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Thermal Findings In Pain Syndromes of the Pelvic-Femoral Region

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Summary

BACKGROUND: Conventional imaging techniques such as X-ray, CT, MRI, and ultrasound cannot identify functional impairments, which can be detected by myoskeletal palpation techniques. Infrared thermography may have the potential to confirm the findings of palpation.

AIM OF THE STUDY: Primary objective was to identify a possible relationship between skin areas with increased thermal radiant exitance and the results of myoskeletal examination of the pelvic-femoral region and goniometric hip measurements

METHOD: We conducted a retrospective evaluation of thermographic and clinical findings of 83 patients presented with pain in the pelvic-region. The myoskeletal examination included a palpation exam of the muscular and fascial trigger points – TrP, painful tendon and ligament attachments (enthesopathies) - TeP, joint play of SI (sacroiliacal) joints. Range of motion (ROM) measurement of the hip was performed and recorded using the SFTR method (Sagittal, Frontal,Transversal and Rotation plane). Thermal images of the lower back, the abdomen and the gluteal region (in dorsal and lateral view) were recorded with a Fluke Ti32 thermal imager.

RESULTS: The prevalence of thermal active focal findings correlates in most cases with the prevalence of clinically significant trigger points , enthesopathies , bursopathies, etc. In case of a blockage of one of the SI joints, there was a thermal asymmetry recorded above the SI joints in the majority of cases, with a slightly predominant finding of increased thermal activity above the SI joint blockage. Differences in ROM of the hip joints were often associated with thermal asymmetry in the proximal or distal gluteal region.

CONCLUSION: Functional impairments of the myoskeletal system detected by palpation can be confirmed by coincidence between tenderness and increased local temperatures.

KEY TERMS: pelvicfemoral region, thermographic images, myoskeletal, goniometry, hypothermia

THERMISCHE BEFUNDE BEI SCHMERZSYNDROMEN DER BECKEN-BEIN REGION

Hintergrund: Die herkömmlichen bildgebenden Verfahren wie Röntgen, CT, MRT, Ultraschall können funktionelle Beeinträchtigungen, die durch myoskeletale Palpation entdeckt werden, nicht erkennen. Die Infrarot-Thermografie scheint das Potenzial zu besitzen, die Ergebnisse der Palpation bestätigen zu können.

ZIEL DER STUDIE: Ziel war es, einen möglichen Zusammenhang zwischen Hautzonen mit erhöhter Wärmeabstrahlung und den Ergebnisse der myoskeletalen Untersuchung in der Becken-Bein-Region sowie den goniometrischen Messungen des Hüftgelenks zu finden.

METHODE: Wir führten eine retrospektive Auswertung von thermographischen und klinische Befunden von 83 Patienten mit Schmerzen in der Beckenregion durch. Die myoskeletale Untersuchung beinhaltete eine palpatorischen Untersuchung der Muskulatur und myofaszialer Triggerpunkte - TrP, schmerzhafte Sehnen- und Bandansätze (Enthesopathien) - TeP, und eine Beurteilung des Gelenkspiels der SI-(sacroiliakalen) Gelenke. Die Messung des Bewegungsumfangs (ROM) der Hüftgelenke wurde nach der SFTR-Methode (Sagittal-, Frontal-, Transversal- und Rotationsebene) durchgeführt. Wärmebilder des unteren Rücken, des Bauch und des Gesäßbereich (von hinten und in einer seitlichen Ansicht) wurden mit einer Wärmebildkamera Fluke Ti32 aufgezeichnet.

ERGEBNISSE: Die Häufigkeit von umschriebenen, thermisch aktiven Veränderungen korreliert in den meisten Fällen mit der Inzidenz von klinisch relevanten Triggerpunkten, Enthesopathien, Bursopathien, etc. Bei Blockade eines SI-Gelenks, fand sich in der Mehrzahl der Fälle eine thermische Asymmetrie oberhalb des SI-Gelenke, wobei überwiegenden eine gering höhere thermische Aktivitäten über der SI-Blockade beobachtet wurde. Unterschiede im Bewegungsumfang der Hüftgelenke zeigten oft gleichzeitig thermische Asymmetrien im proximalen oder distalen Gesäßbereich.

SCHLUSSFOLGERUNG: Funktionelle Beeinträchtigungen des myoskeletalen Systems, die durch Palpation erkannt wurden, können durch eine Übereinstimmung zwischen Druckempfindlichkeit und erhöhten lokalen Temperaturen bestätigt werden.

SCHLÜSSELWÖRTER: Becken-Bein-Region, Thermografieaufnahmen, myoskeletal, Goniometrie, Hypothermie

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Introduction

Pain and disorders in the pelvicfemoral region may have different causes, such as structural skeleton disorders, malignant and inflammatory diseases, lumbar spine disorders, malfunctions of pelvic organs and soft structures in this area – the muscles, fascias, ligaments, insertions, SI (sacroiliacal) joints, symphyseal synchondrosis, and hip joints.

Imaging techniques such as X-ray, CT, MRI, and ultrasound are well established in the diagnosis of structural changes, but fail to detect findings of functional nature. In this case, we must rely mainly on myoskeletal palpation techniques, which may generate highly subjective findings. Apart from the above stated conventional structural imaging methods used to objectify pain sources, we have also used a non-invasive diagnostic tool – thermographic imaging – for over 25 years. Using this method enables us to objectify enthesopathic and myofascial findings by local temperature changes on thermograms caused by increased infrared exitation.

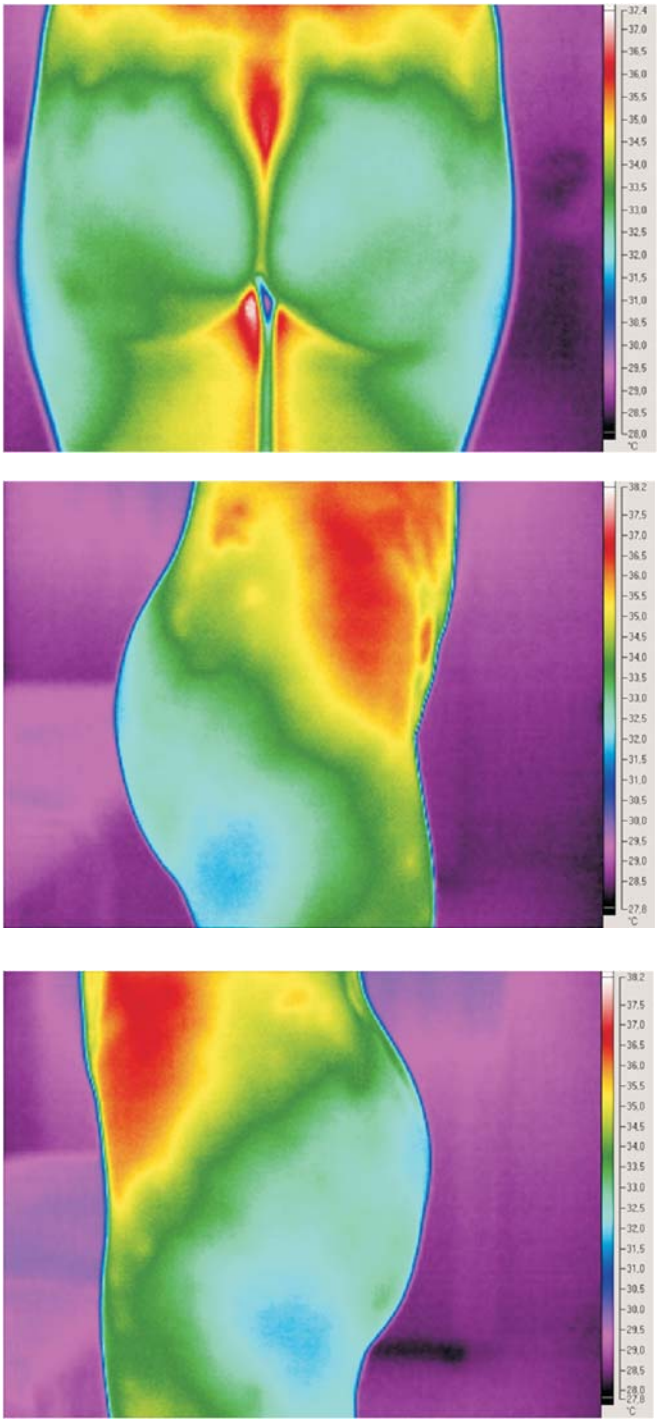

Figure 1.
Normal thermal findings in the pelvicfemoral region.

Method

We conducted a retrospective study that compared the results of thermographic and clinical examinations of patients who experienced pain in the pelvicfemoral area and have been admitted to our clinic between January 2011 – December 2011. The trial excluded patients with severe structural, tumour and inflammatory disorders. All patients underwent: at first a thermographic examination. We used a Fluke Ti32 thermal imager, which can sense the difference of 0.05°C, for image capture.. The examination was performed under standard conditions established by the European Association of Thermology [1] and American Academy of Thermology [2] in standard positions in line with the Glamorgan protocol [3].We assessed areas showing locally increased temperature in the pelvicfemoral region at

- - crista iliaca
- - mm.gluteus medius, minimus
- SI joints
- - spina iliaca anterior superior (SIAS)
- - trochanter major
- - groin
- Thermal symmetry above the distal gluteal region (m. gluteus maximus) and proximal gluteal region (m. gluteus medius and m. gluteus minimus) using rectangular regions of interest. We considered a temperature difference (Tdif) =0,5°C as sign of thermal asymmetry.

Normal temperature distribution

We considered symmetrical hypothermia in the gluteal region combined with an increased thermal radiation in the proximal part of the intergluteal cleft and a butterfly pattern of slightly increased temperature over the sacroiliac area and a continuous narrow strip of increased infrared exitance over the processi spinosi of the lumbar spine as a pattern of undisturbed temperature distribution. Moderately increased thermal activity is observed in the lateral projection in the area of muscle insertions at the frontal part of crista iliaca, spina iliaca anterior superior and spina iliaca anterior inferior.

After thermal images have been recorded and assessed, each patient proceeded to the myoskeletal examination .Palpation techniques were applied in the area of identified hot spots, to detect active and latent myofascial trigger points following the criteria of Travel and Simons [4]. Insertion of tendons at the crista iliaca, the spina iliaca anterior superior (SIAS) and at the trochanter major were checked for tenderness. The joint play in SI joints was assessed according to Lewit [5].

Goniometric assessment of the range of motion of the hip joints was carried out and recorded according to the SFTR method.

We considered a side to side difference equal to 5 degrees in medial rotation as marker of disturbed range of motion. Limitation of the inner rotation was claimed by Cyriax to be one of the early indicators of an impaired hip joint [6].

Aims and Objectives

Our primary aim was to discover a possible association of areas of increased temperature with the results of myo-skeletal examination and to investigate the diagnostic value of thermal asymmetries in the pelvic-femoral region for side differences in the range of hip motion.

1. Association between thermal findings and painful areas detected by palpation.

A. Diagnostic accuracy of hot spots for painful TrPs in the gluteal region.

B. Association between the thermal findings and painful TeP in the area of crista iliaca.

C. Co-incidence of hyperttthermic findings and painful, tender areas in the region of trochanter major.

D Association between the thermal finding and temderness in the groin. or co-incidence of hot spots and pain on palpation in the region of SIAS.

2.Association between thermal findings and restricted sacro-iliacal joint play.

3.Diagnostic value of thermal asymmetries in the distal and proximal gluteal regions for different range of hip motion.

Calculation of diagnostic accuracy of thermal asymmetries detected above the m.gluteus maximus or above m.gluteus medius and m.gluteus minimus for side differences in medial hip rotation obtained by goniometric examination.

Statistical analysis

Descriptive statistics were computed. We calculated diagnostic sensitivity, specificity, positive and negative likelihood ratio of hot spots for pain on palpation found in the gluteal region and of temperature asymmetry for side difference of hip ROM. .

Results

In total, 83 patients:, 42 males and 41females with a mean age: 42,5 (13 - 79) years were included.

The diagram in figure 1 summarizes the frequency of combined clinical and thermal findings the pelvic-femoral region.

Association between thermal findings and tender sites

A. Diagnostic accuracy of hot spots for painful trigger points (TrP) in the gluteal region

33 tender sites were identified by by palpation. 30 of these myofascial foci were thermally active. The number of hot spots (45) surpassed the number of tender sites by 37%

Typical thermograms of tender sites in the proximal part of the gluteal region, characterized by increased temperature are shown in figures 2 A and 2B.

Table 1 shows the number of true and false positive, and true and false negative cases. The calculated values for sensitivity was 90.9 % and 54.5 % for specificity: From these values a positive likelihood ratio of 2.00 (95% confi-

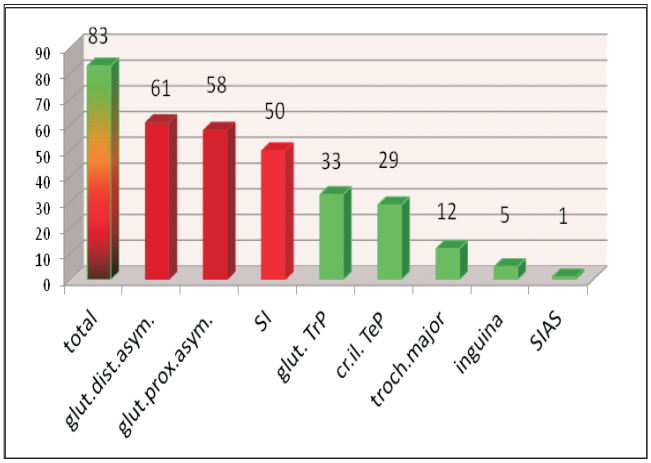

Figure 1.
Frequency of temperature asymmetries in patients with restricted sacroilical joint play and/or tender sites in the pelvic-femoral region

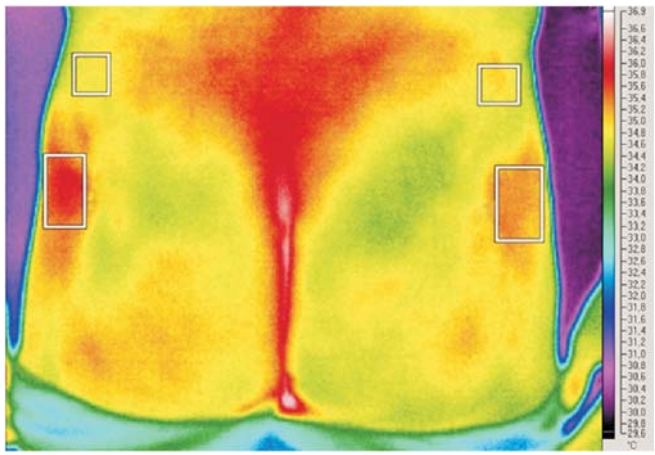

Figure 2 A
Thermal active findings at the both sides. Left temperature is by 0,8° higher compared to contralateral side

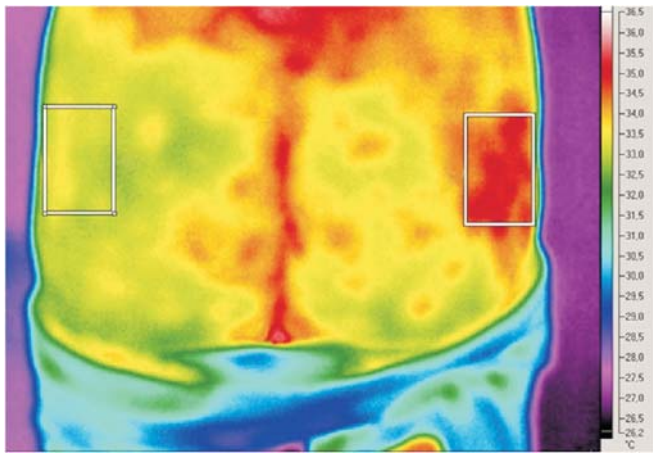

Figure 2 B
ROI over thermal active finding at the right side. Side difference of temperature 1,5°C.

Table 1
Coincidence of tender sites and hot spots

	non tender site	tender site
hot spot	15 (false positives)	30 (true positives)
non hot spot	18 (true negative)	3 (false negatives)

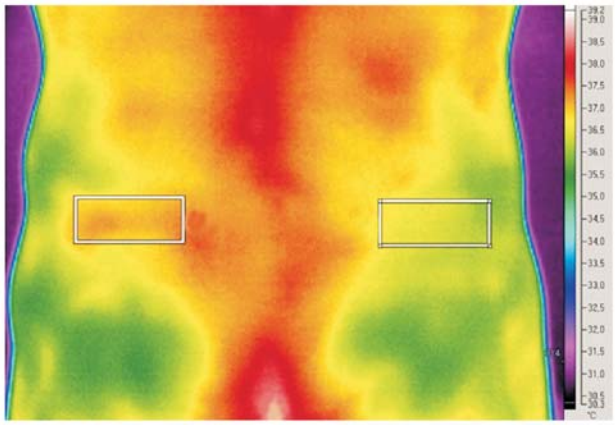

Figure 3
ROI over both crista iliaca. Side difference of temperature 0,6°C in favour of the left side

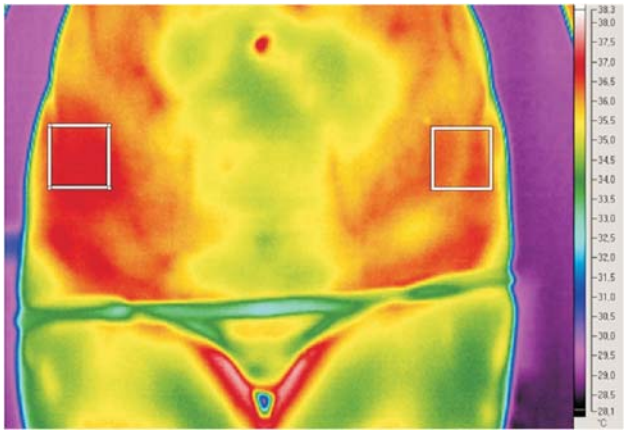

Figure 4
ROI at spina iliaca anterior superior bilaterally. Side difference of temperature 0,5°C in favour of the right side

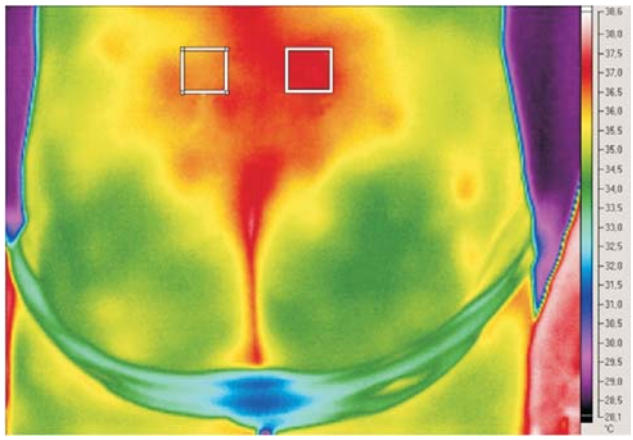

Figure 5
ROI over SI joints; Side difference of temperature 0,8° in favour of the right side.

dence interval:1.36 to ,2.95) and a negative likelihood ratio of 0.17 (95% confidence interval:0.05 to 0.51) were determined.

B. Association between the thermal findings and painful TeP in the area of crista iliaca

In 29 cases out of 30 (29/30) increased thermal activity was detected above the myofascial findings (TeP) at the crista iliaca that was painful on palpation. A typical thermogram is shown in figure 3.

C. Co-incidence of hyperttthermic findings and painful, tender areas in the region of trochanter major

Ws detected In 11 cases out of 14 increased thermal activity upon the painful trochanter major.

D Association between the thermal finding and temderness in the groin. or co-incidence of hot spots and pain on palpation in the region of SIAS

In both locations the groin and the SIAS, clinical and thermographic findings had a low prevalence. In the groin, all 5 tender sitse presented with increased infrared exitance. 1 of 2 cases with pain detected by palpation above the SIAS showed an increase of temperature (figure 4).

Table 2 summarises the association of painful findings detected by palpation or restricted SI joint play joints with thermal findings.

Association between the thermographic finding and the joint play finding in the area of SI joints.

Thermal asymmetry was observed in 50 out of 62 patients with functional SI joint blockage. We detected increased thermal activity in 36 cases with restricted saceoiliacal joint play.

Association between thermal findings in the gluteal region and the goniometric hip examination.

A. Distal gluteal region (m.gluteus maximus) and hip ROM.

In 61 cases there were thermal asymmetrical findings recorded and in 49 (49/61) of them we also recorded asymmetrical ROM.

B.Proximal gluteal region (m.gluteus medius and m.gluteus minimus) and hip ROM.

In 58 recorded cases with thermal asymmetrical findings, 51 (51/58) cases showed a side difference of medial rotation of hip joints. Figure 6A shows a typical thermogram

Table 1.
Painful findings detected by palpation or restricted SI joint play associated with thermal findings

location	palpation pain	↓joint play	T asymmmetry	↑T
SI joints		62	**50**/62	**36**/62
gluteal TrP	33			**30**/33
crista iliaca TeP	30			**29**/30
trochanter major	14			**11**/14
groin	5			**5**/5
SIAS	2			**1**/2

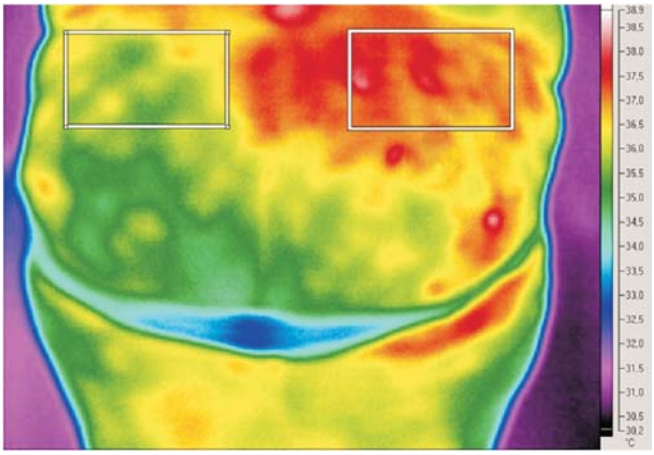

Figure 6 A
Thermal asymmetry in the proximal part of the gluteal region. Temperature at the right side is by 1.2°C higher than contralateral.

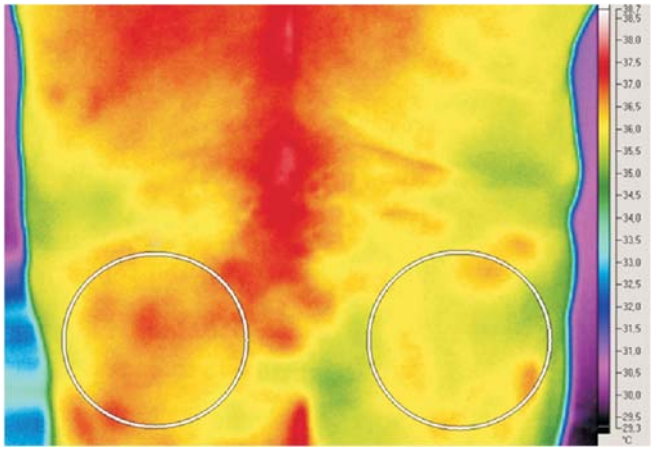

Figure 6B
Thermal asymmetry in the distal part of the gluteal region. Temperature at the lefft side is by 0.5°C higher than contralateral

with temperature asymmetry of the proximal part of the gluteal region and an example of thermal asymmetry in the distal part of the gluteal region is given in figure 6B.. From the coincidence of thermal asymmetry with the difference range of hip motion the following figures for diagnostic accuracy were calculated

Distal gluteal region

Sensitivity . 89,1 % , Specificity: 57,1 %,
Positive Likelihood ratio:2.08
(95% confidence interval:1.34 to 3.22)
Negative Likelihood ratio:0.19
(95% confidence interval:0.03 to 0.43)

Proximal gluteal region

Sensitivity . 77.3 % , Specificity: 41.2 %,
Positive Likelihood ratio:1.31
(95% confidence interval:0.86 to 2.00)
Negative Likelihood ratio:0.55
(95% confidence interval:0.27 to1.14)

Discussion

The fact that muscular activity is the most important source of increased metabolic activity and the contracting muscles contribute to the distribution of heat on the bodily surface of sportsmen was described by Smith et al.[7]. We previously descibed thermal asymmetries and hot spots in the pelvic -femoral area in a study (8,9,10,11) in which we investigated relationship between thermally active focal findings and the type of sport activity or workload in 144 people. Of these, 122 were top athletes of different sports disciplines (weightlifters, power lifters, wrestlers, rowers, footballers, handballers) and 20 were non-athletes (physically active and sedentary administrative workers). The performed examinations were of preventive nature and the examined subjects did not reported painful sensations in any area of the musculoskeletal apparatus at the time of examination.We detected that specific thermal findings were highly predominant in each group of sportsmen. These patterns of temperature distribution allowed clear distinction of each sport discipline.

We detected in 30 examined wrestlers, thermal asymmetries above the area of SI joints in 54% of cases, combined with an area of increased temperature almost exclusively on the left hand side. In 75% of 24 examined football players, were detected hyperthermic foci in the inguinal and gluteal region. After examining 12 handball players, increased thermal activity above the right SI joint was recorded in 77% and hot spots above the SIAS area were identified in 85%. 72% of 15 power lifters presented hyperthermlc foci in the area below crista iliaca and around the great trochanters. The cohort of 31 wrestlers showed in 63% thermal asymmetries in the area of the para-spinal muscles, but no thermal abnormalities in the pelvic- femoral region. The examination of 10 rowers revealed thermal asymmetries in the lumbar spine area and hot spots over the spine in 22% of cases, but again without thermal findings in the pelvic-femoral region. We interpreted our results in a way that thermal findings in top athletes are dependent on the type of the sports activity they perform.

Table 2.
Association between thermal asymmetries in the gluteal region and the ROM in hip.

Location	Thermal finding		ROM symmetry	ROM asymmetry
Distal gluteal region	thermal symmetry	22	16 (true negative)	6 (false negative)
	thermal asymmetry	61	12 (false positive)	49 (true positive)
Proximal gluteal region	thermal symmetry	25	15 (true negative)	10 (false negative)
	thermal asymmetry	58	7 (false positive)	51 (true positive)

There was also a difference noted between the findings of physically working people as opposed to sedentary administrative workers. 6 of 10 physically working people showed hot spots, mostly bilateral, in the area of crista iliaca, and increased thermal activity in the area of SI joints without significant side-to-side dominance. In 8 of 10 subjects, we found an increased thermal activity in the antero-lateral region of hip joints. None of these findings were recorded in the group of sedentary workers. In 70% of them there was a thermal asymmetry detected in the area of SI joints, of which 60% was prevailing on the right side. In non-athletes the findings differ depending on the type of workload. Both sportsmen and non-athletes show increased thermal activity in many skin regions above musculoskeletal apparatus, and also in the pelvic-femoral region. They are mostly located above overloaded muscle groups and tendon insertions, depending on the type of biomechanics of the performed movement pattern. The distribution of hot spots is different in pain free athletes and patients with painful syndromes in the pelvic-femoral area. The prevalence of thermally active focal findings at the groin and the SIAS region is significantly lower.

Sillero Quintana et al. used a thermovision examination of the hamstring region in the group of football players and discovered significant differences in temperature between the painful and painless limb [12]. Fischer and Chang reported that tender areas such as muscle spasms or myofascial trigger points may become visible as areas of increased temperature [13]. Ammer found in patients suffering from lateral epicondylopathy, that visually identified hot spots bear a nine fold increased risk for a low pain threshold on pressure [14].

Diakow et al. [15] compared in 10 volunteers manual-therapeutic findings such as restricted joint play and pain on pressure (=tenderness) with abnormal findings i.e temperature difference to the surrounding tissue in contact thermograms of propands back. Agreement between thermal findings and vertebral blockages was found in 64,7%, tender sites and thermal findings concured in 63,7%. Another study using liquid crystal contact thermography reported in 80% of back pain patients either tenderness or the reproduction of low back pain when high-temperature regions of the low back were palpated [16].

However, Swerdlow and Dieter were unable to confirm low threshold for pain on pressure study over hot spots located on the upper back [17]. A study from Canada could not differentiate tender sites at the upper trapeze muscle by radiometric temperature measurement [18]. As this study was conducted in patients with chronic shoulder girdle pain, this results are not unexpected as pain threshold for pressure at tender sites was 1.8 ± 0.1 kg/cm² and 2.0 ± 0.0 kg/cm²at non tender sites and the related mean temperatures were reported with 32.1 ± 0.1°C for tenderness and 32.0 ± 0.1°C for non tender sites. Both pain threshold values are equal or below the lower limit of normal values as reported by Fischer [19].

The occurrence of hot spots on back thermograms assisting the diagnosis of fibromyalgia or myofascial pain syndromes were reported by Ammer [20], Miranda [21], Shafer [22] and also in a number of our previous research [23,24,]. Araujo et al. reported that centrally localized thermal findings are painful on palpation rather than laterally localized hot spots in patients with low back pain. [25]. Increased infrared exitance in the area of SI joints was described in the research work by Tauchmannová [26]. Neto et al. proposed to divide the lower back into five regions of interest, when investigating SI joints [27]. These measurement areas are identical with the regions that we have used in our research (23,,24). The very first medical report on pubalgia was published by an author named Beer and dates back to 1924. Lima et al. used various colour scales in order to improve the visibility of thermal findings in patients with pubalgia [28].

We detected increased thermal activity adjacent to restricted sacro-iliacal joint play in 36 cases. The cause of this temperature increase remains unclear. A concurrent inflammation at the attachment of the sacro-iliacal ligaments can explain the pain to some extent, but not the temperature findings as the ligaments insert on the dorsal end of internal lip and the tuberosity of the iliac bone. Both sites of insertion are not accessible for palpating fingers. Heat conduction passing through the bony shield presumes a large temperature gradient which cannot be generated by an inflamed enthesopathy. However, the inflammation process leads to vasodilation which increases the area of heat dissipation. Vessels, which connect the vascular bed involved in the inflammation with skin vessels located in the region of the sacro-iliacal joints, may also become dilated and hot spots on the body surface may be caused by this hypothetical process. Pain due to the sacro-iiacal ligaments was also explained by muscle insertion which have their origin adjacent to the sacrum and the medial end of the external lip of the iliac crest [29].

The diagnostic accuracy of hot spots for tender sites was only moderate with high sensitivity, but low specificity resulting in a positive likelihood ratio of 2.0 only. This can be explained by the fact that hot spots in the gluteal region are common findings in asymptomatic subjects as reported in our studies in athletes and physically active and sedentary workers. Although the diagnostic accuracy of hot spots in other parts of the pelvic region was not calculated due to missing information on true negative cases and the small portion of positive findings, the result for the diagnostic value might be in a similar range as for hot spots in the gluteal region when the high prevalence of hyperthermic areas in asymptomatic subjects is considered.

Ammer reported lower temperatures above peripheral joints with a restricted range of motion [30]. We repeatedly provided information in our research on a decrease of thermal activity above knee joints in the presence of chronic overload syndromes (31). Kanie reported a decreased temperature in connection with the hip joint osteoarthritis [32], and the same was observed by Vecchio [33] and Ammer {34] in patients with the frozen shoulder.. In our study, hypo- thermic findings in the gluteal region coincided with restricted range of hip joint motion. In case we detect asymmetrical ROM in the hips, the asymmetry of

thermal activity in the gluteal region might then be caused by asymmetrical activity of the gluteal muscles. However, the diagnostic accuracy of thermal asymmetry for restricted range of hip motion was only moderate. A thermal asymmetry in the proximal or distal gluteal region, might be caused by asymmetric activity of the distally rather than the proximally located gluteal muscles. However, thermal asym-metry in the gluteal region should not be used as diagnostic criterion of hip osteoarthritis.

Conclusion

Functional impairments of the musculoskeletal system detected by palpation can be confirmed by the coincidence between tenderness and increased local temperatures. In pain patients, hot spots located in the gluteal region, in the groin, at the crista iliaca, around the trochanter major and at the spina iliaca anterior superior might be caused by enthesopathies, myofascial trigger points or bursopathies.

The finding of thermal asymmetry above the area of SI joints may predict the presence of functional blockage of one sacro-iliacal joint. and temperature difference in the gluteal region may indicate a restriction in range of hip motion.

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Laser-tissue photothermal interaction: a thermal infrared imaging study

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SUMMARY

A 2-D approach, based on Infrared (IR) imaging for monitoring and optimizing the photo-therapy in dermatology, is proposed. We studied the possibility to employ IR imaging in order to select the laser treatment parameters for each patient. A Pulsed Thermography (PT) model allowed to evaluate morphological information on the specific area to treat after a single laser pulse test. The data were elaborated through a 2-D numerical simulation, which described the tissue temperature profiles for different sets of laser parameters. Based on this approach, it was possible to select the laser parameters according to specific pathology, morphology and phototype in order to achieve the best performances in the phototherapy practice.

KEYWORDS: Laser Therapy; Pulsed Thermography; Infrared; Treatment; Plane Angioma pathology.

PHOTOTHERMALE INTERAKTION VON LASER UND GEWEBE: EINE UNTERSUCHUNG MIT INFRAROT-THERMOGRAFIE

Basierend auf Infrarot (IR)-Thermografie-Bildgebung wird ein 2-D-Ansatz für die Überwachung und Optimierung der Foto-Therapie in der Dermatologie vorgeschlagen. Wir untersuchten die Möglichkeit mittels Infrarotthermografie die Parameter der Laserbehandlung individueller Patienten zu bestimmen. Ein Modell der Puls-Thermografie ermöglichte es, nach einem einzigen Laserpuls die morphologischen Informationen aus einem bestimmten Behandlungsbereich auszuwerten. Die Daten wurden durch eine 2-D-numerische Simulation gewonnen, die Gewebetemperatur Profile für verschiedene Arten von Laser-Parametern errechnete. Mit diesem Ansatz war es möglich, Laserparameter auf Grund bestimmter Pathologien, der Morphologie und des Fototyps aus zu wählen, um bestens mögliche Ergebnisse bei der Lichttherapie zu erzielen.

KEYWORDS: Laser Therapie; Puls-Thermografie; Infrarot; Behandlung, planes Angiom

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Introduction

Experimental studies aimed at evaluating the potential contribute in medicine provided by laser date back to early 1960s [1-2]. Over the years, laser-based treatments in medicine have become affordable, common and reliable, up to become a very well accredited procedure in a variety of medical disciplines such as ophthalmology, urology, neurosurgery, dermatology, oncology, and gastroenterology [3-6].

Reasons for such a success were the possibility of non-contact approach, bloodlessness surgery procedures and the capability of selective treatment of the injured tissue saving unaffected or healthy surrounding tissue [7-9]. The achievement of the optimal performance in laser-based treatments depends on the laser-tissue interaction, which in turn depends on the delivered light power, the emitted light wavelength, the photo-action time, and the use of pulsed versus continuous energy delivery. Different combination of these factors determines different physiological processes according to the desired treatment effects, i.e. regional hyperthermia, blood coagulation, tissue carbonization, and vaporization [10, 11]. In the last decades, the laser technology specialised to offer several standard and/or customizable lasers specifically designed for medical purposes, which accelerated the spreading of this technique in the medical practice [12, 13]. So, while the laser treatment is nowadays considered safe and effective, some relevant problems remain open and impose caution while operating with laser source on human tissue. In particular, concerning the use of pulsed laser sources in some specific skin pathologies, it is required a proper choice of the light pulse in terms of duration and intensity in order to avoid undesired side-effects of the treatment, like surrounding healthy tissue burning, boundary overheating or ineffective treatment [14-16]. For dermatological or aesthetic issues, the medical doctor usually approaches the laser treatment in a somehow empirical manner by following generic guidelines based on skin photo-type and basically exploiting his own experience based on previous or similar treatment outcomes.

A very simple and efficient tool, able to monitor the thermal effects of the laser treatment, to elaborate the data collected by a thermo-camera and to give fast the laser parameter to set as a function of the patient under treatment , would therefore result extremely helpful in view of the treatment outcome.

A potential solution is provided by thermal infrared imaging, which allows to measure directly the in vivo thermal effects associated with managing the laser energy [17-20]. Thermal infrared imaging is in fact a reliable, safe and touch-less technique able to measure even small temperature variations of the interested and surrounding tissue by means of high-spatial and temporal resolution thermal cameras [21-23].

In this paper, an approach for the laser parameters optimization in the treatment of plane angioma, based on infrared imaging, is proposed. We believe that, after accurate clinical tests, this tool can give rise to an advanced medical system constituted of a laser source, IR camera and control unit, useful for future applications. Our approach has been tested on a set of patients suffering from Port Stain Wine (PWS) pathology, which is a relatively common form of plane angioma usually treated by laser irradiation in Fotothermal regime [24, 25].

PWS is a vascular malformation that consists in a blood vessels accumulation, newformed and malformed, under the tissue. This accumulation forms a subsurface plane of vessels localized in the dermis, the thickness and depth of which seem to depend on the specific anatomical region and may largely vary from case to case [26]. Mean blood vessels thickness ranges from 20 to 180 ìm, while the averaged depth ranges from 200 to 1300 ìm. The exact causes of PWS remain unknown. Evidence for genetic influence is lacking. Capillary malformations may result from a neural deficiency of sympathetic innervation of the superficial dermal blood vessels [27-29]. A typical example of PWS is shown in Fig. 1.

This pathology is usually treated according to the method described in literature [10]. The treatment lasts from 1 to 2 years and it depends on the size of the area of the pathology. However, the laser treatment has been effective in approximately 20-25% of cases, partially able to solve the problem in 30-35% of the cases and, unfortunately, without any appreciable improvement in approximately 50% of the treatments. Main issues related to the laser treatment of plane angioma regards the efficacy itself of the treatment, which depends on patient's age, anatomic region over which the angioma is developed, skin phototype, lesion depth and thickness. Moreover, undesired possible formation of scars or dischromic areas may affect the full success of the treatment.

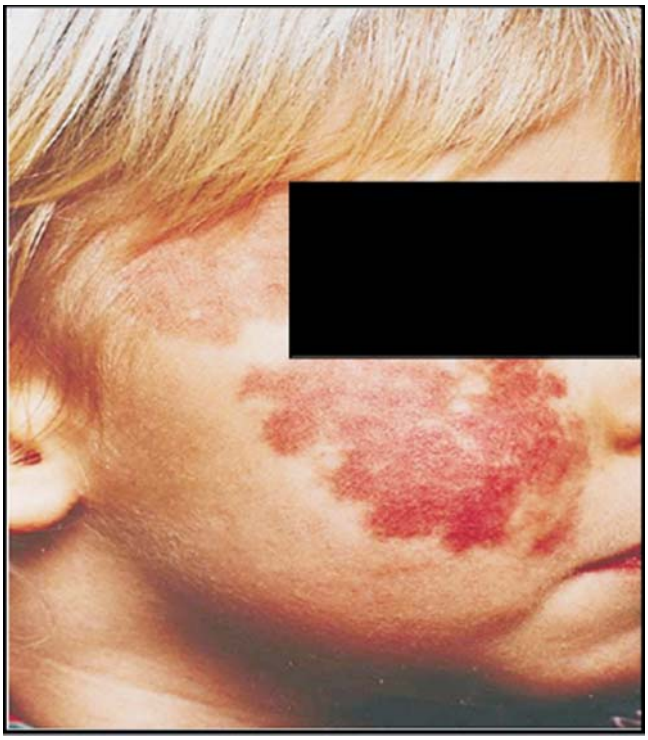

Figure 1.
Patient affected by plane angioma known as Port Wine Stain (PWS) pathology

Description of the method

According to the traditional method for laser treatment of PWS, the operator launches a sequence of laser pulses on the angioma area to treat, setting the incident radiation parameters (light intensity and pulse duration) on the base of the protocol suggested for PWS laser therapy (Table 1).

The methodological approach, that we are proposing here, considers the use of the thermal-camera not only for monitoring directly the interaction laser-tissue during the treatment, but mainly, for collecting thermal data supplied by the output camera software, after the first laser pulse, to be elaborated in real time with the aim to set in advance the laser parameters to adopt for the further pulses. This procedure allows to select immediately after the first laser pulse, the right laser parameters according to the specific morphology of PWS and the phototype. To this goal, we defined a sequence of steps which must be applied at the beginning of each sitting:

a) initial single pulse on PWS area, b) few seconds waiting for collecting thermal response, data elaboration by our software and output data, c) setting the laser parameters according to the final indications, d) continue the treatment using the new parameters calibrated on the specific patient.

In order to find morphological information for the specific plane of vessels (plane angioma) under treatment the temporal sequence of thermal images collected are elaborated by a Pulsed Thermography (PT) model [30, 31].

According to this model, from the temporal evolution of the surface temperature obtained after the first single laser pulse (heat source), it is possible to get a local evaluation of the depth and thickness of a subsurface anomaly present in the anatomic area that the physician is going to treat. In our scheme, we consider the plane angioma as a subsurface anomaly localized in the dermal region. This information permits a morphological reconstruction of the multilayer biological tissue under treatment (Fig. 2).

Subsequently, taking into account this multilayer, a 2D+1 (the two spatial dimensions and the temporal one) numerical simulation based on a biometric heat transfer model is run. In the simulations the thermal behaviour of the biological multilayers can be achieved with different set of laser parameters as input. The numerical output consists of the evaluation of the spatial and temporal temperature profiles. Finally, these results can be used:

o To compare the thermal behaviour simulated on the epidermis with the experimental data recorded with the infrared camera in order to check the approach performed.

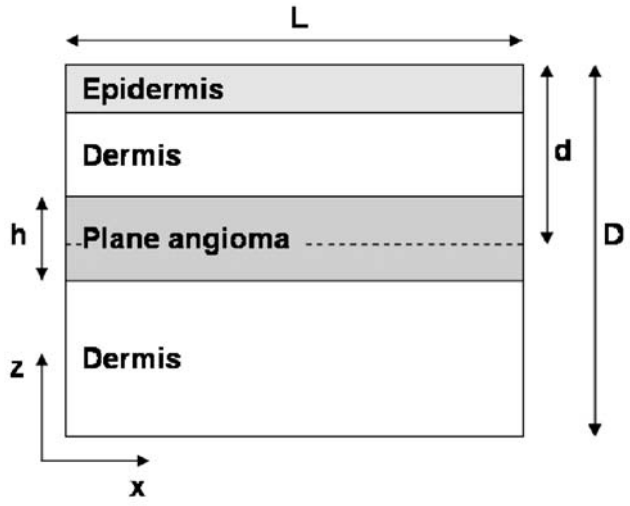

Figure 2
Multilayer biological tissue with plane angioma.

o To optimize the laser parameters in order to achieve suitable local temperatures in the multilayer for the photo-coagulation of the blood vessels and for reducing the risk of scars formation.

According to the flow-chart (Fig. 3), the optimization of the laser parameters is obtained using the results achieved through the simulations as a feedback to change one by one fluence, pulse duration and spot diameter of the laser beam. This procedure allows to select the best set and, as a consequence, to optimize the therapeutic efficiency.

Materials and Method

The thermal images were recorded using a Digital Infrared Camera (Avio TVS 500) with a microbolometer sensor FPA 320x240, a spectral band 8-14 ?m, time resolution is 0.02 s, and the temperature sensitivity is 0.06 K. At the beginning of each measurement session a black body correction was done in order to evaluate and to correct drift and shift effects due to the infrared camera. A skin tone meter has been used in order to evaluate the different phototypes. In particular we have treated two different phototypes (III and VI). For patients with phototype III we used in our calculation a value for emissivity of 0.97 and for

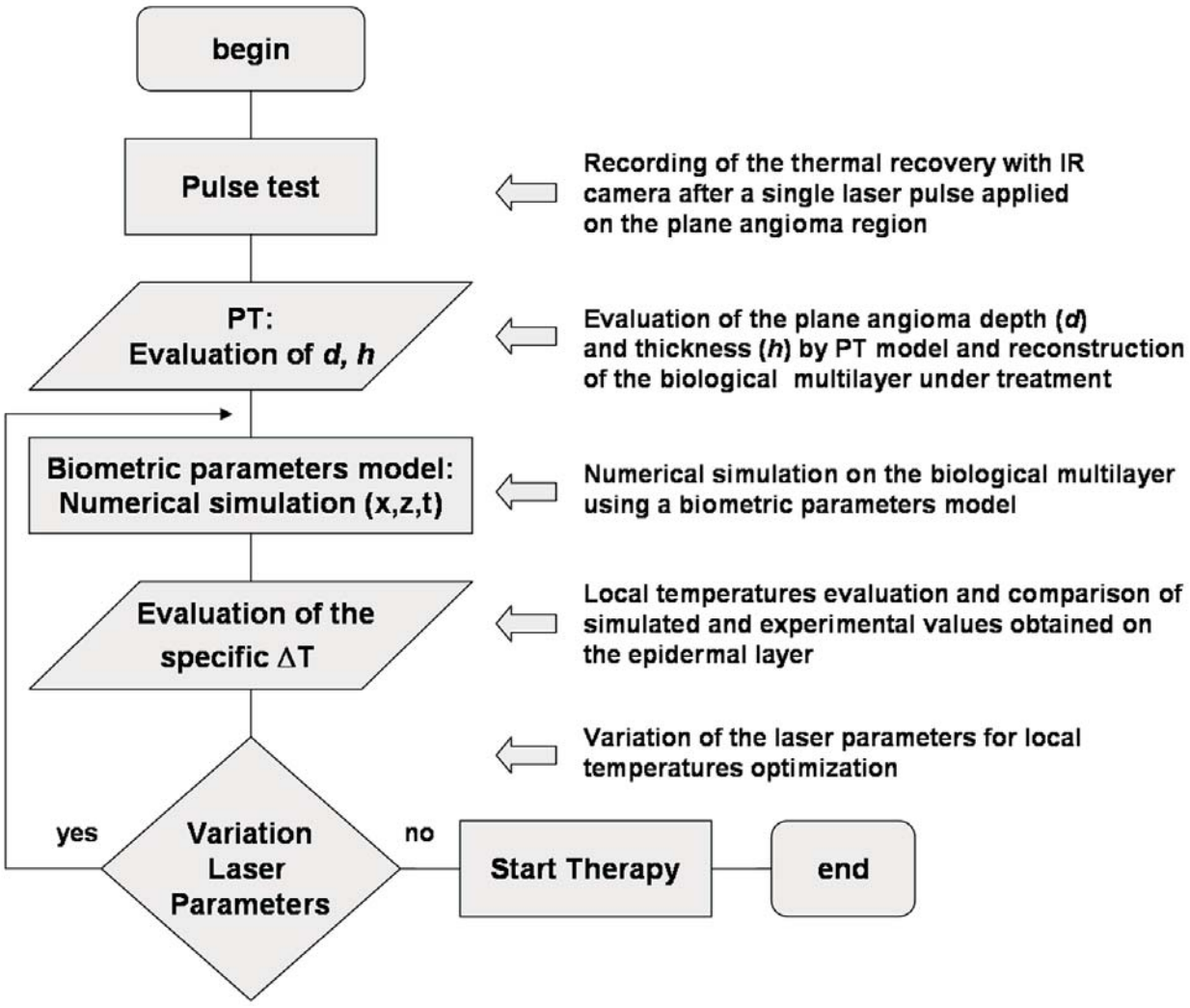

Figure 3.
Flow-chart showing the steps of the new methodological approach for optimizing the laser-tissue interaction.

Table 1
Reference laser set parameters for the PWS treatment and used in the simulations

Wavelength	595 nm
Fluence	7 J/cm²
Pulse duration	5 ms
Spot diameter	7 mm

patients with phototype VI a value of 0.99. The data has been acquired with a resolution of 14 bit. The laser system used was a Pulsed Dye Laser, Deka Dermobeam 2000, gaussian like beam at a wavelength of 595 nm, with fluence (4-15 J/cm2), pulse duration (0.5-40 ms) and spot diameter (2-5-7 mm) selectable. This wavelength is very close to the absorption peak of the target (haemogloblin) as required from the selective photothermolysis principle. The adopted protocol for the experimental tests was established according to the following sequential steps:

- Acclimatization of the subject in the therapy room for a time never less than 15 minutes.
- The anatomic facial region of interest has been cleaned with alcohol in order to remove sweat, cosmetics, dust and so on.
- A single pulse with reference laser parameters (Table 1) has been applied in the middle of the region of interest.
- A sequence of infrared images has been recorded a few seconds before, during and after (for a time of about 30 s) the laser pulse with a frame rate of 20 Hz.
- The time evolution of the thermal recovery of the region of interest has been extrapolated from the sequence.

The measured temperature in each image of the series has been averaged on a spatial region of 25x25 pixels (about 1 cm2). The thermal information recorded have been analyzed following the approach described above. The laser therapy room has been climatized at 24 ± 0.5°C during the measurement. The humidity was about 55 %.

Numerical simulation

Biometric heat transfer model

The morphological information relative to the plane angioma, depth d and thickness h, obtained with the PT model, permits to localize it inside the multilayer biological tissue for each specific clinical situation under treatment. These multilayers have been used as input data for a numerical simulation based on a biometric heat transfer model. This model describes heat transfer in the vicinity of a large blood vessel near to the skin [32]. In our simulation we consider the plane angioma like a single large planar blood vessel. It is assumed that this vessel acts as a volumetric heat source for the surrounding four-layer tissue structure (Fig.2).

The numerical output consists in spatial and temporal temperature profiles obtained on the multilayer after a single laser pulse. It has been also assumed that each layer is isotropic with respect to thermal conductivity k(z), metabolic heat rate q^M, density ρ, and specific heat c of the tissue. The thermal conduction in the tissues surrounding the plane of vessel is dominant in the directions parallel (x) and perpendicular (z) to the skin. We can neglect heat transfer along the y axis because of the presence of other vessels, periodically arranged and similar to that considered. Therefore, the 2D + 1 model assumes the following form:

$$\rho c\frac{\partial T}{\partial t}-\frac{\partial}{\partial x}\left(k(z)\frac{\partial T}{\partial x}\right)-\frac{\partial}{\partial z}\left(k(z)\frac{\partial T}{\partial z}\right)=q^{BL}(x,t)+q^{M}(x,z)+q^{L}(x,z) \quad (1)$$

where T is the temperature, qL is the heat from the laser source, q^M is the volumetric metabolic heat, q^{BL} is the heat due to the blood vessel, k(z) is the thermal conductivity of a particular layer, while ρ and c are the tissue density and the specific heat, respectively. It has been also assumed that each layer is isotropic with respect to thermal conductivity k(z), metabolic heat rate q^M, density ρ, and specific heat c of the tissue.

The heat source term associated with blood vessel depends on the vessel's location (depth) and on its thickness as well as the blood flow speed and temperature. It is assumed to have the decomposition $q^{BL} = u_{BL}(t)r(x, z)$, where u_{BL} is the blood flow speed in the plane of vessels and r(x, z) the modified Bell function:

$$r(x,z)=\mu\exp\left(-\frac{(z-d)^2}{\pi h^2}\right) \quad (2)$$

d and h are the depth and the thickness of the plane of vessels respectively considered as a heat source. μ is defined as follows:

$$\mu=\rho_{BL}c_{BL}\frac{A}{V}\left(T_{vessels}(x,z,t)-T(x,z,t)\right) \quad (3)$$

where ρ_{BL} and c_{BL} are the density and the specific heat of blood respectively, A is the vessels cross section, and V is the control volume of tissue. In the simulation the heat source term associated with the laser source is assumed to have a gaussian expression with a costant value per $0<t<t_p$ dependent on the layer and vanishes for $t>t_p$ where t_p is the pulse duration:

$$\begin{cases} q^L = q_0 e^{-\alpha(z)z} e^{-(x/w(z))^2} & 0 < t \le t_p \\ q^L = 0 & t > t_p \end{cases} \quad (4)$$

with

$$q_0 = L_F A_S \qquad \alpha = \alpha_a + \alpha_s(1-g) \qquad w(z)^2 = w_0^2(1+(z\lambda/\pi w_0^2)^2)$$

Where L_F is the laser fluence, A_S the area of the beam spot, α is the total attenuation coefficient depending on the

biological layer, α_a is the absorption coefficient, α_s is the scattering coefficient, g is the anisotropy coefficient, w(z) is the waist size, w_0 is the half diameter of the beam and λ is the laser wavelength. In the model, the following boundary conditions are considered:

$$T(x,D,t)=T_{dermis} \quad x\in(0,L) \qquad \frac{\partial T(x,0,t)}{\partial z}=\eta\left(T(x,0,t)-T_{air}\right)+q_{ir} \quad x\in(0,L)$$
$$T(0/L,z,t)=T_{dermis} \quad z\in(0,D) \qquad \frac{\partial T(0/L,z,t)}{\partial x}=0 \quad z\in(0,D) \qquad (5)$$

η is the convection heat transfer coefficient, which depends on the air flow.

According to [33]: $\eta = 2.7 + 7.4\,(v_{air})0.67\ (W/m^2 K)$, where v_{air} is the air speed in (m/s), q_{ir} is the radiation heat flux: $q_{ir} = \sigma\varepsilon\,(T_{dermis}^4 - T_{air}^4)$, where σ is the Stefan-Boltzmann constant and ε is the skin emissivity. We assume that the early temperature of the blood in the vessels is the same as the epidermis, dermis and core temperature and equal to T_{dermis}. In constructing this model, it has been assumed that heat flux between the domain of interest (0,L) × (0,D) with the rest of the body, is neglected. This problem is well posed and has a unique continuous solution.

Model Computation

The numerical simulation of the model has been realized using the Finite Volume (FV) approximation with centered cells of size ΔxΔz on a regular space grid. As it is well known, the main advantage of the finite volume method is that it is easily formulated to allow for unstructured and dishomogeneus meshes. Let us denote $T_{i,j}$ the average value T of in the centered FV cells. The discrete version of equation (1) is:

$$T_{i,j}^{n+1}\Delta x\Delta z - T_{i,j}^{n}\Delta x\Delta z - \frac{\Delta t\Delta z}{\rho_{BL}c_{BL}}\left(\Phi_{i+1/2,j}^{n+1}-\Phi_{i-1/2,j}^{n+1}\right)-\frac{\Delta t\Delta x}{\rho_{BL}c_{BL}}\left(\Phi_{i,j+1/2}^{n+1}-\Phi_{i,j-1/2}^{n+1}\right)=\frac{\Delta t\Delta x\Delta z}{\rho_{BL}c_{BL}}\left[\,(\mu\ u_{BL})\left(1-T_{i,j}^{n+1}\right)\exp\left(-\frac{\left(z_j-d\right)^2}{\pi h^2}\right)+q_0e^{-\alpha z_j}e^{-(x_i/w)^2}+q^M\ \right] \qquad (6)$$

In the cell centred in (x_i,z_j),

$$x_i=\Delta x/2+(i-1)\Delta x \quad i=1..N_x \qquad z_j=\Delta z/2+(j-1)\Delta z \quad i=1..N_z \qquad (7)$$

The heat flux values at the wall of the cells are approximated with :

$$\phi_{i+1/2,j}=k_{i+1/2,j}\frac{T_{i+1,j}-T_{i,j}}{\Delta x} \quad i=1..N_x-1 \qquad \phi_{i,j+1/2}=k_{i,j+1/2}\frac{T_{i,j+1}-T_{i,j}}{\Delta z} \quad j=1..N_z-1 \qquad (8)$$

and

$$k_{i+1/2,j}=\frac{1}{2}\left(k_{i+1,j}+k_{i,j}\right) \qquad k_{i,j+1/2}=\frac{1}{2}\left(k_{i,j+1}+k_{i,j}\right) \qquad (9)$$

Where, in the equation 6, $T^{n}_{i,j}$ denotes the temperature of the cell at time ndt.Using the boundary conditions on Φ and T we obtain a classic linear system: $MT^{x,z}=\delta^{x,z}$. At each time step we have to solve a linear system to obtain $T^{n+1}(x,z)$. M is pentadiagonal matrix of size $(N_x \times N_z)^2$. $T^{x,z}$ is a matrix of size $N_x \times N_z$ reshaped from the 2D unknown solution's array $(T_{i,j})$, i=1...N_x, j=1...N_z column-wise or row-wise. In the simulation the grid computation is fixed to $N_x=N_z=64$ and the time step is of the order of 1/50 s which corresponds to the time step between two frames in our thermal camera. The thickness of the epidermal layer has been fixed to 100 μm. The numerical computations have been realized using a home-made Matlab code.

Results and discussion

Simulations have been made on each biological multilayer associated to different clinical situation. In this section, some results achieved from the simulations are shown and discussed. Moreover, different clinical situations are compared among them. In table.2 we report the thermal and optical constants used in the simulation for a wavelenght of 595 nm and patients of phototype III. In the calculation the assumed volume fraction of blood in the plane angioma has been 10%. [10, 34-36].

Results referred to a same multilayer and for different laser parameters

Fig. 4 shows a typical case of temporal evolution. The sequences refer to the dynamics simulated on a structure with a plane angioma at a depth of 600 nm and a thickness of 100 μm obtained after a single laser pulse with the parameters shown in Table 1.

The reported images have been extrapolated from a full sequence obtained by the simulation. The images corresponding to the istant t=0 s refers to the first grid calculated after the laser pulse. It is clear from the sequence that the thermal dynamics in the layers isn't neither homogeneous nor symmetrical as it was expected. The layers more superficial recover quickly than deep layers and the heat, generated from the laser pulse, moves towards the core of the structure. This is mainly due to the different boundary condition present in the model (eq. 5) and associated to epidermis (z=0) and dermis (z=D) layers. Moreover, the biological structure is a dishomogeneous multilayer with optical and thermal properties depending on different tissues. In particular it is possibile to note from fig. 4 how the temperature achieved on plane agioma layers at t=0 is higher than the temperature found for epiderimis or dermis because of the higher absorption coefficient at laser wavelenght (595 nm) of the plane of blood vessels (Table 2). This particular dynamics has been found in all numerical solutions calculated in different situations (for different multilayers and different laser parameters) and it is peculiar for this problem. Changing the biological multilayers and the laser parameters, this dynamics is obviously characterized by different temperatures for the layers and different recovery times.

In Fig.5 the temporal evolutions and the spatial distribution of the induced thermal gap (DT) due to the laser pulse simulated on the plane angioma and on the epidermis are compared. The experimental values recorded on the epidermis with the infrared camera are reported. It is possible to observe that they are in good agreement with the simulated data.

In Fig.6 the dynamics of the same quantity (DT) are compared when two of the three laser parameters in the simulation are fixed and just one is changed. The results show clearly how the induced thermal gap from the laser pulse can vary massively in the range of parameters commonly used in the treatment on plane angioma.

Table 2
Optical and thermal constants used in the simulations referring to a wavelength of 595 nm

	Epidermis	Dermis	Blood vessels
Density *(ρ)*	1 Kg dm	1 Kg dm	1,055 Kg dm
Specific heat (c)	3,7 10 J Kg K	3,7 10 J Kg K	3,6 10 J Kg K
Conductivity (k)	0,209 10 W mK	0,322 10W m K	0,492 10 W m K
Absorption coefficient (α)	35 cm	2,2 cm	147 cm
Scattering coefficent (αa)	470 cm	129 cm	468 cm
Anisotropy coefficient (g)	0.790	0.790	0.995

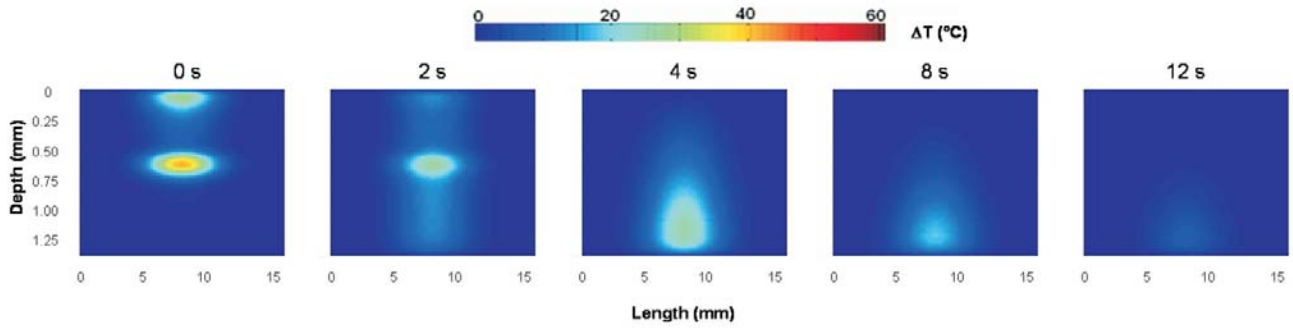

Figure 4.
Temporal sequence of frames extrapolated from the simulations.

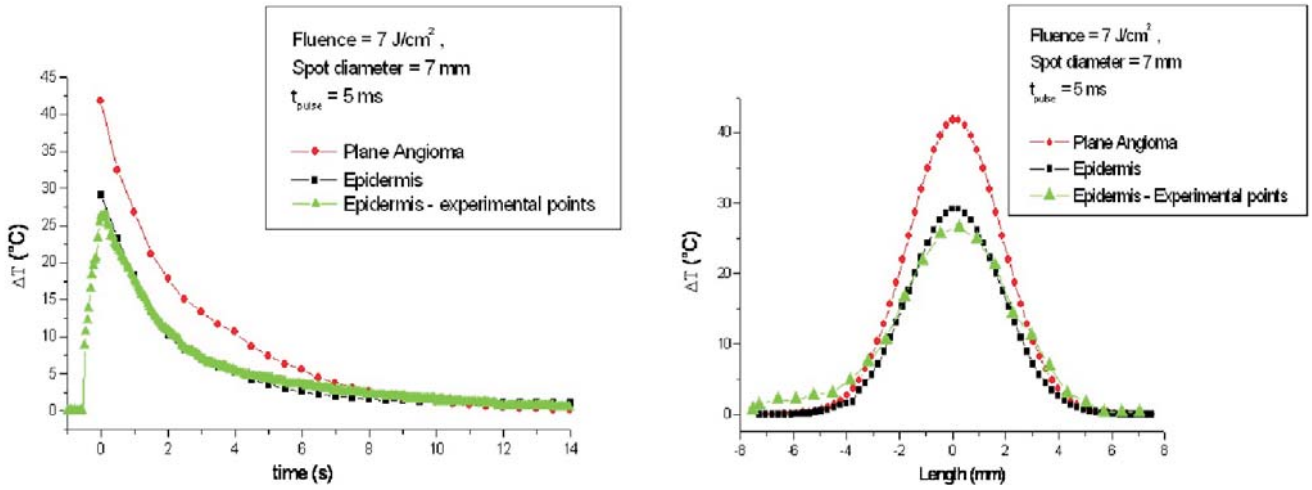

Figure 5.
Temporal evolutions and spatial distribution of DT on the epidermis and on the plane of vessels.

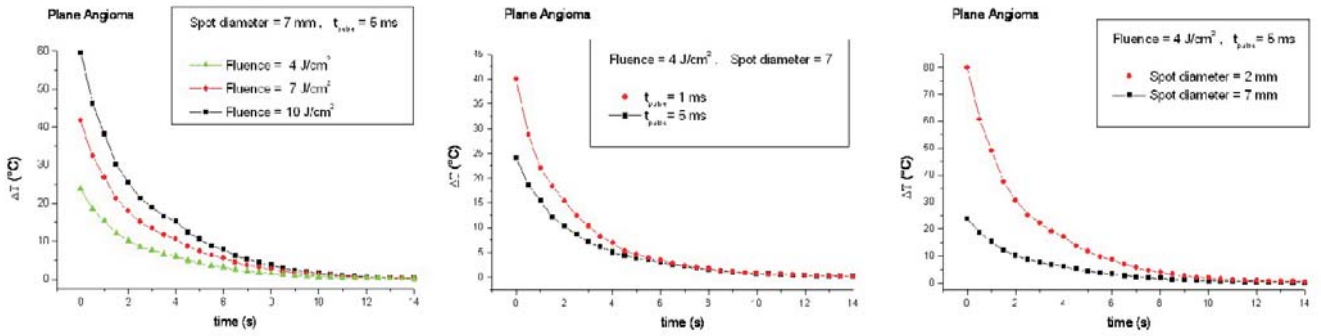

Figure 6.
Temporal evolutions of DT on the plane of vessels for different fluence, pulse duration and spot diameter.

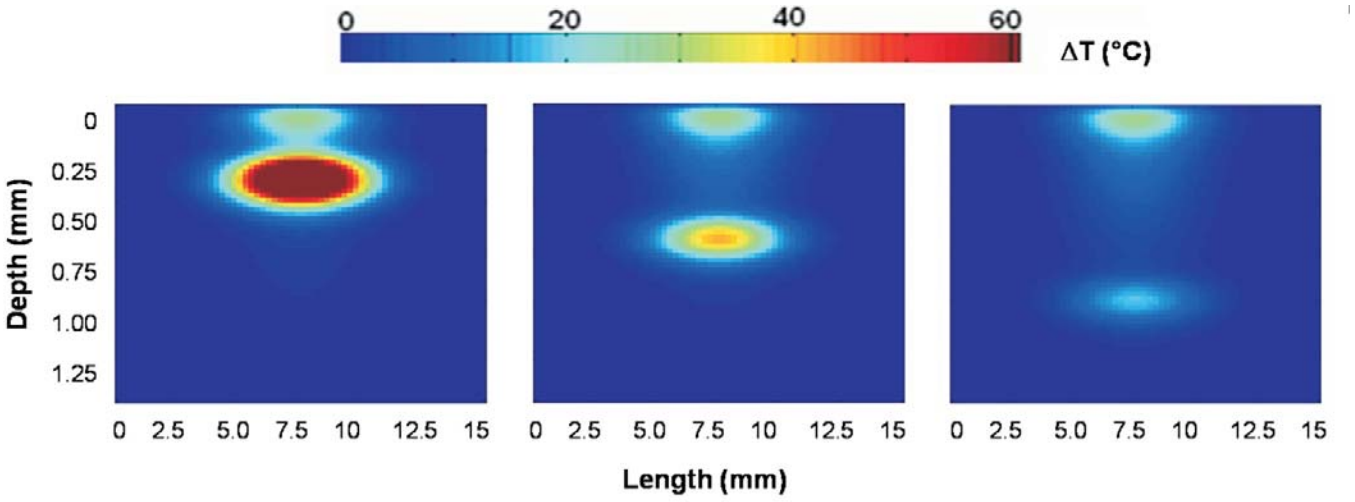

Figure 7.
Distribution of the temperature calcolated at istant subsequent to the laser pulse (t=0 s) for structures with a plane angioma at

Results refered to different structures with the same laser parameters

In this section the results relative to the biological multilayers with a plane angioma at different depths or with different thicknesses are shown. All simulations and results shown in this section refer to the laser parameters reported in Table 1. For sake of simplicity we analyse and compare just two different situation.

The first case is relative to three structures with a plane of vessels at different depth 300 μm , 600μm and 900 μm but with the same thickness 100μm.

In Fig. 7 the false colours images extrapolated from the numerical solutions refer to the distance subsequent to the laser pulse (t=0 s, first frame in the simulation). The temporal evolution and the spatial distribution of DT, in case of both epidermis and plane angioma layers, are reported in Fig. 8. The simulations show how the variations of DT parameter on structures affected by plane angioma at different depths in the tissue, are higher on the plane angioma layers than epidermis layers. For epidermis, DT change in the range between 23 °C to 40 °C, with a gap of about 17°C, and for plane angioma layers from about 25 °C to 75 °C, with a gap of about 50°C. As it is expected, the temperatures obtained on the plane angioma are higher than the temperatures on the epidermis but the ratio DTangioma /DTepidermis decreases for deeper plane of vessels. As it will be discussed later, in order to obtain an efficient and safe interaction, this trend restricts the laser therapy just to patients affected by plane angioma which are not too deep.

In the second case analized, the numerical solutions relative to two biological structures with a plane angioma at same depth, 600 ?m, but with different thicknesses, 100 μm and 300 μm, have been compared (Fig. 9).

With respect to the previous case, the variations on the temperatures achieved in the two situations for the plane angioma and for epidermis are less marked as shown in the graphs reported in Fig.10 and in both situation the maximum gap for DT has been of about 9-10°C. These results demonstrate how the thermal behaviour achieved in the multilayer biologial structures affected by plane angioma is more sensitive to the depth variations than thickness variations.

In Fig. 11 the recovery time and the DT versus the depth of the plane angioma in the tissue are reported. The recovery time is defined as the time occurring by the tissue for recovering the 70% of the induced thermal gap. The data refer to evaluations achieved in the simulations. The values are relative to plane angioma with thickness 100 μm and 300 μm and various depths.

It is clear from the graphs how the recovery time increases with the depth while it doesn't change at all to variations of the thickness. Differently from the previous case, the DT decreases with depth and increases with the thickness of the plane of vessels. In the graphs, the experimental values referred to epidermis and extrapolated from some monitored patients, are reported. The diagrams show clearly a good agreement between simulated data and experimental values in both situations.

The results shown up to now together with the complete study on the patients, give a wide vision about the thermal behaviour of the biological multilayer affected by plane angioma when they are subject to selective laser interactions. We think that these results represent a first step in order to optimize laser parameters for specific clinical situations. In fact, it is possible to choose an optimized set of parameters in order to accomplish the relations in Table 3 for each different biological multilayer.

These ranges, are chosen in oder to photocoagulate the blood vessels of the angioma and at the same time to reduce the risks of scars formations in the surrounding tissues. In fact, when the temperature of epidermis or

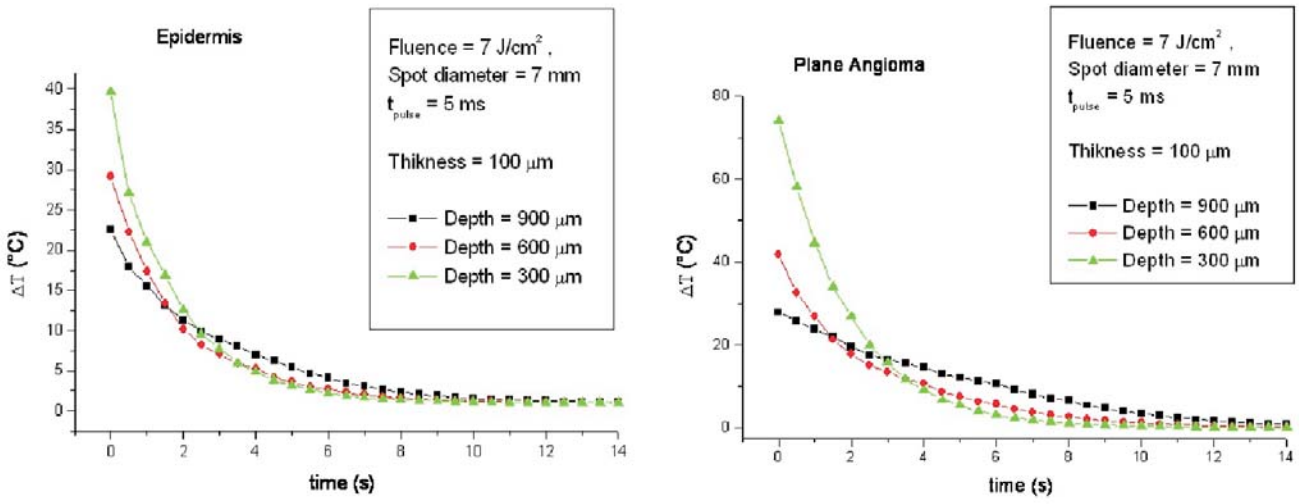

Figure 8.
Temporal evolutions of DT on the epidermis and on the plane of vessels

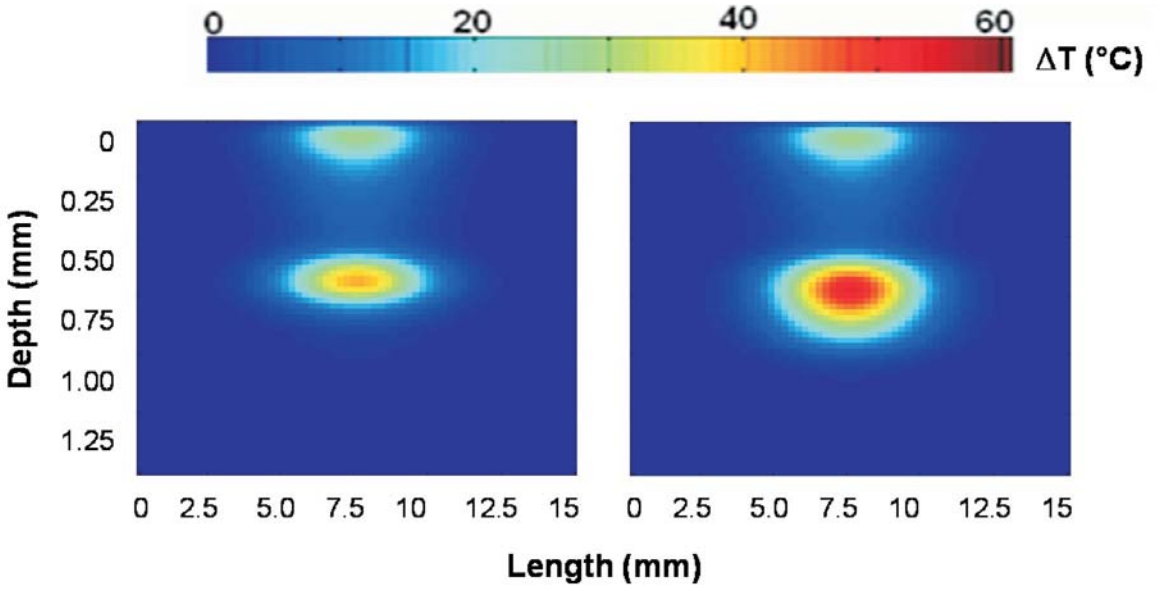

Figure 9.
Distribution of the temperature calculated at instant subsequent to the laser pulse (t=0 s) for structures with a plane angioma at same depth, 600 ìm, but with different thicknesses, 100 μm and 300 μm.

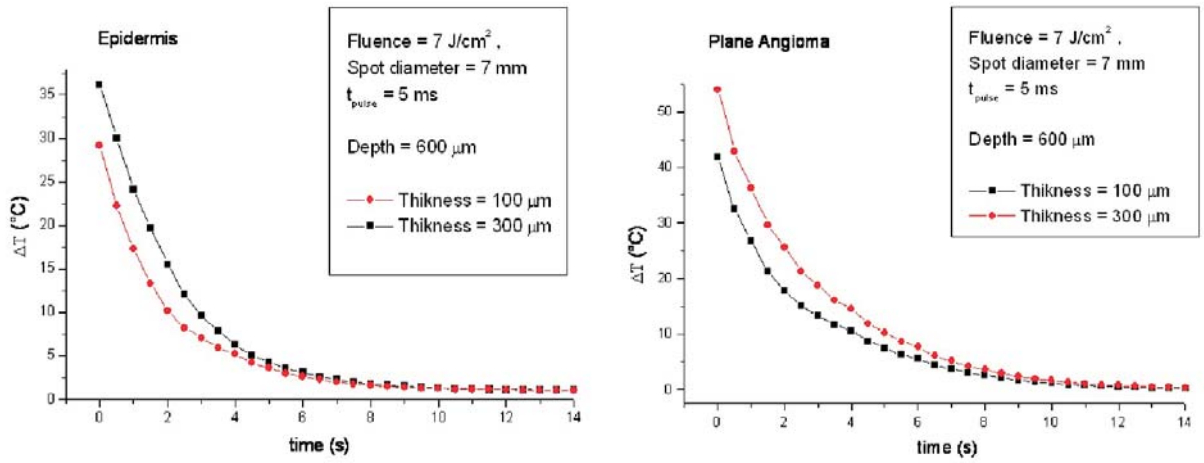

Figure 10.
Temporal evolutions of DT on the epidermis and on the plane of vessels.

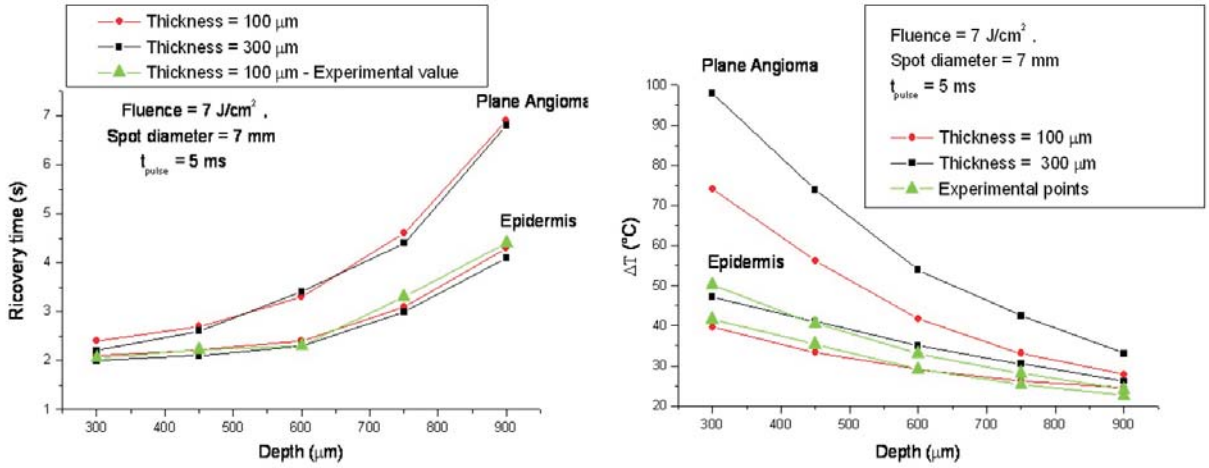

Figure 11.
Recovery time and DT versus depth for two different thickness.

dermis is higher than 60° C denaturations of proteins and collagen present in these layers occurs which leads to necrosis of cells and scars formation [10]. It is important to observe that both condition can be realized for structure that permit a ratio DTangioma /DTepidermis higher than about 1.3. According to our results this condition limit the laser therapy just to patients affected by plane angioma depth no more than 0.9 - 1.0 mm.

In respect to these indications, different set of laser parameters can be proposed with the aim to achieve a more specific and appropriate interaction with the tissue of the patient and to make laser treatments more safety and more efficient.

Clinic tests

In order to validate our method, we arranged an experimental test considering a sample of 52 patients, all affected by plane angioma. 50% of these patients were treated with the traditional laser therapy, while for the other 50% the new approach has been employed. The patients (34 male and 18 female with age ranging from 20 to 50 years), suffered from plane angioma in the facial region. In most cases, the angioma was widespread in different facial region and mainly on cheek, nose and temple. The laser therapy was applied in a photothermal regime using the selective photothermolysis principle.

According to the information obtained with the method that we propose, 26 patients were treated with specific laser parameters suggested by the numerical elaboration and that accomplish the relation in tab.3, while the other ones were treated using the traditional empirical method. We monitored the effects of both methods, during the following months, analysing the evolution of the laser therapy applied for each patient. In this field, the valuation of the therapy is subjective and is entrusted to the experience of the physician. We are studying the possibility to introduce a new method based on a digital analysis of pictures taken in the visible region at different times. This image analysis, in terms of color changes, could give information on the evolution of the disease. The idea is to consider the difference in the color ($\Delta\xi$) between the area affected by PWS and another one very close to this. When tends to zero, we have a situation that we named "bleaching". We are studying the "bleaching effect" in order to adopt an official method for an objective valuation based on technical aspects.

A preliminary and qualitative analysis showed a better clinical situation, for the patients treated with our method, in terms of "bleaching effect" and a considerable reduction of the area affected by angioma. All patients treated using the laser parameters suggested via our method, showed signs of a fastest recovery. These preliminary experimental results confirm that it is possible to obtain concrete and effective clinical improvements, but, at the same time, indicate the importance to arrange a more detailed clinical test, using a stricter protocol on a higher number of patients.

Table 3
Temperature ranges used in phototherapy of Plane Angioma

$T_{EPIDERMIS}$, T_{DERMIS} < 60°C	➡	Safety
60°C < $T_{ANGIOMA}$ < 80°C	➡	Photocoagulation range

Conclusions

In this paper we reported a study on biological tissue interaction analyzed with the support of the infrared imaging technique. We proposed an approach for the laser parameters optimization in the plane angioma treatment. Our methodological approach, based on pulsed thermography, aims to supply the best laser parameters to be used according to the patient under treatment. The biometric heat transfer model, describing the laser-tissue interaction, and the 2D numerical approach adopted in the operative protocol have been explained. Numerical results which refer to different clinical situation and to different laser parameter have been shown. As reported, in the photothermal interaction regime, the temperature induced in the tissue is strictly linked to the hystological modification obtained. Our results point out that with the same laser parameters, changing patient or anatomical region, the effects and so the therapeutic efficiency obtained can differ, ranging from optimal therapeutic results to unwanted harmful effects (for instance scars formation). These observations justify and confirm that a proper laser parameters choice helps to optimize the photo-therapy for plane angioma treatments. With this approach it is possible to choose a set of laser parameters for each biological multilayer affected by plane angioma of different dimensions in order to optimize the thermal interaction and to make laser treatments safer and more efficient. In conclusion, we demonstrated that functional IR imaging can be used with remarkable advantages in monitoring the physical action of the laser light thus giving to the operator information to optimize his activity, in terms of both therapy effect and safety. Finally, for a wide validation of our method, we believe that a larger scale of a clinical test must be arranged. For these tests, with the laser parameters calculated, it will be necessary to compare the therapeutic results with those obtained with the traditional technique, in order to evaluate advantages and disadvantages. This experimental activity is in progress. Last but not least, we believe that, as soon as our method will be validated by a number of significant clinic tests, it will be possible to project and produce an integrated system, constituted of laser-thermal camera and control unit, on industrial scale for the medical market.

Conflict of interest statement

No financial or personal relationships (employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, or grants or other funding) with other people or organizations that could inappropriately influence (bias) this study or its results exist.

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News in Thermology

Courses and Seminar in Epe, The Netherlands

Irma Wensink, who started in 2011 an International Course Centre for Veterinary Thermography, organised a series of courses and a seminar on both, human and veterinary thermography in Epe from 3rd to 7th October 2013. This event started with

Medical Thermography for Injury Prevention by Biomechanical Thermography Analysis

This 2-day course was given by Prof. Dr. med. Marcos Leal Brioschi from Brazil and was indeed very interesting for physiotherapists, osteopaths and medical doctors. The aim of this course was to implement thermography as a complementary assessment of posture and biomechanical conditions that may lead to muscle overload. The results of thermal imaging may be helpful in decision making for the treatment of patients. By mapping the temperature with a thermal imager, we can detect much more abnormalities in a human body than we can sense with our well trained hands during a clinical exam without thermography. However, the relationship between thermal abnormalities and clinical findings is not yet entirely validated.

The course started with a theoretical part about thermography and how to implement in the assessment necessary to provide treatment. Dr. Brioschi presented very interesting case studies to teach and guide the course participants how to interpret the thermal abnormalities in a thermogram.

Correct capture of an infrared thermal image was the aim of the practical part of the course. Choice of the room temperature, acclimatisation of the patient and camera settings have been important topics. Due to its very good structure, this course had high educational value for both, beginners and advanced users of medical thermography.

The Seminar Human and Veterinary Thermology

combined a multi-disciplinary panel of experts from veterinary medicine, human medicine, health professions and software developers for a 2- day seminar. The lectures covered topics such as recent software developments, stan-

Prof. Dr. med. Marcos Brioschi explains to Dr. Serbu MD how to use the software after Dr. Boelhouwer DC has correctly positioned the camera.

dards for thermal imaging, applications od thermography in mainstream and complementary veterinary and human medicine. The audience and the panel of speakers was composed from people coming from the United States, Brazil, United Kingdom, Romania, Belgium, Finland, Austria and the Netherlands.

The following 2 abstracts can probably show the scope of this seminar.

THE BENEFITS AND APPLICATIONS OF THERMOGRAPHY IN ZOO ANIMALS

Daphne van Dongen–Valk , Veterinarian Technician

Artis Natura Magistra Royal Zoo, Plantage Kerklaan 38-40, 1018 CZ, Amsterdam; Netherlands; email d.valk@artis.nl

There are several clinical applications for veterinary use of thermal imaging making it possible to measure temperature differences in a non-invasive way. Thermography can detect localized elevated heat at a distance of several meters. The thermal profile is then displayed as a thermogram. This infrared picture can give information on certain aspects of the animal's health status. Examples include; lameness, bruises, inflammation, neurological syndromes, bumble foot, elephant foot pathologies, injuries, and monitoring of a treatment process. In mega herbivores, it is often difficult to observe injured areas on limbs. Thermography can assist with locating the potential injured area. Other diagnostics such as radiographs can be used in conjunction with thermography. There are many limitations due to environmental factors and over-interpretation of artifacts. For example; water, sunlight, rain, dirt, and strong breezes can disguise or emphasize temperature differences on the animal. Hair, fat, muddy skin, and different coloured skin and coat can also provide influences and lead to an incorrect diagnosis. Sometimes an animal's reluctance to get close to the equipment may result in some limitations. However, with minimal positive reinforcement and patience the animal will allow thermal imaging to occur. Thermography is a valuable technique for diagnosing medical issues in non-domestic animals without affecting the animal in a negative way.

SIMILARITIES AND DISSIMILARITIES IN THE TECHNIQUE OF THERMAL IMAGING APPLIED IN HUMANS OR HORSES

Prof Kurt Ammer, MD, PhD

European Association of Thermology; Vienna, Austria

The application of infrared cameras for imaging humans or animals dates back to the early nineteen sixties. Although infrared imaged have been not fully understood as temperature recording device at that time, first suggestions about procedures and quality assurance have been published in 1964 in the Annals of the New York Academy of Science [1].

For valid and reliable results, adherence to strict protocol is an essential requirement irrespectively what object is imaged with an infrared device. Several sources generating measurement errors and artifacts in thermal images have been identified. These causes for recording poor thermograms are related to a.) The location for thermal imaging b.) The Imaging System c.) The living object imaged and d.) Report generation [2].

Ad a.) The location for thermal imaging of humans and horses is obviously different, for example the size of the examination

Participants at the Course Centre in Epe on Sunday 6th October 2013

room, sufficient with an area of 3 to 4 meters for humans, must be much bigger for horses. Temperature of the room should be displayed irrespectively whether humans or animals are imaged with an infrared camera. The room temperature must be stable by at least ±1.0°C, but preferably ±0.5°C. In humans, regions of high skin temperature will become better visible at room temperatures 18 to 20°C, whilst regions of low skin temperature will be better detected at room temperatures between 23-and 26°C. Room temperature must be within the thermo-neutral zone where humans can regulate skin temperature without shivering at too low temperature nor sweat due to the external heat load. Room temperatures for recording thermal images of horses are not regularly reported in the literature and vary between 15° and 30°. A standard is urgently needed [3]. An indication of the room temperature is necessary, preferable visible on a large display. Avoidance of drafts within the examination room is essential, as air motion will cause convective cooling that will affect the surface temperature of both humans and horses [4].

Ad b.) The specifications of infrared thermal imagers for depicting humans or horses are identical. Therefore, the same procedures for quality assurance should be applied. A battery of simple tests has been suggested by Plassmann et al. [5]. An external black body source within the examination room allows regular checking of the accuracy of temperature measurements performed by the infrared imager.

Ad c) The different anatomy of humans and horses does not allow transferring defined body views for men to horses. It is very difficult to measure the temperature accurately of body parts with a much curved surface by means of an infrared camera [6]. During capturing thermal images correct positioning of the human subject or the horse is mandatory, particularly when thermal images are repeatedly recorded to demonstrate the course of disease. Proposals for positioning regions of interest had been made for humans [7] and horses [8], but only the suggestions made in the Glamorgan protocol for human thermography have proved a high grade of reproducibility of positioning.

Ad d) Reports must include

- Patient data: name, gender, age, medication
- Referral data: referring person or physician, cause of referral and clinical question
- Condition of imaging: room temperature, time for acclimatization, date and time of imaging, equipment),
- All images captured: labelled with the view at each thermal image taken, every image or block of images must carry the indication of temperature range, with a standardised. colour code/temperature scale),
- Quantitative data from standard regions of interest. mean temperature, standard deviation
- The distribution of temperature readings. pattern description

Approved standards for interpretation are neither available for humans nor for horses. Agreement exists in humans that in most applications interpretation based on quantitative data have a better diagnostic accuracy than qualitative evaluation. Some approaches in equine thermography seem to favor qualitative evaluation [9] similar as in thermal imaging of the human female breast.

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Thermal Imaging in Canine Veterinary Practice.

This 1 day course was given by Dr. Kimberley Henneman, DVM, FAAVA, Dip ABT, CVA, CVC , Diplomate Am Coll Veterinary Sports Medicine and Rehabilitation.

Dr. Kimberley Henneman used a set of very informative PowerPoints slides to teach the participants about common injuries in dogs in relation to the disciplines they perform, how to make a correct thermogram of dogs and artefacts that can occur and how to recognise these.

In the afternoon, after lunch, we had a small theoretical part and some case studies of several dogs from the practice of Dr. Henneman.

We closed the day with a practical part, for this, there were a few dogs available with a variety of health problems, from eye disease to undiagnosed vague lameness. For students who did not bring in an infrared camera, there were some cameras available. So all students were able to practise on these dogs and taking correct images (composition e.g.) while Dr. Henneman was giving advice/feedback (figure 3). An educational experience for each attending student.

Figure 3
Image recording of a dog

Meetings

4th-6th April 2014

XVIII National Congress of the Polish Association of Thermology in Zakopane, Poland

Further information: see page 186

10th - 14thApril 2014

Veterinary Thermal Imaging

The course is given by Dr. Tracy Turner, USA

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www.thermografie-centrum.nl

5th - 9th May 2014

Thermosense XXXVI, Baltimore Convention Center; Baltimore, Maryland United States

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Further information
Herbert Kaplan hkaplan@earthlink.net
or Andres Rozlosnik aer@termografia.com

http://thermosense.org/2013/cfp-thermosense-xxxvi/

11th-12th June 2014

MeMeA2014 - 9th edition of IEEE International Symposium on Medical Measurement and Applications in Lisbon, Portugal

Special session on
"Developments and Applications of Thermography"

Organizers:
Joaquim Gabriel, Faculty of Engineering,University of Porto, Portugal, jgabriel@fe.up.pt
Ricardo Vardasca, Faculty of Engineering, University of Porto, Portugal, ricardo.vardasca@fe.up.pt

http://memea2014.ieee-ims.org,

7th-11th July 2014

12th Quantitative InfraRed Thermography Conference, QIRT 2014 in Bordeaux, France

Further information: see page 187

6th - 7th September 2014

Kinesiology and Thermography, in Epe, the Netherlands

The course given by Prof. Dr. med. Marcos Brioschi, Brazil

Information:
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www.thermografie-centrum.nl

26th-28thSeptember 2014

ThermoMed International 2014, 60th Anniversary of the German Society of Thermography and Regulation Medicine, in Langen near Frankfurt

A website for the conference will be online from September 2013 at (www.thermomed.org)

Please send all abstract in parallel to
reinhold.berz@gmx.de and to sauer@hsauer.de.

XVIII NATIONAL CONGRESS OF THE POLISH ASSOCIATION OF THERMOLOGY

ZAKOPANE 4th-6th April 2014

GENERAL INFORMATION

REGISTRATION FEE: 250.- €

ABSTRACT DEADLINE February 15th 2014

ajung@wim.mil.pl or a.jung@spencer.com.pl

Abstract form will be published in Thermology International and in Acta Bio-Optica et Informatica Medica and registration on line

Professor Jung and the Organizing Committee invite you to this annual conference in the beautiful mountain resort of Zakopane in South Poland, which is 2hours journey by bus from Krakow International airport and the city of Krakow. The conference is in HYRNY Hotel with its wonderful views of the Tatra mountains, and short walk from the town centre.

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Prof Adriana Nica MD,PhD (Romania)

Registration fee for non Polish participants will be paid in cash on arrival at the conference.
Registration by e-mail is required before March 1st to ensure hotel reservation.
After registration number is issued, delegates are committed to payment of the fee.

Registration includes welcome dinner Friday 15th
Lunch and accomodation.
Extra night + breakfast + 70 €
Accompaning person – 200 €

Call for Papers

Since 1992, the Quantitative InfraRed Thermography (QIRT) conference is a biannual international forum which brings together specialists from industry and academia, who share an active interest in the latest developments of science, experimental practices and instrumentation, related to IR thermography.

Following conferences in Paris (1992), Sorrento (1994), Stuttgart (1996), Lodz (1998), Reims (2000), Dubrovnik (2002),Brussels (2004), Padova (2006), Krakow (2008), Québec City (2010) and Naples (2012), the 12th Quantitative InfraRed Thermography Conference, QIRT 2014, will take place on July 7-11, 2014, at the Mechanics & Engineering Institute of Bordeaux.

QIRT 2014 will cover, but will not be limited to, the following topics:

• State of the art and evolution in the field of IR scanners and imaging systems allowing quantitative measurements and related data acquisition and processing.

• Integration of thermographic systems and multispectral analysis. Related problems like: calibration and characterization of IR cameras, emissivity determination, absorption in media, spurious radiations, 3D measurements, certification and standardization.

• Thermal effects induced e.g. by electromagnetic fields, elastic waves or mechanical stresses.

• Application of IR thermography to radiometry, thermometry and physical parameters identification in all fields such as: industrial processes, material sciences, thermo-fluid dynamics, energetics, non-destructive evaluation, cultural heritage, environment, medicine, bio- medical science, food production…

Important dates

• Abstract submission deadline: November 20, 2013

• Acceptance notification: January 31, 2014

• Paper submission deadline: April 30, 2014

Abstract and Paper Submission

The participants are invited to submit to the QIRT 2014 Web Site by November 20, 2013 an **extended abstract** of 2 pages (letter size A4 format), either for oral or poster presentation, including key figures and main results. A book of abstracts will be distributed at the conference.

Following acceptance notification, **camera ready, full paper** of 6-10 pages including color figures should be submitted to the QIRT 2014 web site by April 30th, 2014. All submissions for oral or poster presentation will be handled electronically via the conference website **QIRT2014.scientificevent.**

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A Word template to be used for both abstracts and full papers is downloadable at the website. Authors are requested to propose the thematic section in which the paper should be included.

Abstract submission

Web-Based Proceedings and possible publication in QIRT Journal

Presented papers (oral and posters) will be published online in the QIRT Open-Archives, which can be found at the website: **www.qirt.org**. A USB flash drive with all conference papers will be also distributed to the conference participants.

After the conference, the Scientific Committee will carry out a pre-selection of the most prominent presented papers for a possible publication in Quantitative InfraRed Thermography Journal after a subsequent review by two experts.

Tutorials, Technical Visit and Workshop

QIRT short courses

In addition to the main technical program, the conference will include one-day short courses (Monday, July 7). The program and the related fees will be defined soon and presented in the conference website. It will include a general introduction to thermography in the morning and specialized courses on various application fields given in parallel during the afternoon (non-destructive evaluation, thermo- fluid-dynamics, building, thermomechanics…).

Summer course on thermomechanics

A summer-course (given in French) on thermography and thermomechanics of materials will take place from June 30 to July 4. The website will be opened and related to the QIRT conference site in October 2013.

Technical Visits

A lot of research teams are using IR thermography on the Bordeaux University Campus and will be opened for visits.

Student Award

Striving to stimulate young researchers, the organizing committee will award the best conference contribution presented and authored only by students.

Conference fees (VAT included)

Regular participants

- Early rate (deadline: May 20, 2014): (550 €)
- Late rate (deadline: June 27, 2014): (650 €)
- Desk registration rate: (800 €)

Students

- Early rate (deadline: May 20, 2014): (350€)
- Late rate (deadline: June 27, 2014): (450 €)

Fee covers: Book of abstracts, Conference USB Proceedings, Welcome reception, Conference dinner, 3 lunches and coffee breaks. Accommodation is not included.

For regular participants only, fee includes also a subscription to QIRT Journal for 2 years (standard personal subscription rate 100 €/year).

Accompanying persons

- Rate (deadline: June 27, 2014): (120€)

This amount includes the Welcome reception and Conference dinner.

Venue

QIRT 2014 will be held at the Ecole Nationale des Arts et Métiers located in the campus of the Bordeaux University, at 20 min by tram from the historic center of the City. Bordeaux is listed to the UNESCO world heritage. The city is exemplary thanks to the unity of its classical and neo-classical architecture (see www.bordeaux-tourisme.com).

A list of hotels will be given in the conference website. Booking of hotel is not assumed by the conference organization. For students only, low cost accommodations can be booked on the Bordeaux University campus.

Conference website

For further information please visit the site:
QIRT2014.scientific-event.com

or contact the organizing committee at:
QIRT2014@scientific-event.com

European Association of Thermology

Physical Activity and Sports Faculty (INEF). U.P.M.

XIII European Association of Thermology Congress

Thermology in Medicine:
Clinical Thermometry and Thermal imaging

FIRST ANNOUNCEMENT

www.europeanthermology.com

The EAT and the Faculty of Physical Activity and Sports Sciences (INEF) are has the pleasure of inviting you to participate in the XX EAT Congress in Madrid between the 3rd and 5th of September, 2015.

The target of this Congress is integrating professionals and researchers from different fields who are working daily with medical thermography, introducing the latest advances in infrared technology and the new applications arising from them.

The Congress will appeal not only to end users of medical thermography but also to researchers and developers. The congress will focus on free communications and posters in the areas of Human Applications, Animal Applications, and Engineering.

We look forward to seeing you in Madrid in September 2015.

Manuel Sillero Quintana.
Chairman of the Organizer committee.

James Mercer
President of the AET.

VENUE

The congress will take place at the Physical Activity and Sport Sciences Faculty (INEF Madrid) which belongs to the Technical University of Madrid (UPM) located in the University City of Madrid. It has an auditorium with 600 places and two conference rooms with seating for 140 and 120 persons and are fully equipped with modern audio-visual equipments

XIII EAT CONGRESS 3rd to 5th September 2015, Madrid.

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SCIENTIFIC PROGRAM

From September 2014 the Congress will be open for abstract, free communications and posters submissions in the areas of Human Applications, Animal Applications, and Engineering.

At the same time a draft of the scientific program will be included in the "call for abstracts" announcement.

KEY DATES

September 2013. Publication of the First Announcement.

Late September 2014. Publication of the "Call for Abstracts" document.

10th October 2014. Opening of abstract submission and registration.

30th January 2015. Abstract submission deadline

27th March 2015. Acceptance notification to authors.

17th April. End of Early bird registration and deadline for presenting authors registration.

XIII EAT CONGRESS 3rd to 5th September 2015, Madrid.

REGISTRATION FEES (*)

	Early Registration (Until 17-4-15)	Late Registration (Until 31-7-15)	Last-minute Registration (After 31-7-15)
EAT MEMBER	300 €	360 €	400 €
New EAT member	350 €	410 €	450 €
Non-Member	400 €	460 €	510 €
Student (**)	150 €	200 €	240 €
Accompanying person	200 €	260 €	300 €

(*) Further information about the registration process will be provided in the "Call for abstracts" document.
(**) A certificate with ECTS credits will be provided by U.P.M.

TRAVEL INFORMATION

Madrid-Barajas Airport is a large international and domestic airport with frequent direct flights from many international destinations. There is a train service directly from Terminal 4 (T4) to Príncipie Pío Station (35 minutes, about 2.50 €), where the two official hotels are located. They are also metro and buses from the Airport to the city center (40-50 minutes, about 5-6 Euros). A taxi from the Airport could be another option but a little bit more expensive.

The radial structure high-speed train (AVE), regional trains and buses allow travel to Madrid from the most important cities of Spain. Furthermore, Madrid has an excellent underground system, a frequent bus network and many reasonably priced taxis for local transportation. We encourage our attendees to use the public transport.

ACCOMODATION

Many tourist will be visiting Madrid at the same time of the congress. For this reason, the organizers of the EAT Congress has negotiated a large number of hotel rooms at attractive rates in our two official hotels:

+ **Hotel Celuisma Florida Norte**** (100 rooms already reserved):
- 35.35 € (incl. 10% VAT) per person in double bed room including breakfast (buffet).
- 59.35 € (incl. 10% VAT) single room including breakfast (buffet).

+ **Hotel Acta Madford***** (Number of rooms and prices available by September 2014). Actual normal price is about 55 € per a single room including breakfast.

Both hotels are 25 minutes walking to the venue and 10 minutes walking to the city center, and they have a bus station in front of their main entrance. Further information for booking them at the special prices of the congress will be provided in the "Call for abstracts" document.

There are cheaper youth hostels and bed-and-breakfast in the city center. In the next announcement we will provide a list with the most convenient ones according to their location and conditions.

Publications on Thermology 1989 to 2012 - An electronic archive DVD

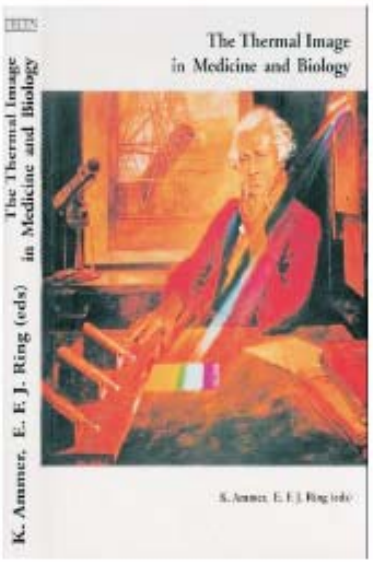
This data compilation contains all issues of

Thermologie Österreich
May 1991 to April 1997
European Journal of Thermology
July 1997to October 1998
Thermology international
January 1998 to October 2012

Plus

The Thermal Image in Medicine and Biology

edited by K.Ammer and E.FJ Ring
Uhlen Verlag, Wien (1995)



Plus

Published Papers on Thermology and Temperature Measurement

Volume 1: 1989 to 2004

Volume 2: 2005 to 2006

Volume 3: 2007 to 2011

Plus

Proceedings of the First Thermological Symposium of the Austrian Society of Thermology

Thermographie, evozierte Potentiale, edited by O.Rathkolb and K.Ammer

Plus

Proceedings of the Second Thermological Symposium of the Austrian Society of Thermology

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