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Specifying and Testing a Thermal Camera For Medical Applications

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Guidelines for specifying and testing a thermal camera for medical applications

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SUMMARY

An infrared thermal camera used for medical thermography operates as a Medical Device, but few thermal imagers on the market meet the requirements of the EU Medical Devices Directive. The onus is therefore on the purchaser to ensure that the risks arising from the use of thermography in a medical context are identified and minimised.

Herein we present guidelines for the procurement and operation of an infrared thermal imager for medical thermography. Camera specifications, whole-lifetime costs, risk assessment, ongoing quality assurance and service/maintenance are among the issues addressed.

We encourage the reader to adopt an analytical approach to the procurement of medical thermographic equipment, in order to ensure safe practices and reliable measurements.

KEY WORDS: infrared thermal camera, medical thermography, risk assessment, quality assurance

ANLEITUNG ZUR SPEZIFIZIERUNG UND AUSWAHL EINER WÄRMEKAMERA ZUM EINSATZ IN DER MEDIZIN

Eine Infrarot-Kamera , die zur medizinischen Thermographie verwendet wird, ist als Medizin-Gerät zu betrachten, auch wenn nur wenige der am Markt zur Verfügung stehenden Wärmekameras die Vorausssetzungen der EU-Direktive für Medizin-Geräte erfüllen. Daher liegt der Nachweis und die Verringerung des Risikos, das beim medizinischen Einsatz der Thermographie entsteht, beim Käufer und Anwender dieser Technologie.

Hier wird eine Anleitung für die Beschaffung und den Betrieb einer Infrarotkamera für die medizinische Thermographie gegeben. Die Spezifikationen, die Kosten für die Lebensdauer der Kamera, Risikoeinschätzung, kontinuierliche Qualitätssicherung sowie Service und Instandhaltung werden besprochen.

Die Leser werden ermutigt, bei der Beschaffung von Gerätschaften zur medizinischen Thermographie analytisch vorzugehen, um einerseits sowohl eine sichere Anwendung der Technologie als auch zuverlässige Messungen zu gewährleisten.

SCHLÜSSELWÖRTER:, Infrarotkamera, Medizinische Thermographie, Risikoeinschätzung, Qualitätssicherung

Thermology international 2009: 19: 5-14

Background

Medical infrared thermography (MIRT) has a history going back some 40 years [1]. At that time there was limited regulation of medical technology. Today, in the ionizing imaging modalities, image optimisation in the face of dose reduction has driven the need for Quality Assurance (QA) checks. The Medical Device Directive, issued by the European Union, has introduced the concept of the "medical device" [2]. The UK Medicines and Healthcare Products Regulatory Agency (MHRA) defines a "medical device" as an instrument used for the purpose of, *inter alia:*

- diagnosis or monitoring of disease, injury or impairment
- investigation of the anatomy or of a physiological process.

Therefore, for medical thermographic applications, in both clinical and research settings, an infrared thermal imager unquestionably operates as a "medical device."

Healthcare institutions must work to clearly defined policies for the procurement and management of medical devices. Such policies are designed to ensure that

- correctly specified equipment is operated appropriately by competent staff, and
- an ongoing programme of funded equipment maintenance and QA is in place to ensure the equipment continues to perform within specification.

A properly implemented medical equipment management policy is a tool to ensure that risks to the patient and the health care institution are minimised. Risks can arise from the consequences of equipment failure (e.g. non-availability of the device in clinic), from misdiagnosis (because the device is not operating properly) or from some other adverse event (e.g. trips, falls or electrical fault hazards) [3]. Cogent procurement and management will ensure that, over the life of the equipment, value-for-money is obtained.

MIRT is still in transition. After a period of decline – due to exaggerated claims and disappointments - the introduction of reliable and sensitive focal plane array (FPA) imagers has led to resurgence in the numbers of cameras being procured for medical applications. Despite this increase in in-

terest, no guidance is yet published relating specifically to the procurement and equipment management of imagers for medical thermography. The potential therefore exists for exposure to risk from inappropriately procured thermal imaging equipment, operated without any QA plan.

Herein we describe the basic principles of procurement and equipment management pertaining to MIRT. Whilst local issues will inevitably necessitate amendments to our guidelines, our intention is to provide broad advice which provokes the initiation or refinement of medical equipment management at thermographic centres.

Procuring a thermal imager

In England, the MHRA document DB2006(05) [4] outlines the process by which medical devices should be procured and managed within the English National Health Service (NHS). Central to this document are principles of good financial governance, the concept of best value for money for NHS institutions (and how to win it), and an emphasis on costing equipment over its whole lifetime. A device with an inexpensive purchase price may prove extremely costly over its entire life if, for example, service and repair costs are not competitive.

Fig. 1 charts the life-cycle of a typical thermal imager in medical use. Below we will consider the key elements to this life-cycle in detail.

Identifying a clinical need

The provision of any new clinical service or research application starts with a number of decisions prior to the actual procurement of medical equipment:

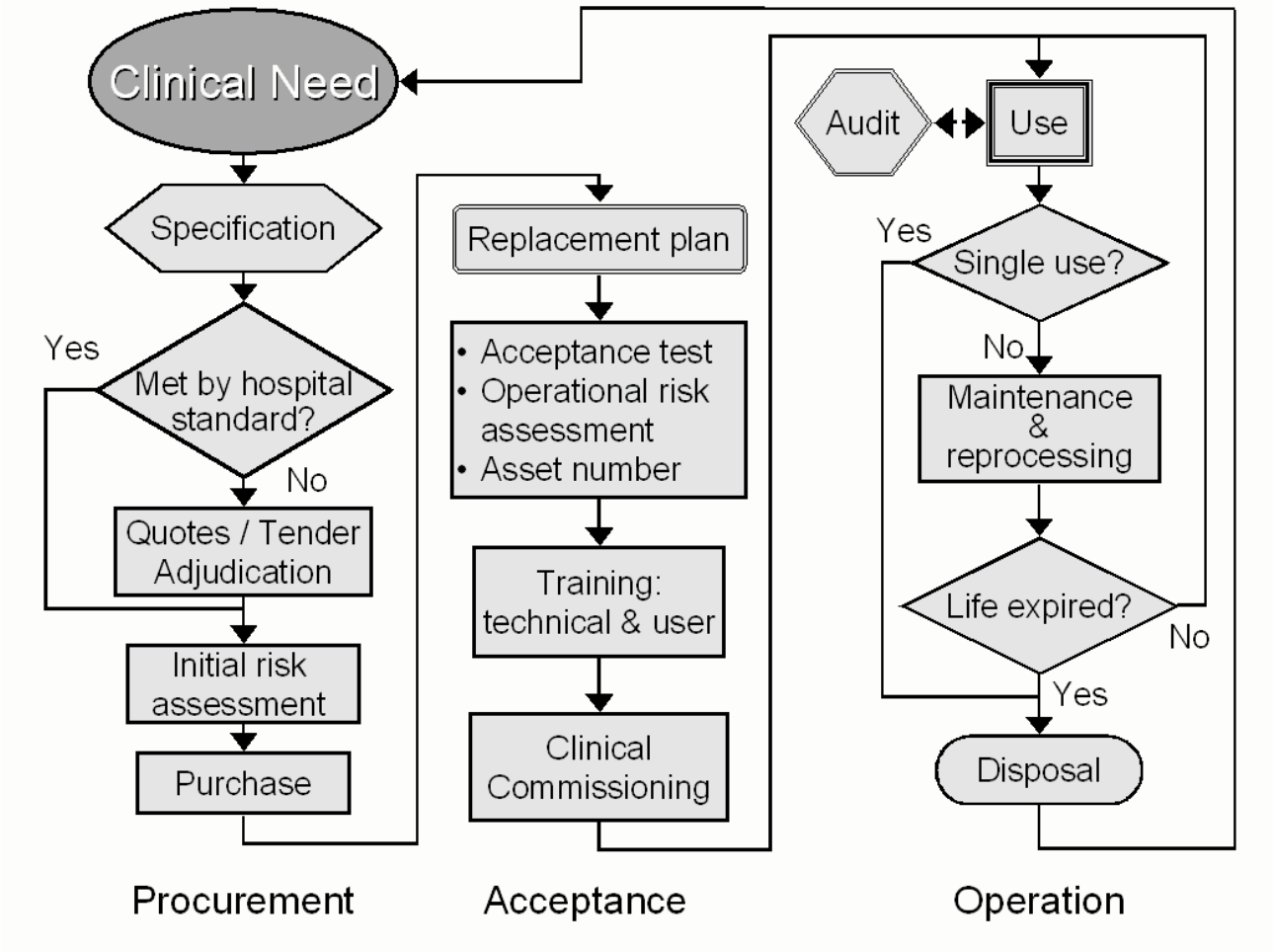
- "What are the diagnostic needs of our clinical service?"
- "What equipment do we need to procure in order to fill that diagnostic need?"
- "In what environment should the equipment be operated, and by whom?"

In the case of thermography, meticulous research is therefore required at the outset to ensure infrared imaging is an appropriate modality for assessment of the clinical question in hand. It may be necessary to perform thermography in an accurately temperature-controlled room.Trained staff who can dedicate appropriate time to this exacting discipline will need to be identified. A number of educational courses in MIRT are available, which will add specific competence in thermographic techniques to the core knowledge of physicians or clinical scientists.

Specifying the thermal imager and talking to suppliers

FPA technology has revolutionised the thermal imaging market, bringing to the customer an extensive choice of high-performance, competitively-priced infrared cameras. The equipment available can now meet the most demand-

Figure 1
Typical life-cycle of a medical device



ing medical thermographic needs. Identifying the imager most appropriate for those needs, however, can be difficult.

The vast majority of thermal imagers sold worldwide are destined for use in industrial, security or defence applications. Medical thermography remains a niche market. A key problem for healthcare customers is that biomedical know -ledge amongst thermal imager suppliers is, at best, extremely limited. The specification of thermal imagers, and the presentation of their sales material, is normally also geared to non-biomedical markets. A good sales team will work closely with the customer to identify the product most appropriate to their need. The ultimate responsibility for ensuring the equipment is properly specified for medical use, however, will lie with the purchasers. They should have a basic understanding of some of the key thermal imager specifications, as discussed below

Detector type

Modern FPA detectors fall into two categories: "cooled" and "uncooled" [5]. Choice of detector is the first decision facing the customer.

Cooled detectors are typically arrays of photon sensors, whereby incident IR radiation causes electrons to move across the energy gap of a doped semiconductor material. Since this process will occur at any temperature above absolute zero, it is necessary to cool the detector to reduce inherent noise in the image. Compact and robust mechanical coolers for thermal detectors are now readily available, and the use of liquid nitrogen to cool detectors is now not necessary. Nonetheless, mechanical cooling introduces a moving part into the imager, which is quite likely to be the earliest source of equipment failure. Mean time between failures (MTBF) of mechanical coolers is usually quoted at several thousand hours [6]. For "high-end" medical applications (e.g. measuring fast dynamic processes [7,8] or small temperature variations across one image), cooled detectors remain the technology of choice due to their high sensitivity and rapid response times.

Uncooled detectors are typically arrays of resistance microbolometers. There is a change in electrical resistance of the detector material in response to a temperature change elicited by incident IR radiation. Imager life is likely to be dictated by the life of the detector array itself. Uncooled detectors tend to have slower response times than their cooled counterparts, and a somewhat lower sensitivity. For many biomedical applications, which involve slowly changing temperatures of the magnitude of a few tenths of a Kelvin or more, these limitations of uncooled detectors may not be important. More significant can be the drift in output of uncooled detectors in response to changes in ambient temperature, and the time taken for the detector to reach stability after switch-on (which can be minutes or even hours) [9]. The performance of uncooled detectors has improved in the last five years, however, and many imagers perform very adequately within minutes of switch-on in a stable temperature controlled room. Such data may not be available from the manufacturer, however, and if the user conducts their own investigations there is no guarantee that another "identical" machine will behave in the same way.

Thermal accuracy and sensitivity

The *thermal sensitivity* of a thermal imager reflects its ability to detect temperature differences between two parts of the same image, and is typically a fraction of one tenth of a Kelvin for modern FPA imagers (best for cooled systems).

The *thermal accuracy* poses a bigger challenge in medical thermography. This is the absolute accuracy of the temperature reading, which must be measured against some accepted standard (ideally traceable to ITS-90, the international temperature scale of 1990) [10]. The quoted thermal accuracy of high-end imagers is often little better than budget models: typically ± 2 K at ambient temperatures. This implies an inherent inaccuracy of perhaps 20% of the range of human skin temperature, and is a potential severe limitation to the application of thermography across multiple healthcare institutions.

Fortunately, this disappointing thermal accuracy arises from the limitations of factory calibration of thermal imagers. As we will see later, thermal accuracy can be greatly improved by the use of traceable, *in-situ*, calibration sources. A quoted thermal accuracy of ± 2 K is therefore not necessarily a problem, although provision must be made for *in-situ* calibration of the thermal imager in use.

Optics, array size and resolution

The infrared lens, which forms the thermal image on the detector, is one of the most expensive components of a thermal imager. Many cameras accept interchangeable lenses for normal, "close-up," or "wide-angle" views, so it will be necessary to discuss which lenses might be required with the supplier.

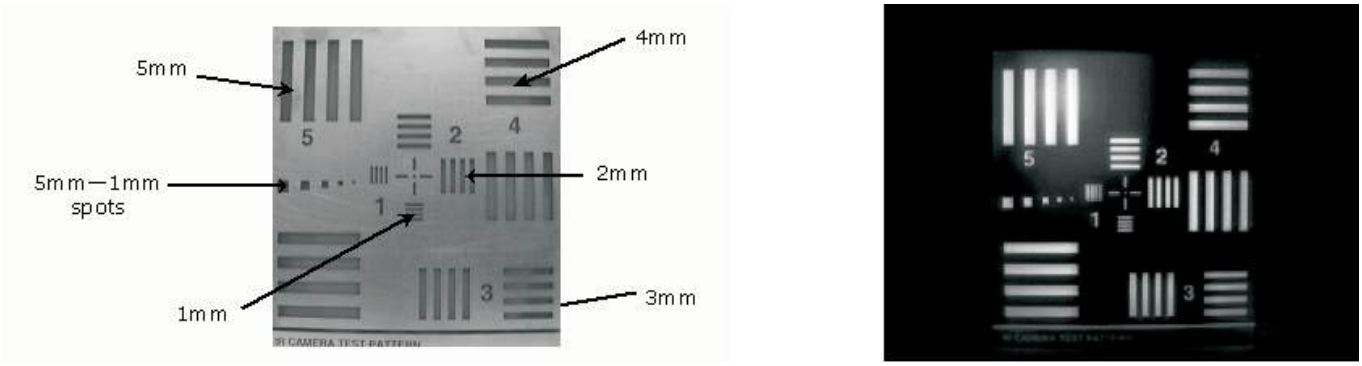
In medical applications we would often like the *spatial resolution* of the imager to be as high as possible, implying that finer detail in the infrared image can be detected. Since each detector element in the focal plane array is responsible for a pixel in the output image, resolution and array size are related. Standard array size is typically 320 x 240 pixels for medical use, but smaller arrays may be useable for some applications. A new generation of larger arrays are now coming onto the market, with some imagers now incorporating up to 640 x 512 pixel arrays.

Despite the relationship between array size and resolution, differences in the quality of the array, optics and imager processing firmware mean that resolution will vary between imagers with the same array size. Hence the only way to reliably assess imager resolution is to observe the minimum resolvable detail in the image. Fig. 2 shows a desktop test array developed for this purpose by Prof. Francis Ring and co-workers at the Royal National Hospital for Rheumatic Diseases in Bath, UK [11]. The array consists of a pattern of vertical and horizontal heated bars spaced apart at a variety of distances, to allow comparison of the minimum resolvable detail of different imagers in both the x and y planes. When viewing this test array, any image distortion due to the lens optics is also clearly visible.

Image capture and analysis software

Medical thermal imagers only rarely are used as standalone devices. More commonly, the image output is captured to a

Figure 2.
Photograph and thermogram of the IR Camera Test Pattern developed by Ring and Dicks



computer where appropriate image processing, reporting and storage take place. Thermal imaging software is therefore a key element of the medical device package.

The suitability of imaging software can only really be assessed by using it, so it is important to ask the supplier for a demonstration. If the customer's own computer is to be used to run the software, the demonstration should take place on that machine to ensure that there will be no software or hardware compatibility issues. It is often helpful to make a list of requirements that the software will need to fulfil specific to the clinical application. Some more generic questions to ask might be:

- Can the software capture timed sequences of images, or just single frames?
- What analysis tools are available? Can regions of interest relevant to medicine be drawn for the extraction of temperature data?
- Are the values extracted by the software accurate? Has the program been written under a quality system? The quality of images, and accuracy of temperatures extracted, is dependent on the integrity of the software code. Regular calibration and QA of the thermal imager will be completely undermined if the software compromises the data output from the imager.
- Are the tools for reporting of images adequate? Can intuitive colour palettes be applied to images, and are they exportable to word-processing, graphics, or spreadsheet packages?
- How will the images and reports be made available? Is PACS an option? Are images compatible with the Dicom standard [12]?
- How are images stored, tracked, encrypted and backed up [13]?

Whole lifetime costs of a thermal imager

The purchase process will depend on the institution purchasing the thermal imager. For many research applications, the purchaser will be free to choose the imager of choice from a number of quotes, subject to the constraints of budgets and the procurement rules of grant awarding bodies etc. For clinical applications within organisations like the NHS, the preferred procurement method is by competitive tender, where bids to supply equipment that meets a defined specification are submitted by suppliers, and the winning bid is that which represents best overall "value for money," as judged by pre-defined criteria. The competitive tender process has been shown to provide best "value for money" for NHS institutions, but it is not always well-suited to procuring unusual or "one-off" items like thermal imagers. Many of the criteria that constitute "value for money" for the device will not be previously defined, and will need to be identified carefully before the tender process can proceed. Misjudgements in this process can lead to clearly inferior equipment achieving the winning bid.

Assessing the "whole lifetime" cost of a medical device is essential for the good financial governance of the clinical service the device assists in providing. Institutions need to budget not only for the purchase cost of a thermal imager (including sales tax, where applicable), but also the ongoing costs of operating the device throughout its projected life. For thermography this is likely to include annual service and calibration of the imager. A decision also needs to be made regarding the financial arrangements for coping with unexpected breakdown of the equipment. Most suppliers are willing to place thermal imagers under service contracts. Otherwise, the user will need to cope with the cost of repairs as and when unexpected equipment failure occurs. Returning the imager to the supplier for planned maintenance or remedial repairs after a breakdown may incur less tangible costs that should also be included in the budget. This includes the loss of revenue from thermographic procedures that cannot be performed while the equipment is unavailable.

An accurate assessment of whole lifetime cost of a thermal imager is dependent on good estimates for the likely life of the device. For cooled detectors, the cooler life is likely to be the limiting factor, and this is normally given in manufacturers' specifications. For uncooled detectors, where detector life is probably the limiting factor, an accurate prediction of lifetime is more problematic. Detector arrays are notoriously variable in their longevity, and stories abound in the medical thermography profession of users with identical models of FPA imager who have achieved greatly differing imager lifetimes. As with much integrated microcircuitry, this is probably a shortcoming in the consistency of the detector manufacturing process. Uncooled detector MTBF is rarely quoted by manufacturers, but 30,000 hours is not untypical [6] (this is a summary statistic and provides

no information about the population distribution). Where an imager remains in constant operation (either because of clinical need or to ensure detector stability) this amounts to little more than three years of continuous use. The stability of uncooled detectors soon after switch-on has improved in recent years to such an extent that continuous operation is rarely necessary, however.

In table 1 we conjecture the approximate costs in the first year of both procuring and operating a new uncooled thermal imager as part of a busy rheumatological or vascular service.

Table 1
Example costs for procuring and operating an uncooled thermal camera in the first year.

Thermal camera	€30.000
Test equipment, camera stand and isolation transformer	€8.000
Annual service	€1.500
Annual downtime (QA and service)	€10.000
Total for first year	**€49.500**

Risk assessment

Prior to the purchase of the thermal imager, a thorough initial assessment of the risks associated with the use of the imager should be carried out. Thermal imagers are not normally sold as "medical devices" and are therefore not CE marked as such to MDD 93/42 EEC. In the eyes of European law, therefore, thermal imagers are not proven fit and safe for medical use, and the onus is on the thermographer to procure and operate the device in a manner which minimises risk to the patient.

Risk can be defined as:
(consequence of an event) x (probability that the event will occur).

Table 2 shows one approach [3] to risk assessment, with the consequences of an event scaled from 1 to 5 (1 = negligible consequence, 5 = multiple fatalities), and the probability of an event also scaled from 1 to 5 (1 = impossible, 5 = certain). Risk scores of 15 or above can be considered "high risk," while conversely scores of 3 or less pose "low risk" or "no risk." This is often applied when analysing adverse incidents, however, it is equally applicable in prospective risk assessment.

At the procurement stage the major risk to the organisation relates to the non-compliance to the MDD. As there are very few thermal cameras meeting the MDD on the market, the actions arising from the initial risk assessment relate to management processes the user can implement to best overcome this deficiency.

Acceptance of the new medical thermal imager

All the preliminary work of costing, specification and risk assessment is of course performed with the aim of delivering to the institution an appropriate thermal imager which will pass an acceptance test, and move smoothly and expeditiously into clinical use.

Acceptance test

Immediately after delivery, the imager and any attached electronic components should undergo an appropriate acceptance test as outlined in DB2006(05) [4}. This typically consists of:

- Paperwork and asset logging: has all the correct documentation, such as instruction manuals, been supplied with the imager? Add the equipment to the institution's database of medical equipment, and label the device with its asset number.
- Visual inspection: any apparent damage to the casing, lenses or connectors?
- Functional check: does the device function in line with the supplier's information?
- Basic electrical safety: e.g. continuity of earth connection, leakage current (*inter alia*), consistent with IEC601 – the standard for medical electrical equipment [14]. Computer power supplies can have earth leakage currents that far exceed the limits of IEC601.
- An assessment of the instrument (and its stand) under PUWER (Provision and use of work equipment regulations in the UK – from EU directive 89/655/EEC) (15)

Operational risk assessment

Now is the moment to perform a repeat risk assessment, this time with the device operating *in situ,* and bearing in

Table 2
Qualitative risk assessment matrix, adapted from [3]

QUALITATIVE RISK ASSESSMENT MATRIX – LEVEL OF RISK

CONSEQUENCES	PROBABILITY					
	Impossible 0	Rare 1	Unlikely 2	Moderate 3	Likely 4	Certain 5
Negligible – 0	0	**0**	**0**	**0**	**0**	**0**
Minor – 1	0	**1**	**2**	**3**	**4**	**5**
Serious – 2	0	**2**	**4**	**6**	**8**	**10**
Major - 3	0	**3**	**6**	**9**	**12**	**15**
Fatality – 4	0	**4**	**8**	**12**	**16**	**20**
Multiple Fatalities - 5	0	**5**	**10**	**15**	**20**	**25**

KEY: No risk Low risk Moderate risk Significant risk High risk

mind the findings of the acceptance test. Infrared thermography, as a non-contact, non-ionising imaging technique poses only very minimal physical risk to the patient *per se*. However, other risks to the patient and staff (operator) may arise. These can include:

- ·Electrical safety hazards (e.g. risk to cardiac patients who come into physical contact with the camera or stand, if the equipment is poorly electrically isolated). An isolation transformer may be appropriate depending on the result of an electrical safety test at acceptance.
- ·Trip and fall hazards. (Patients and staff can trip over trailing wires or other lab equipment, camera stands can be knocked over, imagers can fall from their stands). Consider a unipod medical imaging stand for the thermal imager, rather than the unstable and inflexible tripods often offered with thermal imagers. Cold water challenges may allow water and electricity to mix with explosive consequences.
- ·Inappropriate arrangement of equipment in the lab. The layout with the imager present may be ergonomically unacceptable for patients and staff.
- ·Risk of wrong diagnosis. (Erroneous and misleading temperature readings arising from poor imager calibration or QA). Without a careful programme of imager quality assurance, this is undoubtedly the greatest risk to the patient posed by thermography.
- ·Long hours in front of a poorly-configured visual display or badly designed workstation introduce further hazards for the operator (Display screen regulations - Directive 90/270/EEC) [16].

Thus risk assessment plays a vital role in fulfilling the obligations of healthcare institutions to comply with health and safety regulations that protect patients and workers. A formal risk assessment is shown in appendix 1.

Calibration and quality assurance

The thermal imager supplier undertakes to supply equipment that performs within specification. As discussed above, however, that specification is unlikely to be rigorous enough to satisfy the requirements of medical thermography. Quoted temperature accuracy is typically as poor as ±2 K, and there is drift in readings after initial switch-on of uncooled systems. The typical accuracy specified by many suppliers arises because most imagers are used in industrial settings where the dynamic range is broad, ambient temperature may vary greatly, or the imager may be expected to be used immediately after switch-on. Fortunately most of these limitations can be overcome by operating the imager within careful constraints (e.g. stable ambient temperature, not imaging until the detector reaches stability), but it is vital the performance of a newly-procured imager is fully investigated at the outset to enable an appropriate operating protocol to be adopted. Furthermore, these investigations should be regularly repeated as part of an ongoing process of imager quality assurance: camera performance can and does change with use. Where the imager no longer performs within the medical specification required, remedial action will be required.

Temperature calibration

Some form of *in situ* device which can provide a known traceable standard temperature is essential to validate the absolute accuracy of the thermal imager. This normally takes the form of a *black-body source* i.e. a target or set of targets which can be held at an appropriate temperature [17]. The radiant emissivity of the target(s), ε must be known very precisely, and is typically as near to unity as design will allow. The temperature output of the thermal imager can then be compared against a range of target temperatures to produce a calibration curve for the thermographic device. Ideally, a source should also be included within the field of view during the imaging of the patient, in order to validate the temperature readings within each specific image.

Many of the black body sources commercially available are not appropriate for medical use because they only provide calibration across an inappropriate temperature range. Producing a reliable, cost-effective black body source which will operate at near-ambient temperatures - i.e. in the medical range of approximately 293 –313 K (20ºC – 40°C) - with an accuracy of better than ± 0.1 K is technically quite challenging. However, a small number of devices which meet this requirement are available. An ice-water mixture provides an approximation of a black body source, but requires the camera to be mounted pointing downwards and is outside the medical range. It is nonetheless the basis for some QA (see below).

In the UK, the National Physical Laboratory has developed a Thermal Imager Validation System (TIVS) [18] which is ideally suited to the calibration of medical thermal imagers. TIVS consists of portable black body sources utilising either the solid-liquid phase transition or the eutectic temperature of eutectics. They retain highly stable temperatures at their respective phase transitions for prolonged periods. The use of more than one source facilitates the validation of the imager output at more than one temperature point within the medical temperature range. The sources are small and robust enough to be included within the imaging field of most medical images, thus providing a true *in situ* validation of each thermal image during thermographic procedures.

The accuracy one is looking to achieve from a thermal imager will depend on the particular medical application, and the imager purchased. In a steady ambient temperature, even an uncooled modern FPA imager which has stabilised after switch-on should be achieving an accuracy of a very few tenths of a degree Celsius, and this is sufficient for most medical applications.

Other quality assurance tests

Plassmann et al [9] describe a number of further quality assurance tests that should be performed on thermal imagers immediately after procurement, and also regularly on an ongoing basis while the imager is in medical service. These tests are also outlined on the World Wide Web at **www.medimaging.org**. The tests can be performed using ice and water to give a basic degree of confidence in imager performance, but the use of an appropriate black body source as the temperature reference is preferable for some of the tests.

•*Offset drift after switching on*. Uncooled imagers can exhibit a drift in temperature reading of several degrees Celsius over hours, prior to the detector reaching acceptable stability. This is vital to investigate: it dictates how long the user must wait before the imager is performing optimally, and the findings should be built into the operating protocol for thermographic studies.

•*Long term offset drift*. Provided ambient temperature remains constant, and the detector has reached stability after switch-on, the thermal imager should give a reproducible measurement of black body target temperature on different days. Variations of more than a few tenths of a degree might invalidate longitudinal thermographic studies

•*Offset variation over range*. This is a check to ensure the imager is accurate at all temperatures across the medical range, and is particularly easy to perform using the TIVS system.

•*Thermal flooding*. This investigates the effect on measured target temperature of introducing a second target at a different temperature into the field of view. The effect should be minimal, but the performance of FPA imagers varies in this respect.

Service and maintenance by the supplier

The final aspect of thermal imager equipment management is the maintenance service offered by the supplier. This falls into three categories: *ad hoc* repair; maintenance contract; and planned preventative maintenance and calibration. Before entering into any contract it is important to understand what is being offered. Once again a risk based approach is sensible. How often does a camera fail? What is the consequence for the clinical service (loss of revenue, rescheduling appointments)? What is the claimed response time of the company? And what do other users say is the reality? Where is the service carried out? Is the workshop accredited? Where are spares held? Is it better to put the cost of a maintenance contract towards a second camera? How is the imager calibrated against a black body source during annual service? Is the calibration across a sensible range of temperatures for medical applications? If not, it may be an expensive exercise which gives less validity to medical measurements than inexpensive *in situ* calibrating equipment tailored to the medical temperature range. Is the calibration traceable to ITS-90?

Sending an imager to the supplier for routine maintenance potentially creates a gap in the clinical thermography service. Few medical thermography centres have the luxury of owning more than one thermal imager, but this is the preferred situation since the second imager, with known performance characteristics, can take on some of the clinical load in the absence of the first. It also offers your clinical service resilience – in a financial model the cost of a camera may be small compared with other fixed overheads.

Some suppliers can offer a loan instrument during the service period. However, since the performance characteristics described in section 3 above will need to be known about the loan device to validate any clinical work, this is not always necessarily an acceptable solution. It cannot be assumed that even identical models of thermal imager have identical performance characteristics.

Unlike the validation of the thermal imager *in situ* against a black body source, the black body calibration which occurs at the service centre will result in adjustments being made to the imager firmware which permanently alter its output. Hence, the calibration must be *certificated* by the supplier i.e. documentation should be supplied which details the changes that were made to the instrument, and accredited – i.e. those changes are traceable and standardised. In this way, the user should be able to account for any changes in the imager performance that occur on its return from manufacturer's service. Time must be set aside for re-assessing the imager using the in-house protocol before it returns to clinical service.

Discussion

Inexpensive, high-performance focal plane array thermal imagers have presented the medical thermal imaging community with an excellent opportunity over the last decade. For the first time, high quality thermographic measurements are attainable for medical applications by almost any practitioner. Ongoing improvements in imager technology mean this is an exciting time for medical infrared thermographers [19].

With this technologically-driven opportunity, however, have come threats to the discipline of infrared thermography. As infrared equipment becomes easier to acquire at relatively low cost, the likelihood it will be misused by the uninitiated increases. Thermal imagers procured for medical use should not be considered straightforward pieces of consumer electronic equipment, but rather specialised physiological measurement tools which must be subject to rigorous quality assurance protocols. Provided the highest standards of application of the technology prevail, the benefits will be seen to have greatly outweighed the risks.

In this paper, we have limited our discussion to technical performance of the imager. It should not be forgotten by the reader that other opportunities to misapply thermography in medicine exist. In particular, the importance of applying rigorous, reproducible patient preparation and image capture protocols has been clearly demonstrated [20, 21]. Analysis of thermal images with consistent, appropriate statistical tools and "regions of interest" is also vital.

Arguably the biggest risk to both patient and user from thermography, however, remains the misuse of the thermal imager through ignorance of its technical performance. This risk will only be minimised by education of thermographers (and potential thermographers) about the technology "inside the camera case." In this, suppliers could potentially play an important role. The medical community must in turn communicate its requirements from infrared technology to suppliers. In particular, there needs to be rapid adoption of *in situ* methods of thermal imager validation which are appropriate to the medical temperature range. Without this, meaningful multi-centre trials utilising thermographic measurement are impossible – a limitation which has invalidated major studies in the past [22].

In conclusion, we would encourage the reader to adopt a thorough and analytical approach to the procurement of a medical thermal imager. Consider the whole-life cost of your purchase to ensure value for money, and ascertain the exact specification of infrared imager you will require. A careful risk assessment should be performed, and the performance of the imager should be investigated both at the commissioning stage, and on an ongoing basis throughout the imager lifetime. The supplier can also contribute to imager quality assurance, but talk with your service centre about how they can offer maintenance that is really applicable to medical measurements.

These efforts, which are analogous to little more than the precautions we might take in keeping a motor vehicle in roadworthy condition, will ensure years of reliable infrared measurements for your thermographic service.

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Appendix 1. Example risk assessment for a thermal imager in medical use.

Department/Area: Microvascular Laboratory Rheumatology Department	**Date of Assessment:** **5/3/2008**	**Assessment No:** **12345**

DESCRIPTION OF ACTIVITY

USE OF AN FPA THERMAL CAMERA TO PRODUCE THERMAL IMAGES OF PATIENTS

Patients – both adults and children - will be imaged. They will be asked to disrobe as required, and to equilibrate to ambient in the room with the camera. They may be imaged standing or sitting.
The images taken will then be used to support clinical diagnosis.
They might undergo a cold challenge of the hands with water at 15 ^{o}C
All equipment should be used according to manufacturer's instructions.

HAZARD IDENTIFICATION

1. Inappropriate or incorrect use
2. Failure to set up the equipment safely for the working environment
3. Imaging equipment is not classified as a medical device
4. Equipment does not comply with requirements of IEC601 for electrical safety of medical devices.
5. Failure to maintain the equipment
6. Failure to perform initial image QA
7. Failure to perform ongoing QA
8. Failure to plan for contingencies – including equipment failure and planned replacement.

PERSONS AT RISK (who might be harmed and how? are there any groups especially at risk?)

Patients requiring clinical service, staff, and visitors

1. Images obtained and their interpretation may be incorrect (Patient)
2. Trips, slips, and accidental contact with equipment (All)
3. Equipment might not be fit for medical purpose (Patient)
4. Exposure to electricity (All)
5. Equipment fails and no image is obtained (Patient)
6. No understanding of imager performance (Patient)
7. Change in image quality resulting in misdiagnosis (Patient)
8. Suspension of service (Staff, Patients)

EXISTING PRECAUTIONS (what controls are currently in place?)	other risk assessments
1. Professional capacity of thermographer 2. Ergonomic design of laboratory – equipment away from patient flow. Patient and visitors not left unsupervised. 3. Recognition by thermographer and clinicians of limitations of equipment. 4. Protection against fluid ingress, isolation transformer if leakage currents excessive. 5. Annual assessment of equipment. 6. Acceptance QA 7. On-going QA 8. Contingency plan not in place	

ANALYSIS OF EXISTING PRECAUTIONS (are the precautions effective; if not, why not?)

1. Effective
2. Partially effective – environment is cramped
3. Effective
4. Isolation transformer; electrical items mounted above for level away from sink and cold challenge area
5. Effective.
6. Adequate.
7. Insufficient resource for proper QA programme.
8. Not sufficient

.

ACTION REQUIRED (what further action needs to be taken to control/reduce the risk?)

Action	By whom	Target date	Date completed
Draw-up business contingency plan	KH	**01/06/2008**	
Write business case for QA support	KH	**01/07/2008**	
Feed into area refurbishment	KH	**31/12/2008**	

REVIEW DATE

General review – 31/12/2008

PERSON(S) CARRYING OUT THE ASSESSMENT

Kevin Howell -

Roy Smith – Head of Medical Electronics

Print: **Signature:** **Date:**

Thermology on the Internet- An Update

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SUMMARY

This paper is an update of a report which information on Thermology is available on the internet. In total three searches was performed, one in the standard version of Google using the search term "thermology". Google Scholar and Embase was searched for "thermography" and "clinical"and "medicine" both restricted to the year 2008. 572 links to websites related to thermology were found, but none of the previously published webadresses were re- identified. Many hits in Google were linked with thermographic services, mainly infrared breast imaging. Some findings were linked to academic thermology societies. The scientific impact of journals publishing papers on temperature related topics is discussed in brief.

The searches for publications on thermography and clinical medicine found that only 31 of 174 papers identified in Embase were also found in Google Scholar. After combining the results from Embase with publications traced by the first 200 hits of the search in Google Scholar, 242 papers were related to clinical medicine, 10 to veterinary medicine and the the remaining 74 to applied sciences. Many medical papers discussed the use of thermography in patients with complex regional pain syndrome, in vascular disease and in surgery. In conclusion, the current literature on medical thermal imaging shows similar use of the technique as last years review. Searching for scientific papers in Google or Google Scholar, obtained mediocre scientific information only, despite a large number oft hits.

KEY WORDS: thermology, internet, literature search. Google

THERMOLOGIE IM INTERNET - EINE AKTUALISIERUNG

Diese Arbeit ist die Aktualisierung eines Berichtes über die im Internet verfügbare Information zum Begriff Thermologie. Insgesamt wurde drei Suchen im Internet durchgeführt. Zuerst wurde in der Standardversion von Google eine Suche nach den Begriff "Thermoloie" durchgeführt. Dann wurde in der Datenbank Embase und in Google Scholar nach "Thermographie" und "Klinische Medizin" mit Einschränkung auf Publikationen aus 2008 gesucht. Obwohl 572 Links auf Webseiten gefunden wurden, die sich auf Thermologie bezogen, konnte keine jener Adressen wieder gefunden werden, die bereits in einem früheren Bericht publiziert worden waren. Viele der Treffer in Google wiesen of thermographische Dienstleister, vorwiegend zur Infrarotthermographie der weiblichen Brust, hin. Einige Ergebnisse führten zu akademischen Thermologie-Gesellschaften. Die wissenschaftliche Bedeutung von Zeitschriften, die Temperatur bezogene Arbeiten publizieren, wird kurz diskutiert.

In den Literatursuchen nach Arbeiten zur Thermographie und klinische Medizin fanden sich nur 31 der 174 in Embase entdeckten Publikationen auch bei der Suche in Google Scholar. Nachdem die Ergebnisse der Suche in Embase mit den Daten aus den ersten 200 Treffern in Google Scholar kombiniert worden waren, bezogen sich 242 Publikationen auf klinische Medizin, 10 auf Veterinärmedizin und die restlichen 74 auf angewandte Naturwissenschaften. Viele der medizinischen Arbeiten diskutierten den Einsatz der Thermographie bei Patienten mit chronischem regionalen Schmerz-syndrom, bei Gefäßerkrankungen und in der Chirurgie. Als Schlussfolgerung kann gesagt werden, dass die aktuelle Literatur einen ähnliche Verwendung der medizinischen Thermographie anzeigt wie die Literatursuche im Vorjahr. Die Suche nach wissenschaftlicher Information in Google oder Google Scholar hat trotz einer hohen Anzahl von Treffern nur Arbeiten von mittelmäßiger Qualität gefunden.

SCHLÜSSELWÖRTER: Thermologie, Internet, Literatursuche, Google

Thermology International 2009, 19(1) 15-28

Introduction

Ten years ago, an overview on thermological resources was published in this journal [1]. New equipment and providers of infrared imagers have appeared, since. Standards for recording and evaluation of medical images [2] and an abundance of scientific results related to the diagnostic and therapeutic applications of heat and temperature have been published [3.4], which can accessed on the internet, partly free of charge. In addition, Google became the number one of internet search engines [5] and provides a particular option for searching scientific references. Google Scholar is meanwhile connected with most databases of publishers including PubMed, the search engine of the American Library of Health.

An interesting feature of Google Scholar is the automatically generated number of citations of identified articles.This tool for trackin citations is now used by number of internet publishers including HighWire and Biomedcentral. Such information is normally only provided by Thompson Scientific Web of Science, and by Scopus since 2004 [6], both available on paid access. However, the number of citations appearing in Web of Science is restricted to

journals and proceedings which are listed at Thompson Scientific..

It seems of interest to update this ten year old report [1] on information on thermology on the internet.

Method

A search was conducted in Google using the term "thermology". Another search was performed in Google Scholar with the terms " thermograpy clinical medicine" and restriction to the year 2008. To avoid duplications of hits, the automatic exclusion tool of the Google Software was activated by moving to high search hit numbers. Finally, a search was conducted in Embase using the term "thermography" with restriction to publication from 2008.

All web pages found were allocated to the catagories equipment, applications, users and publications. Links related to

Table 1
Revision of Web adresses related to equipment as puiblished in [1]

SITE IN FUNCTION

Compix
http://www.compix.com

Electrophysics
http://www.electrophysicscorp.com

Infrared
http.//www.infrared.com

Jenoptik
http.//www.jenoptik-los.de/
http.//www.infratec.de/ittgsyst.htm

Land
http://www.landinst.com/infr/

Lumitron
http://www.lumitron.com

Meditherm
http://www.meditherm.com

Mikron
http://www.mikroninst.com

SE-IR
http://www.seir.com

Thermascan
http://www.thermascan.com - **now mainly thermal imaging service**

Thermal Wave
http://thermalwave.com

Vision Technologies
http://www.visiontechnologies.net/ir.html

ONLY THE MAIN ADDRESS IS IN FUNCTION, BUT ALL SUBPAGES ARE OUT OF FUNCTION

Agema
http://flir.com/products/rd/570.htm

ETO-Sensors
http://www.darpa.mil/eto/sensors/index.htm

Flir
http://flir.com/products/
http://www.electricnet.com/cofolder/flirsys.htm

Raytheon
http://www.raytheon.com/rtis/

SITE CHANGED

ADDITIONAL http//thermographie.com - **now graphic design company**

Agema
http:http://equitronics.com/agema.htm - **now medical information site**

Amiris
http://www.cplath.com/products/amiris2100.htm - **now marine supplier**

Inframetrics
http://www.inframetrics.com/index.htm-**now search engine**

SITE OUT OF FUNCTION-HAS NOW A NEW ADDRESS

Ashwin (Teletherm)
http://www.home1.gte/infrared-**s**

Eidam (regulation thermography)
http.//home.t-online.de/home/EidamMedTech

NEC San-ei:
http://nbn.de/thermo.htm
http://www.ebs-thermography.com/data-d/index.htm

SITE UNABLE TO ACCESS

Bales
http://www.balesscientific/equipment/-

Cincinnati Electronics
http://www.cinele.com/products/dmdl/

Eidam (regulation thermography)
http://www.thermography.net

ISI
http://www.isigroup.com/products/index.html

Nikon
http://www.klt.co,jp/Nikon/LAIRD

Optimas
http://optoelectronic-world.com/vsd/vsdco/ optimas.htm

Raytheon (früher Amber):
http://lot-oriel.com/de/thermogr.htm
http:// lot-oriel.com/uk/amber.htm

Spectrum
http://spectrum-instruments.com/iis.htm

Stressphonics
http://www.stressphonics.com

Western Sensor
http://www.dmi.net/ir-sensor/index1.htm

applications were further devided into industrial and technical, medical, veterinary and other biological usage. Webpages of users were allocated to institutions, thermographic services and scientific societies dedicated to thermology. In addition, all web addresses published in the article from 1999 [1] were checked if the are still available and in function. To avoid the impression of unbalanced promotion of any thermographic service, web addresses are not provided with the exception of web addresses published previously in the overview ten year ago.

Publications were classified as medical, other biological, industrial or science article.and were checked if the have been published in a peer reviewed journal. Papers were further analysed with respect to the year and language of publication. Medical papers were also allocated to the respective speciality.

Results

The search Google obtained originally 26 200 hits of which 572 links remained. The 435 references found in Google Scholar, were reduced to 433 after activation of the exclusion tool for duplications . The search in Embase revealed 176 hits.

Equipment

It was stated ten years ago that nearly all manufacturers of infra red imagers have their own website, partially produced in cooperation with their main distributers.This is still true in 2009. However, only about one third of the web addresses collected in 1999 are still in function. Table 1 provides an overview of changes in reportd web sites of thermology equippment. The search in Google did not identify any of the previously published web links.

The main player on the thermal imager market, FLIR, has established a network of national web sites around the globe, which provides information on equipment, applications and education for thermographers.

Applications

Due to the search term "thermology" the majority of hits in Google was related somehow to medicine. This may be caused by the definition of thermology in the the internet encylopedia Wikipedia which states: " *Thermology is the that derives diagnostic indications from highly detailed and sensitive images of the . Thermology is sometimes referred to as medical infrared imaging or tele-thermology and utilizes highly resolute and sensitive infrared (thermographic) cameras*" A more general definition of thermology, often found in links to dictionairies and encylopedias is: " *A discourse on, or an account of hea*t.".

Only some links were related to industrial applications such as non- destructive testing and maintenance or surveillance services.

Medical thermography

The majority of web links were related to thermal imaging services and most of them offer infrared breast imaging. These companies are often owned by health professionals and for interpretation of the breast thermograms the co-operate with physicians. Medical doctors are seldom interpreting breast thermograms in these imaging business. Many the interpreting physicians had an academic training in chiropractice and were often board certiied by one of following thermography societies.

- International Academy of Clinical Thermology
- International Thermographic Society
- American Academy of Medical Infrared Imaging
- American Academy of Thermology

Sometimes the companies that offer infrared breast imaging offer also complementary health care for breast diseases. Some clinics for chiropractice or physiotherapy provide also whole body infrared imaging.

The medical information available on the websites of breast imaging services usually follows the same pattern. Some of these articles have been published in non peer-revied journals or in health magazines [7-10]. All these papers suffer from an unbalanced selection of references by ex- clusion of studies that report unfavourable results of infrared breast imaging. These articles are in contra-d iction to a number of health in- surance policy statements which have a similar unbalanced selection of papers which disfaour infrared imaging and exclude all results that support the diagnostic value of this imaging technique. [11-14].

Three companies were found that offer veterinary thermal imaging for horses, cattle and other domestic animals..

Medical Thermology Societies

The search identified 5 societies located in North America, 1 societies in the Far East and 3 societies in Europe. Altough most of the American societies claim to be non-profit.organisations, the list of links on their websites to commercial infrared imaging companies may raise some doubt in the label "non-profit organisation"

American Academy of Thermology (AAT)

The AAT was founded in 1971 as the American Thermographic Society and was reorganized in 1983 as the American Academy of Thermology. It is the only non-commercial, non-proprietary, multi-disciplinary and peer-based organization involved with medical thermology in North America. The Academy offers memberships to state-licensed medical, osteopathic, chiropractic and veterinary physicians; to accomplished medical scientists in physiology and to thermology technologists under their direction. The AAT provides training programmes for these technologists, and fellowships for professional education in various sub-specialties in thermology. The AAT holds annual conferences for the presentation of scientific and professional papers and contributes to Thermology International.

International Academy of Clinical Thermology (IACT)

The following description of this society can be found on their webpage.: *"Founded in 1983, the IACT serves as a non-profit organization providing resources in clinical thermography to both the health care community and the general public.*"

The professional section of the IACT web site provides information on

"Choosing an Infrared Imaging System"

"IACT Certification Program" an application form.

"Thermography Guidelines (Standards and Protocols)",

Some articles and case studies are exclusively dedicated to breast thermography . The IACT considers two categories of membership: *Professional members* fulfill at least one of the following requirements:

- Possess a license with powers to diagnose pathology and or disease
- Possess a Ph.D. or equivalent in a health care related science

Associate membership is provides for thermographic technicians, thermography-related businesses, and students majoring in a field directly related to thermography..

Institute for the Advancement of Medical Thermology (iAMT)
This society offers 4 categories of membership which are:

- Professional Member – MD, DO, DC, PhD
- Associate Member – Certified Thermographe
- Affiliated Member – All others
- Resident/Student Member

Similar tothe IACT, the main focus of the iAMT is breast thermography., but the provided educational articles are mainly taken from peer reviewed journals and include papers from Parisky [15], Head & Elliot [16-19]

American College of Clinical Thermology Inc (ACCT)

This society claims to be the the fastest growing , nonprofit professional organization dedicated to the advancement of thermology and thermography. A long list of indications for thermal imaging is provided. However, most of the socalled indications are poorly supported by the literature and the evidence of the diagnostice value of thermography is ambiguus in the best case. The ACCT offers three levels of professional certified thermography training and provides a long list of ACCT approved thermographic clinics around the world. A close relationship between the ACCT and Meditherm Inc becomes obvious comparing the list of ACCT approved thermogrphic clinics with the list of testomoniials for Meditherm equipment.

International Association of Certified Thermographers (IACT)
This association may be confused with the International Academy of Clinical Thermology because both use the same acronym. The website provides full information on bylaws, mission statement, code of ethics, Conflict of Interest and Confidentiality Policies and standards and protocolls for medical thermography. At the moment, there is a personal overlap of executives between International Academy of Clinical Thermology, the International Thermographic Society and International Association of Certified Thermographers. The IACT was created with the intentention that thermographers from diverse backgrounds can have an accessible place for unbiased information and services to enhance their business in the predominant three fields of application of thermography: building sciences, condition monitoring and medical infrared imaging .

Korean Society of Thermology
The home page does not have an english version, although the name of the society appears in English and some lecture titles of meeteings as well. Using the translation tool of Google allows the visitor to get a rough idea of the contents of this Korean site.

PULSE Balkan Association of Medical Thermology
This Association is described as non profit organisation , the International Thermology Association PULSE. It shares the website with s private health centre and centre for occupational medicine of the same name. All three institutions are located in Varna, Bulgaria. Three papers related to vascular and traumatic changes recorded by thermography are also available on this website

Romanian Society of Thermology (SRO)

The biligual website (Romanian and English) provides information on the history, structure, statutes, board members and meetings of the Romanian Society of Thermology, which is one of the seven national member societies of the European Association of Thermology (EAT).

European Association of Thermology (EAT)

The Statutes of the European Association of Thermology (EAT), the federation of national thermology societies in Europe, is available om the web site of the Medical Imaging Research Group at the University of Glamorgan. Information from the EAT is regulary published in the journal "Thermology internatuional, which serves also the AAT and the Brazilian Society of Thermograpy as publication organ. A new website of the EAT is under construction

The Google search missed some web pages of thermology societies including the Brazilian Society of Thermology (SOBRATHERM), the United KingdomThermology Association (UKTA), the Japanese Society of Thermology and the German Society of Thermography The webs site of the German Society of Thermology was removed already in 2006. The Australian Thermology Association seems to play a similar role as the ACCT in supporting and promoting Meditherm equipment.

Publications.

Thermology journals

Thermology international
The home page provides tables of contents, abstracts of original articles and reviews, information from thermologyl societies and abstracts and announcements of meetings. Abstracts and the newsletter can be accessed free of charge.

Last year, an inofficial impact factor was calculated based on citations found in Google Scholar, Thompson Scientific

Table 2
Bibliographic measures of biomedical journals related to thermology, period 2002 to 2007 [20]
A. Cites/document (2 years)

	2002	2003	2004	2005	2006	2007
Thermology international	0.000	1.167	0.609	0.640	0.889	0.654
Journal of Thermal Biology	0.694	07.33	1.069	0.914	1.010	0.902
International Journal of Hyperthermia	1.890	1.814	2.209	1.924	2.380	2.915

B. Citable documents (3 years)

	2002	2003	2004	2005	2006	2007
Thermology international	0	12	23	37	38	40
Journal of Thermal Biology	217	222	215	252	265	286
International Journal of Hyperthermia	121	128	131	151	166	178

C.. Total cites (3 years)

	2002	2003	2004	2005	2006	2007
Thermology international	0	14	14	17	27	21
Journal of Thermal Biology	172	170	315	235	311	275
International Journal of Hyperthermia	213	221	304	327	416	491

Web of Science and self citatations within the journal [19]. This year some bibliographic measures derived from SCImago [20] are reported SCImago uses the citation information provided by Scopus, which is based on a further development of the algorithm Google PageRank. Besides the SCImago Journal Rank (SRJ) indikator and the Hirsch Index SCImago generates also cites/document in a period of 4 to 2 years . The impact factor, generated by the Web of Science, is equivalent to cites/document within 2 years period.

At the moment Thermology international is allocated to the category "Physical Therapy, Sports Therapy and Rehabilitation" . Based on cites/document in 2 years period, it achieved in 2007 rank 4 of 28 journals with a mean score of 0. 65 The journals in this catagory are comparable in the number of citable documents in 3 years period, ranging from 0 (European Journal of Sports Traumatology and Related Research, Spoort en Geneeskunde, Apunts Medicine de l'Esport) to 194 (Rigakuryoho Kagaku) with a mean number of 49 articles.

Scopus indexed 32 journals that show the syllable "therm" in the journal title. Only the Journal of Thermal Biology, . the International Journal of Hyperthermia and Thermology international are related to medicine or biology. It can clearly seen from table 2, that the Journal of Thermal Biology, the International Journal of Hyperthermia and Thermology internationathe had ratio of citeable documents (3 Years) of 1 :7 :4.5 in 2007. The ratio of cites/document (2 years) was 1 : 1.4 : 4.5.

Biomedical Thermology

The webite of Biomedical Thermology was the other thermology journal identified. The language of this site is Japanese. Although the table of contents of some previous issues are in English, an english navigator through this webpage is not available. All abstracts and full text are password secured.

Other pulications

Some papers were identified in the Google search, but most of them published prior to 2008. No overlap in identified publication was found for the Google search and the search in Google Scholar. 31 publication of the 176 hits in Embase were also identified in Google Scholar. After exclusion of these doubles, 200 links in Google scholar were traced for the abstract or full version of the publication.

Papers in non peer reviewed journals

Most papers in non peer reviewed journal have been published years ago, but 2 appeared in 2008 [7,9]. The quality of this information was already discussed in the section Medical Thermography.

Patents

10 Patents were found, 4 of them were related to temperature measurement devices, the other were related to the synthesis of compunds or drugs.

Thesis

3 Thesis related to thermography were identified. One thesis used thermography for diagnosing spinal disease in Dachshund [21], the other investigated changes on the foreram duringr data entry [22]. The third thesis submitted for the degree of Master of Public Health investgated screening facilities for brest disease in females [23]. The statement related to thermography was "the clinical evidence indicates that the modality is ineffective as a screening tool".

Articles in peer reviewed journals

The combined results from the search in Embase and in Google Scholar resulted in 350 hits. After exclusion of 10 patent documents, 3 previews of books and 22 papers which appeared completly in Chinese letters, 316 publications remained in the database. 242 of these publications were related to clinical medicine [22-261], 8 to veterinary medicine [21, 264-270] and 2 to insects [.262, 263]. The topic of the remaining 74 references was applied sciences with a large amount of papers related to chemistry due to

thermal analysis of the described compounds.[291- 332] The predominating method used in these studies was differential scanning calorimetry. The objectives of the other applied science papers were applied physics[271-277], modelling [278-283], instrumentation [284-290] and image processing [333-335].

The largest number of clinical publications was related to vascular medicine [47-89]. Two thirds of the vascular papers discussed intravascular imaging modalities [54-82], particularly the characteristics of vulnerable plaques and their thermal features. Raynaud´s phenomenon and thermography was main topic of 7 papers [83-89], and mentioned in 7 rheumatological publications, most of them related to systemic sclerosis or other connective tissue diseases[217-223].

Papers on acupuncture and complementary medicine had the second rank in number of publications [24-43], followed by rheumatology [214-229], surgery [230-245], Breast disease [99-112], physiology [194-2005], urology [246-256], chronic complex pain syndrome(CRPS) [113-122], dermatology [131-140] and endocrinology including diabetes [141-150]. Each of the following specialities had less than 10 publications: anastesiology [44-46], measurement of body temperature or fever, respectively [90-98], dentistry [123-127], temporomandibular joint disorders (TMJ) [128-130], hyperthermia treatment [151-153], medical imaging techniques [154-158]. Laser [159-162], neurology [163-166], orthopaedic medicine [167-169], occupational medicine [170-175], ophtalmology [176-182], psychology [183-186], pediatrics [197-193], quality assurance [206-213] and wounds [257-261].

Diskussion

Since Google has conquered the Internet information market, the value of this search engine to identify reliable scientific information was repeatedly discussed [336-339]. The results of this search on "thermology" shows clearly, that using the standard search option of Google is not able, to identify any recent scientific information related to thermology. Most of the papersidentified have been published years ago, articles from non peer reviewed journals compete with reviewed publications. Commercial information such as thermology services seems to function much better. However, even these websites, intended to promote and raise business, appear in versions from different years, sometimes spanning a period up to 5.years. It is out of discussion, that Google cannot be blamed for not updated websites., but it can be blamed for crawling these sites. .

The performance of Google Scholar was much better than of standard Google. However, the relevance of the publications of identified papers remains questionable due to the search algorithm used be Google. This algorithm is ueseful to find quickly authors of cited papers, but may find a number of irrelevant references, just because the search term is mentioned just once somewhere in the article..I give an example related to the search term "thermography". The company "Pain Diagnostics Thermography, Inc., Great Neck. *NY*, USA" manufactures and distributes pressure algometers, which have been used in many studies [340-342]. This company name will be found by Google whenever it is mentioned in an article, but most of these studies may not have used thermography.

Although this literature search is much less comprehensive than previously [2, 3] due to a reduced number of search terms and databases, the results allow to get an idea, where and by whom medical thermology is used. Discrepancies exist between numerous facilities in the US for breast thermal imaging and the number of papers on breast thermography published in peer reviewed journals. Furthermore, the AACT promotes academic chiropractors as experts for infrared imaging., but the scientific outcome of this profession as measured by published papers in peer-reviewed journals is minimum.

Similar as last year, the trend using infrared imaging in patients with complex regional pain syndrome or for the intravascular investigation of artherosclerotic plaques continues. The application of infrared thermography in surgery is also of great importance, particulary for monitoring perfusion as a condition that predicts tissue viability.

In conclusion, this updated report on thermology on the internet confirms that the internet is a valuable source of information. However, the scientific quality of papers related to thermology is rather poor when the standard version of Google is used. Google Scholar identifies information of better quality than the standard version of Google. However, a high number of non relevant papers may be retrieved by Google Scholar. Searching in established medical databases such as Embase or Medline is still the best option to achieve reliable scientific information about thermology.

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News in Thermology

Historical infrared images

It is now 99 years ago, that a scientific lecture described the possibility of using infrared rays for the generation of photographic images. R. Wood, Professor for experimental physics at the John Hopkins University, demonstrated for the very first time a number of infrared photographs at the Traill-Taylor lecture of the Royal Photographic Society in 1910. He used a special filter to exclude all other wavelengths but infrared. In colour photographs, the infrared filter leads to a dramatic change of the palette, where blue becomes nearly black and tree leaves and grass turn into white (Wood effect). Foliage reflects infrared light when generally chlorophyl absorbs all light colors but green. Figure 1 shows one of Wood's infrared landscape photographs.

The contribution of Wood to infrared photography was the cobalt glass filter transparent only for infrared and experiments with the silver halide film emulsion, which was sensitized for infrared rays by adding dye. Nevertheless, exposition times up to 10 minutes were needed to get printable pictures.

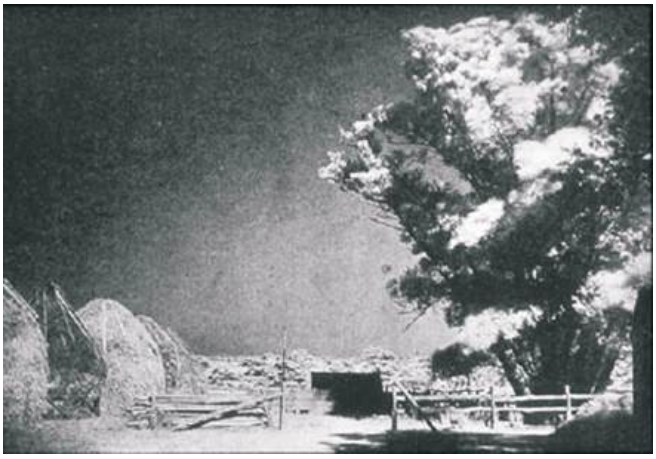

Figure 1
Infrared landscape photograph by R.Wood, 1910

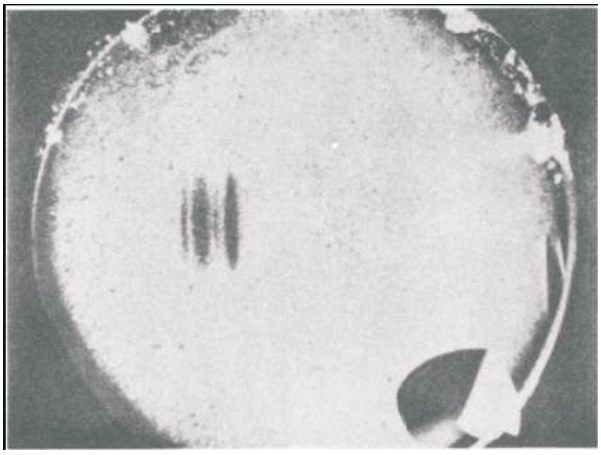

Figure 2
Infrared spectrum, imaged by Czerny in 1928 using evaporography

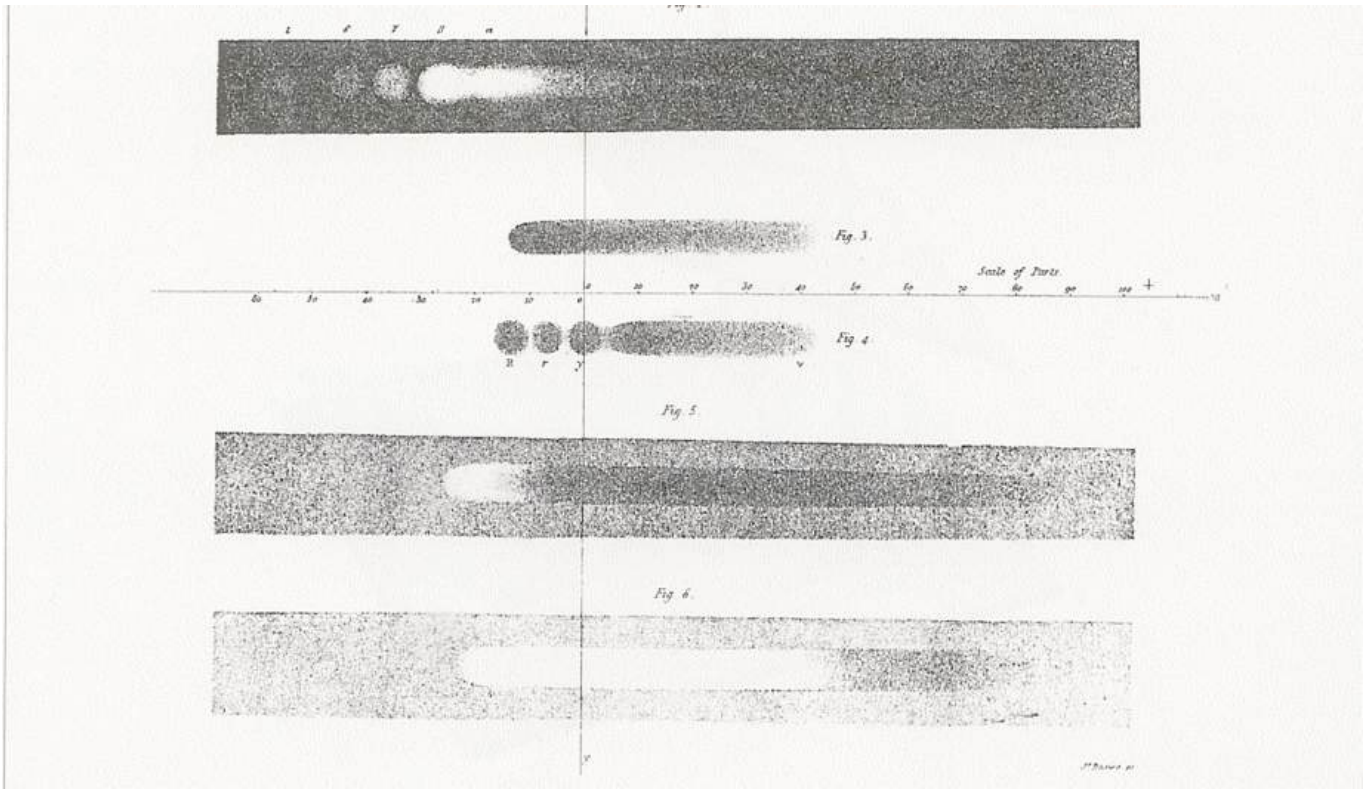

Figure 3
The solar"thermogram" baned by J,Herschel 1840

20 years later Czerny developed evaporography [2] to image the infrared spectrum (figure 2] His approach of preparing the recording medium was very close to the procedure of John Herschel, who made the very first thermogramm , when he imaged the sun track across the sky in 1840 . Both used a mixture of soot with some in heat evaporating fluid which fixed the soot on the underlying surface.

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The two German Thermology Societies have merged

The number of members of the German Society of Thermology decreased in recent years. In a ballot prior to the last General Assembly the majority of the remaining 30 members voted for merging with the German Society of Thermography Regulation Medicine instead of closing the society. Since January 2009, only one medical society of thermography exists in Germany.

The merger of the two societies resulted in approximately 200 members of the German Society of Thermography Regulation Medicine. This society celebrates its 55th Anniversary during the 11th European Conference of Thermology, held in the region of Frankfurt from 17th-20th September 2009.

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2009

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/eng/Pages/2009/Thermo2009/index.php and for previous 15th THERMO
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17th -20th September 2009

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55th Annual Congress of the German Society of Thermography and Regulation Medicine

22nd Thermological Symposium of the Austrian Society of Thermology

Conference of the German Society of Thermology (DGT)

Venue: Region of Frankfurt/Main, Germany

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Topics: History of temperature measurement

- Current developments of temperature measurement devices for human and veterinary medicine
- Standards and Guidelines for Thermal Imaging in Human and Veterinary Medicine
- Thermal Physiology
- Temperature Measurement and Thermal Imaging as a diagnostic tool or outcome measure in
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Complementary and Alternative Medicine
Dermatology
Gynaecology and Breast Imaging
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