INTERNATIONAL SYMPOSIUM ON BIOMEDICAL THERMOGRAPHY AND 8th MEETING OF JAPANESE SOCIETY OF BIOMEDICAL THERMOGRAPHY

The Symposium and the Meeting were held in the Kikaishinko Building at Shiba Park on the 19th and 20th of June 1976. The Symposium and the Meeting were organized and chaired by K. Atsumi.

The Meeting of the Japanese Society of Biomedical Thermography was held on the first day and consisted of two scientific sessions which concluded with the invited lectures of Prof. M. S. Lapoyowker (U.S.A.) and Prof. M.M. Aarts (The Netherlands). On the second day the Symposium was held and opened with a lecture of Prof. K. Atsumi.

Acta Thermographica feels obliged to publish the summaries that the contributors presented in Tokyo in order to allow further a faster exchange of information between thermographers around the world.

M. S. LAPAYOWKER (Philadelphia, U.S.A.)

Current status of thermography in the United States

The *current status* of thermography in the United States at this time is that of a diagnostic tool whose true place and value are still under investigation. After a period of relatively slow growth in a few major centers, its use has become much more widespread in the last few years, particularly for the diagnosis of breast disease, but there are many other areas where thermography has been and is being utilized and where it may have significant value. The *equipment* has improved significantly in the last four to five years with the availability of better detectors, such as mercury cadmium telluride or indium antimonide. The newer equipment is also able to present an almost instantaneous visual display. The problems which have arisen in regard to thermographic diagnosis in the United States have been primarily due to its non-specificity and difficulty in interpretation. The value of medical thermography for the diagnosis of *breast disease* has been seriously questioned in the past few years, corrisponding in time to the change from its use as an essentially experimental tool to a widespread clinical modality. Added to this was the problem that there were almost no agreed upon standardized objective criteria for deciding whether a thermogram was normal or abnormal. The technical quality was also quite variable in different settings. Evaluation of thermograms from many Breast Cancer Demonstration Projects by a quality control committee showed that the quality of thermograms from different institutions was quite variable. Variations in cooling, focusing, and contrast can easily obscure detail and give false appearances. More exacting calibrations and standards are still needed. Objective work is needed on such things as the relationship of the thermographic appearance to the diurnal and menstrual cycles in that the literature to date is replete with contradictory information. Articles are now being produced which stress the failure of thermography and its poor results but still without specifying criteria and frequently not relating to the problems of false positive and false negative interpretations. These factors have all led to considerable confusion, mistrust and antagonism to a modality which may have something to offer in terms of screening a population which is at a high risk from breast cancer, a disease which is the leading cause of death in women in the United States. Last summer we were fortunate to be able to have a group of thermographers meet and agree on a standardized set of criteria which could be used for evaluation of breast thermograms as well as some criteria for obtaining thermograms. It is hoped that the use of these standardized criteria and terms could improve the quality of thermography. It was agreed that adequate cooling is necessary for satisfactory thermograms. Patients should be cooled with their arms raised and examined without having changed their position. Five to ten minutes is considered adequate, and this may vary in different institutions. This can be chacked by obtaining serial minute interval films at each location where thermography is performed. The room should be between 68” and **71”** Fahrenheit with no direct drafts on the patient. It was felt by the group that while the use of extremely complicated baffle systems and extremely strict regulation of temperature would be desirable, it was probably not necessary for obtaining readable, satisfactory thermograms. Regular photographic film was recornfended over, but not to the exclusion of, Polaroid film because of the latitude of densities and general quality of the film. This may only be practical for installations examining a large number of patients, although a camera which has the capacity for cutting 70 mm. film after each usage would be extremely valuable. The erect position is generally satisfactory for most patients. In women with pendulous breasts, care should be taken to include the areolar areas. Having the patient lean backward may help to visualize the lower half of the breasts. The supine position may well add to better visualization of large breasts, but if a large volume is being performed, this may not be practical. Both anterior and oblique views should always be obtained. It was felt that it would be advantageous to use at least one film recording of the opposite mode for each patient, both white hot and black hot.

Adequate thermograms should show a sharp focus for the entire breast, and brightness and contrast settings should be such that a broad range of, shades of gray was obtained. The criteria for interpretation was divided into graphic and thermal criteria, and the final interpretation categorized into normal, suspicious and abnormal, based upon the number and type of different findings on the thermogram. The normal breast thermogram graphic criteria include vascular patterns, which may be avascular, vascular of the linear type, and minimal to marked in degree, as well as vascular, reticulated or mottled type. Mixtures of any of these types can be present in the same breast should be symmetric with no flattening, rigidity, or distortion of the margin. Thermal criteria should include evaluation of vascular temperature and the non-vascular surface temperature, including the areolar areas. Suspicious or asymmetric thermograms should be those which are not clearly normal or abnormal. This category should include unilateral or asymmetric vascularity with vessels of normal caliber and temperature. Localized rigidity, such as the edge sign, is included in this group of graphic abnormalities. Under thermal criteria for a suspicious thermogram, a unilateral increase in vessel temperature of approximately 2” Centigrade or less without increase in vessel number or caliber is included. A localized or focal area of increased nonvascular surface temperature of approximately 2” Centigrade or less, including the areolar area, in also one of the thermal criteria. Any two of the above criteria found in one breast should be considered as a clearly abnormal breast thermogram. The abnormal thermograms are those which show a marked unilateral increase in vascularity in terms of number, caliber, or abnormal configuration of vessels or diffuse rigidity of contour of the breast. Under thermal criteria of abnormal thermograms, a focal increase of approximately 3” Centigrade or more, including the areolar area, global hyperthermia, or diffuse regional or quadrant hyperthermia is considered. It is hoped that the widespread use of these criteria will lead to standardization of teaching and interpretation of thermography so that there will be more uniformity of interpretation among thermographers in the diagnosis of breast disease.

Since thermography is so non-specific, many of us have been trying to place thermography in its proper prospective in relation to mammography, physical examination, and the whole problem of whom to screen for breast cancer, how often, and by what method. I feel that we are beginning to see that a relatively high risk group can be identified by abnormal thermograms, and that somewhere between 75% and 95% of cancers will fall within that high risk group. The application of relative operating characteristic curves to thermographic interpretation suggests that increasing the number of false positives, or in essence over-reading, will cut the number of false negatives even without changing the criteria used. With improvement in criteria, such as we now hopefully have, we should be able to expect an overall improvement in detection without an extremely high false positive rate. If this requires 30% of thermograms be considered positive, we might still affect a marked reduction in the mammography radiation dosage to a large population and pick up an extremely high percentage of the cancers, particularly if epidemiologic factors are taken into consideration in picking a high risk group. The enormous advantage of thermography in the diagnosis of breast disease is that we have a diagnostic modality or indicator which causes absolutely no harm or discomfort to the patient compared to ionizing radiation, venipuncture, or any other diagnostic study. It is of interest that at this point we still have no definite proven idea as to the actual significance of some abnormal appearing thermograms and no proven reason why thermograms may become positive with cancer although there are many theories available. It certainly may be that cancers are more metabolically active at certain stages and that this causes an increase in venous temperature as well as an increase in general surface temperature by direct conduction of heat away from the tumor. An increase in periareolar heat is seemingly explained by there being less insulating fat at the areola, but this is certainly not uniformly seen in abnormal thermograms. The *computerization of results,* either directly from the thermographic machine or indirectly by scanning the thermogram, may also be of value in screening for breast disease. Computerized reading of thermograms is being investigated in our institution and several others, and we have so far shown a high degree of correlation between human and computer readers with 95% concurrence. The study has also suggested that by using specific criteria the computer may be even more accurate in assessing thermograms than human observers. *Liquid cholesferic crystals* which have been available for some ten or twelve years have received added interest recently with the development of an easily pealable black background material which can be applied to the skin. It may have a place in isolated or small communities that could not justify the expense of a thermographic unit. It is my feeling at this time that thermography may well have a place as a *pre-screening tool* which can categorize a high risk group without missing a significant number of cancers and cause a significant reduction in the radiation dosage being given to a large population. There is certainly an enormous need for more interdisciplinary research into discovering the causes of abnormal thermograms and surface changes secondary to deeply located abnormalities. Thermography has been increasingly used in the United States for the evaluation of *peripheral vascular disease.* Pre-operative evaluation of patients with vascular problems has revealed general non-specific patterns, and a few recognizable patterns, particularly those connected with occlusion of the femoral artery and collateral circulation around the knee. The thermograms in these cases show increased infrared emission around the knee, which is normally cool. The non-specificity of the method requires close correlation with clinical information. Evaluation of Raynaud's disease and Raynaud's syndrome, scleroderma, and other disease causing vascular insuficiency has been performed in more and more institutions in the United States. In addition, post-operative evaluation for vascular graft patency represents an easy and non-painful method of corroborating and substantiating clinical impressions. Evaluation of carotid blood flow for vascular stenosis or occlusions in the carotid circulation has been practiced for many years. It is felt by those using this method most widely that thermography provides a very valuable tool for screening patients at a high risk from cerebrovascular accidents. In cases of thrombophlebitis, it is our feeling that thermography represents an extremely sensitive indicator of this disease. In our experience, this has proven in many cases to be more sensitive and sometimes more revealing than performing venography. Again, the non-specificity of the method requires close correlation with clinical information, but the presence of increased heat in the calf or thigh in a clinically suspicious patient may be extremely valuable if venography does not fill a completely occluded vein. This use of thermography represents an extremely exciting possibility in the evaluation of patients with calf pain and after hip prosthesis surgery where there is a high incidence of thrombophlebitis following surgery. The ability to repeat the examination at frequent intervals is especially advantageous. The use of thermography in the evaluation of *neuropatkic artkropatky* was first reported several years ago with positive thermograms seen before radiographic changes. In patients with established diabetes mellitus with foot pain, swelling, or deformity about the ankle or cuneonavicular joint, a thermogram should be performed. In instances where the thermogram was positive in the absence of obvious infection, a diagnosis of neuropathic tarsal disintegration could be made and preventive treatment initiated regardless of x-ray findings. More recently, in patients with Hansen's disease, thermography has been used to evaluate reactive hyperemia and inflammation resulting from stress. A persistent increase in temperature after exercise and contrast between the temperature in the feet may be very important in evaluating early trophic changes. The use of thermography may well be of more value in *following* up proven conditions by repeated examination rather than in initial diagnosis, again because of its non-specificity. Evaluation of rheumatoid arthritis is receiving widespread attention, particularly in terms of obtaining baseline studies and the ability to use this method for repeated examinations to follow the course of the disease and the response to various medications.

Various investigators have reported the use of thermography in the evaluation of *paratkyroid* and *thyroid tumors,* correlating the findings with isotope scans. A hot thermogram with a cold isotope scan has been found in some cases to be indicative of a malignant thyroid adenoma, and the opposite condition also applies. Increased temperature over parathyroid adenomas has also been found helpful in localizing these small, difficult masses. Thermography has also been used in the evaluation of *malignant melanoma,* where a widespread increase in infrared emission around a lesion may indicate the malignant nature of the lesion as well as the extent to which a biopsy site should be removed. Unfortunately, many malignant melanomas are removed at outlying hospitals prior to complete work-up, and it is difficult to evaluate the exact place of thermography in this disease. In summary, the current major uses of thermography in the United States have been discussed and their value noted. It is the feeling of many investigators that the non-specificity of thermography requires close correlation with clinical information in some disease conditions, but that in view of the complete harmless nature of the method, it may well prove to be quite valuable in screening for breast disease and other conditions.

N. J. M. AARTS (St. Elizabeth Hospital, Tilburg, The Netherlands)

Current status of thermography in Europe

To appreciate the actual situation of 1976, it is necessary to draw a comparison line. What was going 10 years ago in the field of thermography? At that time it was a new method for Europe which seemed to have a brilliant future. Only a few people could boast to have some experience. Most appropriate for acceptance was the absence of ionizing radiation.

A Symposium was held in Strasbourg, France. There was a display of machines: Barnes Thermograph (U.S.A.); AGA-Thermovision (Sweden); Bofors I.R. - Camera (Sweden), C.S.F., I.R. 813 (France); Smith Pyroscan (U.K.); a prototype of Philips L.E.P. (France). There was a difference of opinion on the type of detector. The original and first machine, the Barnes' Thermograph was proud to claim the best spatial and thermal resolution with the thermistor-bolometer, a slow reacting type of detector.

Among the producers of fast machines there was a discussion on the type of detector to be used, the Indium Antimonide cell which covered the infrared spectrum up to 5.9 micron or the Mercury Cadmium Telluride cell that covered the spectral range up to 20 micron? It is hardly believable but the way of scanning, linear, circular or even spiral was a subject of discussion too! Now there was the choice between machines that produced one image in several minutes via an image every two seconds or two images every second to 16 images per second. The Pyroscan had an adjustable scanning time up to 180 seconds for one image. The Polaroid film was extremely expensive as compared to the use of ordinary black and white film. Also an electrochemical paper was available. A real temperature measuring was impossible; the difference in temperature was more important. The Barnes' Thermograph needed a grayscale and a densitometer to evaluate the pictures and to measure temperatures and the so-called A T's. Thermography seem to be on the move at that time. As a major possible application breast cancer came first. But intracranial tumours, placental localization, thyroid tumours, peripheral vascular disturbances, cerebra-vascular insufficiences, drug reactions and immunological responses had been studied also. There was a report on treatment control of rheumatoid arthritis by means of this new method. Lloyd Williams, the first European to use the heat emission of the skin as a tool in medical diagnosis, impressed with some colourful pictures of lyquid crystals as a new possibility. All came in the line of Gershon Cohen's prediction: << thermography might be better than radiography >>. With thermography the pioneers of 1966 of whom I has one, opened a new area in clinical diagnostics. I happened to have introduced thermography in my country, The Netherlands, in early 1965. Lloyd Williams warned for too much enthusiasm indirectly: << We do not even know what we are looking at >>. In Germany a group existed which believed in temperature measuring of the body at certain points in a dynamic procedure (Fig. 1). The point of measuring and the seat of the disease could be far apart. They had already founded a Society as far back as 1953. They were absent at this Symposium. After Strasbourg a tremendous activity developped in Europe. It seemed that Europeans were eager to participate in the evaluation to thermography. Thermography appeared as a subject on the programme of different scientific meetings of national or European size. Not only radiologists were interested in the infrared radiation as a tool in medical diagnosis, but, neurologists, surgeons and gynaecologists too. In 1971 the European Thermographic Association was founded. It counted 12 members, half of them being in the Board. The aims were directed towards the application of thermography in medicine and biology. In the statutes there was a paragraph devoted to basic research also. With great enthusiasm the preparation of the first European Congress on Thermography started. It took place in Amsterdam in 1974. lt was a successful meeting. Not only Europeans attended, but also Americans, some Australians and some Japaneses. Prof. Atsumi, participated and addressed the **E.T.A.** during the opening cerimony.

But now Europe and 1976. In Europe machine are made: the AGA Corporation of Sweden has modified its original machine into a thermograph for medical use (Fig. 2), by using modern integrated circuits, or << prints > the device has become smaller in size and more handly. Colour isothermogramms have been added as well as profile scanning (Fig. 3). There has been constructed an external temperature reference source and a colour monitor. A direct input into a computer became possible too. The detector is still InSb-cell and there is a 16 images per second as before. The second machine of European make is a Philips/Bofors IR Camera (Fig. 4). It is the original Bofors Camera that came out in 1967. Philips Laboratoires were developping their own machine in 1966, with a few prototypes using the Mercury doped Germanium cell. In time they abandonned their own project enables a quick and easy reading of temperature differences. A third machine of European make is the british Barr and Strout. This machine does not only produce images but gives a

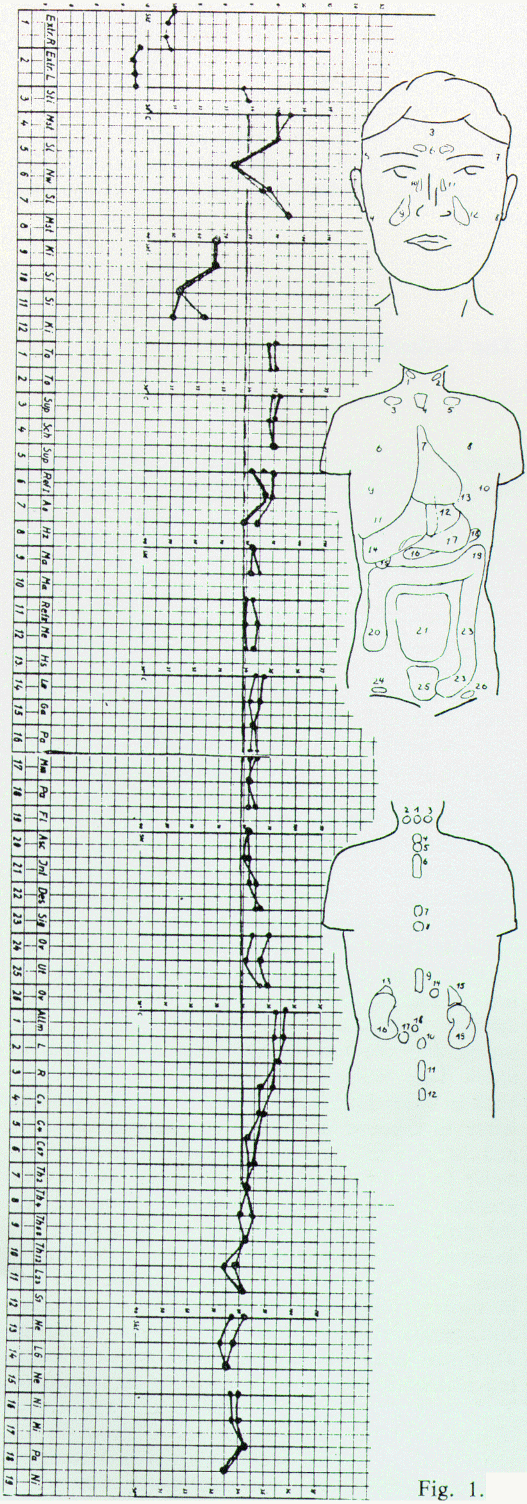

Fig. 1.

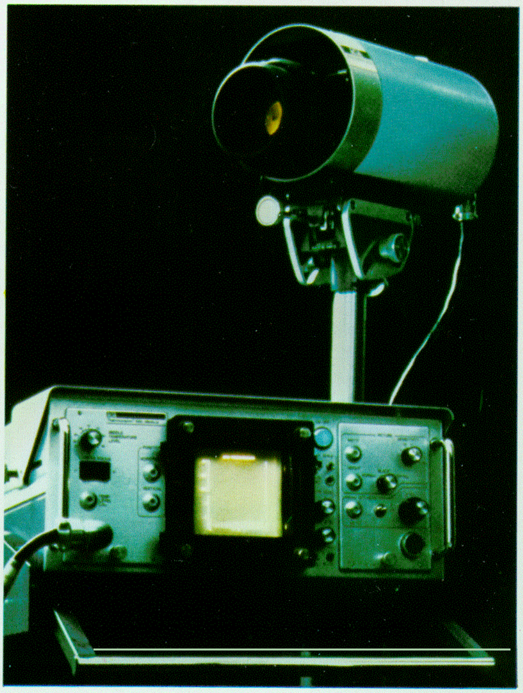

Fig. 2

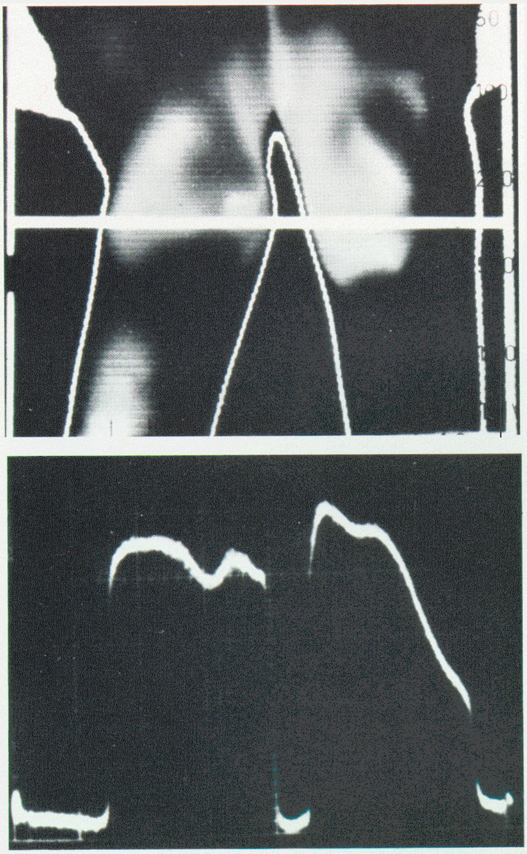

Fig. 3.

known for a long time the application hab been very difficult. Instigated by some American publications, Tricoire from Paris succeeded to produce a workable method using mylar-sheets with embedded crystals. The Tropon factories of Cologne (G.F.R.), part of the Bayer Concern, was able to bring an apparatus consisting of liquid crystal sheets and a camera to take pictures. Another firm, a French one, has come with the same system, with changeable sheets. As a matter of fact the sheet thermography has become a method that may be considered for general application, with a lot of

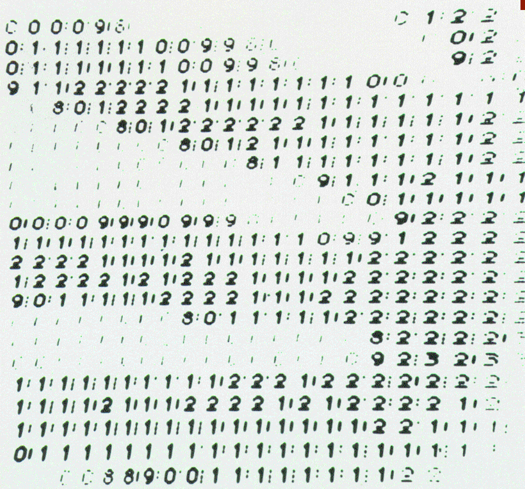

Fig. 5.

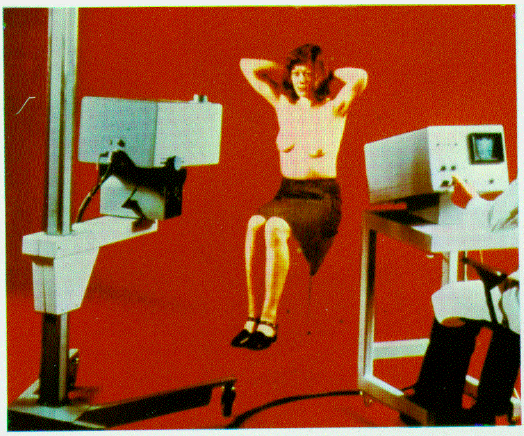

Fig. 4.

digital outprint of the readings (Fig. 5). Another method has made a breaktrough in the field of thermography. the liquid crystals. Although already

restrictions, however. At least three European companies arc investigating the use of other detectors such as the pyroelectric detector consisting of an array of tryglicine sulphate (Fig. 6), in their laboratories. This array scanned electrically along its length and optically along the orthogonal axis. As this detector has a spectral response from 2-75 m the faceplate has to be selected appropriately. The best method of creating the desired temporal change in the thermal scene seems to be camera panning. The minimum resolvable temperature is depending of the required spatial resolution (Fig. 7). ‘There is no cooling needed digital processing of signals is standard. By means of a storage system a flicker free picture can be displayed. In 1976 three electronic machines have been left and two very similar devices for thermography with embedded liquid crystals have appeared. Very recently a Company in the United States came out with a heat sensing bra, liquid crystals embedded in some material usable for brassieres. Liquid crystals have become a some sort of competitor of electronics in the field of heat sensing devices. They certainly are more important for clinical use than been thought previously. The reliability is comparable with that of the machines, whereas the costs are only a fraction of the others. The interpretation of the images is the most important, but not too difficult. It is a form of contact thermography and used for breast cancer mainly. The current applications of thermography in Europe include breast cancer as the most common disease in the female in Europe. There was good hope to have at hand an harmless, easy to perform method for mass-screening for breast cancer in the early days of thermography. It was applied in pilot studies and bigger screening programmes. There was a trial in Sweden. It appeared that thermography was insufficient as too many false negatives and false positives occured. The former being more serious than the latter, of course. The cause of this failure, sustained in different centres throughout Europe was a lack of appropriate programming. There was a misconception of the kind of information, too. Thermography gives functional information concerning mainly heat transport and in some way heat production. The heat at the surface never can be pathologic by itself. Even measuring an increase of temperature never can be diagnostic for pathological processes. Sensing the heat coming from a radiator of the central heating system never can lead to conclusions on the kind of burner used. Heat by itself never is pathologic. More important information is gained by serial thermography. Changes in the thermal picture of the female breast is most important as Dr. Stark from England could show. For mass-screening thermography can give a clue not by its unique image but by its sequential application. The use of thermography in a more extended way shows differences between the northern part of Europe and the southern. In Marseille they use a TH grading system from normal via benign, uncertain, suspect to mostlikely malignant in their diagnostics. In Strasbourg they have their own classification for prospective use. How to explain that the spreading of thermography is strickingly better in the Southern part of Europe than in the Northern co-

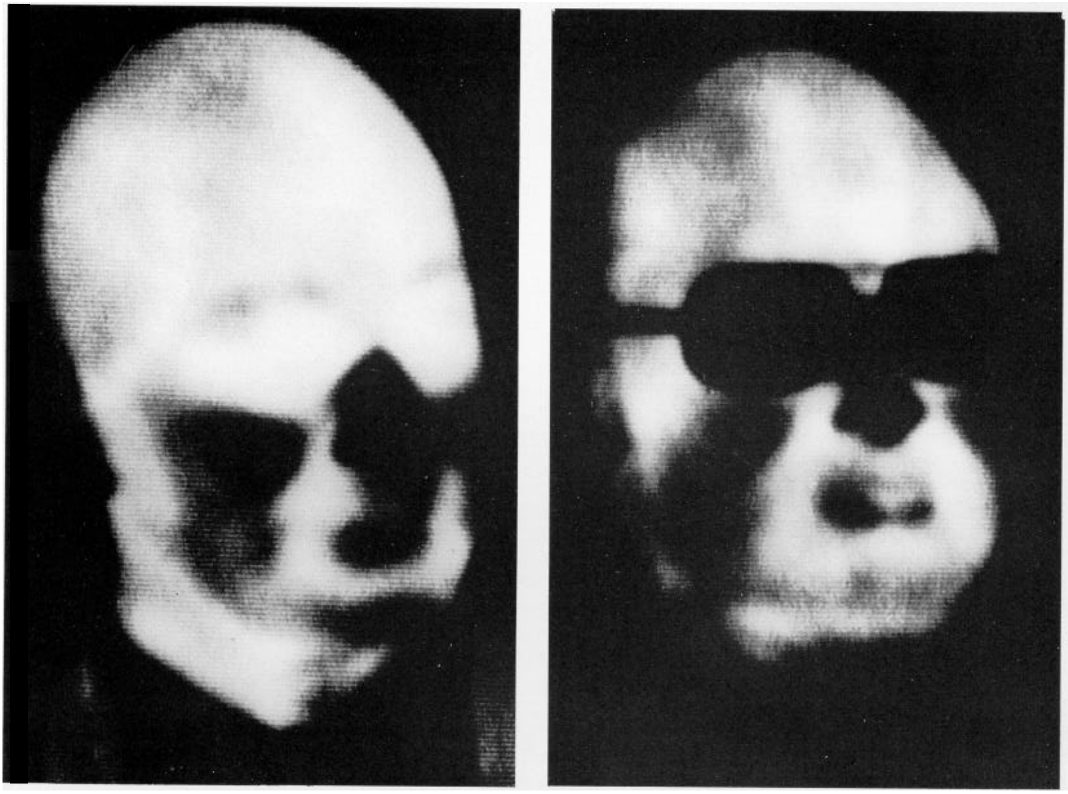

Fig. 6.

untries? The policy of the surgeons shows a difference also. Mastectomy, more or less extended, is more common in the Northern countries, whereas in the Latin regions irradiation as therapy is more commonly applied. It might be of some influence on the use of thermography. A mixed anglodutch study group is dealing with problem of breast cancer and thermography. Thermography is not a method by itself. This group tries to find relevant information suitable for evaluation by a computer. The aim is also to find a thermographic index. The possibilities of such has to be convassed therefore a standard procedure has been adepted. 1) Patient's *preparation:* (a) skin free from talcum poweder, oils or ointments; (b) cooling for 15' at 19± 1 °C ambient; (c) hands on hips. 2) *Examination*: (a) in standing with hands on hips; (b) three positions: anterior, left and right oblique; (c) temperature calibration source in the field of view obligatory; (d) no changes of calibration, temperature range or sensitivity; (e) temperature sensitivity of 1 °C per scale division. This is the only way to get adequate information, that can be digitalized for analysis by a computer. From Russia not much information is available. Personal communications from Dr. Kondratjev from the Institute of Oncology in Leningrad reveal an increasing interest in medical thermography. In 1974 a second National Congress on Medical Thermography was planned. Several books have been published as well as some papers in journals. The content is only appreciable out of the summary. For 1972 there appeared to be three machines of Russian make, but none in serial production. In the control of the therapy in rheumatic diseases thermography has become important. This is due to the establishing of a thermographic index by a group in Bath, England. In Poland, thermography is a normal procedure in rheumatic diseases as Dr. Maria Sadowska Wroblewska, in charge of thermography at the Institute in Warsaw, reported recently. An other important field for thermography is circulatory diseases. In this respect a distinction has to be made between veins and arteries at the one side and between sites at the other; eg: peripheral extremities and cerebral. Starting with the veins the application of thermography has cristallized in two ways; the imperfect perforator veins in varicosis and the early diagnosis of deep venous thrombosis. The former is very difficult and only additive to clinical examination and phlebography. Together it is possible to locate successfully about 90% of these insufficient perforator veins. The varicous vein itself shows perfectly in the thermogram.

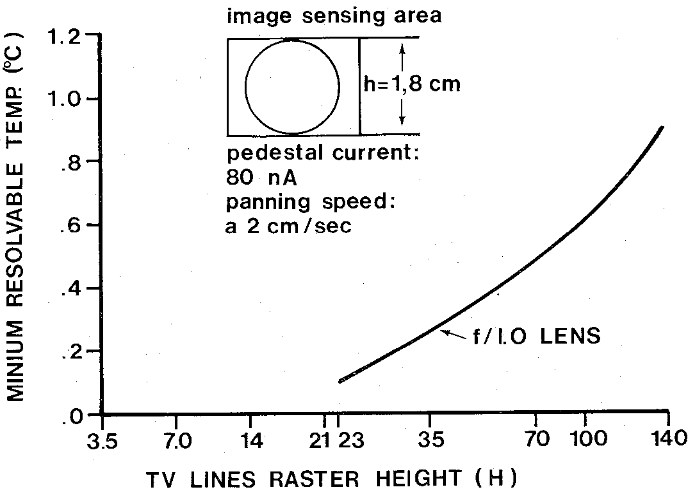

Fig. 7.

Much more important is thermography in the early diagnosis of deep venous thrombosis. The major sign of deep venous thrombosis is the disappearance of the pretibial cold zone due to enlarging of the superficial system to cope with the inactive deeper veins. Dr. Cook of London has shown what can be achieved by this simple and harmless method. The arteries of the extremities, the upper and the lower ones, are very important for thermography. Arteriosclerosis and Burger's disease are among the common disturbances that can be analyzed by thermography. Only to a certain level the heat picture can be used for localizing arterial insufficiences or even complete stops.

More important is the functional information gained, to be considered as a certain screening procedure before angiography. In peripheral circulation disturbances not only a static thermographic examination has to be performed but also a dynamic analysis. For Raynaud's disease it is essential to perform dynamic studies, testing the reaction and measuring the time needed for rewarming. Normal within 20' after cooling has stopped a hyperthermia appears, or at least the precooling temperature has been restored. If this rewarming takes more than 20' a spastic disturbance is present. Traumatic peripheral arterial lesions can be analyzed by thermography also. This must be completed by thermography after vasodialting drugs have been applied. This delineates the site of the lesion perfectly. This also is a preangiographic procedure. Very important is thermography in cerebrovascular insufficiences: the big problem of stroke and its preceding syndrome of T.I.A., the transient ischaemic attacks. The feasibility of thermographic survey in prevention of stroke has been proven. Also has been demonstrated the reliability of thermography in the evaluation of surgical treatment. There appears to be a good concordance between thermographic pattern and clinical state. In an advanced state of preparation is a programme for screening the high risk groups. More defined the high risk group enclose people who experienced already a T.I.A., but also the patients with vague symptoms of cerebrovascular insufficiency. Above all the transitory phenomenon is important in this respect. Dynamic studies are essential. Not only for evaluation of existing disabilities but also in predicting the effect of a particular treatment. In dysbasia one might quantify the change in thermal pattern after applying different drugs and use the one giving the highest response. In a rather substantial study we evaluated the possibility to treat trophic ulcers with iontophoresis of xantinol nicotinate. We detected that a response with increase in temperature more or less guarantees a successful treatment. Where such a response failed to show a treatment failed too. The ulcer stayed and did not close. The cause of these failures was infection with the proteus bacterium. Such applications are a mixture of predicting examination and controlling ones. In this respect surgical treatment can be judged in its effect by thermography in the same easy way. The thermogram can provide the clinician with sufficient. and reliable information. Thermography for controling purposes is also used in inflammations. There are good reasons to consider thermography also suitable for analysing the cervix of the womb. There are some rather small series from French and Italian authors in which the normal picture and some affections such as erosions and cancers has been analvzed. A classification of images. based on 50 thermograms in 43 patients even tries to correlate with the colposcopic classification. The problem arises here concerning the emissivity of mucous membranes as compared with the skin and the black body. It is of extremely importance to have the patients skin free from talcum powder, oils or ointments and water, which effects the emissivity of the skin and lead to artifacts. The question of the influence of skin-affections as in eczema on the emissivity has not been cleared yet, either. It has been shown that burned skin up to carbonization shows no change in its emissivity as compared to normal skin. This underlines the suitability in chronic eczema and frostbited and burns. In chronic eczema thermography can contribute to deciding to end treatment as healing has been achieved, at least for the moment. Thermography could be the guide for the dermatologist in his therapy of skin diseases. There is an higher recurrence rate in chronic eczema showing a temperature elevation of 2 °C or more as compared to the surroundings at the end of treatment. As regards burns, policy of treatment differs very much throughout Europe. Several centres advocate a primary transplant; others feel better with playing a waiting game. The former need a real fast diagnosis giving the borderline between vital and avital skin tissue. These are the users of thermography in the evaluation of where to bring the graft and to what extent. In London the Hospital for Plastic and Reconstructive Surgery could not do without the thermographic analysis. The latter are afraid of more damage to environment. Next to this they fear the enchancement of infections.

Normally the diagnosis of a malignant melanoma should not be difficult. If the diagnosis has been made clinically it is of the utmost importance to know the spreading of the disease. This is an unique opportunity for thermography. The more malignant even a small lesion is the more disturbed the thermal pattern. At the other hand if not distinct diagnosis can be made on clinical signs an increased temperature at the site of the lesion matches better with a malignant than with a benign affection. The interpretation of thermal patterns is absolutely impossible without information from the clinician. If a « hot spot » around the knee comes without information of the clinician, the only thing that may be said should be: << there is an increased infrared radiation caused by some change in metabolism and or circulation . . In inflammation this thermal disturbance might be produced by an osteomyelitis; in a patient with haemophilia the finding of an hot knee thermographically indicates a recent haemorrhage. In osteoarthrosis the same thermographic phenomenon might indicate an inflammatory factor present. In these cases the thermal pattern will become normal with proper treatment. In a malignant disease as for instance osteosarcoma a returning of normal temperature hardly can be expected. If radiotherapy is successful it might happen. For the clinician, who gave sufficient clinical information, the thermal picture will add to the diagnosis. At the same time the thermographic data will indicate the degree of activity next to possibly a clue for E.T.A., yet. The European Association itself created two Commissions in 1974. The first one on Terminology. The most outstanding physicians and physicists together with an expert in international law combine their efforts to compose a dictionary of definitions of technical terms, descriptions of the elements of the image as well as subjective terms. The aim is to publish a commonly accepted standard formulation of all terms, descriptions

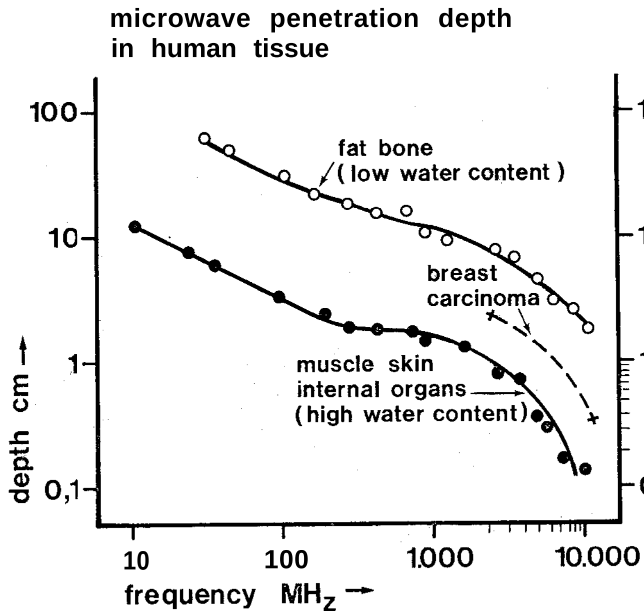

Fig. 8.

the prospects. The thermographer can be very informative also. If he traces changes in the thermal picture he has a possible clue to present. In a case of tonsillar carcinoma the normalization of the thermogram proved the success of the telecobalt treatment. For promoting thermography collaboration is needed nationally and certainly internationally. As already pointed out the European Thermographic Association started with 12 members in 1971. At this moment there are already over 350! Even in Eastern Europe some colleagues are on the membership list. To maintain an exchange of experience with them is difficult and has mainly to be done by writing. Not all Europeans involved in thermography are on the membership list of E.T.A. There are affiliation with National Societies in Belgium, France, Germany, Italy and Spain. There are mixed study-groups, sponsored by the E.T.A. but not organized by it, as for instance the Anglo-Dutch Study-Group. The members of these societies or groups are not all members of the and definitions used in thermography. This book on terminology is expected to be published in the course of 1977. The second Commission of the E.T.A. is one on Teaching. The aim is to publish a Thermography Digest as a joint work of the commission members. An international group of teachers from different Universities have composed a brochure on thermography covering the physical foundations, the physiological ones and a scope of clinical applications. The title will be « An Introduction to Medical Thermography ». It is intended for medical students. Thermography does not appear on the study programmes of the European medical schools as a rule. In only a few training programmes of postgraduate level thermography is included. The aims of the editing of such a brochure therefore are the promotion of the teaching of thermography and to establish teaching programmes in thermophysics, thermophysiology, thermopathology and in clinical thermography. Another group is the Study Group on

Biothermometrology. The subject in this group is to study the influence of biological processes on the thermal pattern including emissivity changes. ln the time elapsed since 1971 there has been formed a section Industrial and Environmental or Ecological Thermography also. In this section are gathered experts on infrared emission and pollution, experts on conditions of the soil related to infrared emission, the use of thermography in industry etc. Many engineers and researchers are rallied to discuss basic problems and practical ones. The development within the field of thermography in Europe has changed a lot, either instigated by the E.T.A. itself or spontaneously elsewhere. In both the E.T.A. had to be a meeting-place. It broadened its goal by incorporating medical and biological thermography together with industrial and ecological one, to create a meeting place for those who use thermography or temperature measuring and those who are interested in this discipline from a practical point of view or basic reasearch. Both groups need each other for mutual information. In five years a lot has changed, the originally apparant favourable future of thermography in clinical diagnostics has been deviated towards reserve at the one side and rejection at the other. In between an enthusiastic group still exists, the active members of the European Thermographic Association. In Europe it has been decided to combine efforts and to accept also non-medical thermographers within the E.T.A. Analyzing the past ten years spreading of thermography appears not so be so impressive at all. In this respect there is a boundary between the people with a more Germanic language and the people of Latin origine. At the other hand too much pessimism is not necessary either. Thermography and its possible role has been studied more profoundly. This has led to a better understanding of the method. A better insight will bring a more directed application. A more critical attitude with regards to « when, where and why » will bring medical thermography back to where it belongs. The dialogue between physicians, physicists, engineers and manufactures will lead to a less vague information and to better machines. A very promising method is already visible at the horizon: the micro-wave thermography that penetrates much deeper and produces local thermal profiles (Fig. 8). For the future also liquid crystal thermography might proof to be of more value than ever thought before. Even the progress of pyroelectric detectors where cooling of the patient is unnecessary might be very important for the development of thermography. As this system provides a digital outprint

Fig. 9.

also a computerized analysis seems not imaginary any more. Never a method as such fails but that the missinterpretation of data makes originally excellent methods to failures. In worldwide collaboration the right way to look at thermal patterns and the exact meaning of the superficial and deeper temperatures can and will be established. This is the current status of thermography in Europe, which started centuries ago with Galileo Galilei (Fig: 9).

1. FUJIMASA (Tokyo, Japan)

Biological applications of thermography

In thermography the biological applications are a new and important area. In this article, the medical application and the veterinary application are omitted. But, in Japan, as the medical thermographic instruments are manly installed in medical hospital or in medical centers, the veterinary applications of thermography are limited to only a few cases. Acute inflammation of joints in race horses was detected by thermography. That is only one practical application of thermography to veterinary medicine in Japan. This remote sensing technic has been applied to plant physiology and in agriculture. Looking at the landscape with the new eyes of multi-band filters, plant diseases can be detected. But, in this application, reflected infrared radiation of short wavelenght is mainly used. In my opinion, thermography has truely important biological application. It is one of the foundamental analysing tools of thermics for physiological, ergonomical, behavioral and environmental sciences. These applications are as follows: 1) Human biology: a) unusual environmental thermal physiology; b) thermal invironment and thermal responses in ergonomics or human factors engineering; c) thermoregulation in sports physiology. 2) *Thermal response of homeothermic animals and its utilization in human life. 3)* In the *behavioral science,* the thermal responses of homeo, ecto, or polikilothermic animals. 4) *Plant thermal physiology* and its applications in agriculture and environmental science. In Japan, some new exploratory efforts especially in human biology have been made. A thermal simulator, thermography in weather, an ergonomical study of finger motion and its thermal analysis are examples of applications of thermography on human biology.

Y. SAKURAI, K. TANISHITA. M. KIKUCHI. M. ASANO, S. OGAWA (Tokyo, Japan)

Physiological study of skin temperature. - Profile with thermographic measurements

Since there are two major factors affecting the distribution of skin temperature, i.e. factors originating from the body and the environment, we need to know how environmental effects affect the skin temperature profile in order to see physiologically genuine skin temperature. Hence we investigated the several environmental effects on skin temperature profile using the AGA Thermovision System.

T. TOGAWA (Tokyo, Japan)

Deep body thermometry

Deep body thermometry is a new technique of non-invasive deep temperature measurement, introduced by Fox and Solman (1971). The method was improved by the author and collaborators. Applications of deep body thermometry extend widely into clinical medicine.

Principle. If a zone of no heat dissipation is created on the skin surface, the skin and deep temperatures may equilibrate after sufficient time passes. Fox and Solman had realized a zero-heat-flow requirement on the skin employing a serve controlled heater system in the thermometer probe. In order to reduce heat dissipation from the circumference of the probe, the author introduced a heat conductive guard (aluminum block).

Device. The thermometer probe is disc-shaped, 40 mm in diameter, 12 mm in thickness and about 25 g in weight. The initial response time of 15-20 minutes is required to establish thermal equilibrium when the probe is applied to the skin surface. During a continuous measurement, the observed temperature within a few minutes had an accuracy of around 0.1 °C when was compared with a direct measurement using a fine thermocouple placed 10 mm from the skin surface.

Clinical Findings. Forehead deep temperature was always closed to blood temperatures measured in the internal jugular vein or in the left atrium and acceptable as a core temperature instead of rectal temperature. Deep temperatures measured on the chest or abdominal wall were close to forehead temperature. Palm and heel deep temperatures were accepted as an index of peripheral (forehead or heel) temperature records seemed to be mirror images. In an intensive care room, simultaneous recording of core and peripheral temperatures was used as circulatory monitoring. Dissociation between these two temperatures was a sign of circulatory failure. In the shock patient, deep temperature dissociation always preceded by arterial pressure drop. Deep temperature monitoring was also employed as a monitor of general anesthesia, cardiopulmonary bypass, the febrile patient, delivery or the newborn.

T. NISHISAKA (Tokyo, Japan)

Co-operative diagnosis with thermography and other non-invasive methods

Many kinds of instruments, which are able to produce pictorial or imaging information about living bodies, have been developed for non-invasive diagnosis. Those instruments of which thermography is a representative, are divided into different sorts:

1) Static image of body

A) *Surface:* photography conventional; infrared; stereography; miore topography; holography; thermography (infrared; liquid crystal). B) *Inner:* plane roentgenography (soft X-ray; hard X-ray); compterized tomography; ultrasound imaging.

2) Dynamic or/and reactive image

A) *Surface:* holographic interferometry; thermography with some manipulation. B) *Inner:* acoustical holography; ultrasound imaging; roentgenography with contrast medium.

3) Image using specific a finity of target organ

Scintigram. On the other hand, there are many analyzable properties in the living body, listed as follows: 1) Thermal property; 2) Structural property; 3) Outer shape; 4) Movement of tissue and organ; 5) Functional property; 6) Distribution property. Utilizing a combination of methods we will get more properties of the living body for diagnosis and prognosis.

K. NISHIJO (Tokyo, Japan)

Health and thermography

The temperature of the skin is considered a dynamic indication, in heat, of the metabolic function of the human body. In oriental medicine, the body surface symptoms and the information of temperature, perceived by the senses as cold and heat, have been the objectives of observation of disease patterns as important signs of life phenomena.

Dynamic thermography. The changes in reaction of human bodies following the changes in body position were observed and evaluated. In the standing and sitting position, the heat transmission from the deep organs and tissue showed strong influences upon the distribution of skin temperature. On the other hand, in the supine position, influences of distribution of the blood stream on the body surface were found to be particularly strong at the thoraco-abdominal region.

« Keiketsu » in oriental medicine. Lines and points with temperature of 0.5-1°C higher than the surrounding regions were noted through the thermography of the thoraco-abdominal region. Individual variations could be noted in the patterns of the distribution of the high temperature, but they appear mainly in the regions many years ago called « Boketsu ». It was inferred that arterial branches greater than arterioles are involved in the locations which have been admitted as « Keiketsu ».

Acupuncture. The regulation of blood circulation with AVA could be deemed one of the mechanisms of therapeutic effects with acupuncture.

K. YANAGI, H. SUGAHARA, Y. ONODERA, Y. OHIICE (Tokyo, Japan)

A thermographic study of the lower legs in CVA patients with hemiplegia

Skin thermograms of the lower legs in 79 cases with CVA were taken for studying the changes before and after immersion into hot water. 1) In 71 cases, the skin temperature of the paralyzed leg was lower, and in 8 cases slightly higher than that of the non-paralyzed leg. 2) The patterns of the skin thermograms before and after immersion into hot water were classified into 5 types. The patterns of the skin thermogram taken within 7 month after the stroke, changed into these 5 types. 3) In 23 cases of 31 with CVA; the skin temperature of the lower legs after tibia1 nerve block with phenol to the paralyzed leg was higher than that before the treatment.

Y. MIKI, T. KAWATSU (Tokyo, Japan)

Thermography in collagen disease

Inflammatory changes of the joints in rheumatoid arthritis and Raynaud's phenomena of the extremities in systemic lupus erythematosus, systemic progressive sclerosis, and dermatomyositis have been the main subjects of thermographic studies in collagen disease. In addition to thermography in equilibrium with the room temperature, cooling and/or warming have been found to better disclose the pathological changes. The thermographic abnormalities in collagen disease have been shown to correspond well with the clinical as well as laboratory findings, including plethismography, capillary microscopy, hematology and immunology examinations. It is considered to be a valuable tool to the understand and evaluate the vascular or inflammatory changes in the disease, though the circadian or seasonal rhytmic influences have not been fully understood.

T. ITO (Tokyo, Japan)

The present status of thermography at the radiological departments in Japan's Nippon Medical School

At the meetings of the Japan Radiological Society 1975 and 1976, one can find two thermological studies by us concerning breast disease, and by Kawakami about nodular thyroid tumor. In 1975 we reported 75% true positive in the breast cancer group, 60% true negative in benign disease, lOO,% true negative in normal cases using Gros's criteria for breast disease. In 1976, we announced 82% true positive in the patients with breast cancer, 70% true positive in benign disease of the breast by modifiing criteria of malignancy: when there is over 2°C of difference of temperature between the focus and the other side, and when after cooling of the chest wall skin by alcohol in those cases where over 1.5°C of this difference are found. Kawakami reported good results obtaining the thermological pattern of nodular thyroid tumors after cooling the neck skin. We use thermography as a way of observing cases with disorders of the vessels found by angiography; as well as for the evaluation and diagnosis of the focal portion, the effect of operation and of social rehabilitation in cases who suffer from disc herniation.

Thermography is a useful study without exposure to ionizing radiation, it is a complementary procedure to roentgenological examination, and may be practical when installed at the radiological center.

H. SUDA (Tokyo, Japan)

Recent survey of thermographic studies in obstetric, gynecologic and associated fields

Recently thermography has been introduced into the field of clinical medicine and surgery, and has achieved extensive applications, since the visualized change of infrared emission frequently correlates with a pathologic process. Therefore it is valuable in the early diagnosis of diseases. The technique also is regarded as a useful tool for the examinations and diagnosis of certain female problems, such a breast changes during normal pregnancy, or puerperium, or in pathological conditions. It is moreover applied to the estimation of hormonal influences either from pregnancy or from oral contraceptives, to a placental localization, and to the follow-up of wound healing after surgery. Besides the main subject of thermographic studies, the diagnosis or even differential diagnosis of breast cancer, now, some actual subjects of interest at present are as follows: thermal patterns of the healthy female breast: physical and physiological considerations (the thermographic pattern of the human female breast in health is sufftciently constant so that it can be readily identified in an individual not only from week to week during the menstrual cycle, but actually from year to year. Thermographic patterns of female breast development between 7 and 18 years); the biorythm and the possible thermographic control regarding some female cyclic phenomena; thyroid gland thermography; the relation « steroidic structure-thermic gradient >> in the breast thermography; thermographic determination of milk secretion in the lactating breast; the thermographic observation of the vascular behaviour in response to local anesthetics and pressor agents; objective thermography in sympathetic disturbances; thermography in migraine and cluster headache; breast temperature as a test for pregnancy. Serial graphing of warm areas in the body during thermographic analyses may warn of either normal or dangerous metabolic activity to which clinical attention may be quickly applied. With the advent of thermography, a sensitive, safe, and reliable method is offered particularly in obstetric and gynecologic practice. These situations will be successfully appraised by this method, without exposing mother or fetus to the hazard of irardiation or radioactive isotopes.

A. NAGASAWA (Tokyo, Japan)

Application of thermography to oral surgery

Few reports on thermography in oral surgery have been made public up to this time. This is a report of thermography applied to maxillo-facial and oral surgery in Japan.

Infrared apparatus: 1) Medical infrared thermometer; 2) Thermistor thermometer; 3) Medical infrared camera; 4) Thermal data processor.

Method: 1) Measurement of surface temperature of a body; 2) Recording of progress of surface temperature of a body; 3) Thermoprofile or temperature distance curve; 4) Thermogram; 5) Thermal recovery method; 6) Thermal data processing etc.

Applications: 1) It was confirmed experimentally that emissivity of salivary surface is about equal to emissivity of skin. Thermography of mucous membrane of oral cavity is possible as with skin. Approximate value of body temperature can be obtained instantly by measuring temperature of oral mucous membrane by infrared thermometer. 2) Body surface temperature monitoring. Recording progress of skin temperature in course of operation, it is observed that temperature drops with an accident such as shock. Accident can be expected by a simple pretest applied to the above facts; thermal recovery curve and others. 3) Thermographic observation in progress of orofacial diseases, especially inflammation and cancer. 4) Objective evaluation of effects of anti-inflammatory and anti-cancer drugs. 5) Objective evaluation in progress of transplanted skin flap. 6) Thermal recovery method is to observe thermal reaction of a body to cooling or heating and local circulation or heat activity can be measured quantitatively. This process enhance a thermal phenomenon of the body surface and makes thermographic diagnosis more valuable. It is applied to various cases. 7) Digitalized thermal data is obtained by data processor, thermometer and thermal recovery.

Thermographic diagnosis. Diseases such as inflammation, malignant tumor and hemangioma are hot, while lipoma, foreign body and cyst are cool. Benign tumors do not show generally specific temperature. Inflammation, hemangioma, lipoma, mucocele and foreign body have clear demarcated thermal patterns, while malignant tumor and chronic inflammation show unclear pattern. However, benign tumors are difficult to find by thermal pattern. The condition of hot pattern in inflammation varies depending on progress of it. Thermographic characteristics of malignant tumors in maxillo-facial and oral region are the following: surface temperature or focus is 0.5-l.0°C higher than their healthy symmetrical part and thermal pattern of it has unclear demarcation, then the focus is barely recognized as a slightly higher pattern. Face is the hottest area of the body.

Y. OHASHI (Tokyo, Japan)

Present status of thermography in cancer research

The diagnostic accuracy of breast thermography at present is less 80%. The difficulties lie in that small cancers or cancers in stage I often demonstrate no accurate hot spot, and conversely positive thermograms were obtained even in many benign lesions. In thyroid tumors differentiations seemed more difficult between benign and malignant tumors. In limphomas not all cases showed positive thermograms, and in malignant melanomas there was a hot spot on thermogram which had no pathological confirmation.

Z. YAMAZAKI (Tokyo, Japan)

Thermographlc studies on peripheral vascular disease and intestinal circulation

Thermography has been widely used in the field of vascular disease. In addition to routine thermography, local cold application or administration of vasodilatator reveals more accurate information of vasomotor functions in the diseased region, thus thermography is now a useful electronic tool for modern vascular surgery. In gastro-intestinal surgery, the great problem is whether or not the graft or intestinal segment has survived from the point of view of blood supply. To decide the survival of the intestinal segment, the thermogram has been confirmed as the most accurate and the easiest objective index, comparing it with the conventional methods, such as the color, the arterial pulsation, the back **flow** pressure, tissue PO_2, and venous PH, PO_2, PCO_2, in our dog experiments.

A. MUNAKATA (Tokyo, Japan)

Thermographic study in dermatology and plastic surgery in Japan. - Its present status and future

A) Dermatology. The first report of a thermographic study in dermatology in Japan was given by Dr. Miki in 1972. It was followed by 21 papers and abstracts. The present tendency in thermography is to study the following items: 1) adjunctive diagnosis of vascular disease of the extremities; 2) adjunctive diagnosis of neoplastic lesions of the skin; 3) percutaneous penetration from keloid; 4) adjunctive diagnosis and observation of the course of various dermatoses; 5) influences of ointment application on the skin temperature; 6) thermographic venography; and the following two headings which are not only limited to dermatology: 7) finding the effects of drugs and 8) computer-analysis of the thermogram.

B) Plastic surgery. The first report of a thermographic study concerning plastic surgery was given by Dr. Fakuda et al. in 1968. Ever since, there have been 10 papers and abstracts that are reported in this field. The present tendency is to study the followings items: 1) early detection of rejection reaction of the skin graft, and applications in animal experiments of skin transplantation; 2) evaluation of the circulation of the skin tube, flap and graft (a) planning for the tube and flap-making; (b) follow-ups after removal of the tube, flap or skin graft; (c) evaluation of the surgical « delay » technique.

Future view. Thermography is not widely employed in those two fields in the present in Japan. Further experiences with healthy cases (by age and by sex) as well as pathological ones are needed. Many cases of a kind of dermatosis must be studied. There may be a possibility of finding a new aspect that is unexpected now when the further study of many kinds of dermatoses is carried out. The above-stated matters can be said in the field of plastic surgery especially.

Y. NASU (Tokyo, Japan)

A review of thermographical studies on vibration syndrome in Japan

In industrial hygiene, thermography has been utilized mainly for medical examination of vibration syndrome and related researches. This syndrome is caused by the long-term use of vibrating tools such as chain saws or chipping hammers and is characterized by Raynaud's phenomenon. To examine the changes of skin temperature thermographically, two methods have been applied: one is to photograph the static thermal pattern of the observed area. The patterns obtained were classified into 4 types according to distribution, with the combination of a cold load test. The other method is quantitative time-transitional analyses of skin temperature changes elicited by various kinds of stimulation. The thermographic changes on the back of the left hand due to vibratory stimuli delivered to the right hand were studied in normals and patients with Raynaud's phenomenon. The gradual changes on each thermogram photographed every 10" were expressed as an integrated density value by an experimental optical densitometer. Recently, a data-processor has become available. Among stimuli of 40, 80, 90, 100, 110 and 120 Hz in frequency and 0.5 mm in amplitude, stimulation of 100 Hz was found to be most effective in causing temperature decreases and making its recovery delayed. The changes observed were more remarkable in the patients than in normal controls. However, it is interesting that the patients without Raynaud's phenomenon showed only small changes in spite of long-term use of vibrating tools. Effects of cold and loud noise stimulation on skin temperature were also studied in relation to the pathophysiology of vibration syndrome.

R. KANIE (Tokyo, Japan)

Thermography in orthopaedic surgery

In this field, in Japan, thermography has been applied to various diseases such as osteoarthritis of the hip and the knee, rheumatoid arthritis, periarthritis scapulohumeralis, cervicobrachial syndrome, thoracic outlet syndrome, peripheral neuropathies, spinal paralysis, hemiplegia due to CVA, skin grafting, and others. I introduce the outline of these works and indicate my opinion about the significance of thermal imaging in the correlation between pain and peripheral circulation and elucidate the clinical value of thermography from the orthopaedic point of view.

ERRATUM

R. E. Woodrough: « *Thermographic screening for scoliosis in adolescents* ». *Acta Thermographica,* Vol. 1, N. 2, 1976.

The colour isothermograms were laterally inverted during printing. Yellow should be at the right hand end of the scale and represents a higher irradiance than blue which should be on the left. Similarly, the calibration disk is always *against the subject's left* arm.