16th CONGRESS OF THE POLISH ASSOCIATION OF THERMOLOGY and Certifying course: ”Practical application of thermography in medical diagnostics”

Zakopane, March 16th – 18th, 2012

Scientific Committee:
Prof. Jung Anna MD, PhD
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Prof. Wiêcek Boguslaw
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Murawski Piotr Msc, Bsc
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Prof. Jung Anna MD, PhD
Zuber Janusz MD, PhD
Kalicki Boleslaw MD, PhD
Rustecka Agnieszka MD

Conference venue:

Hotel “HYRNY”

Zakopane, Pilsudskiego str 20

Organizers:

Paediatric,Nephrology and Alergology Clinic
Military Institute of Medicine, Warsaw, Poland
phone: +48 22 6817236; fax: +48 22 6816763

Chairman of the Organizing and Scientific Committee

Prof. Anna Jung MD, PhD

Scientific Programme

Saturday, March 17 2012

09:00 – 11:15 Session I
Chairman: Prof. Francis Ring, Prof. Anna Jung

1. Ring E., Ammer K - Thermal Imaging in Rheumatology a Review.
2. Keresztes KG, Sims MR, Coats TJ - Medical Infrared Therma Imaging? It’s Place in Emergency Medicine.
3. Ammer K - Variation of the longitudinal temperature gradient of fingers over time.
4. Kalicki B, Jung A, Rustecka A, Zylak A, Zuber J - Evaluation of skin changes using infrared thermography.
5. Strakowska M, Wiêcek B, DeMey G - Multilayer thermal model of human skin for thermovision screening applications.
6. Kalicki B, Jung A, Rustecka A, Zylak A, Zuber J, Murawski P, Bilska K, Wozniak W. - Infantile hemangiomas – the possibility of using infrared thermography in the assessment of propranolol efficacy - preliminary study.

11:30 – 13:30 Session II
Chairman: Prof. Kurt Ammer, Dr med. Janusz Zuber

1. Kalicki B., Jung A., Zylak A., Rustecka A., Koszycka A., Stankiewicz W.- Tietze’s syndrome and the role of infrared thermography in the differential diagnosis of acute chest pain in adolescents.
2. Nica A.S., Mologhianu G., Murgu A., Mitoiu B., Lili M., Moise M. – Thermographic evaluation of a young patient with posttraumatic sequelae of lower limb.
3. Wysoczański B. – Thermal evaluation of treatments using the methods of Dr. Ackermann in selected cases during the first minutes after the procedure.
4. Strakowski R., Strakowska M., Strzelecki M. – Movement correction in provocative thermovision medical investigations.

14:45 – 16:15 Session III – Training course
Chairman: Pof. Boguslaw Wiêcek, Dr med. Janusz Zuber

1. Murawski P., Gontarski K., Jung A., Kalicki B., Zuber J. - Standards project of thermology laboratory for hospital.

2. Wiêcek B. – Practical camera and environment parameters determination in quantitative thermovision measurements.

3. Rutkowski P. – Nowoœci sprzêtu termowizyjnego.

16:15 – 17:00 EAT board meeting

Abstracts

VARIATION OF THE LONGITUDINAL TEMPERATURE GRADIENT OF FINGERS OVER TIME

Ammer K

Institute for Physical Medicine & Rehabilitation, Hanuschkrankenhaus, Vienna, Austria

BACKGROUND: The magnitude of the longitudinal temperature gradient from the dorsal hand to the fingertip is a well accepted thermographic sign of Raynaud´s phenomenon. Temperature gradients have also been used as outcome measures in trial of vasospastic disease. However, information about the variation of baseline temperature readings prior to the cold challenge is scarce.

AIM OF THE STUDY: To observe the daily variation of the longitudinal temperature gradient for a period of two to three weeks

METHOD: Thermal images of the hands of 1 female and 2 male subjects were recorded after acclimatisation with bare forearms to a room temperature of 24 ± 1°C. For 1 male and the female, the images were recorded daily between 14.10 and 14.30 for three weeks, but not on the weekends. In the male subject, additional images were taken in the second week on 2 consecutive days between 11.17 and 12.31 hours, and on 3 consecutive days of the third week between 10.21 and 11.05 hours. The second male was followed for 2 weeks and two series of images were recorded on 3 consecutive days with a time interval of 6 days in between.

The mean temperature of the total dorsal hand, the dorsum of the hand and of all fingertips were recorded. The longitudinal temperature gradient for each single finger was determined by subtracting the mean temperature of the dorsum of the hand from the temperature of the finger tip. Temperature measurements recorded in the morning and in the early afternoon of the first male subject were analysed separately. For calculation of the reliability of temperature measurements, the 6 thermal images recorded from the 2nd male subject were evaluated 3 times.

RESULTS: There was a larger range of variation of longitudinal temperature gradients when thermal images were taken in the morning than in images recorded in the morning. The range of variation was smaller in an elderly male than in a young female. The maximum difference in range of temperature gradients between 3 readings was 0.55. Table 1 shows minimum and maximum values of longitudinal finger gradients.

CONCLUSION: There is a large range of temperature variation from one day to the next, which may also vary at different time points of the same day. The method of temperature reading contributes little to the variation of temperature.

Table 1
Minimum and maximum values of longitudinal temperature gradients

		G1R	G2R	G3R	G4R	G5R	G1L	G2L	G3L	G4L	G5L
Male A morning	minimum	-4,62	-5,39	-5,93	-6,44	-6,67	-4,72	-5,48	-5,79	-5,85	-6,19
	maximum	0,64	0,46	0,56	0,23	0,10	0,83	0,40	0,84	0,39	-0,48
	range	5,26	5,85	6,49	6,67	6,77	5,55	5,88	6,63	6,24	5,71
Male A afternoon	minimum	-1,62	-1,95	-2,84	-3,49	-3,76	-2,20	-2,04	-1,92	-2,46	-2,21
	maximum	2,70	2,47	1,55	1,09	0,51	1,41	1,70	1,05	0,93	0,89
	range	4,32	4,42	4,39	4,58	4,27	3,61	3,74	2,97	3,39	3,10
Female	minimum	-3,24	-3,76	-4,55	-5,16	-5,61	-2,80	-3,18	-3,57	-3,93	-4,61
	maximum	1,58	0,93	0,27	0,57	0,08	1,31	0,93	1,08	0,95	0,51
	range	4,82	4,69	4,82	5,73	5,69	4,11	4,11	4,65	4,88	5,12
Male B 1st reading	minimum	0,42	-0,59	-0,41	-1,15	-1,33	0,31	-0,16	-0,75	-0,53	-0,42
	maximum	1,67	1,09	0,94	1,41	1,08	1,59	1,28	0,91	1,09	1,03
	range	1,25	1,68	1,35	2,56	2,41	1,28	1,44	1,66	1,62	1,45
Male B 2nd reading	range	1,27	1,73	1,90	2,16	2,62	1,58	1,94	1,66	1,53	2,00
Male B 3rd reading	range	1,30	1,92	1,76	2,18	2,69	1,35	1,69	1,62	1,84	1,82

MEDICAL INFRARED THERMA IMAGING- IT'S PLACE IN EMERGENCY MEDICINE ?

Keresztes KG, Sims MR, Coats TJ*

Space Research Centre, Department of Physics and Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK

*Department of Cardiovascular Sciences, University of Leicester, Level G, Jarvis Building RMO, Infirmary Square, Leicester, LE1 5WW, UK

Medical diagnosis today tends to be based on invasive measurement techniques. In accident and emergency (A&E) it is important to provide a quick, painless and ideally non-invasive medical diagnosis to enable treatment of a wide variety of different medical conditions. The University of Leicester, UK has created a so called Diagnostic Development Unit (DDU) which focuses on real time non-invasive diagnosis, in the A&E department, at the Leicester Royal Infirmary (LRI). This work is conducted in collaboration with the (local) University Hospitals NHS Trust. The DDU is investigating three different types of measurement methodologies for disease detection: breath and gas analysis, cardiovascular monitoring, and imaging (mainly hyper-spectral imaging and thermal imaging). The DDU challenge is to overcome the limitations in emergency medicine environment as the ideal clinical standard conditions cannot be applied e.g. problem of limited space, need for rapid measurement etc.

At present, we have ethics approval for 500 A&E population patients to ascertain both parameters-data associated with a normal population and those with commonly presenting A&E complaints. The equipment has been installed and commissioned in a modified room in A&E next to a resuscitation bay where the measurements will take place. Various funding applications are in progress e.g. study of heart failure.

Our pilot study, from a thermal imaging point of view, consists of the 500 patients being imaged using a FLIR SC620 high resolution camera (640x480 pixels). We are aiming to look at circulatory dynamics of the standard A&E population, fever detection using the inner canthi with at least 9 pixels in accordance with standard measurement technique, and limb and body measurements as deemed appropriate to the study protocols.

THERMAL IMAGING IN RHEUMATOLOGY – AN OVERVIEW

Francis Ring , Kurt Ammer

Medical Imaging Research Unit, Faculty of Advanced Technology, University of Glamorgan, Pontypridd U.K.

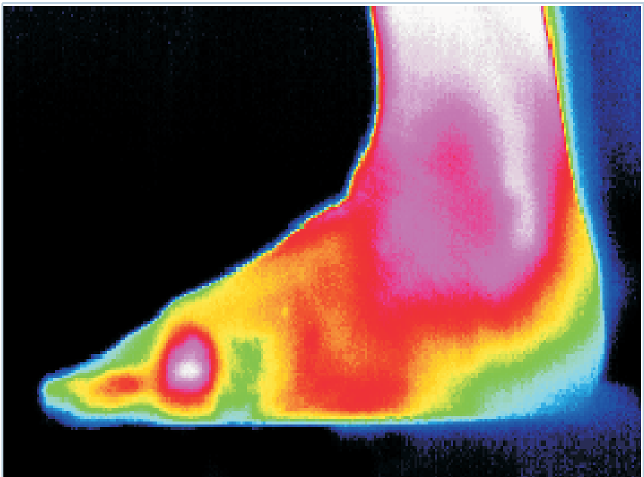
This paper presents an overview of some of the publications that show evidence for the application of infrared thermal imaging in Rheumatological practice. The subjects included are: Inflammatory arthritis, Osteoarthritis, Soft tissue Rheumatism, Complex regional pain syndrome and Gout. In inflammatory arthritic conditions, there is usually a marked change in the thermal image over affected joints, especially at the extremities, i.e. hands knees feet and elbow joints. The anterior knee thermograms in particular typically show cool areas over the patellar region in normal healthy joints. This pattern is changed when acute or chronic inflammation is present, and there can be an increase in mean temperature of that area of 2-3 degrees C. Effective anti-inflammatory treatment by oral or local injection has been shown to reduce temperature of the inflamed joints which can be objectively measured and documented with thermal imaging. This does require careful standardized technique and adherence to a suitable protocol, so that the series of images recorded on different days over time can be used for validated change and response to treatment. In studies of corticosteroids, Esselynckx et al in 1978 [1] and Bird et. al. in 1979 [2] are among the authors that showed that in a controlled trial, the thermographic measurements provide reliable evidence of dose response studies of these compounds in rheumatoid arthritis. Other papers have shown that with a placebo washout, different oral non-steroid anti-inflammatory treatments can also be evaluated by this method, and many of the common treatments in regular use today have been studies in clinical trials involving quantitative thermography, and published in peer reviewed journals.

In osteoarthritis, studies have revealed that increased temperature monitored by thermography is associated with even slight degenerative changes shown on radiography. Low temperatures have been found in more advanced [3],and severe disease [4].

There are many different conditions that can be classified under the general heading of soft tissue rheumatism, ranging from muscle injury, repetitive strain, tennis elbow to fibromylagia. In the latter case there have been a number of studies on the location of tender points, hot spots and investigations to see if these can be used as an outcome measure. However, Ammer et al.[5] found that reproducibility of hot spot counts from a thermogram is poor.

In complex regional pain syndrome, the affected limb can be hypersensitive to touch or pressure, which produces acute limitations of movement and a fall in temperature, shown on the thermogram as a loss of symmetry. Gulevitch and Conwell et.al. in 2010 [6] confirmed that using the cold challenge test on these patients provided high sensitivity and specificity, while McCabe et.al. [79 using mirror feedback, early cases of CRPS (type 1) were able to restore function and regain thermal symmetry of the limbs within 6 weeks by daily exercises before a mirror.

Gout, often affecting the foot and the great toe joint can produce significantly high localized temperatures shown by thermography. With correct treatment, the hyperthermia can be resolved within a few days, and thermography provides good objective evidence of change.



Thermal image of a gouty arthritis of the big toe

More details of these and other allied conditions can be found in a recent publication by Ring & Ammer [8.]

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EVALUATION OF SKIN CHANGES USING INFRARED THERMOGRAPHY

Kalicki B, Jung A, Rustecka A, Zylak A, Zuber J

Department of Pediatrics, Pediatric Nephrology and Allergology (Head of Department: Prof.Dr hab. med. Anna Jung) , Military Institute of Medicine, Warsaw, Poland

Thermographic imaging of the skin can be widely used to assess ongoing processes of the skin surface as well as processes within the subcutaneous tissue. The possibility to apply visual images to thermographic images of skin changes allows to gain additional information which can be of great importance for their clinical interpretation. The role of infrared thermography in the diagnosis of inflammatory processes (abscesses, periodontal infiltrations, inflammatory processes with submandibular lymph node involvement) of the skin and surrounding tissues was previously described. Thermographic imaging is an objective diagnostic tool in the interpretation of skin tests with allergens, especially in cases when the skin is covered with other lesions or has a different color.

The purpose of our study is to present new opportunities of using thermographic imaging in the evaluation of ongoing processes of the skin surface and within the subcutaneous tissue.

1.The appearance of skin lesions described as allergic urticaria is characterized by great diversity. Typical lesions (wheals) usually show up a few minutes after contact with the allergen and can resolve in a short period of time. Infrared images of the lesions show, that they are far more expressed than in the visual assessment. Infrared images can also become valuable clues for clinicians, because they describe the activity of the continuing process and thereby can influence the treatment.

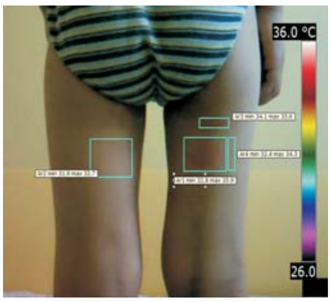

Figure 1

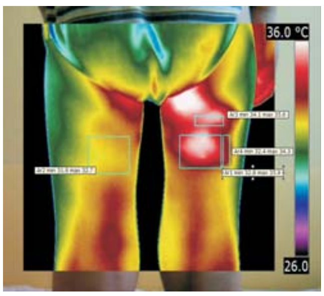

Figure 2

In figure 1 a rectangular area, outside the wheal (A4), was selected. After applying a thermographic image we can see a clearly visible area of increased temperature induced by the wheal, with a far greater range than seen in the visual image. The thermo- grafic image was taken in a standard environment using the infrared camera FLIR T-640, which allows applying visual images to thermographic images

2.Skin carcinomas require careful analysis of the surgical field range to determine appropriate and safe surgical margins. On the other hand the cosmetic effect after surgery is very important, that is why surgeons try to minimize the scar. Infrared thermography allows to precisely determine the range of the neoplastic lesion, which very often has a greater size than primary observed.

Figure 3

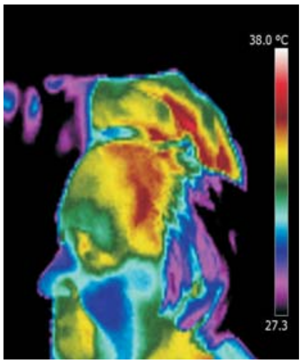

Figure 4

A skin lesion in the temporal region (figure 3) represents a squamous cell carcinoma, which was qualified for surgical treatment. The surgical field range is intuitively set by the surgeon during the procedure. A histopathologic section is examined under the micro- scope to ensure safe surgical margins. Infrared images can be helpful in determining the surgical field range.

3.The clinical presentation of infantile hemangiomas is characterized by great diversity. Their range in spatial dimension can be difficult to assess in routinely performed Doppler ultrasound. Recent studies have shown a good effect in treating infantile hemangiomas with prolonged propranolol therapy. The involution of hemangiomas during propranolol therapy is associated with formation of atrophic foci.

Infrared thermography allows to assess the temperature of hemangiomas, their size in metric units (by using special software). Because of the diversity of hemangiomas, their location, the age of children, the progress of the healing process (atrophy of the hemangioma) it seems that the comparison of average temperatures between an area registered within the hemangioma and an area registered within a symmetrical body part is the most reliable method to describe the treatment efficacy. In cases of an unfavorable location of the hemangioma (i.e. nose area, forearm), it is more objective to compare temperatures between the hemangioma and an adjacent, healthy tissue.

Figure 5

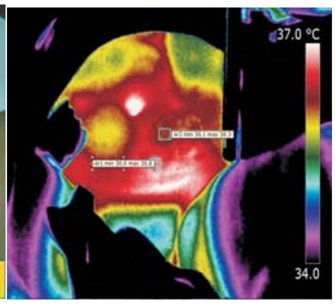

Figure 6

In the thermogram of a 12- months old girl with an infantile hemangioma 2 areas were marked: A1 is an area with high blood flow within the hemangioma determined by Doppler ultrasound, A2 is an area with marked atrophy of a highly vascularized region due to propranolol therapy. The average temperature in the area A1= 36.8°oC, in the area A2 36.2°oC. Delta of average temperatures (Figures 5,6)= 0,6oC

Figure 7

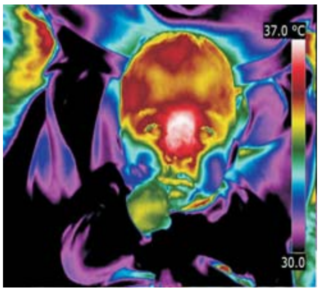

Figure 8

A 7-months old boy with an inflamed and tender infantile hemangioma of the nose, after 4 months of propranolol therapy. The tenderness of the hemangioma limited the use of Doppler ultrasound. Visual and thermographic evaluation allows to fully control the healing process.

CONCLUSION:The presented opportunities of using infrared imaging in the evaluation and interpretation of ongoing pathologic processes of the skin surface and the subcutaneous tissue indicate the high value of thermography as a diagnostic method.

MULTILAYER THERMAL MODEL OF HUMAN SKIN FOR THERMOVISION SCREENING APPLICATIONS.

Strakowska M, Wiêcek B, DeMey G

Institute of Electronics, Technical University of Lodz, Wolczanska 211/215, 90-924 Lodz, Poland,
(*) University of Gent, Electronic and Information Dept. Sint Pieternieuwstraat 42, B-9000 Gent, Belgium,

Thermal modeling of human skin is still a challenging task [1-5]. Such model is multilayer and includes the rate of perfusion and can applied to determine the thermal parameters of the skin during screening. In this communication we propose one dimensional analytical thermal analysis being an extension of single layer well-know and widely used Pennes model (Fig. 1) [1].

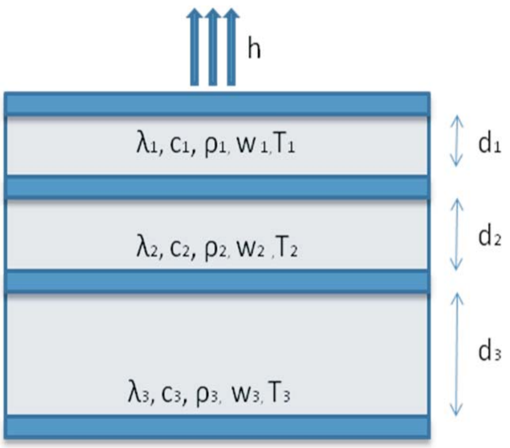

Figure 1
D 3 layers model of human tissue

Pennes model (1) describes bioheat transfer in human tissue.

$$\rho \cdot c \frac{dT}{dt} = \lambda \frac{d^2T}{dx^2} + Q_{per} + Q_{met} \qquad (1)$$

where: ρ – tissue density, kg/m^3, c – specific heat, J/kg*K, λ– thermal conductivity coefficient, W/mK, Q_{per}, Q_{met}.– perfusion and metabolic heat.

Heat absorption corresponding to the perfusion is expressed by

$$Q_{perf} = w \cdot c_b \cdot \rho_b (T_B - T) \qquad (2)$$

where T_B – is bulk blood temperature (core temperature),
w – perfusion coefficient, 1/s, ρ_b – tissue density, kg/m^3,
c_b – specific heat, J/kg*K.

Q_{met} is a constant value heat corresponding to metabolic processes in a tissue and depending on physical state of human. This parameter takes values between 245-24500 W/m^3. In this approach we neglect Q_{met}.

If one assumes $T_B = 0$, we obtain equation (3).

$$\lambda \frac{d^2T}{dx^2} = \rho \cdot c \cdot \frac{dT}{dt} + w \cdot c_b \cdot \rho_b \cdot T \qquad (3)$$

It is much easier to perform the analysis in the Laplace domain.

$$\lambda \frac{d^2T}{dx^2} = \rho \cdot c \cdot s \cdot T + w \cdot c_b \cdot \rho_b \cdot T \qquad (4)$$

Finally, for each layer we have the following equation

$$\lambda \frac{d^2T}{dx^2} - T(\rho \cdot c \cdot s + w \cdot c_b \cdot \rho_b) = 0$$

$$\lambda \frac{d^2T}{dx^2} - \frac{T}{L^2} = 0$$

$$L(s) = \frac{1}{\sqrt{(\rho \cdot c \cdot s + w \cdot c_b \cdot \rho_b)/\lambda}} \qquad (5)$$

where L is a thermal diffusion length in m.

The model uses the heat transfer coefficient (h) in form of convective cooling boundary condition. The analytical solution of eqn. (5) while boundary condition are taken into account, leads to so-called Nyquist plot of thermal impedance of the human skin. As an example of the simulation result we present the Nyquist plot of the human skin thermal impedance obtained from the model (blue) and thermographic measurement (red) in an arbitrary chosen frequency range for the chosen set of the skin parameters – Fig.2. The agreement is quite satisfactory. In the next step of the research we plan to use the optimization procedures to adjust the thermal parameters of the skin automatically by comparing the results from the modeling and thermographic measurement.

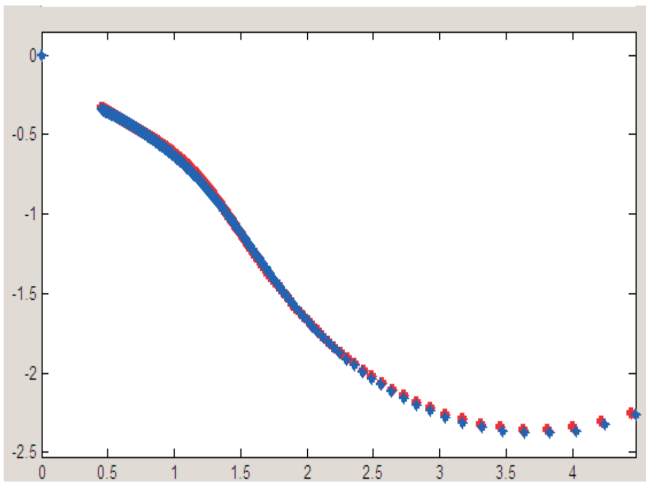

Figure 2
Agreement of Nyquist plots of the thermal impedance of human skin obtained from the 3-layer model and the thermographic measurement

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INFANTILE HEMANGIOMAS – THE POSSIBILITY OF USING INFRARED THERMOGRAPHY IN THE ASSESSMENT OF PROPRANOLOL EFFICACY - PRELIMINARY STUDY.

Kalicki B[1], Jung A[1], Rustecka A[1], Zylak A[1], Zuber J[1], Murawski P[1], Bilska K[2], Wozniak W[2].

[1] Department of Pediatrics, Pediatric Nephrology and Allergology (Head of Department: Prof.Dr hab. med. Anna Jung) , Military Institute of Medicine, Warsaw, Poland,

2 Department of Oncological Surgery of Children and Adolescent (Head of Department: Prof. Dr hab. med. Wojciech Wonziak)s, Mother and Child Institute, Warsaw, Poland.

METHOD:

Thermographic images of infantile hemangiomas were taken from 42 children being under the care of The Hemangioma and Naevus Clinic at the Department of Onco- logical Surgery of Children and Adolescents at the Mother and Child Institute in Warsaw. There were 14 boys and 28 girls among the examined children. Average age- 12,5 months. The children were participating in the propranolol therapy program. ECG's, echocardiographic studies, biochemical blood studies and Doppler ultrasound studies were performed in all cases. According to the length of treatment with propranolol the patients were divided into 2 groups.

Group I- 7 children (3 boys, 4 girls- average age- 7 months) who were examined using infrared imaging before starting propranolol treatment or during the first follow- up visit (after 6 weeks of treatment)

Group II- 28 children (21 girls, 7 boys- average age- 15 months) who were examined using infrared imaging after several months of propranolol treatment, usually successful treatment with regression of clinical symptoms.

Out of 42 children, 7 were disqualified from treatment because parental consent could not have been obtained. Their measurement results were excluded from further analysis.

The thermographic images were taken in a standard environment using the infrared camera FLIR T-640. The obtained images were analyzed with the program QuickReport.

OUTCOME:

The difference in average temperatures between an area measured within the hemangioma and an area measured within a symmetrical body part or an area adjacent to the hemangioma was in group I -1,29 ^{o}C, in group II -0,47 ^{o}C (Table 1, Pictures 1,2)

DISCUSSION:

Infrared thermography allows to assess the temperature of hemangiomas, their size in metric units (by using special software). Because of the diversity of hemangiomas, their location, the age of children, the progress of the healing process (atrophy of the hemangioma) it seems that the comparison of average temperatures between an area registered within the hemangioma and an area registered within a symmetrical body part is the most reliable method to describe the treatment efficacy. In cases of an unfavorable location of the hemangioma (i.e. nose area, forearm), it is more objective to compare temperatures between the hemangioma and an adjacent, healthy tissue.

In the group of examined children, hemangiomas and the treatment outcome were assessed using Doppler ultrasound with blood flow assessment. In very active infants, with a haemangioma located on the lid, nose or lip, usually being inflamed, Doppler ultrasound is very difficult to perform and less precise. Infrared thermography can become the method of choice in the initial assessment and follow- up of hard- to reach hemangiomas.

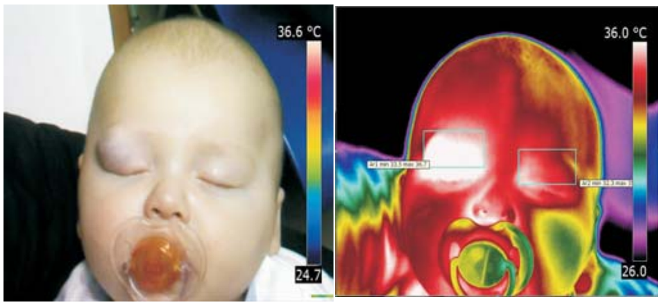
Our results are still preliminary and need more verification on a larger population. Our study will be continued.

CONCLUSION:

1.Infrared thermography can be a helpful diagnostic method in monitoring and assessment of propranolol treatment efficacy, irrespective of the location and size of the hemangioma.

2.Thermographic monitoring allows a more accurate determination of propranolol treatment length.

3.Infrared imaging is also useful in the follow- up of haemangiomas after finished propranolol treatment.



Figures 1, 2
A 2- months old infant with an infantile hemangioma of the right upper lid before treatment. The lesion is compressing the eyeball..This is a difficult location to assess blood flow using Doppler ultrasound. The difference in average temperatures between symmetric areas is 1,5 ^{o}C.

Table 1
The difference between average temperatures in compared patients groups

	Average age (months)	Number of examined children	Girls	Boys	Difference between average temperatures (^{o}C)
Group I	7	7	4	3	1,29
Group II	15	28	21	7	0,47

TIETZE'S SYNDROME AND THE ROLE OF INFRARED THERMOGRAPHY IN THE DIFFERENTIAL DIAGNOSIS OF ACUTE CHEST PAIN IN ADOLESCENTS

Kalicki B[1]., Jung A[1]., Zylak A[1]., Rustecka A[1]., Koszycka A[1]., Stankiewicz W[2].

[1] Department of Pediatrics, Pediatric Nephrology and Allergology (Head of Department: Prof. Dr habil med. Anna Jung) Military Institute of Medicine, Warsaw, Poland
[2] Military Institute of Hygiene and Epidemiology, (Head: Plk Dr med. Janusz Kocik) Warsaw, Poland

Tietze's syndrome is an inflammatory process affecting one or more chondrosternal joints of the anterior chest. It is characterized by a painful and tender swelling , with a predilection to the upper ribs. The diagnosis is made on clinical grounds after exclusion of other conditions presenting with acute chest pain. Physicians are still looking for simple, safe and non- invasive diagnostic method to support the diagnosis of Tietze's syndrome. Infrared thermography, an innovative diagnostic method, can be used to diagnose Tietze's costochondritis. Thermography allows to see variations in temperature of the skin and organs caused by an ongoing inflammatory process.

Figure 1
Visual image of the changes noticed during the physical examination of the patient.

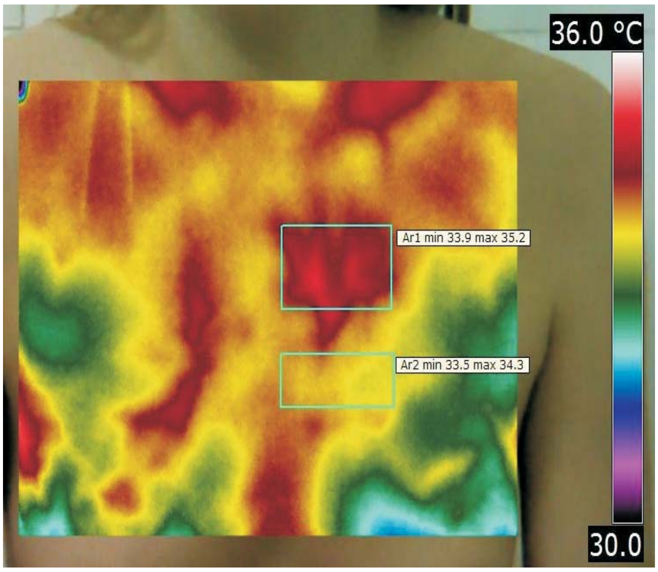


Figure 2
Thermographic image of the same chest area as presented in the visual image above.

Because of the possibility of increased participation of infrared radiation in the region of the vascular trunk, area A1 was compared to area A2, located below the swelling of the chest wall. The difference between A1 and A2 was 1,4°C for minimal temperatures and 0,9°C for maximal temperatures.

CONCLUSION:Infrared thermography may be a helpful and noninvasive supplementary diagnostic method in the diagnosis of Tietze's syndrome.

THERMOGRAPHIC EVALUATION OF A YOUNG PATIENT WITH POSTTRAUMATIC SEQUELAE OF LOWER LIMB.

Nica AS, Mologhianu G, Murgu A, Mitoiu B, Lili M, Moise M.

National institute of Rehabilitation- Bucharest, Romania, University of Medicine and Pharmacy Carol Davila-Bucharest, Romania

A patient suffered from an injury by falling (during a football game)) on October 15, 2011 resulting in double fracture of the right ankle. He was admittted to the orthopaedic department, where fixation and osteosynthesis of the fractured medial and the lateral malleolus were performed The course of recovery from the injury was favourable due the surgical intervention and under the complex pharmacological treatment (antibiotic, anti -inflammatory, anticoagulant.) The patient was referred to the rehabilitation department one month after surgery.

Patient, with a posttraumatic and post surgical history, was evaluated at the rehabilitation ward clinically from a functional point of view. The results of clinical and functional assessment have been completed with imaging investigations: such as ultrasound of the anterior-lateral right leg, radiographs of both legs including the ankle-foot complex, and thermography to detect changes of the peripheral temperature distribution.

The patient underwent a comprehensive rehabilitation programme including electrotherapy for pain reduction and muscle stimulation and adapted exercise therapy.

Thermography was performed daily, before and after treatment, recording changes in thermal skin reaction possibly inducedb y the rehabilitative interventions .

The dynamics of thermal activity were recorded and graphically and statistically analysed..

THERMAL EVALUATION OF TREATMENTS USING THE METHODS OF DR. ACKERMANN IN SELECTED CASES DURING THE FIRST MINUTES AFTER THE PROCEDURE

Wysoczański B

Department of Rehabilitation, Józef Pilsudskis Academy of Physical Education in Warsaw

INTRODUCTION: Most of the pain within the musculoskeletal system is due to mechanical causes, leading to functional changes, which can result structural changes. The structural osteopathy and chiropractic by Dr. Ackermann is based on a detailed study of the spatial setting of the skeletal system. In this method, physiotherapist is using manual techniques for the selected motor segment, using appropriate locking on segments and fast thrusting.

The purpose of the study was to examined the impact of Ackermann Method and the dynamics of changes on the thermographic images in areas that the patient reported as the most troublesome (painful).

METHODS: Study subjects were 10 people aged 29 - 61 years. Subjects were treated once by manual therapy. It was performed at all joints (excluding the upper limbs), which showed during the osteopathic tests functional changes. Patients did not report a history of medical comorbidities. Patients before surgery sat for

15 minutes with an uncovered treatment site. After that time the infrared picture was taken, using thermal imaging camera FLIR A325, and after that treatment begins. Another thermal image was made 15 minutes after the treatment.

Maximum temperatures and the average temperatures of the surgical site on the first and second picture was compared to each other. The symmetry of the temperature distribution on the affected side was compared to a healthy (not painful) side. Patients were asked the question whether the treatment applied to reduce the nuisance caused, increased or did not cause any change.

RESULTS: In two cases, the average temperature of the tested area increased (by 1.4 and 0.2 ° C). In two other the average temperature was unchanged, but the maximum temperature recorded in the studied area rose (0.1 and 0.9 ° C). In other cases, both the highest temperature recorded in the studied region and the average were reduced. At all thermal images were noted improvement (higher symmetry) of the temperature distribution. Eight people reported an immediate improvement in previously painfull areas. One of the patients don't felt pain relief or improved mobility in the joints, and one of the respondents felt the improvements until the next day.

MOVEMENT CORRECTION IN PROVOCATIVE THERMOVISION MEDICAL INVESTIGATIONS

Strakowski R., Strakowska M., Strzelecki M.

Institute of Electronics, Technical University of Lodz, Wolczanska 211/215, 90-924 Lodz, Poland,

The paper shows the recent studies using dynamic infrared imaging in medicine and problems of proper data extraction which is the result of an object movement. The method of movement correction based on cross correlation calculated for dynamic thermal imaging is presented. The influence of movement correction on extracted data and point tracking precision is shown. The proposed method has been successfully applied for cold stress diagnosis during breast cancer screening.

INTRODUCTION: There are many approaches to use dynamic thermovision imaging in medical application [1,2,3]. The most important and difficult task for sequence of images analysis is an extraction of appropriate data. In most cases there is a need to get measured values from the same point or area of human body surface. It is quite hard for people to keep a stable position and do not move during the measurement. Although, in some cases the position of a part of human body is stabilized, in other cases it is impossible because of breathing. There are few examples of movement compensation methods in order to extract correct data from the sequence of images. Most of them are using some markers which are put on the skin, and indicates the reference points' position. Moreover, some of them are using also the reference image sequence taken from visual CCD camera at the same time as acquisition of thermograms [3,4,5]. The drawback of these methods is that the patient should be prepared correctly before examination (marking the reference points) and tracking the point has to be performed after acquisition by the specialized software. Proposed method of movement correction for thermographic images do not need any special preparation before starting the measurement.

MOVEMENT CORRECTION: Proposed movement correction algorithm is based on normalized cross – correlation [6]. This approach uses a template. The template is a reference image, typically the first from the sequence. The normalized cross – correlation function computes the output matrix of correlation coefficients, which size is the same as the size of the image and takes values from the range <-1, 1>. The highest absolute value of the coefficient defines the position of the area in image which is the most similar to the template. The implementation follows the formula:

$$\gamma(u,v)=\frac{\sum_{x,y}\left[f(x,y)-\overline{f_{u,v}}\right]\left[t(x-u,y-v)-\bar{t}\right]}{\left\{\sum_{x,y}\left[f(x,y)-\overline{f_{u,v}}\right]^2\left[t(x-u\cdot y-v)-\bar{t}\right]^2\right\}^{0.5}}$$

(1)

where:

f is an image,

t is a template image,

$\bar{t}$ is the mean of template,

$\overline{f_{u,v}}$ is the mean of $f(x,y)$ in the region under template.

Proposed method of movement correction determines the shift of region of interest by calculating the position change of reference area - template. The reference area is marked manually in the first image in the sequence of thermograms. The best template matching is computed in every frame and new position is obtained. Calculating the position difference between N, and N+1 frame, the new position of each point is designated.

The template area selection is crucial for high algorithm efficiency. The main assumptions while selecting area are as follows:

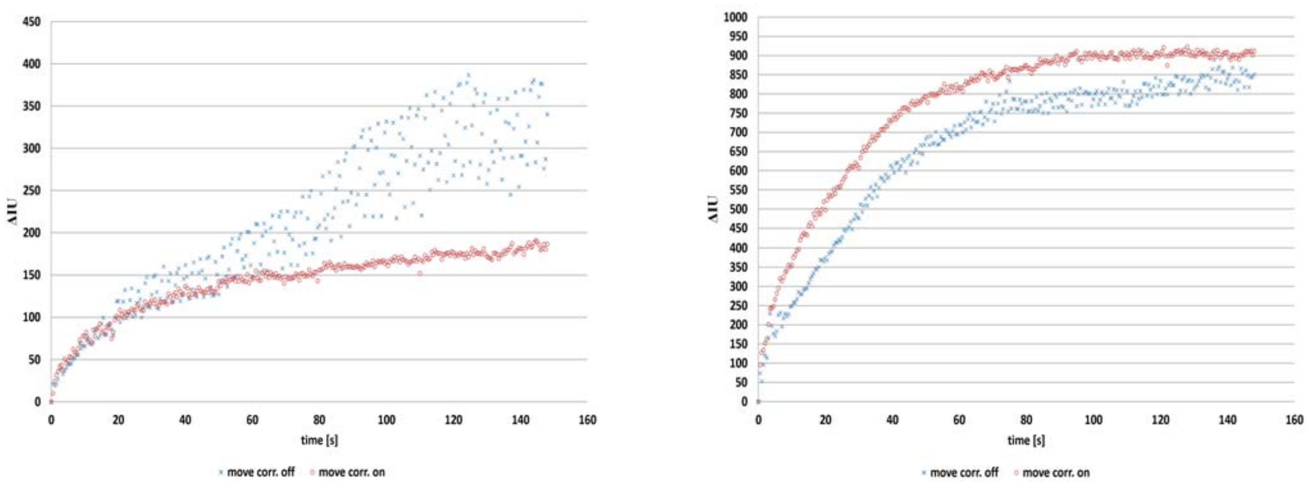


Figure
Data extracted from test image sequence for two point with and without movement correction

-area is not under thermal excitation,

-no significant change of temperature is inside the selected area,

-the best areas with high gradients of temperature are selected, i.e. edges of the body.

PRELIMINARY RESULTS: Designed movement correction method has been tested using the sequences of thermodiagrams made during the cold stress for breast cancer screening. The main problem in this case was the movement caused by breathing. Fig. 1 presents the data obtained for two points on each frame in the sequence. Two plots show data from the same starting point with and without movement correction.

Each curve is calculated as the mean value of 25 pixels around the point of interest, which is marked at the beginning of the sequence. The tests were also made for different number of surrounding pixels. The effectiveness of movement correction method were calculated by fitting the extracted data to mathematical model, i.e. exponential curve, and deviation of data samples was calculated. The algorithm was also tested with multiple templates areas.

Additional tests with marker on the body surface were made to calculate and present the error of movement correction method and the same body point localisation.

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PRACTICAL CAMERA AND ENVIRONMENT PARAMETERS DETERMINATION IN QUANTITATIVE THERMOVISION MEASUREMENTS

B. Wiêcek

Institute of Electronics, Technical University of Lodz, Wolczanska 211/215, 90-924 Lodz, Poland

Thermal resolution NETD

Noise Equivalent Temperature Difference (*NETD*) is one of the very basic and important parameter of the thermal detector and thermovision camera itself [1]. It describes the noise characteristics of the system. This parameter limits the camera temperature span (range) and has an impact on the quality of the image. Quantitatively, the higher value of *NETD* means that we are not able to distinguish the value of the temperature that is lower than the certain level. Typical temperature evolution in time of a chosen point in the image is shown in Fig. 1. One can easily notice the long time drift and high frequency noise. *NETD* refers to the noise.

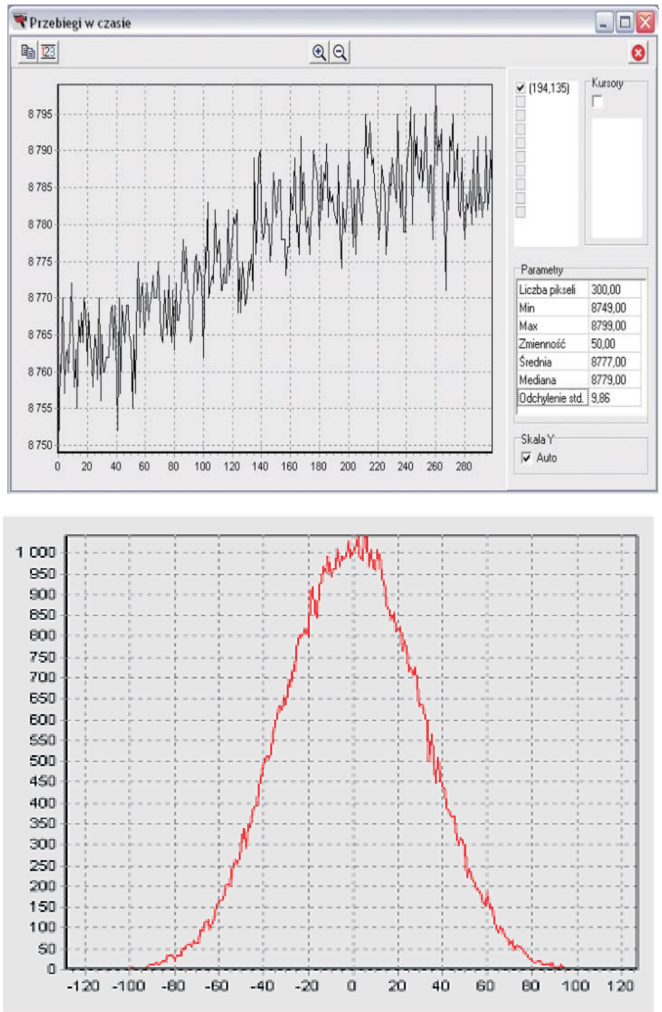

Figure 1.
Thermal drift and temporal noise (left) and statistical distribution of noise value

Estimation of *NETD* can be performed by calculating probability density function (pdf – fig. 1) of the temporal noise. Practically, we record long-time thermal image sequence, e.g. a few thousands frames. Next, the pdf is calculated. Typically, the probability distribution of the temporal noise is very similar to the Gauss function shape – eqn. (1).

$$n(T) = e^{\frac{(T-\bar{T})^2}{2\sigma^2}} \quad (1)$$

One can calculate the standard deviation for the noise using eqn. (2).

$$\sigma = \sqrt{\frac{\sum_{k=1}^{N}\left(T_k-\bar{T}\right)^2}{N}} \quad (2)$$

where *k* is a number of the thermovision image, *N* is a total image number.

Finally, using the standard deviation of the pdf of the temporal noise, *NETD* is estimated by the following relation.

$$NEDT = \sigma \frac{\Delta T}{\Delta IU}, mK \quad (3)$$

where *DT* is a camera temperature span, *DIU* is the span expressed in so-called isothermal units (digital values).

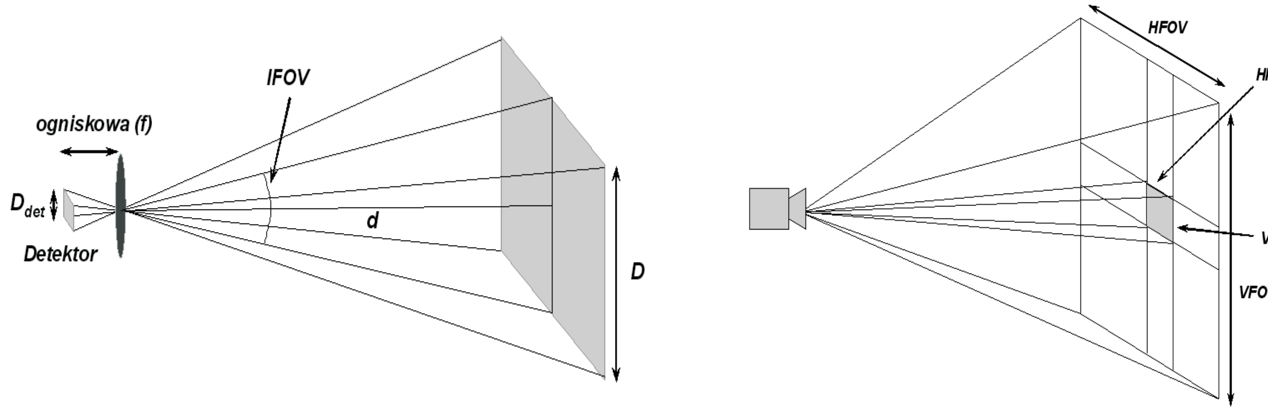

Figure 2
Definition of IFOV and FOV of the thermal camera

Spatial resolution

Spatial resolution of the thermal camera is expressed by *Instantaneous Field of View* (*IFOV*) corresponding to the single detector in the matrix, and *FOV* (*Field of View*) which characterizes the whole IR system – figure. 2.

IFOV is defined as

$$IFOV = 2arctg\frac{D}{2d} \approx 2arctg\frac{D_{Det}}{2f}(w^{\circ}\ \mathrm{lub}\ mrad) \qquad (4)$$

where D_{det} is the characteristic lenght of the detector pixel and f is the focal length of the lens.

Minimum resolvable temperature difference

Minimum resolvable temperature difference *(MRTD)* is a parameter which includes both the noise and spatial characteristics of the thermal camera. This parameter is estimated in the subjective way, and it has the main application to the military systems to determine the ability of detection the target. The method to obtain *MRTD* is based on slit test as presented in fig. 3. The slits having the room temperature are located above the hot plate with the temperature decaying in the bottom part of the tester. The operator has to detect the slits and the temperature difference between the background and the room temperature is assigned to *MRTD* of the thermal system.

In Institute of Electronics, Technical University of Lodz for the postgraduate studying courses [1], a training of *MRTD* estimation is offered using the simulation program. We can simulate different cameras with different level of the noise, i.e. bolometer uncooled and photon cooled systems. The final result of the lesson is presented in the form of MRTD curves as in figure 4.

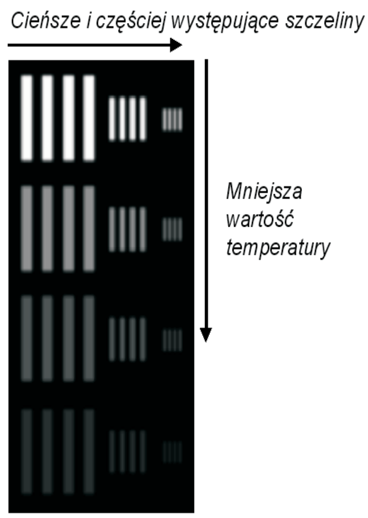

Figure. 3.
Slit tester for MRTD measurement

Reference

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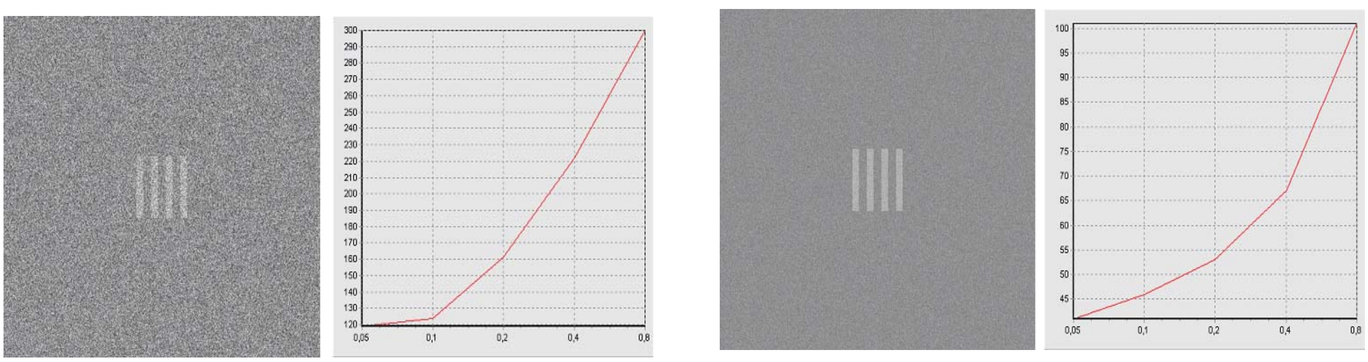

Figure 4.
Simulations of slit tests for different camera (NETD ˜ 80 mK –left, 20 mK - rigth) I with MRTD (in mK), curves, Ox axis is presented in units cycles/mrad