KA) Prof F Ring (FR), Dr P Plassmann (PP).

Timetable:

1st day
A Theoretical and Historical basis of Thermal Imaging in Medicine

10.30-11.20am History and development of IR Imaging (FR)

11.35 – 12.25 Physical Principles of heat transfer (FR)

12.30pm Lunch Green Room – Gallery Restaurant

1.30-2.20 pm Principles of Thermal Physiology 1 (KA)

2.20-2.30 pm Film (cold and warm baths)

2.30-3.20 pm Principles of Thermal Physiology 2 (KA)

3.20-3.50 break Bytes Cafe

4.00-5.00pm Standard protocols for image capture (FR)

2nd day B Clinical Applications of Thermal Imaging

9.00 – 9.40am Provocation tests 1 (FR)

9.45- 10.25am Provocation tests 2 (KA)

10.25 – 10.50am break Bytes Cafe

11.00 – 11.30 Film (living body)

11.30- 12.30 Lab demonstration cold stress test

12.30pm Lunch Green Room GalleryRrestaurant

1.45-2.30pm Causes of temperature increase (KA)

2.30-3.00 Causes of temperature decrease (KA)

3.00 – 3.30pm break Bytes Cafe

3.30- 4.00pm Image capture (PP)

4.00 – 5.00pm Introduction to CTHERM software (PP)

3rd day C Practical session capturing and analysing images

9.00-10.15m Picture composition, standard views and resolution (FR
Analysis of thermograms regions of interest etc. (FR)

10.15-10.40 break

10.40 t- 12.15 Practice session in J150

12.15 – 12.30 Producing a thermographic report (KA)

12.30pm Lunch

1.30 – 2.00pm Archive CD of thermographic papers demo (PP)

2.00-2.45pm. **Future developments of Thermal Imaging in Medicine**

1. Digital cameras and processing (PP),

2. Integration into hospital DICOM systems (FR)

Medical Education, Journals and conferences (KA)

March 1 - 2, 2002

The 8th International Conference on Infrared Thermal Imaging

TAMPA, FLORIDA U.S.A.

Sponsored by ASI Inc.

Conference Times:

Friday, March 1, 2002 - 9:00 a.m. - 5:00 p.m.
Saturday, March 2, 2002 - 9:00 a.m. -1:00 p.m.

Location: Tampa, Florida

Hotels: Hyatt Regency, Marriott Airport Hotel, Radisson, Wyndham Westshore, Sheraton Suites, Hampton Inn Westshore.

Airport: Tampa International Airport

REGISTRATION INFORMATION

Get registration form at
http://www.thermology.com/conference8.htm

Print the registration form and send via Regular Mail with Conference Fee

Fee: $195 per person - if registered by January 1, 2002 - space is limited

Payable to: Ashwin Systems International Inc. P.O. Box 1014, Dunedin, FL 34697 U.S.A. - 727/785-5844

April l-5, 2002 - Orlando

Thermosense XXIV, Opryland Hotel in Orlando, FL, USA

Abstract Due Date: 20 August 2001,
Manuscript Due Date: 7 January 2002

All authors are STRONGLY ENCOURAGED to submit their abstracts by the due date using the Web form available on the SPIE Web site. If this is not possible, please choose only one of the following options:

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Shipping Address: 1000 20th Street, Bellingham, WA 98225-6705 USA

or FAX one copy to SPIE at 360/647-1445 (send each abstract separately).

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conference code 50 (Example) [or50]

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27. April 2002, Wien

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Theme: Standards in Thermology

Venue: SAS Raddison Palais Hotel, Vienna

Information:
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Ludwig Boltzman Research Institute for Physical Diagnostics, Hanuschkrankenhaus, Heinrich Collinstr.30;
A-1140 Vienna;Austria

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September 24-27, 2002

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