Journal of Engineering Physics and Thermophysics, Vol. 69, No. 3, 1996

METHOD OF THERMOGRAPHY IN DIAGNOSING CARDIOVASCULAR DISEASES

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UDC 616.1-073.65

We investigated the possibility of using infrared thermography (IT) in diagnosing the commonest cardiovascular diseases: ischemic heart disease (IHD) and hypertensive disease (HD). We show that the IT method allows one to evaluate the condition of peripheral blood flow, but the results of examination depend greatly on the presence of accompanying diseases (osteochondrosis, varicosis). The IT method is not specific enough to evaluate the functional state of a myocardium.

Infrared thermography ranks among noninvasive methods of diagnosis and control of the state of a patient suffering from disorders of various organs and systems.

The IT is based on distant measurement of spontaneous infrared radiation, as an equivalent of the thermal balance of skin, with the possibility of determining the regions of enhanced or reduced heat production. There are numerous reports on the successful application of IT in diagnosis of inflammatory [1-3], degeneration-dystrophy processes, malignant and benign tumors [4-6].

As indicated in some communications, it is possible to use IT in the diagnosis of cardiovascular diseases. At the early time of myocardial infarction a hypothermia zone is detected in the projection of the heart, and a temperature asymmetry of more than $1^{\circ}C$ appears [7].

Using thermography together with load tests (cooling, heating, drug therapy), it is possible to reveal hidden coronary incompetence invoking the dynamics of thermographic examinations before and after loading [7].

We established the functional dependence of circular processes at the periphery on cardiac activity, therefore in diagnosing cardiovascular diseases IT is made not only of the region of heart, but also of limbs. Some authors think that the initial thermoasymmetry and the symptom of the "amputation of phalanges," as well as delay in the reaction to cold [8], are characteristic of atherosclerotic changes of peripheral arteries. For a hypertensive disease an expressed reaction to thermal stimuli and a long time for recovery of the initial thermal picture are typical; the initial thermoasymmetry and "amputation of phalanges," asymmetry of face, and a paradoxical reaction of limbs to a thermal stimulus (vasospasm) [9-11] are characteristic of neurocirculatory dystonia.

Thermography is also used in conducting differential diagnosis of IHD with a number of cardialgias, including the most frequently encountered vertebrogenic cardialgias for which an increase in temperature reaction in the zone of spinous process and paravertebral region is characteristic [12].

Despite numerous publications testifying to great possibilities of the IT method in the diagnosis of a number of diseases of organs and systems and a few communications demonstrating the potential of thermography in cardialogia, many problems connected with the application of IT to patients with cardiovascular diseases require development and refinement.

In light of what has been said, the aim of our work was the study of the possibilities of infrared thermography in evaluating the functional state of myocardium and the creation of a procedure of unified thermographic examination of cardiological patients.

In the course of the work we examined 81 persons aged from 25 to 67. Their assignment to groups with different nosological forms and degrees of circulatory insufficiency is presented in Table 1.

Belarusian Scientific-Research Institute of Cardiology, Ministry of Public Health of Belarus, Minsk, Belarus. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 69, No. 3, pp. 494-499, May-June, 1996. Original article submitted March 20, 1996.

1062-0125/96/6903-0395$15.00

TABLE 1. General Characteristic of Persons Examined by Nosology Forms and Degree of Circulatory Insufficiency (CIn)

Nosology	Degree of CIn				
	In 0	In I	In IIA	In IIB	Total
HD	14	10	10	1	35
IHD	6	13	4	3	26
Pneumonia	11	0	0	0	11

TABLE 2. Characteristic of a Thermographic Picture of a Chest of Healthy People

Characteristic of thermographic picture	Forefront projection $n = 8$		Rear projection $n = 9$	
	abs.	%	abs.	%
Thermoasymmetry is not revealed	5	62.5	8	88.9
Hyperthermia on the left	3	37.5	0	–
Hyperthermia on the right	0	–	1	11.1

TABLE 3. Characteristic of the Thermographic Picture of Upper Limbs of Healthy People

Characteristic of thermographic picture	Hands $n = 5$		Forearms $n = 5$	
	abs.	%	abs.	%
No HTA	0	–	4	80
Hyperthermia on the left	5	100	1	20
Hyperthermia on the right	0	–	0	-
No VTA	5	100		
Hypothermia of hands	0	–		

To develop methodological approaches to the creation of a unified procedure of thermographic examination, we selected patients with the commonest cardiovascular diseases: hypertensive (35 persons) and ischemic (26 persons) heart disease.

To compare results, we selected two control groups: patients with acute focal pneumonia (11 persons) and healthy persons (9).

For developing an IT procedure we selected vascular zones that represent both the projection of a heart on a chest and peripheral zones.

We studied 10 vascular zones: face (frontal projection), chest (front, rear, and two side projections), forearm, hand, crus (front and rear projections), and symmetric surfaces of thighs.

In interpretation of thermograms we evaluated: the presence of thermoasymmetry with determination of vertical (forearm-hand, crus-foot) (VTA) and horizontal (left-right halves) (HTA) temperature gradients, the character of thermoasymmetry (hypo- or hyperthermia), and also the presence of focal thermoasymmetry was noted.

According to the resulting data, the IT of chest at the front of healthy persons (Tables 2 and 3) is characterized by the presence of a small (no more than 1°C) HTA (in 30%), or identical thermal distributions between the left and right halves. The absence of HTA (>85%) or unexpressed HTA, most commonly to the right and on the rear surface of a chest, are typical for healthy people.

The absence of VTA (forearm-hand) and a small excess of HTA (left hand) are also peculiar to healthy people.

The pattern of thermal distribution on the chests of pneumonic patients changes considerably. In the case of localization on the left side, the HTA zone did not have characteristic left-hand manifestations on side projections, or these manifestations were expressed insignificantly (on the front projection).

TABLE 4. Characteristic of Thermographic Picture of a Chest of Pneumonia Patients (left-hand pneumonia – 3 patients/27.3%, right-hand pneumonia – 8 patients/72.7%)

Projection	Characteristic of thermographic picture	Number of persons examined			
		Left-hand		Right-hand	
		abs.	%	abs.	%
Forepart	Thermoasymmetry is not revealed	1	33.3	4	50
	Hyperthermia on the left	2	66.7	2	25
	Hyperthermia on the right	0	–	2	25
Side	Thermoasymmetry is not revealed	3	100	1	12.5
	Hyperthermia on the left	0	–	3	37.5
	Hyperthermia on the right	0	–	4	50
Rear	Thermoasymmetry is not revealed	1	33.3	0	–
	Hyperthermia on the left	0		0	–
	Hyperthermia on the right	2	66.7	8	100

In the case of localization on the right side, the HTA was detected on the right on the rear projection for all of the patients examined, and on the front and side projections for 50% of the patients.

Peripheral IT of hands, forearms, and feet was characterized by the absence of HTA (in 80%) or insignificant left HTA irrespective of the localization of pneumonia and by a more expressed VTA (in 73%).

As a result of thermographic examination of patients suffering from hypertensive disease, we found that even in the presence of signs of circulatory insufficiency of IIA stage the left HTA is detected not in all of the patients examined. On the whole, 37% of patients with hypertensive disease have no HTA of the chest on the front and 60% on the back. Right-side back HTA was noted in 17% of HD patients (Table 5).

The analysis of the IT of limbs shows that often (above 60%) the signs of VTA and HTA are absent in HD patients. Somewhat more expressed changes in a thermographic picture are observed in IHD patients compared to those with HD. A local left-hand HTA of a chest on the front was discovered in 60% of persons examined, where 100% were those with circulatory insufficiency of IIB stage (Table 5).

The IT of chest on the back revealed HTA on the right in 25% of patients and on the left only in 2 patients (16.7%).

Thermographic examination of the chest on the back much more often detected focal hypothermia at the place of vertebral column (in 80% of patients), which is due to the presence in this group of patients of a widespread osteochondrosis supported by both clinical data and results of roentgenologic examination.

Thermographic examination of hands, forearms, and cruses of IHD patients revealed a moderately expressed HTA on the left and VTA also there. Two patients displayed the phenomenon of thermal amputation of a hand, which was connected with the phenomena of obliterating atherosclerosis of the arteries of a left arm.

The results indicate that infrared digital thermography can be classed with the methods of noninvasive distant examination of the state of vascular zones. Though the method is based on very accurate measurements of the absolute values of temperatures, the penetration depth is insufficient for estimating even such relatively localized diseases as acute pneumonias for which the results obtained are ambiguous and often contradictory.

The possibilities for estimating the functional state of a myocardium by the IT method are very limited, since the heart is located rather deep in the chest (for infrared radiation) and is covered by tissues with different heat transmissivities.

Moreover, in many cases (in 60% according to our data) there are accompanying changes (osteochondrosis) that thermographically are brought to the fore and alter the thermographic picture.

TABLE 5. Characteristic of the Thermographic Picture of Patients with HD ($n = 35$) and IHD ($n = 26$)

Projection	Characteristic of thermographic picture	HD Patients							
		In 0 $n = 14$		In I $n = 10$		In IIA $n = 10$		In IIB $n = 1$	
		abs.	%	abs.	%	abs.	%	abs.	%
Chest front	Number of examined	9		9		10		1	
	No thermoasymmetry	5	55.6	4	44.4	4	40	0	–
	Hyperthermia on the left	4	44.4	4	44.4	4	40	1	100
	Hyperthermia on the right	0	–	1	11.2	2	20	0	–
Chest back	Number of examined	10		9		4		1	
	No thermoasymmetry	5	60	7	77.8	7	77.8	0	–
	Hyperthermia on the left	1	10	0	–	0	–	0	–
	Hyperthermia on the right	3	30	2	22.2	2	22.2	1	100
Upper limbs hands	Number of examined	13		8		9		1	
	No HTA	8	61.5	5	62.5	5	55.5	1	100
	Hyperthermia on the left	2	15.4	1	12.5	2	22.2	0	–
	Hyperthermia on the right	3	23.1	2	25	2	22.2	0	–
	No VTA	8	61.5	3	37.5	5	55.6	0	–
	Hyperthermia of hands	5	38.5	5	62.5	4	44.4	1	100
forearms	No HTA	10	76.9	5	62.5	3	33.3	1	100
	Hyperthermia on the left	0	–	2	25	3	33.3	0	–
	Hyperthermia on the right	3	23.1	1	12.5	3	33.3	0	–
Inferior limbs	Number of examined	10		8		8		1	
	No hypothermia of feet	8	80	6	75	6	75	0	–
	Hypothermia of feet	2	20	2	25	2	25	1	100

Projection	Characteristic of thermographic picture	IHD Patients							
		In 0 $n = 5$		In I $n = 13$		In IIA $n = 4$		In IIB $n = 3$	
		abs.	%	abs.	%	abs.	%	abs.	%
Chest front	Number of examined	5		12		4		3	
	No thermoasymmetry	5	100	3	25	1	25	0	–
	Hyperthermia on the left	0	–	9	75	2	50	3	100
	Hyperthermia on the right	0	–	0	–	1	25	0	–
Chest back	Number of examined	5		12		4		3	
	No thermoasymmetry	4	66.7	6	50	2	50	0	
	Hyperthermia on the left	0	–	2	16.7	0	–	0	
	Hyperthermia on the right	2	33.3	4	33.3	2	50	3	100
Upper limbs hands	Number of examined	5		12		4		3	
	No HTA	3	60	5	41.7	3	75	2	66.7
	Hyperthermia on the left	1	20	7		0	–	1	33.3
	Hyperthermia on the right	1	20	0		1	25	0	
	No VTA	2	40	5	41.7	2	50	1	33.3
	Hyperthermia of hands	3	60	7	58.3	2	50	2	66.7
forearms	No HTA	2	40	4	33.3	3	75	2	66.7
	Hyperthermia on the left	2	40	7	58.3	0	–	1	33.3
	Hypethermia on the right	1	20	1	8.4	1	25	0	–
Inferior limbs	Number of examined	1		5		3		3	
	No hypothermia of feet	1	100	4	80	2	66.7	1	33.3
	Hypothermia of feet	0	–	1	20	1	33.3	2	66.7

The estimated data on the state of peripheral blood circulation is of great interest, but here too the possibilities of the IT method for examining the functional state of a myocardium are greatly reduced by frequently encountered additional changes in the form of varicosely altered veins or manifestations of peripheric atherosclerosis.

Thus, the algorithm developed for IT examination (10 vascular zones) and the procedure of the analysis (VTA, HTA, local hypo- and hyperthermia) allow one to study separate vascular zones, to reveal peripheral changes or accompanying diseases.

The possibility of obtaining a reliable documented (the production of a "hard copy") picture of the state of peripheral blood circulation is one of the basic advantages of the thermographic method. The IT-aided detection of accompanying diseases with an identical clinical picture of cardialgias (osteochondroses) will make it possible to decrease the number of roentgenologic examinations for confirming a given pathology.

The evaluation of the functional state of a myocardium by the method of infrared digital thermography presents great difficulties due to ambiguous changes, and can be only tentative.

CONCLUSIONS

1. The developed algorithm of thermographic examination allows one to isolate separate vascular zones and evaluate the state of blood flow in these zones.

2. The thermography method can be used for examining cardiovascular patients as an auxiliary method or even for a tentative estimation, and these results need additional clinical and instrumental confirmation.

3. The most accurate results of IT can be obtained in diagnosis of cardiovascular diseases with expressed peripheral manifestations (varicosis, obliterating atherosclerosis of the arteries of limbs).

4. For estimating the condition of the microcirculatory bed and more accurate determination of the effect of the therapy employed, it is necessary to conduct repeated thermographic examinations in the zones of the hand and forearm where the level of thermoasymmetry is higher, while the accompanying diseases (varicosis, obliterating atherosclerosis) exert a lesser effect on the general picture of heat distribution.

5. The IT method can be used for differential diagnosis of cardialogias (the back of a chest), since it reflects the thermographic picture with changes in the vertebral column (osteochondrosis).

6. The method of digital thermography in the version developed cannot be used for estimating the functional state of a myocardium and pulmonary circulation due to ambiguous interpretation of the results obtained and their great variability; this is associated with a low transmissivity of infrared radiation through a chest, frequent presence of accompanying diseases of a chest and vertebral column, and anatomic aspects of the location of the heart in the chest.

REFERENCES

1. K. A. Morozov, L. G. Vashkevich, V. P. Mel'nikova, et al., Vrachebn. Delo, No. 4, 73-75 (1979).
2. T. A. Savchenko, Zdravookhr. Belarusi, No. 9, 53-55 (1984).
3. N. V. Strizhova, E. P. Zaitseva, and N. M. Gasparyan, Akusher. Ginekol., No. 1, 48-51 (1980).
4. V. I. Amenov, Yu. S. Chernyaev, and S. D. Chernova, Infrared Imaging Method of Examination in Obstetric-Gynecologic Practice, Methodological Recommendations [in Russian], Leningrad (1976).
5. V. P. Varganova, V. F. Sukhanova, and N. M. Zubekhin, Infrared Imaging in Diagnosis of Pulmonory Diseases [in Russian], Leningrad (1989).
6. L. N. Shekhter and L. G. Rozenfel'd, Vestn. Rentgenol. Radiol., No. 1, 70-76 (1987).
7. G. P. Peklina, Vrachebn. Delo, No. 11, 71-78 (1986).
8. A. L. Parygin and O. A. Mirolyubova, Abstracts of papers submitted to the All-Union conference "Infrared Imaging Medicinal Apparatuses and Practice of Its Application," Frunze (1985), p. 213.
9. I. S. Zozulya and D. D. Fedotov, Vrachebn. Delo, No. 12, 66-69 (1984).
10. I. P. Korolyuk, V. N. Fatenkov, N. M. Kurlichenko, and E. I. Galkina, Klinichesk. Meditsina, No. 7, 33-36 (1980).
11. A. D. Solov'yova, O. A. Kolosova, M. M. Loseva, et al., Zh. Nevrol. Psikhiatr., No. 6, 905-910 (1985).
12. V. A. Karlov, I. D. Stulin, and V. I. Shmyryov, Meditsin. Tekhn., No. 4, 47-49 (1980).