LECTURE

The past studies and developments on bio-medical thermography in Japan

by K. Atsumi

Institute of Medical Electronics, Faculty of Medicine, University of Tokyo, Tokyo (Japan)

INTRODUCTION

The aim of medical thermography is to accurately measure the changes in distribution of surface temperature. From this may be determined the physiological state of the body and how this may apply to the diagnosis of various diseases. Thanks to recent advances in the field of optical-electronics, including development of an infrared radiometer and infrared camera, it is now possible to obtain, in a very short time, a continuous pattern of the surface temperature resolution. With the present apparatus this may be as high as 0.03 — 0.1°C.

In Japan, medical thermography has been studied by the authors since 1965. The first Japanese Medical Thermography Conference was held in May 1968, and the second conference in September 1969. Further conferences were held in 1970, 1972, 1973, 1974 and 1975 with one exception (1972-Osaka) all were held in Tokyo. An International Symposium was combined with the eighth annual meeting of Japanese Society of Biomedical Thermography in June 1976 in Tokyo.

The Japanese Medical Thermography Society currently has a membership of about 150. At the first conference 19 papers were read, at the second conference 10 papers, at the third conference 11 papers, at the forth conference 16 papers, and 19 papers were presented at the fifth conference. 17 papers were given in the sixth conference, 27 in the seventh. At the eighth conference in 1976, 30 papers were read, and two invited speakers — Dr. N.J.M. Aarts and Dr. M. S. Lapayowker — took part.

Two books have been published in Japan. « The Atlas of Medical Thermography », edited by the Tokyo University Society of Thermography (Chairman, Dr. K. Atsumi), was published in Japanese in 1971 by Igakushoin Limited. « Medical Thermography » edited by Dr. K. Atsumi, was published in English, in 1973 (Tokyo University Press.).

MEDICAL THERMOGRAPHY APPARATUS IN JAPAN

In the early studies on medical thermography in 1965, an infra-red camera « Thermograph Model-M » made by Barnes, and an « AGA Thermovision », were used. However Japanese infra-red cameras for medical-use have come into use since 1968.

In 1968, Fujitsu Limited constructed the first prototype « Infra-eye », a medical infrared imaging apparatus for clinical applications, utilizing In-Sb as the detector. This was followed by other trial models, the « Medical Infravision » of Nippon Electric Co. Ltd. (NEC), « Thermoscope » of San-ei Instrument Co. Ltd., « Thermoviewer » of Japan Electron Optics Laboratory Co. Ltd. (Jeol), « Thermocamera CT-2 » of Canon Inc. and « Hithermo » of Hitachi. These have all been applied to clinical studies in Japan.

These six companies have been marketing

Lecture presented in the « International Symposium on Bio-Medical Thermography », Tokyo, July, 1976.

infrared cameras for domestic medical use since August of 1971.

The principle specification of the apparatus mainly used in clinical work are listed in Table I.

Infra-red cameras for medical purposes can be roughly divided into two categories as follows.

a) High-speed;

b) High-resolution.

The former, aimed at shortening picture-taking time, does so at the expense of absolute temperature measurement and is inferior to the latter in both temperature and image resolution. The latter type requires a longer time to take pictures, but provides measurement of the absolute temperature, with better temperature and image resolution.

Infravision (NEC) and Thermocamera (Canon) were designed as high-speed types while Infra-Eye (Fujitsu) and Thermoscope (San-ei) were produced to a high-resolution specification.

The thermoviewer of JEOL in 1971 was made to satisfy both high resolution and high-speed requirements.

In 1972, Fujitsu and JEOL both introduced new high speed types.

In 1974, medical thermocameras utilized in Japan have all been replaced by high speed and

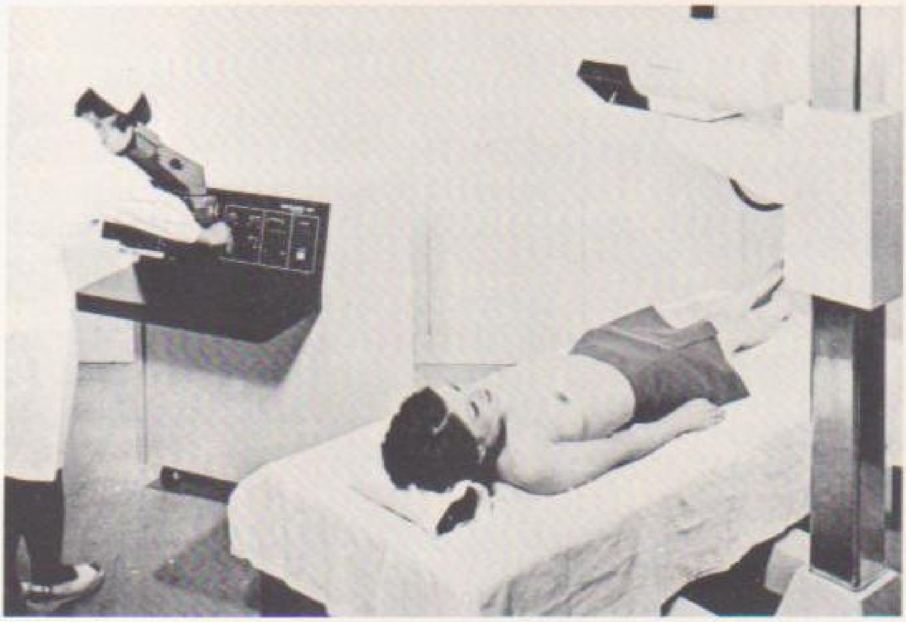


Fig. 1. Infra-eye 103 (Fujitsu).

Fig. 2. Thermoviewer (Jeol).

Fig. 3. Cannon-CT 6A.

high resolution types with a light weight optical head e.g. Thermoviewer JTG-MT, MC, MD (JEOL), Infra-Eye 102 (Fujitsu) and Thermocamera CT-6A (Cannon) (Figs. 1, 2, 3, 4).

By 1974 medical infra-red cameras were in use in institutes and hospitals in Japan.

By June 1976, most of the equipment used was Japanese, with the exception of three american (Barnes Engineering) and five swedish cameras.

In 1968, the first thermographic instrument for medical use was installed in the Cancer Institute and in 1969, a second instrument was installed in the Kansai Labor Hospital. Thereafter, the number of thermographic systems installed in hospitals and medical facilities has increased annually (Graph. 1).

It is estimated that there are now twenty different types of instruments for medical thermography available in the world market, and the selection for medical applications is more difficult.

A research survey was made in our institute to identify the requirements for the medical-use of an infra-red camera (Table II).

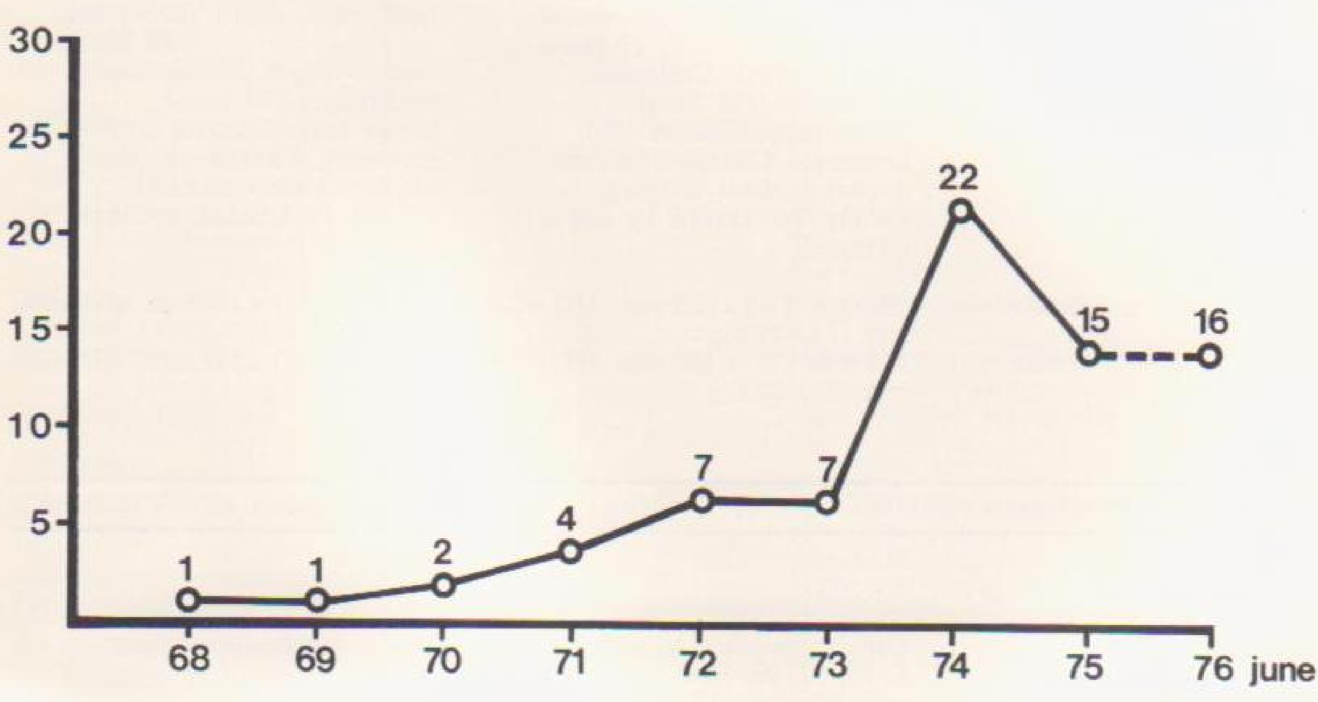
CLINICAL APPLICATION

In Japan, the technique of thermography has been applied to many differing fields of medicine and health care. An example of the clinical investigations with thermography in University of Tokyo up to 1972 is shown in Table III.

1) Normal studies

The distribution of a healthy person's skin temperature in front and back is shown as almost symmetrical pattern from the midline of the body. This is generally true with regard to the temperature distribution in the area of head, face, back and limbs.

When an asymmetrical pattern is detected in these areas, the seat of a disease can be quan-



Graph. 1. Trends of numbers on thermographic instruments installed in Japanese health and medical facilities.

Tab. I. **Specification of thermographic cameras used clinically in Japan.**

	Infra - eye 102A (Fujitsu)	*Infra - eye 103* (Fujitsu)
Temperature range:	0°C - +50°C	0°C - +50°C
Detector:	Cd Hg Te (Coolant Lq. N_2)	Cd Hg Te (Coolant Lq. N_2)
Thermal resolution:	0.07°C	0.05°C
Field of view:	20°H × 15°V	20°H × 15°V
Focal distance:	0.5 - 5m	0.5 - 5m
Number of horizontal scanning lines:	78(0.5), 157(1), 314 lines (2 sec)	185 lines
Picture elements in a horizontal-line:	174 elements/line	174 elements/line
Frame time:	0.5, 1, 2 sec	10 sec
Display:	5" CRT °Thermal picture and wave form °Wave form enlarged for accurate temperature measurement	5" CRT °Thermal picture and wave form °Wave form enlarged for accurate temperature measurement
Angular resolution:	2m rad × 2m rad	2m rad × 2m rad
Power consumption:	AC100/220V, 50/60Hz, 200VA	AC 100/220V, 50/60Hz, 400VA
Type:	Movable type	Setting type
Weight:	Scanner ... 20 Kg Indicator ... 25 Kg	Scanning ... 190Kg with special stand Indicator ... 145 Kg

	Thermo viewer M. C. (Jeol)	*Thermo viewer M. D.* (Jeol)
Temperature range:	0°C - 50°C	0°C - 50°C
Temperature width (Sensitivity):	1, 2, 3, 5, 7, 10, 15, 20, 30, 50°C (10 steps)	1, 2, 3, 5, 7, 10, 15, 20, 30, 50°C (10 steps)
Temperature resolution:	0.07°C	0.05°C
Frame time:	1 sec, 2.1 sec, 4.2 sec	1 sec, 2 sec, 4 sec
Number of scanning lines:	125 line, 250 line, 500 line	120 line, 240 line, 480 line
Horizontal resolution:	More than 550 elements per scanning line	More than 300 elements per scanning line
Field of view:	25° (vertically) × 30° (horizontally)	20° (vertically) × 25° (horizontally)
Focal range:	40 cm - ∞ (by remote control)	20 cm - ∞ (by remote control)
Display mode:	Isothermal, Multi isothermal (5 lines) step (5 steps), Deflection modulation (30 lines) Image magnification (2x) Inversion, Change-with-time display (1 sec - 40 min)	Isothermal, Multi isothermal (5 lines) step (5 steps), Deflection modulation (30 lines) Image magnification (2x) Inversion, Change-with-time display (1 sec - 20 min)
Infrared detector:	Cd Hg Te (cooled by liquid nitrogen)	Cd Hg Te (cooled by liquid nitrogen)
Dimensions and weight:		
Optical head:	294 mm (W) × 259 mm (H) × 268 mm (L), 18 Kg	165 mm (W) × 195 mm (H) × 262 mm (L), 4 Kg
Display unit:	565 mm (W) × 195 mm (H) × 440 mm (L), 30 Kg	291 mm (W) × 185 mm (H) × 325 mm (L), 9 Kg

	Thermocamera CT-4A (Canon)	*Thermocamera CT-6A* (Canon)
Use:	Medical	Medical
Objective temperature range:	0 - 50°C	0 - 50°C
Black and White temperature range:	Can be switched to 1, 2, 3, 5, 8, 10, 15, 20, 50°C	2-50°C *continuous setting*
Minimum detective temperature difference:	0.03°C	0.1°C

segue

	Thermocamera CT-4A (Canon)	*Thermocamera CT-6A* (Canon)
Scanning angle:	30° (horizontal) × 18° (vertical)	25° (horizontal) × 20° (vertical)
Focus range:	0.12 m - ∞	0.15 m - ∞
Number of horizontal scanning lines:	50 lines per second 300 lines per five seconds	77 lines 230 lines 460 lines switching
Horizontal resolution:	400 picture element (TV indication method)	290 picture element (TV indication method)
Number of picture elements:	120,000 (in picture for 5 seconds)	140,000
Picture scanning time:	1-second, 5-second switching	0.8-second, 2.4-second, 4.8-second switching
Display size:	130 mm (horizontal) × 100 mm (vertical) (including data section)	130 mm (horizontal) × 100 mm (vertical) (including data section)
Display picture:	Monochrome picture, isothermal picture, temperature wave form isothermal line indication (4 stages, 10 stages)	Monochrome picture, isothermal picture, temperature wave form isothermal line indication (5 stages, 10 stages)
Liquid nitrogen preservation time:	6 hours	6 hours
Photographing camera:	Polaroid camera 35 mm still camera	Polaroid camera 35 mm still camera
Power requirements:	AC 100V, 120 W, 50/60 Hz	AC 100V, 150 W
Size:	Thermocamera head 535 mmW × 322 mmH × 323 mmL Display unit: 320 mmW × 370 mmH × 550 mmL	Thermocamera head 190 mmW × 190 mmH × 350 mmL Display unit: 230 mmW × 310 mmH × 573 mmL
Weight:	Thermocamera head 25 Kg Display unit: 20 Kg	Thermocamera head 8 Kg Display unit: 17 Kg

Thermovision 680 Medical (Gadelius)	
Camera Unit	
IR Lens:	25° × 25° f.o.v. (53 mm f/1.8) 15° × 15° f.o.v. (87 mm f/1.8)
Range of focus:	0.6 m ~ ∞
Instantaneous filed of view:	2.5 m rad (25° lens) 2.0 m rad (15° lens)
Detector:	InSb or HgCdTe
Display Unit	
Picture size:	90 × 90 mm, 67 × 74 mm
Picture field frequency:	16/sec.
Raster lines per frame:	210 (interlaced)
Resolving power:	160 picture-elements/line
Thermal resolution:	0.1°C at 30°C
Temperature:	Differential or absolute temperature measurement with calibrated level control
Power requirements:	100V AC, 200 VA, 50-400 Hz
Dimensions	
Camera unit:	200 x 240 x 490 mm (W x H x L), 13 kg.
Display unit:	450 x 200 x 530 mm (W x H x L), 23.7 kg.

Features

(1) Real time presentation
(2) Lens extension ring for close-up examination
(3) Compact and noise less
(4) Easy to operate
(5) Wide range accessories

Tab. II. **Requirements of thermographic instrument for medical use.**

1. Spectral region of detector: preferable longer than 10 μ
2. Filter: cut off blow 3 μ
3. Cooling method: liquid nitrogen is allowed
4. Picture temperature range: 8 steps (1°, 2°, 3°, 5°, 7°, 10°, 15°, each subdivided into 10 ranges)
5. Target temperature range: 5-50°C
6. Thermal discrimination: 0.1°C
7. Frame time: 1/10-2 seconds
8. Optical angular resolution: 1 miliradian
9. Number of lines and elements per frame: 100 × 150 = 15,000 — 500 × 600 = 300,000
10. Displayed data
    a) black and white pattern
    b) central temperature in thermogram
    c) temperature range
    d) room temperature
    e) gray scale
    f) count mark number (patient number)
    g) with or without reflecting mirror
11. Stability and reliability
12. Easy operation
13. Camera head: multidirectional

Fig. 4. Infra-eye data processor.

titatively diagnosed. However, in some cases, the temperature distribution in normal subjects is not uniform, particularly the female which may show a punctate distribution (Figs. 5, 6).

Temperatures of the head, face, fingers and toes, which are usually exposed to open air, are 2 - 5°C degrees higher than those of the trunk of body in equilibrated condition in a constant warm temperature (23-27°C) room. In the area of the chest and the back, the midsection has a temperature of 0.5 - 1.0°C higher than the peripheral sections. The temperature of left side of chest corresponding to the location of the heart, tends to show a slightly higher temperature compared with that of the right side.

The distribution of superficial veins on the female breast is not symmetrical, therefore diagnosis of breast diseases requires special attention. The temperature of the hip, and subcutaneous fat around the knee, in which bone and skin are in close contact, and of the frontal area of the tibia, all show rather low temperatures.

The breast temperature of a woman is grea-

Tab. III. **Clinical cases of thermography in university of Tokyo.**

Infrared Camera M1 (Barnes Engineering) Thermovision (AGA), Infra-eye (Fujitsu) Thermoviewer (JEOL), Hithermo (Hitachi) Thermocamera (Canon)

Control (normal)	173
Gynecology & obstetrics	104
Newborn	5
Benign tumor	78
Malignant tumor	66
Peripheral vascular disorder	137
Collagen disease	39
Neural disease	40
Muscular disease	6
Acute inflammatory disease	14
Skin transplantation and skin roll	48
Kidney transplantation	3
Dermatology & orthopedics	22
Miscellaneous	29
Total	764

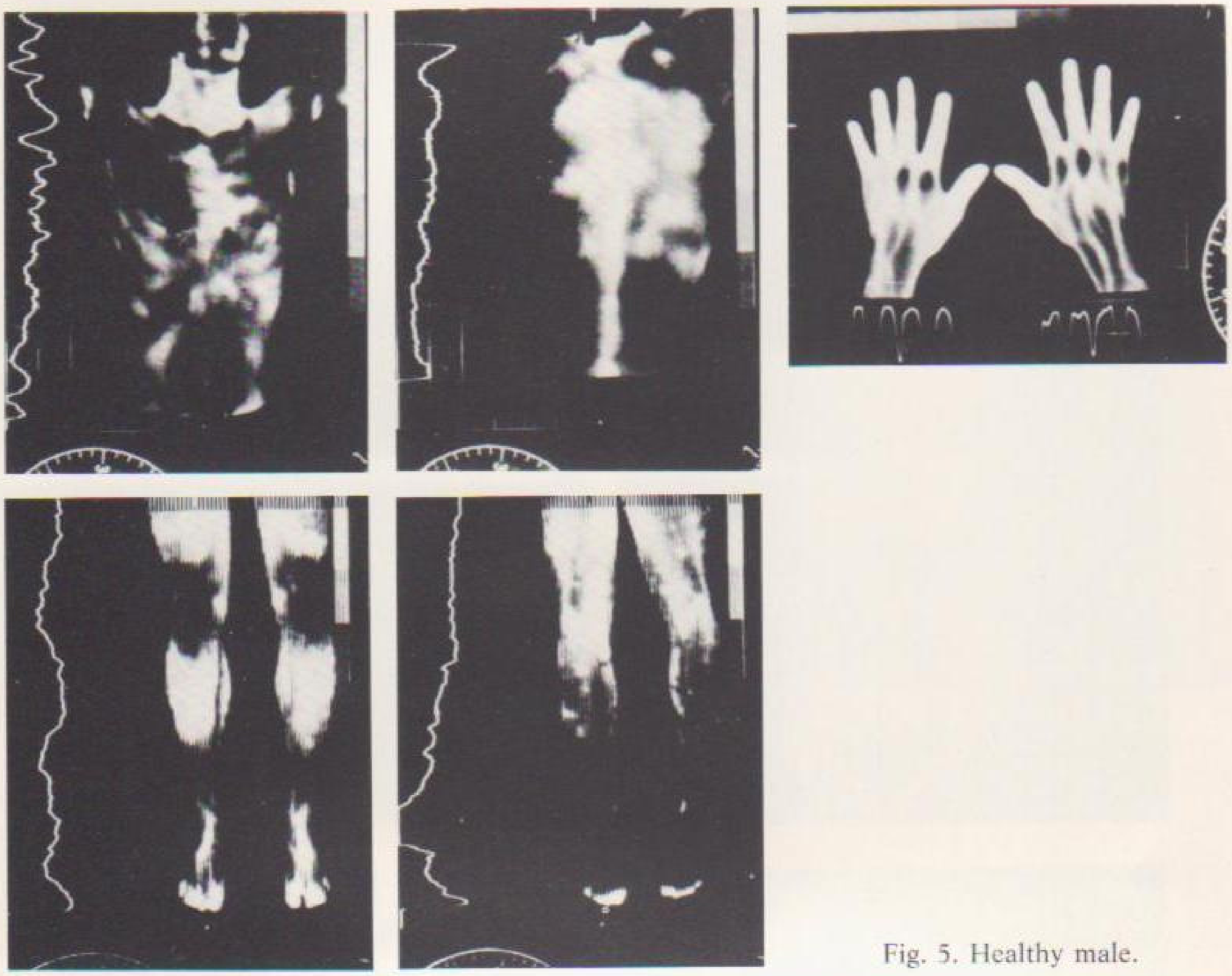


Fig. 5. Healthy male.

tly affected by her menstrual periods. A low breast temperature is usually detected immediately after the periods. However, if she becomes pregnant or has taken an oral contraceptive, the temperature rises as a result of dilatation of the breast skin vein.

2) Tumors

a) **Benign tumors.** In the case of a benign tumor, lipoma and cystic struma, the difference in temperature with the surrounding normal tissues is very small, about 1°C at most. The superficial benign angioma, in which the blood flow is increased, shows a higher temperature compared with that of surrounding tissues. Therefore, the area of an angioma can be estimated quantitatively and the information used for the indications for surgery (Fig. 7).

b) **Malignant tumors in superficial areas.** In the case of superficial malignant tumors such as cancer of the breast, carcinoma of the thyroid, cancer of the upper jaw, Ewing's sarcoma, etc., 2 - 3°C rise in temperature above the surrounding normal tissues is detectable.

In some cases, metastases of the regional lymphatic nodes from malignant tumors could are observable as hot spots of high temperature.

One particular application of thermography is as a screening test for breast cancer, on which many international reports have been published to date (Fig. 8).

The tumor may be judged malignant or benign, although the criteria of temperature difference varies according to opinion. When the temperature of a tumor site is 1 - 2°C higher than that of the surrounding normal tissues, the tumor may be classified as malignant. Yamazaki and Ouchi have been studying the difference in detectability of breast cancer using mammography and thermography,

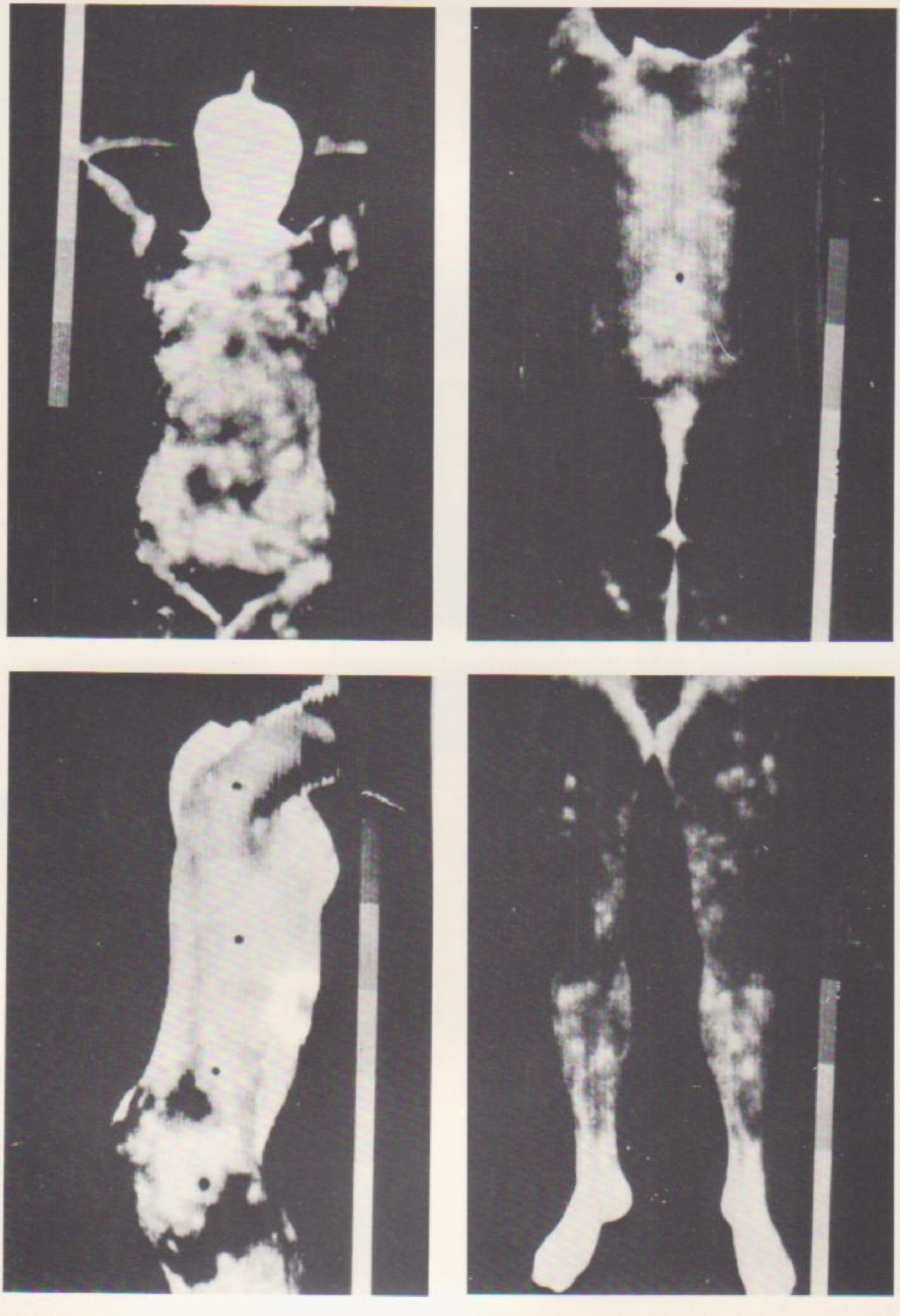


Fig. 6. Healthy female.

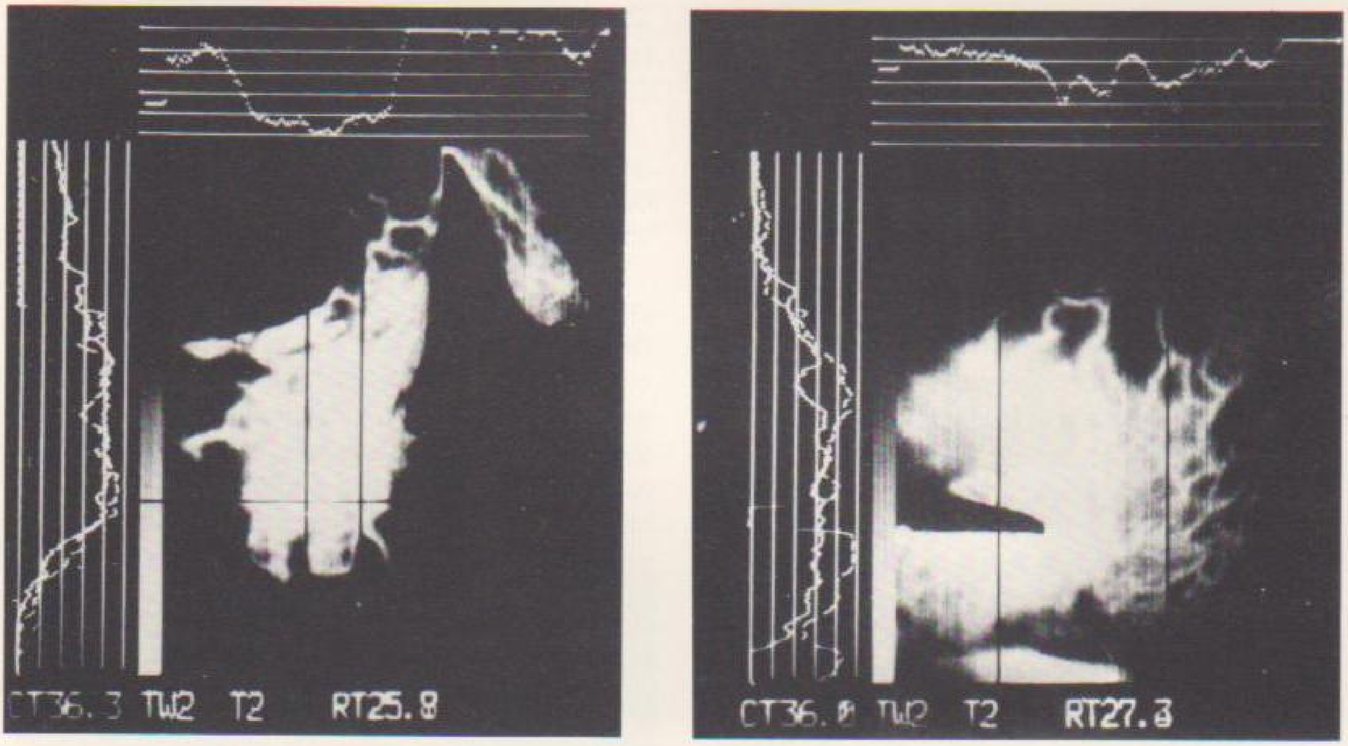


Fig. 7. Hemangiom in shoulder.

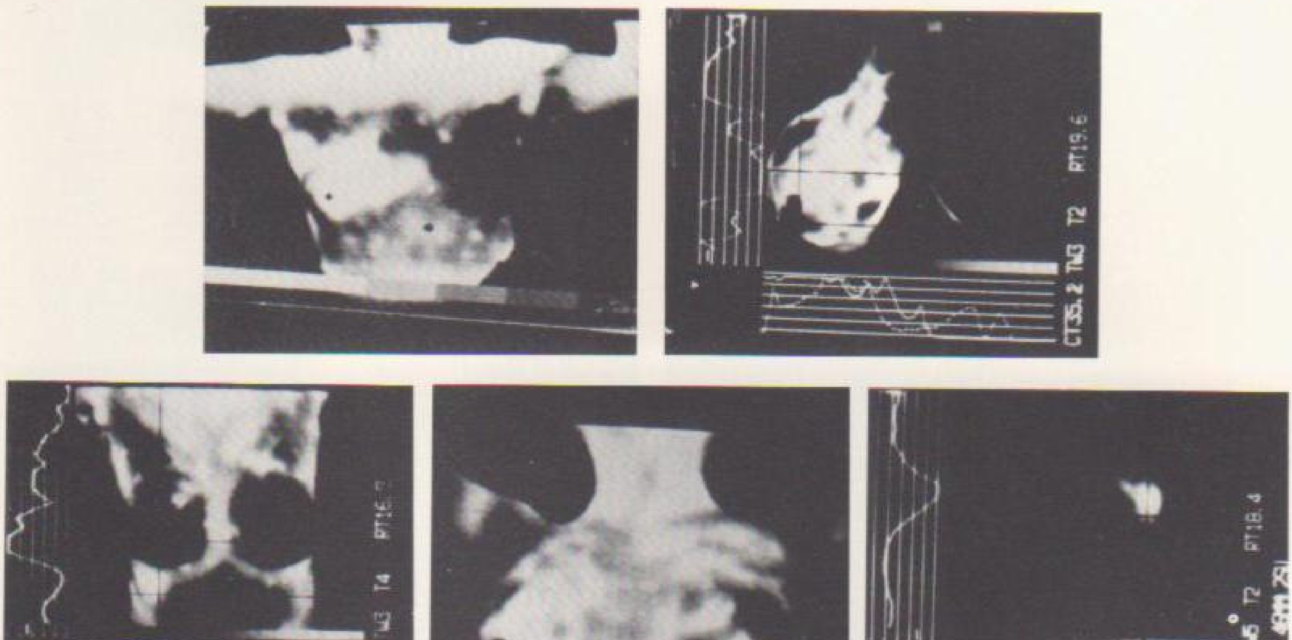


Fig. 8. Breast cancer (1. 3. 5.), mastitis (2) and silicone in left breast (4).

and the correlation between the temperature, tumor depth and size examined with a breast phantom model.

The combined examination with infrared phlebography of superficial veins using infrared radiation is a useful method in the detection of breast cancer. This technique has been used in National Kyushu Cancer Center Hospital and in certain other hospitals.

c) **Deep-seated malignant tumors.** One lung cancer was detected by the author, by finding a hot spot on the skin which exactly corresponded to the site of a tumor. One case of chronic inflammation of deep pancreas was also detected from a thermogram of the back. However, no cases of carcinoma of the liver could be detected with thermography.

Kurauchi reported a hot spot of high temperature indicating a suprapharyngeal tumor lurking 4 cm deep in the body.

3) Inflammation

The area of acute inflammation also shows a high temperature because of its active metabolism and the increase of local blood flow. Therefore, the differential diagnosis of acute inflammation from malignant tumors is very difficult.

Nagasawa proposed a method for differentiating the diagnosis of malignant tumors from inflammation, he described as a « thermal recovery method ».

The area of a malignant tumor, although rapidly cooled, takes a long time to recover to the original high temperature.

However, the area of an inflammation which can also be cooled rapidly, rapidly recovers to the original temperature. By applying this method — heating and cooling — diagnosis of malignant tumors differentiating from inflammation has been achieved.

If inflammation is treated by the administration of antibiotics, the local temperature of the area decreases. The therapeutic effects of antibiotics can therefore be judged both qualitatively and quantitatively.

4) Diseases of peripheral vessels

Thermographic diagnosis of the physiological and pathological changes in the vessels of

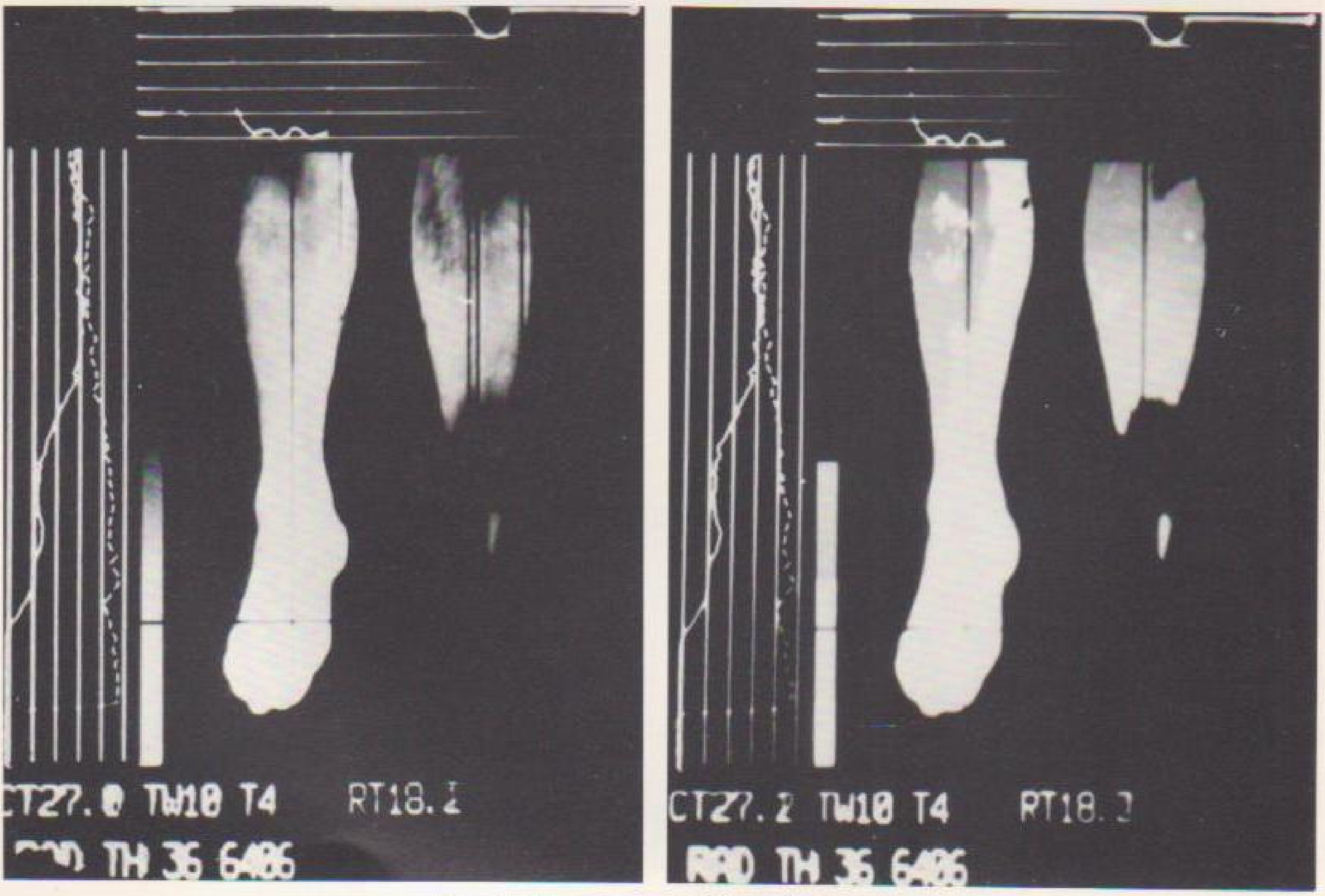


Fig. 9. Chronic arterial occlusion.

upper and lower extremities in man is simple, as the temperature distribution is almost symmetrical. However, there is a local temperature difference of 4 - 6°C in the upper and lower extremities. In general, the lower extremity shows lower temperatures of 2 - 3°C compared with that of the upper extremity.

In patients arteries with arterial occlusion in their extremities, the blood flow in the peripheral vessels either decreases or disappears, resulting in low temperature. Diagnosis of sclerotic obstructive arteritis, Burger's disease and Raynaud's syndrome is simplified with thermography (Figs. 9, 10).

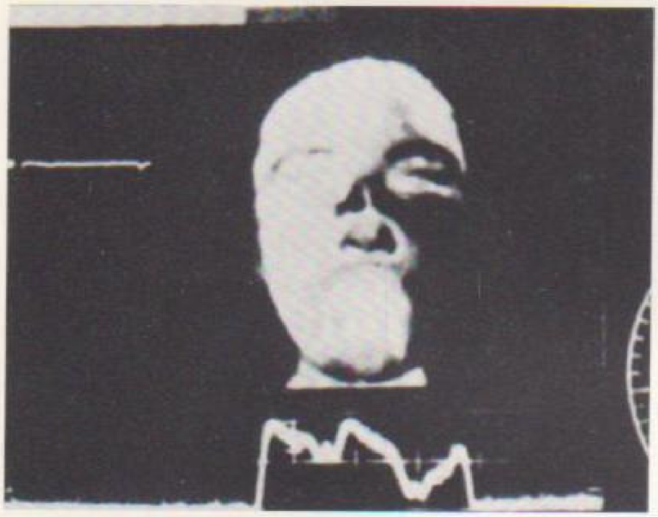


Fig. 10. Pulse-less disease (obstruction of A. carotis externa).

In arterial occlusion of the extremities, the cold temperature occasionaly shows in more central areas than the predetermined one, due of the development of a collateral bypass. These results are useful in surgery for deciding exact amputation lines.

Local blood flow increases and high temperatures have been seen in the arterial venous fistulae, varix and hemangioma.

The thermovenography technique reported by Miki et al. of Osaka University combines a venoangiographic method with thermography. After dipping the patient's hand or foot in warm water bath, the blood flow through surface vein increases and the venous pattern on the surface of the extremities can be more clearly examined.

5) Burns and frostbite

In the treatment of burns and frostbite the degree of severity is of clinical importance. Burns of first degree bring reactive hyperaemia and indicate high temperature, but burns of third degree show lower temperatures of 2 - 3°C due to the absence of a blood flow in the pathological area.

6) Skin grafts and organ transplantation

In skin grafts and organ transplantation, the success of their grafting after reconstruction is often judged empirically by the surgeon. However it can be monitored by thermography as a measure the local blood flow. A skin graft test is also made to determine the histocompatibility of an organ to be transplanted, in which case, thermography can be used to indicate the reject reaction (Fig. 11).

In the transplantation of organs such as the kidney, rejection causes a high temperature, while malfunction of the transplanted organ results in a low temperature. Thermographic techniques can provide useful informations in the detection of immunological response to organ transplant.

7) Collagen diseases

Collagen diseases are usually combined with peripheral vascular disorders. Through the study of thermograms from collagen disease patients, Katsuta reported abnormally low temperatures in the fingers of patients suffering from Raynaud's syndrome.

For these patients, medical thermography combined with a cooling test (submesing the hand in water) has proved a useful method and abnormal skin temperature patterns can be studied.

Inagaki reported that the knee joint of rheumatoid arthritis showed a high temperature, and an injection of steroid hormone produced a fall in temperature corresponding with the pain relief (Fig. 12).

8) Orthopedic diseases

Thermographic diagnosis of a number of orthopedic conditions, fractures, arthritis, and soft tissue injuries is simplified with a local skin temperature rise occuring in the pathological sites.

9) Brain and nervous diseases

Meningioma of the brain tends to show a raised temperature when it is located very

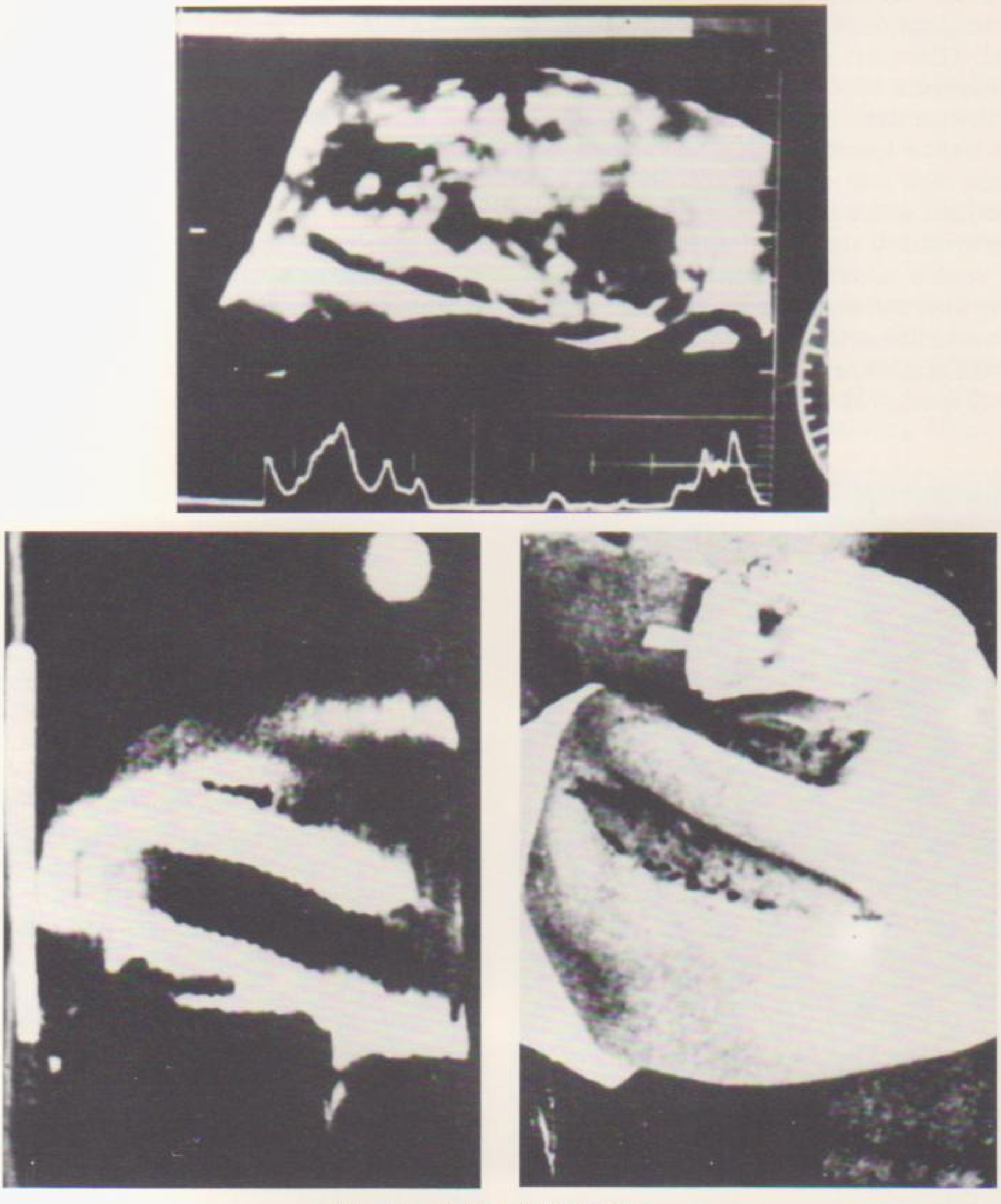


Fig. 11. Skin roll transplant.

close to the cranium. In a patient suffering from hemiplegia following an attack of apoplexy, the temperature distribution of the paralysed extremities can be detected by thermography and used in quantitative diagnosis. Immediately after paralysis, the temperature in the extremities are fairly high, but rather lower temperatures of 0.5 - 1.0°C are detected in the chronic condition compared with the control values from the unaffected side of the patient.

In facial paralysis, where a change in thermal distribution of the face has been suspected, the thermogram showed no temperature difference compared with normal side of the face (Fig. 13).

10) Hormonal diseases

Thyroid glands normally register high temperatures due to their active metabolism. In patients affected by hyperthyroidism, the affected side shows a high temperature, but in patients with a cyst, the corresponding area is cool.

The breast temperature of pregnant females is raised by about 2°C. However a hydatid mole showed no increase in temperature detection.

11) Examination of placenta attachment

Detecting the localization of the placenta is possible by thermography, because of increase in the local blood flow. This examination method is called thermoplacentography.

A study on thermoplacentography was carried out by Sakamoto, Usuman and Suda. According to Sakamoto, in twenty ont of twenty six cases was confirmed by this technique (Fig. 14).

12) Assesment of pharmaceutical drugs

It is possible to assess and monitor the reopening of the peripheral vessels after a sympathetic nerve block.

Furthermore, in clinical studies, the effect of vasodilator or vasoconstrictor drugs can be tested safely and repeatedly, without pain or inconvenience to the patient.

This application has been used to check the drug's in vivo effect in individual patients prior to medication.

In this respect medical thermography may be frequently utilized to certify the effects in vivo of many drugs, such as antibiotics, hormones, etc.

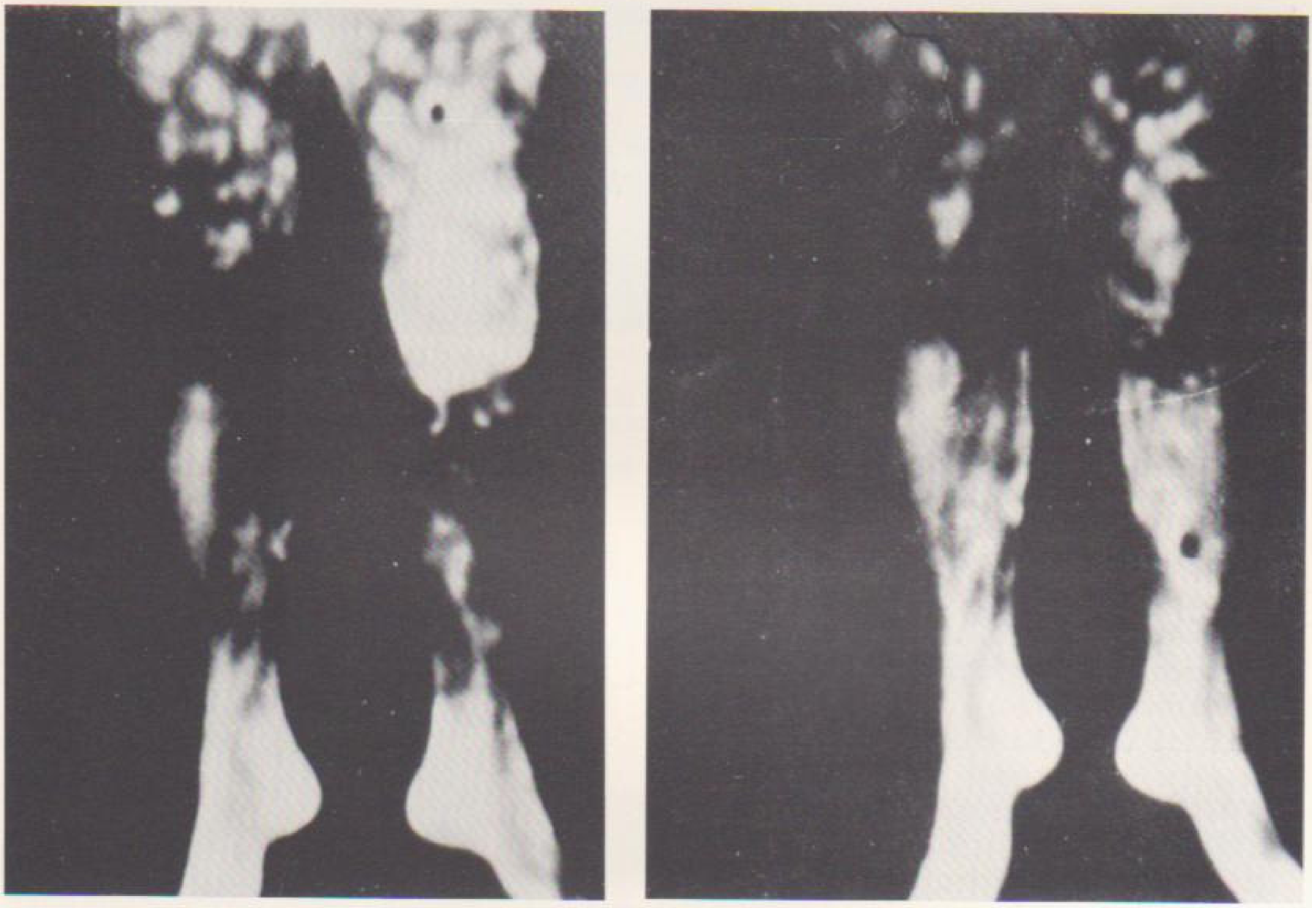


Fig. 12. Rheumatic arthritis in knee joint. Hot spot showen in left knee disappeared after steroid injection.

13) Oriental medicines

Serizawa and Nishijo have applied thermographic techniques in the interesting field of oriental medicine. They reported that the Kei-ketsu, technique demonstrated hot spots in thermograms at relatively cold room temperatures (15-20°C). Recently, they have studied similar effects from acupuncture.

DATA PROCESSING ON THERMOGRAMS

Thermograms obtained by scanning with the infra-red camera may be shown in black-and-white or as color patterns.

From the viewpoint of human engineering, man can discriminate almost five levels in black-and-white patterns and ten or more in color patterns. It is therefore more difficult to detect fine thermal abnormality from the conventional thermograms.

Fujimasa et al. attempted to solve this problem by the use of digital data processing. Thermal signals from the output of the infra-red camera were transmitted to magnetic tape and converted to digital values with A-D converter. These data were typed out in a two-dimensional thermo-matrix (Graph 2).

Thermograms in human body are symmetrical through body's midline in front and back of it's surface. Utilizing this phenomena, processing of thermographic images was carried out by subtracting one normal half-pattern from the abnormal pattern of opposite side with digital computer (Graph 3, 4).

However, the thermal patterns in breast were not symmetrical and were so complex that it was impossible to use this method for screening malignant tumors. If the subtraction method is applied to processing of thermograms, the patient's normal thermographic pattern is needed as a control.

Miki and Ouchi have also studied data processing on thermograms with the computer. They attempted the diagnosis of breast cancer by digitizing the thermopattern and discriminating the abnormal temperature area from the breast thermograms.

31.0+a×1/10 (°C)

00	00	00	00	13	30	23	20	19	21	09	19	11	12	13	00	00	00	00	00	3-1
00	00	00	00	20	22	22	23	26	13	19	18	17	16	13	00	00	00	00	00	3-2
																				3-3
00	10	18	17	05	19	19	18	25	24	29	28	31	27	21	25	23	25	25	06	3-4
00	00	10	15	17	15	19	18	19	24	26	28	30	28	22	22	21	23	17	00	3-5
00	00	10	20	10	24	29	22	22	10	15	23	27	25	21	18	16	12	08	00	3-6
00	00	17	20	08	13	18	24	20	20	15	20	24	22	18	10	15	09	00	00	3-7
00	00	15	20	11	14	20	25	26	26	26	25	22	21	15	13	14	08	00	00	3-8
00	00	14	20	12	13	17	25	29	33	33	28	22	19	12	10	14	07	00	00	3-9
00	00	04	12	09	12	14	20	21	27	29	24	19	16	12	08	17	00	00	00	3-10
00	00	08	10	10	09	14	20	22	27	30	25	22	16	13	14	13	00	00	00	3-11
00	00	00	04	10	12	15	17	23	26	26	29	18	16	13	15	11	00	00	00	3-12
00	00	00	01	10	17	17	18	22	28	35	26	24	28	11	13	04	00	00	00	3-13
00	00	00	00	10	14	14	18	25	27	25	22	18	17	14	12	00	00	[illegible]	00	3-14
00	00	00	00	12	16	13	16	23	23	22	17	17	16	15	09	00	00	[illegible]	00	3-15
00	00	00	00	09	17	16	15	18	22	20	18	16	17	10	07	00	00	00	00	3-16
00	00	00	00	12	16	16	18	21	21	22	17	14	18	11	05	00	00	00	00	3-17
00	00	00	00	12	19	17	20	21	19	22	20	18	18	10	00	00	00	00	00	3-18
00	00	00	20	13	18	17	17	23	17	23	23	15	13	11	00	00	00	00	00	3-19
00	00	00	00	13	19	17	17	19	18	18	19	14	15	15	00	00	00	00	00	3-20
00	00	00	00	13	16	18	22	24	17	15	15	12	12	05	00	00	00	00	00	3-21
00	00	00	00	12	24	17	16	17	11	11	14	09	06	06	00	00	00	00	00	3-22
																				3-23
00	27	25	06	20	11	08	20	15	24	29	26	25	27	10	18	25	12	00	00	3-24
00	06	29	25	04	03	12	10	14	18	17	25	25	24	15	09	06	24	25	00	3-25

Graph 2. Thermomatrix of thoracic surface.

In these studies, before software can be developed, the criteria for diagnosis must be definitive.

Digital display of thermograms will be required for certain applications in the future. To meet this demand, a digitizing thermographic unit has been made available for one Japanese medical thermocamera as an optional extra (Fig. 13).

SURGERY

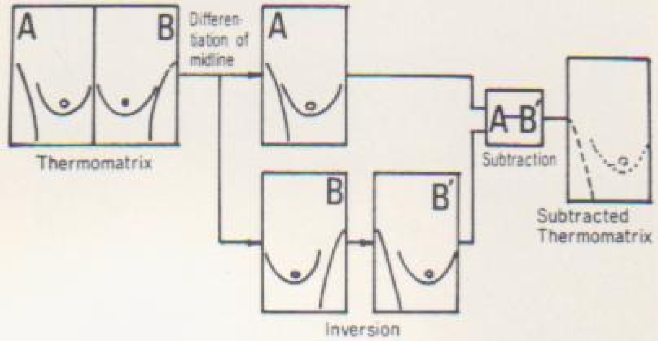
Even in the surgical operating room, thermography can be applicable.

Yamazaki of Tokyo University has reported an thermoangiography of the mesenterial artery in the opened abdomen of the animal, and prognosticated necrosis of the intestinal tract in cases of ileal occlusion.

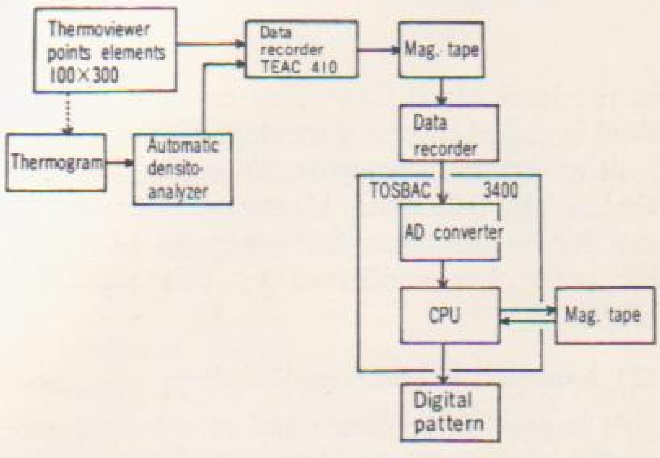
The clinical applications of this technique are currently under investigation.

In ICU or CCU, it is useful to examine the state of shock of a patient.

Tsuji and Togawa used thermography combined with a deep body temperature thermo-

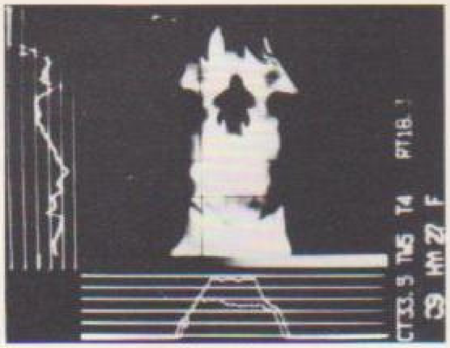


Graph 3. Process for subtracting thermomatrixes.



Graph 4. Schematic diagram of automatic digitalization of a thermogram.

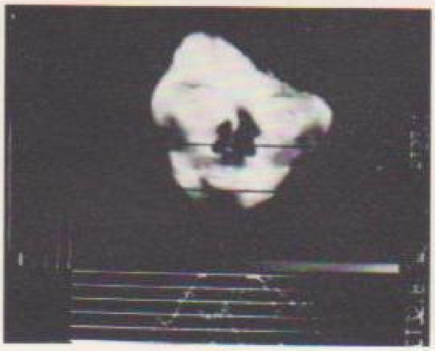
r. zygoma fracture



enameloma (r. mand.)

l. carotis graft

v. mandibulitis



nasal furuncle

facial palcy (1)

Fig. 13. Various kinds of facial diseases.

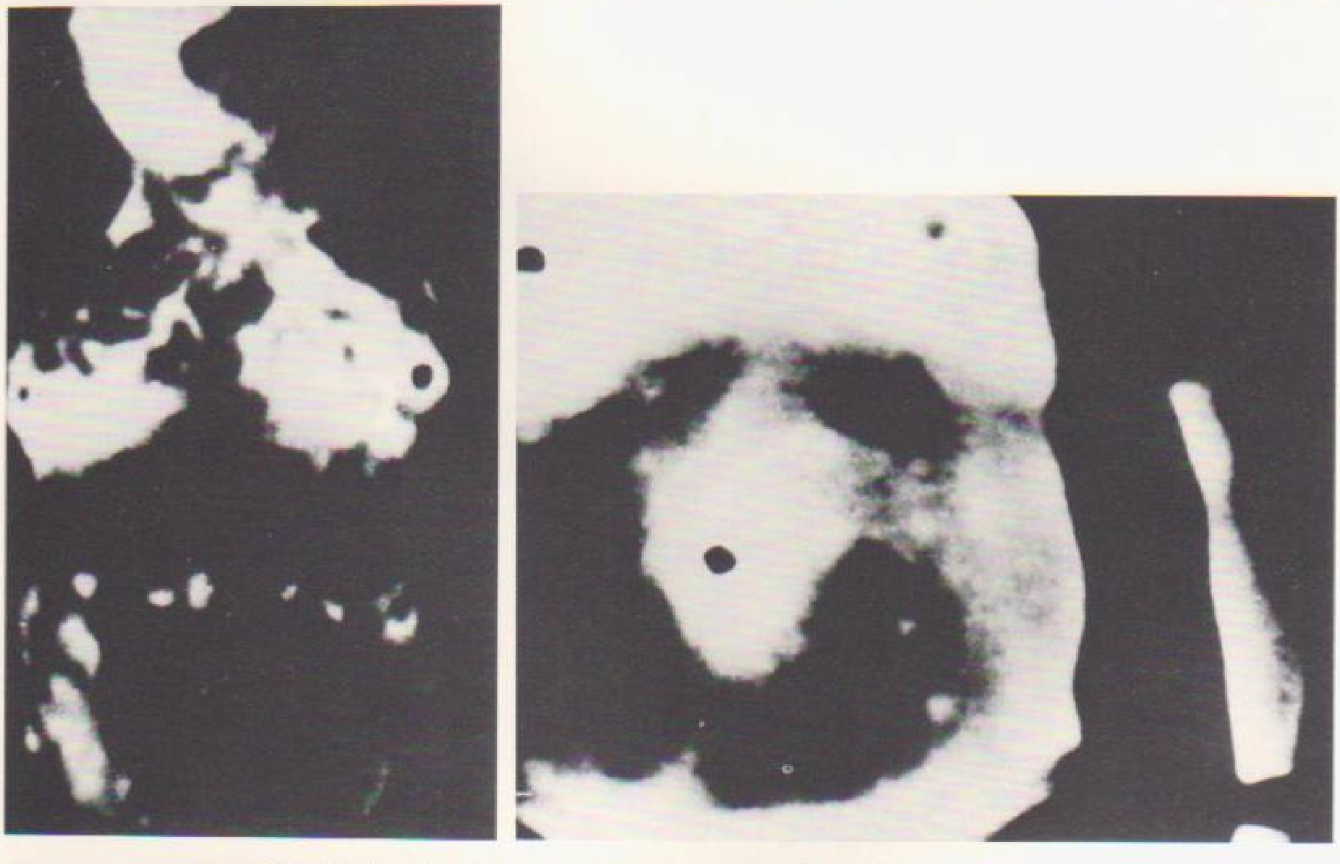


Fig. 14. Breast and placental attatchment in a pregnant woman.

meter developed by Fox for the useful indicator to check the patient's condition after cardiovascular surgery.

FUTURE PROBLEMS ON RESEARCH AND DEVELOPMENT IN MEDICAL THERMOGRAPHY

From more than ten year's experience, we would like to draw attention to the problems requiring more research and development in medical thermography. They may be divided into two major groups, for engineering and medical problems.

A) Engineering problems

1) scanning surface for body curvature; 2) color display; 3) image processing of thermograms; 4) analysis of the thermogram by computer; 5) miniaturization of apparatus; 6) reducing the cost of apparatus.

B) Medical problems

1) Data aquisition and analysis of normal controls (a - conditions for static examination, b - dynamic techniques); 2) standardization of technique; 3) quantitative analysis for diagnosis (criteria); 4) development of complementary methods.

CONCLUSIONS

Medical infra-red thermography has the following merits: 1) it is a non-contact method; 2) it causes no harmful complications; 3) it is a painless examination; 4) repeated examination is simple; 5) operation of the apparatus is simple and examination is completed in a short time; 6) a continuous temperature distribution pattern is obtained; 7) by stimulating the object being measured, the response and the reaction can be observed; 8) quantitative measurement of the correlation between areas and temperature is possible.

With various improvements to be added in the future, thermography is expected to be widely used in Japan in every field of medical study and health care.