STATE OF ART

Disorders of the cardiovascular system: the thermographic technique

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SUMMARY. Thermography is ideally suited to the study of the peripheral circulation. In some cases the thermograph is the primary instrument for such studies. For example, circulation of the individual toes and fingers can he studied effectively with this instrument, some specific heat patterns suggesting the etiology of disease. For example, osteoarthritis, rheumatoid arthritis, synovial membrane infections of the hand. However, most pictures are non specific and suggest anatomical areas of altered temperature or physiologic changes in certain parts of the body consistent with a variety of different disease states. Thermography should he a part of every non invasive vascular laboratory where studies on the peripheral circulation are being made. The arterial circulation from the neck to the head, venous thrombosis and peripheral arterial diseases at the extremes of the circulation are among the useful areas for this device.

Key words: thermography; peripheral circulation; arteries; veins and lymphatics.

In some cases the thermograph is the primary instrument for the study of the circulation. Arterial disease of the fingers and toes is often detected most readily thermographically. Also, for screening for cerebral vascular disease, this instrument is of primary importance. The purpose of this paper will be to point out the value of thermography in the cardiovascular diseases which will include disease of the heart, chest and lungs as well as those of the upper and lower extremities, as well as the arterial circulation of the head.

INSTRUMENTS AND METHODS

We used the Barnes black-and-white scanner, the Barnes color instrument, the AGA Thermovision black-and-white scanner and the General Electric Spectrotherm 1000 black-and-white instrument. All instruments were capable of giving satisfactory information for their intended uses. The Spectrotherm has a high resolution, the AGA a medium resolution, and the Barnes a lower resolution. The time taken to record the photographs varied from a fraction of a second to two seconds with the Spectrotherm and AGA instruments, to four minutes for the Barnes instrument. For many studies, the patient was able to lie quietly, and the longer scan period was thus not a hindrance.

The color display of the Barnes instrument, the first color instrument available, was especially useful for studying the peripheral circulation. It appears that the isothermic display on a color basis is well suited to the peripheral circulation: in contrast, high-resolution black-and-white may be preferred when studying the breasts and other areas where details of vascular patterns must be displayed. The pseudo-color

technique was useful for converting black-and-white to color pictures [1]. For purposes of this publication, the color displays were photographically converted to black-and-white; in this process some definition is lost.

The patients were studied in a clinic environment. The studies were carried out in a minimal-draft room at 73°±1.5°F after 10-20 minutes of equilibration. For studies of the cerebral circulation, in which the forehead is uncovered, less equilibration time was generally needed; for legs or arms which had been covered by clothing, however, a longer period of equilibration was needed after removal of the clothing.

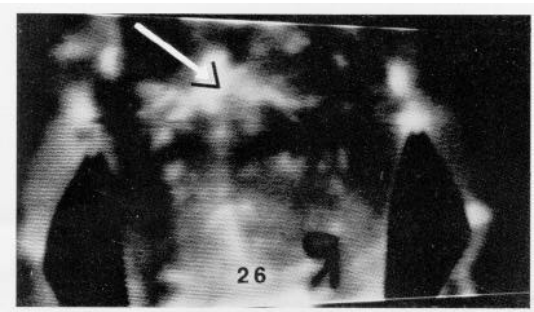

Fig. 1. Tender chest wall due to osteochondritis (arrow). Clinically the warm area was tender.

HEART AND CHEST

Generally, the heart is difficult to study thermographically; in certain conditions, however, cardiovascular abnormalities emit a characteristic heat pattern. For example, coarctation of the aorta shows an unusually warm upper chest wall and upper back due to the rich collateral circulation above the coarctation [2]. The collateral arteries are close to the skin, and increases in skin temperature occured in these areas.

Pericardial effusion of certain types, when the effusion was sterile and of large amount, sometimes produced a cool precordial area; a septic pericardial effusion may not produce a similar result. It appears that the aseptic effusion serves as a heat shield which prevents the heat generated by the metabolism of the heart from reaching the anterior chest wall.

It has been stated in the literature that large pulmonary infarcted areas show a cool chest area with respect to the normal side, whereas pulmonary infection, such as lobar pneumonia, shows an increase in chest temperature on the infected side. We have had little experience with these disorders, but they deserve further study [3].

Pacemakers which had been subcutaneously implanted were studied to determine if there was a change in thermographic pattern. The pacemaker sites normally became cool a few weeks after insertion and after healing of the found. However, certain patients had persistently hot pacemaker sites which represented chronic inflammatory reactions around the pacemakers. In one case, it was necessary to replace the pacemaker because of this inflammatory reaction. The electronic circuitry was not a cause of pacemaker heat in these cases.

The tender chest wall syndrome was usually difficult to identify (Fig. 1). Generally, there was acute tenderness clinically around several of the costochondral junctions. In about 25% of the cases, this area was warm thermographically; in one case, a bone scan showed evidence of costochondritis with increased uptake of radioactive material over the warm spot. This ultimately turned out to be metastatic carcinoma of the pancreas. Sternotomy scars which resulted from open chest coronary bypass surgery were studied at intervals after surgery. Immediately and a few weeks after surgery, these scars were warm. However, the scarred area returned to normal temperature remarkably rapidly, often within a month. In certain cases, hot areas along the incision were observed. These represented local areas of irritation caused by protruding wires, sometimes with abcess formation, which required reopening of the wound.

DISORDERS OF THE UPPER EXTREMITIES

The diseases are divided into abnormalities of the arteries, the veins, the lymphatics, the nerves, the soft tissues and joints and other conditions. Some of the conditions are of vascular origin, while other5 are not. When the thermogram5 were being read, it became necessary to distinguish, if possible, the vascular from the nonvascular states. This often had to be done on the basis of the clinical examination, since the heat patterns were often not specific [5, 6, 7].

The arterial diseases [6] produced lesions which were either cool or hot. Cool lesions were been with acrocyanosis, whereas warm lesions, such as arteriovenous fistulae, showed heat over the fistula [8]. Of the venous disorders, thrombophlebitis produced a heat pattern which was either localized or diffuse. Superficial thrombophlebitis, such as that from a chemical injury, was often localized and warm, whereas deep vein thrombophlebitis of the axillary or brachial vein often gave total heating of the entire limb [9]. Lymphatic abnormalities showed normal temperatures with chronic inactive lymphedema, such as lymphedema preacox; lymphedema associated with lymphangitis, on the other hand, was hot, and was also difficult to differentiate from acute deep vein thrombophlebitis.

Lesions of nerves in which irritation was the major phenomenon produced coolness of the limb distal to the level of irritation; however, there was often a warm lesion at the site of the irritation itself. For example, a brachiitis due to muscular strain produces heat in and around the neck and shoulder, with a cool arm and hand. The carpal tunnel syndrome, which in itself produces a cool digit because of nerve irri-

Fig. 2. Synovial membrane infection produces triangular temperature pattern which is characteristic of this condition.

tation, has been generally difficult to recognize because it is often associated with arthritis, which produces warm extremities. Hemiplegia produces a cool limb because of disuse with a low metabolism in the paralyzed part. Peripheral neuropathy produces drying with associated increased heat in peripheral areas, as does a sympathectomy. Radiculitis from the back, such as from a disc, often produces a warm back and a cool limb as measured thermographically. Acute soft tissue injuries, such as tendonitis or contusion, produce warm areas.

Other conditions, such as cervical rib compression and costoclavicular syndrome, are very irregular in their temperature responses. Often there is no temperature abnormality [4].

Hyperhydrosis produces cooling as a result of sweating. Fractures produce warm lesions. Peripheral vascular drugs such as Roniacol (nicotinyl acid tartrate) produce peripheral warming [9].

Warm patterns of the upper extremities

Pattern recognition, when possible, is important in reading thermograms. Unfortunately, different disease states often produce similar patterns; thus the clinician must, consider the thermal pattern in light of his general knowledge of the patient. There are certain thermal patterns, however, which strongly suggest various disease states.

, Warm proximal interphalangeal joints are seen in arthritis - especially rheumatoid arthritis - when it is in an active phase; the picture was rather specific. Warm distal interphalangeal joints suggest osteoarthritis.

A warm triangular pattern on the dorsum of the hand was characteristic of synovial membrane infection (Fig. 2). Such infections often appear first as a sinus at the distal phalangeal joint. This sinus becomes infected, and early in the course of the disease, a single joint becomes infected. As the infection spreads along the synovial space, the typical triangular picture of synovial membrane involvement in seen.

Warm areas of one wrist could be arthritis or sprain; when both wrists are involved and are warm, however, it is more likely that arthritis is the cause of this heat abnormality.

A warm finger or fingers, on one hand only, was characteristic of paronychia, fracture, sprain or contusion.

A hot palm or dorsum of the hand was a nonspecific finding seen with AV fistulae, trauma and other conditions.

Hot fingers with respect to the palm were seen in normally dilated individuals; this finding also appeared in cases with extreme vasodilatation like that which sometimes occurs with Weir-Mitchell's disease or after administration of drugs.

Cool patterns of the upper extremities

« Bite » defects of a fingertip were seen in diabetes and Buerger's disease as well as in disseminated lupus and early arteriosclerosis. The bite defect is important to recognize, since early disease often manifests itself at the most distal parts of the circulation. Thus tell-tale lesions on the tips of the fingers may signal the existence of more serious disease elsewhere in the body.

Localized cool spots on a hand with normal temperature patterns of the fingers were seen with old skin grafts, old scars, old hematomas and dermoid cysts.

Bilateral coolness of both hands and the fingers was seen normally and with ergotism, smoking and hyperinsulinism. Use of dynamic thermography is of extreme importance in these cases to note the rate of cooling or heating of the hands when employing body heating or cooling. Bilateral and equal rates of cooling or heating of the hands signify a bilateral and equal vascular state of the hands, which occurs normally. If the hands differ in rates of response to

body heating, vascular disease is usually present.

Bilateral cool fingers with normal temperatures of the palms and the hands were seen with primary Raynaud's disease [11] and acrocyanosis.

Unilateral coolness of the hands, wrist and fingers was seen for example, with arterial occlusion [12]. This finding was characteristic of brachial artery occlusion with the temperature line approximately at the wrist. With axillary or subclavian artery occlusion, the temperature line was often at midbrachial level.

Coolness of one finger on one hand was often traumatic.

Coolness of certain fingers on both hands was common in many disease5 - scleroderma and diabetes.

DISORDERS OF THE LOWER EXTREMITIES

Thermography of the lower extremities can employ a technique that is either static or dynamic. Static thermography is generally used to determine heat patterns which might suggest diseases of the arterial, venous or lymphatic systems. Dynamic thermography is utilized primarily to isolate and display the perforating veins which help burgeons visualize those which are not readily palpated or seen.

The patients observed in this series included those with diseases of arteries, veins, lymphatics, nerves, soft tissue and joints, and other conditions. These lesions were divided into those which characteristically were cold and those which were warm. It should be kept in mind, however. that the same disease may be cold in one phase and warm in another; sclcroderma, for example, may produce cool digits, but a flareup of the condition associated with increased metabolism causes the skin to become inflamed and results in a warm lesion in place of the cool one. Similarly, lymphedema was often two-phased; the temperature was normal in the inactive phase but increased during the stage of inflammation.

Warm lesions of the lower limbs

In the area of the lower abdomen and groin, thrombophlebitis often involved the pelvic vein5 or the femoral vein (Fig. 3); these produced significant amounts of increased heat [9]. In the leg, deep vein thrombophlcbitis may be confined to either the calf or the thigh area. In certain phases of thrombophlebitis of the deep vein5 of the thigh, the thigh may be warm and the foot cool. This temperature difference may be caused by diversion of blood from the toes to the area of increased metabolism, or it may come about as a causalgic reaction when the nerves are involved in the phlebitic process. Stasis dermatitis is a consequence of either deep vein thrombosis or severe venous insufficiency, which results in capillary hypertension, skin changes and increased heat. Often, the stasis dermatitis produces increased heat which lasts for years. When ulceration occurs, the ulcerated area itself is wet and a thermogram of the ulcer is cool due to evaporation.

Perforator veins were readily identified and were warm [13].

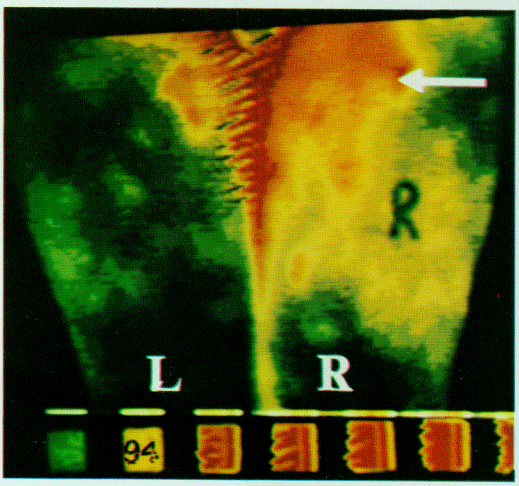

Fig. 3. Iliofemoral vein thrombosis producing heat in the region of the groin and upper thigh.

Hot lesions arc seen when sprains, contusions, infections and arthritis are present. Burns [10, 14] and frostbite [10] were warm at times. The rate of healing of burns could be evaluated [15].

Gout gives hot lesions of the toes; however, these lesions cannot be differentiated from those produced by acute arthritis or fractures. Local conditions of the toes, such as bacterial or fungus infections, paranychia and fractures, often produce hot lesions.

The healing process after calf venous thrombosis, is readily evaluated through the use of aerial thermograms.

Cold lesions of the lower extremities

In the hip area, hypogastric artery occlusion produces a picture that shows cooling. This is often important in handling patients with impotence or with vascular disease in and around the aorta or the large arteries. Nerve root irritation can sometimes produce cooling in this area; this must be differentiated from arterial occlusion on a clinical basis. Aortic occlusion (Leriche syndrome) produces thigh cooling bilaterally. Lesions in the common femoral artery produce temperature lines in the lower thig area. Ostructive lesions such as superficial femoral artery and popliteal artery occlusions, produce temperature lines at the mid-calf level. Occlusions of arteries of the dorsum of the feet are characterized by an inability to visualize the dorsalis pedis artery. Individual toes are often cold when digital artery occlusion is present - as in peripheral arteriosclerosis, for example. When the lesions are scattered widely, foot microemboli are considered. A warm foot often follows successful posterior tibia1 nerve block. An irritating lesion such

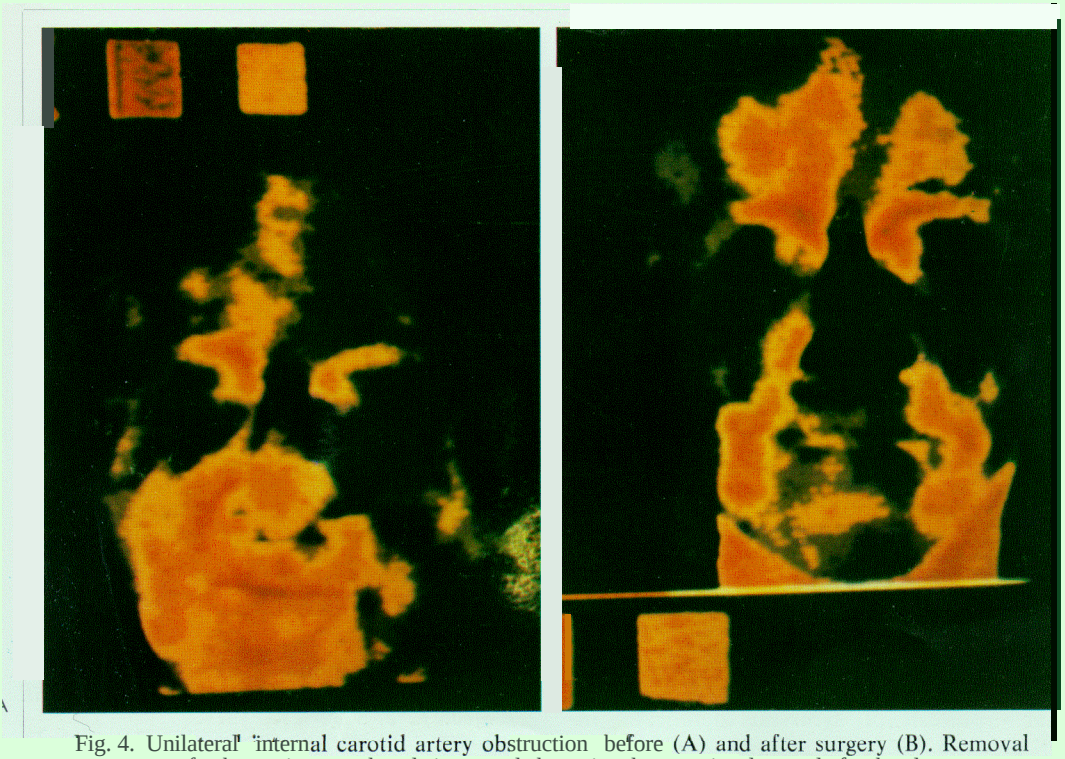

Fig. 4. Unilateral internal carotid artery obstruction before (A) and after surgery (B). Removal of obstruction produced increased heat in the previously cool forehead.

as radiculitis often produces coldness of the limb,

DISORDERS OF VESSELS OF THE HEAD AND NECK

Arterial obstruction of the internal carotid arteries gave a cold spot across the forehead on one or both sides in our series. The exact temperature pattern on the forehead depended upon the nature of the collateral circulation to the forehead. When a frontal or supraorbital artery is obstructed, this circulation may be through the external carotid and temporal arteries into the obstructed internal carotid. Another collateral vessel is from the external carotid artery across the angle of the jaw, and along the side of the nose to the branches of the internal carotid artery. Thus, the head patterns can vary considerably when internal carotid disease is present. Figure 4 shows an 85 year old male before and after removal of an obstructing internal and carotid lesion. A cold spot on the forehead was present before surgery; this was converted to a hot spot after successful surgery.

DISCUSSION

Thermography is, in many cases, a primary instrument for the discovery and subsequent following of the course of vascular disease. When evaluating the digits of the hands and feet, for example, individual arterial disorders can be revealed easily and quickly. The device is also of importance in studying certain cardiac disorders such as pericardial effusion, irritation caused by pacemakers, and delayed wound healing after chest surgery [5]. There are certain characteristic thermographic patterns of the limbs - e.g. the « proximal nodular » pattern of rheumatoid arthritis; the distal interphalangeal pattern of osteoarthritis; the « triangular » pattern of synovial membrane infection; the bilateral dicuse « rainbow » finger pattern of primary Raynaud's disease, acrocyanosis and functional vasoconstriction; and the « mottled » pattern of Buerger's disease. Thermography is the instrument of choice in following the course of disease such as healing of fractures, the resolution of thrombophlebitis and the improvement in circulation following medical or surgical treatment.

Dynamic thermography assists in the examination of the venous system, defining perforator veins in order to assist the surgeon in the removal of such veins.

Diffuse vascular patterns in the feet suggest microemboli from the aorta or a lesion higher up.

AV fistulae can be localized thermographically, and a Bresica-Cimino shunt can be evaluated as to its state of patency.

Pelvic thrombophlebitis or femoral vein thrombophlebitis can be demonstrated; this ability is important because of the relationship between thrombophlebitis and embolism.

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