SHORT COMMUNICATIONS

Infrared Thermography in Diabetes Mellitus

A preliminary study

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Summary. Infrared thermography revealed characteristic abnormalities in the emission patterns over the hands and feet of 16 young diabetics with or without manifest vascular complications. Infrared thermography seems to be a method well suited for further studies of circulation and metabolism in the hands and feet of diabetics.

La thermographie d'infrarouge dans le diabète sucré.

Résumé. La thermographie d'infrarouge a permis de démontrer les anomalies caractéristiques de l'image d'émission au niveau des pieds et des mains de 16 jeunes diabétiques avec et sans manifestations de complications vasculaires. La thermographie d'infrarouge semble être une méthode utile pour l'étude de la circulation et du

métabolisme au niveau des mains et des pieds chez les diabétiques.

Infrarot-Thermographie bei Diabetes mellitus.

Zusammenfassung. Die Infrarot-Thermographie zeigte typische Abnormitäten in den Emissionsbildern über Händen und Füßen von 16 jungen Diabetikern mit oder ohne manifeste Gefäßkomplikationen. Die Infrarot-Thermographie erscheint methodisch gut geeignet für weitere Untersuchungen des Kreislaufs und Stoffwechsels in den Händen und Füßen von Diabetikern.

Key-words: Diabetes mellitus, infrared thermography, peripheral circulation, peripheral vascular disease, diabetic angiopathy, diabetic neuropathy, vasodilation.

Thermography records the infrared emission from a whole part of the body. It has been used for studying peripheral vascular diseases, mainly in order to evaluate its clinical usefulness (SKVERSKY et al., 1964; WINDSON and BENDEZU, 1964). Some diabetics with manifest vascular complications were included in the latter studies.

In the present investigation infrared thermography was used for studying a group of young diabetics with

or without vascular complications, together with the action of a vasodilator.

Material and Methods

The series comprised 16 diabetics, 12 women and 4 men, 19 to 43 years of age averaging 28 years. The mean duration of disease was 13 years. Pertinent data are set out in Table 1. The patients were all on insulin

Table 1. *Clinical findings*

Age (years)	Sex	Duration (years)	Retinopathy	Nephropathy	Neuropathy	Oscillometry	Skin temperature measurements	Vascular calcification in legs	Blood pressure mm Hg	Dermal vascular wall thickness
19	F	11	0	0	0	N	N	0	135/95	4+
20	F	9	0	0	0	N	N	0	115/70	3+
21	M	7	0	0	0	N	N	0	120/80	1+
22	M	6	0	0	0	N	N	0	120/90	2+
22	F	2	0	0	0	N	N	0	115/70	2+
23	F	2	0	0	0	N	N	0	120/80	2+
23	M	20	+++	+	+	N	N	0	130/80	2+
23	F	13	++	+	+	N	N	0	135/90	—
25	F	23	++	+	+	P	P	+	135/80	1+
28	F	3	0	0	+	N	N	0	130/80	3+
30	F	22	++	+	+	N	—	+	145/80	4+
30	F	16	++	0	0	N	P(?)	0	125/85	3+
33	M	13	++	0	+	—	P	0	130/80	4+
36	F	33	++	0	0	N	N	0	160/85	3+
42	F	27	++	0	+	N	P	+	150/95	3+
43	F	10	0	0	+	N	P	0	140/80	—

N = Normal P = Pathological — = Not examined

and at the time of the investigation in a satisfactory metabolic state.

Infrared Thermography

The normal infrared emission from the body in the spectral region 2–20 μ was recorded with AGA Thermovision Equipment, which works on a scanning principle. The object is scanned by a system of mirrors and prisms directing the emission to an indium antimonide detector cooled by liquid nitrogen. The optical signal

Clinical Methods

All patients underwent a routine examination on admission to the hospital. The eyegrounds were examined in the Ophthalmiatric Clinic, retinopathy being graded as follows: 0 = no changes; + = microaneurysms; ++ = microaneurysms and bleeding with or without exudate; +++ = proliferative changes. Constant proteinuria without signs of infection (negative bacterial urine culture) was attributed to diabetic nephropathy. Diabetic neuropathy was

Fig. 1 a and b. Emission patterns over hands and feet in a healthy volunteer with no signs of peripheral circulatory disturbances

Fig. 2. Hands of a 28 year old female with diabetes of 3 years duration, and feet of a 33 year old male with 13 years duration. Emission patterns in hands and feet before (a and c) and 30 minutes after (b and d) intramuscular administration of 7.5 mg isoxysuprenaline. Note tapered emission patterns over fingers and sharp transverse boundary over feet at metatarsophalangeal joints in a and c. After the injection the emission increased but pointed appearance persisted. The emission over toes was markedly increased

is transformed into an electronic impulse, which is amplified and modified to give a picture on an oscilloscope screen. This visible picture can then be photographed. An isotherm can be set at various temperature levels and introduced in the infrared picture on the screen in order to obtain an objective measure of differences in emission levels.

The measurements were taken in an air-conditioned room at 18–20°C after the subject had been resting for 15 to 20 minutes. Vasodilator action was studied by recording thermograms before and 30 minutes after injecting isoxysuprenaline (Duvadilan®, Ferrosan) intramuscularly in a dosage of 7.5–10 mg.

diagnosed on at least two typical neurological signs (e.g. bilateral Achilles areflexia, diminished vibration sense). The skin temperature was measured on the toes after indirect heating according to BRATTGÅRD et al. (1951) in the Clinical-Physiological Laboratory. Oscillometry was performed on the lower limbs using Recklinghausen's oscillometer. Any arterial calcifications in the legs were sought in plain radiograms. Skin

biopsy specimens were taken from the dorsum of the foot and the wall thickness of capillaries and venules was estimated according to SÄVE-SÖDERBERGH et al. (1967).

Results

All the diabetics had emission patterns over the feet which deviated from those of healthy subjects (BRÄNEMARK, unpublished observations) of similar age (Fig. 1a, b). The emission over the toes and metatarso-phalangeal regions was distinctly decreased and gave a sharp transverse boundary which became more accentuated when isotherms were introduced (Fig. 2c). Sometimes the emission from the great toe was almost normal but reduced from the lateral toes. On each toe a tapered pattern arose.

Little or no reduction of the emission was shown over the dorsum of the foot and tibia. Only slight differences could be seen between the left and right foot. Asymmetric patterns were recorded from the only diabetic with local gangrene (Fig. 3a, b, c; cf. Fig. 4).

The emission over the fingers was in most cases reduced and there were usually conspicuous pointed or tapered emission patterns over each finger (Fig. 2a). Occasionally the emission over the thumb was so reduced as to give a transverse boundary (compare foot). The thermographic emission abnormalities over the hand were less pronounced and less extensive than those over the feet.

The vasodilator increased the emission over the feet in all diabetics. This was particularly true over the great toe, but in many cases the emission was increased over the other toes as well (Fig. 2d). The emission over the hands was invariably increased, sometimes resulting in a normal emission pattern, and in those cases with tapered pattern over the fingers it became more normally rounded (Fig. 2b). The vasodilator occasionally increased the pulse rate slightly. No changes in blood pressure or flush reactions were noted; the patients had no subjective discomforts.

Discussion

Infrared thermography revealed that all the 16 diabetics had abnormalities in the emission patterns from feet and hands. The emission was reduced over the toes and metatarsal regions, resulting in a characteristic pattern. The changes over the hands were less pronounced and comparatively less extensive, the emission being reduced particularly from the fingers. This gave rise to a typical tapered pattern. Healthy subjects had stronger emission over the tips of the toes and fingers than over the dorsi of feet and hands, whereas in diabetics the situation was reversed.

The series included some diabetics with diabetes of short duration and no other clinically manifest abnormalities. Interestingly, these patients too, exhibited emission reductions of the same degree as diabetics with pathological readings at conventional skin

temperature measurements and/or manifest vascular complications, e.g. retinopathy or dermal microangiopathy.

Fig. 3. a) Emission patterns over feet of a 30 year old woman with diabetes of 22 years duration, 30 minutes after administration of 7.5 mg isoxysuprenaline. — b) 2 weeks after a daily dose of 20 mg $\times$ 3 isoxysuprenaline. Note increased emission over toes of right foot and especially over great toe. Over left foot except for the first and second toes emission also increased. Observe area of high emission over metatarso-phalangeal region of these toes, representing inflammatory reaction with increased vascularization. — c) 2 weeks later. Clear delineation of border zone between cold gangrene and vascularized tissue

The infrared emission from the skin bears a direct relationship to the surface temperature (cited from LLOYD-WILLIAMS et al., 1960) which under resting

Fig. 4. Dorsal view of feet shown in infrared thermograms in Fig. 3

conditions is thought mainly to reflect the blood flow of the underlying tissues in hands and feet (SKVERSKY et al., 1964). If this applies to diabetics as well is not clear, and at our present state of knowledge it is only possible to obtain general information on the circula-

tory and metabolic conditions in hands and feet with the aid of infrared thermography.

Our investigation demonstrated that thermography yields a good idea of the extent of the cool regions in diabetics, and it turned out that after administration of a vasodilator temperature elevations were recorded which occasionally approached normal levels. Thermography has the advantage that the recording is carried out by an instrument not in contact with the skin.

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