

Use of thermography in clinical allergy

Chintana S. Phipatanakul, M.D., and Raymond G. Slavin, M.D.
St. Louis, Mo.

Thermography was used in evaluating: (1) immediate skin reactions in darkly pigmented skin; (2) altered vascularity in atopic dermatitis; and (3) nasal response to ragweed challenge. In detecting immediate skin reactions, thermography had great usefulness in dark-skinned patients in whom clinical evaluation was difficult. Under controlled environmental conditions, atopic individuals with and without atopic dermatitis demonstrated a tendency to increased skin temperatures at areas of predilection for atopic dermatitis as compared to nonatopic persons. Changes in the nasal region with simultaneous changes in the region of the paranasal sinuses were recorded thermographically following ragweed challenge in ragweed-sensitive subjects. Thermograms remained abnormal after the physical examination had returned to normal. The results of this study indicate that thermography can be useful in clinical allergy.

Thermography, an infrared imaging of skin surface temperatures, has had wide medical application in recent years. The technique is felt to have value in many situations including detection of carcinoma, vascular occlusion, placenta localization, and inflammatory joint disease.¹ Our interests in applying thermography to the field of clinical allergy have been in evaluation of immediate skin reactions in dark-skinned patients, abnormal vascularity in atopic dermatitis, and nasal responses to antigen challenge.

Interpretation of immediate skin reactivity in patients with dark skin is a problem, as the reaction manifested by wheal and erythema is difficult to visualize. Occasionally, the wheal can be felt but erythema cannot be seen. For this reason, the use of thermography as an aid in interpretation of the skin test was attempted.

Individuals with atopic dermatitis exhibit alteration in the reactivity of cutaneous vessels which is suggested by the frequent occurrence of white dermographism, delayed blanching following intradermal injection of acetylcholine or Mecholyl or the topical application of nicotinic acid esters, and occasional absence of flare in the histamine skin test. Temperature recordings in patients with atopic dermatitis at areas of predilection demonstrated less than normal vasoconstriction in a cold environment and more rapid vasodilation in a warm environment.² An objective of our study was to assess the vascular reactivity at areas of predilection under normal environmental conditions.

The third approach to the clinical use of thermography was in evaluating changes in the nasal region in response to antigen challenge with attention to the simultaneous changes in the region of the paranasal sinuses.

From the Section of Allergy and Immunology, Department of Internal Medicine, St. Louis University School of Medicine.

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Reprint requests to: Dr. Slavin, Department of Internal Medicine, St. Louis University School of Medicine, 1402 South Grand Blvd., St. Louis, Mo. 63104.

PRINCIPLES OF THERMOGRAPHY

Thermography is a form of radiography portraying body surface temperatures, and thermograms are photographic reproductions of infrared rays spontaneously emanating from the body. The instrument used works according to a scanning principle with the use of the normally occurring infrared emission from the body in the spectral region of 3 to 20 μ , with the maximum at about 10 μ . Although these wave lengths are invisible, they may be collected optically and the optic signal is transformed into an electronic impulse. This is amplified and modified to give a picture on an oscilloscope screen, which is recorded photographically. The thermograms obtained are composed of various shades, the lighter indicating the hotter areas and the darker the colder regions of the body's surface. Evaluation of different emission levels on the thermal map of the patient's surface temperatures can be done by using the thermoprofile technique³ or the densitometer.⁴

Hardy⁵ concluded from extensive studies that the human skin behaved like a black body. While skin pigmentation plays a major role in emissivity in the visible spectrum, it does not exert any influence in the infrared regions. Thus, meaningful skin temperature measurements may readily be made in this region regardless of race.⁶

Thermography must not be confused with infrared photography, which requires that the subject first be illumined with an extraneous source. Infrared photographs can be taken with an ordinary camera equipped with film sensitive to rays at the red end of the spectrum and a filter to eliminate visible light. Thermograms, on the other hand, can be taken in total darkness, and the subject needs no illumination.

MATERIALS AND METHODS

The Barnes medical thermograph and densitometer* were used throughout the studies. Briefly, the technique consisted of exposing the test areas to the mirror of the thermograph machine. This gave a picture on a screen which could be recorded photographically.

The thermogram photographs were evaluated with the use of the densitometer. This is a device which measures the relative temperature differences in test areas. The differences were recorded between darker areas (colder regions) and lighter areas (hotter regions).

Immediate skin reactivity

Nineteen subjects were studied for immediate skin reactivity. They were divided into 3 groups. Group 1 consisted of 5 nonatopic Caucasian subjects tested with histamine phosphate intradermally at various concentrations. Group 2 consisted of 4 atopic Caucasian patients tested with the prick method to specific allergens. Group 3 consisted of 10 atopic Negro patients tested with the prick method to specific allergens.

The procedure was done in an air-conditioned room. The back was unclothed and exposed to an ambient temperature of 21.1 to 22.2° C. (70 to 72° F.) for 10 to 15 minutes. This period of exposure permits the skin temperature to come into equilibrium with the environment and tends to maximize the display of temperature differences. Subjects were seated with the exposed back facing the Barnes medical thermograph. The back was scanned for about 10 to 15 minutes until a homogeneous background on the oscilloscope screen was obtained. The test materials were then applied on the back and the response read in 15

*Barnes Engineering Company, Stamford, Conn.

TABLE I. Criteria used for reading skin tests

Reaction	Symbol	Criteria
Prick tests		
Negative	—	No reaction
Plus-minus	±	Mild erythema
One plus	1+	Erythema smaller than 10 mm. in diameter
Two plus	2+	Erythema larger than 10 mm. in diameter
Three plus	3+	Erythema larger than 10 mm. in diameter plus wheal larger than 10 mm. in diameter
Four plus	4+	Erythema larger than 10 mm. and wheal with pseudopods
Intradermal tests		
Negative	—	No reaction
Plus-minus	±	3-5 mm. wheal without erythema
One plus	1+	3-5 mm. wheal with erythema
Two plus	2+	5-10 mm. wheal with erythema
Three plus	3+	Over 10 mm. wheal and erythema without pseudopods
Four plus	4+	Over 10 mm. wheal and erythema with pseudopods

minutes (Table I). At the same time thermograms were taken in all subjects. They were available for study 20 seconds after the scan was completed using Polaroid film. Measurement of the temperature difference at test sites and surrounding normal skin beyond the area of wheal and erythema was done by using the densitometer. Black and white photographs were taken after 15 minutes in 7 Negro patients and compared with thermograms taken at the same time.

Atopic dermatitis

Thirty-two subjects were studied for vascularity in areas of predilection for atopic dermatitis. They were divided into 3 groups. Group 1, a control group, consisted of 6 normal subjects, 1 male and 5 females aged 4 to 41 years. They had no personal history of atopy (hay fever, asthma, hives, or eczema). Group 2 consisted of 11 atopic subjects without atopic dermatitis. There were 5 males and 6 females aged 3 to 34 years. Group 3 consisted of 15 patients with atopic dermatitis; 7 were males and 8 were females aged 2 to 18 years; 7 had active atopic dermatitis, 4 had healed atopic dermatitis with normal-appearing skin, and 4 had healed atopic dermatitis with dry, lichenified skin.

The procedure was performed in the same way as in recording results of skin testing. Areas of predilection (neck, antecubital fossa, and politeal fossae) were exposed to the thermograph, and thermograms were taken. Temperature difference between areas of predilection and surrounding normal skin was measured with the densitometer.

Nasal challenge

Six ragweed-sensitive subjects were studied by use of nasal challenge with antigen. All tests were performed outside of the ragweed pollination season, and no subjects were primed by repeated exposures. Subjects were seated facing the thermograph. After the base-line

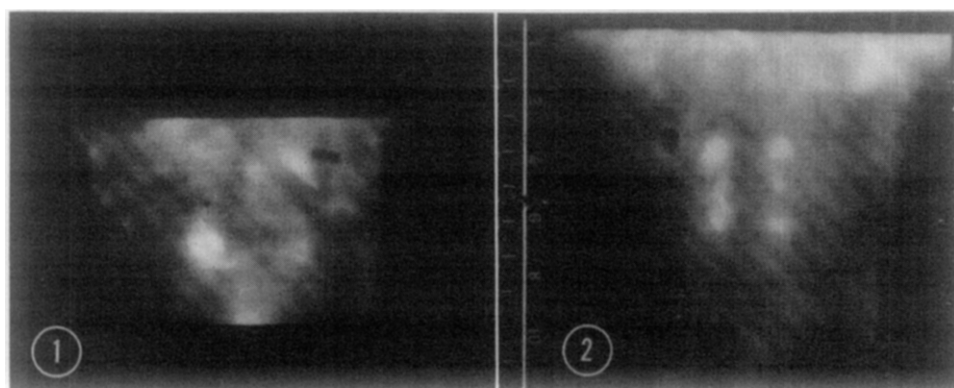


FIG. 1. Histamine phosphate skin reaction in Patient A. A. The dark spots on the right upper and left lower are due to the placement of paper clips as markers. The top left and middle right skin tests while both read as negative, recorded temperature differences on the densitometer.

FIG. 2. White skin reaction to allergens in Patient J. P. The dark spots are due to the placement of coins as markers.

TABLE II. Histamine skin reactions

No.	Patient	Concentration of histamine		Skin reactions by clinical evaluation		Infrared temperature ($^{\circ}$ C.) difference (ΔT) between test reaction and surrounding normal skin	
		Left	Right	Left	Right	Left	Right
1	D. K.	1:270,000	1: 30,000	1+	1+	+2.64	+3.12
		C*	1:810,000	-	1+	0	+1.32
		1: 10,000	1: 90,000	3+	1+	+4.08	+0.84
2	A. A.	1:270,000	1: 30,000	-	2+	+0.60	+2.76
		C	1:810,000	-	-	0	+0.24
		1: 10,000	1: 90,000	3+	1+	+3.60	+1.32
3	J. M.	1:270,000	1: 30,000	-	$\pm$	+0.96	+1.32
		C	1:810,000	-	-	0	0
		1: 10,000	1: 90,000	3+	-	+2.76	-0.24
4	A. L.	1:270,000	1: 1,000	-	4+	0	+3.12
		C	1:810,000	-	-	0	+0.36
		1: 10,000	1: 90,000	2+	-	+0.24	-0.12
5	L. A.	1:270,000	1: 1,000	$\pm$	4+	+0.12	+3.36
		C	1:810,000	-	-	0	+0.36
		1: 10,000	1: 90,000	3+	-	+1.92	+0.12

*Control (sterile phosphate-buffered saline).

thermograms were taken, 0.5 ml. of 1:100 mixed aqueous ragweed pollen extract* was atomized into each nasal cavity with a DeVilbiss No. 15 hand atomizer. The subjects were instructed to maneuver their heads as needed to retain the solution in the nose. Symptoms, appearance of turbinates, and thermograms were recorded every 5 to 10 minutes for 30 minutes.

*Hollister-Stier Laboratory, Downers Grove, Ill.

TABLE III. Allergens skin reaction in white skin

No.	Patient	Antigens		Skin reactions by clinical evaluation		Infrared temperature ($^{\circ}$ C.) difference (ΔT) between test reaction and surrounding normal skin	
		Left	Right	Left	Right	Left	Right
1	J. P.	Alternaria	Birch	3+	4+	+1.62	+2.04
		Timothy	House dust	2+	2+	+1.14	+0.90
		Ash	Western-water hemp	3+	3+	+1.26	+1.62
2	J. C.	Alternaria	June grass	-	4+	+0.72	+3.36
		Timothy	Pigweed	4+	-	+2.28	+0.12
		Lamb's quarter	Kochia	2+	-	+0.96	0
3	B. N.	Giant ragweed	Birch	4+	1+	+4.44	+2.28
		Cottonwood	Short ragweed	2+	4+	+2.40	+3.24
		Western-water hemp	Oak	-	1+	+0.72	+0.96
4	P. W.	Sycamore	Oak	3+	3+	+2.28	+1.20
		Giant ragweed	Short ragweed	4+	4+	+2.64	+2.28
		Maple	Ash	3+	3+	+2.04	+1.20

RESULTS

Immediate skin reactivity

Group 1: Histamine phosphate response (Table II): There was general agreement between the temperature differences recorded and the skin reactions by clinical evaluation. The densitometer was capable of discriminating a temperature difference between the test reaction site and surrounding skin of as little as 0.01° C. It is interesting to note that temperature differences were recorded in some test areas which showed no reaction on clinical evaluation (Fig. 1). The negative responses in Patients J. M. and A. L. at a concentration of 1:90,000 may be explained in part by the possibility of underlying cooler skin background or other factors such as technical interference.

Group 2: Allergen skin reactions in white skin (Table III). There was accord between the clinical evaluations and the emission differences at the test sites in white skin. Again, temperature differences existed in the test areas presenting with the same degree of clinical reactions (Fig. 2). Among these 4 patients, 4+ skin reactions varied in a temperature difference range from 2.04 to 4.44° C. with a mean of 2.90° C.; 3+ reactions', temperature difference ranged from 1.20 to 2.28° C. with a mean of 1.60° C.; and 2+ reactions', temperature difference ranged from 0.90 to 1.14° C. with a mean of 1.00° C. In Subject J. C., the negative skin reactions varied in a temperature difference range from 0 to 0.72° C. This indicates the sensitivity of the thermograph in recording minor temperature elevations.

Group 3: Allergen skin reaction in dark skin (Table IV). Clinical evaluation was done on the basis of estimated areas of wheal and erythema, although

TABLE IV. Allergens skin reactions in dark skin

No.	Patient	Antigens		Skin reactions by clinical evaluation		Infrared temperature ($^{\circ}$ C.) difference (ΔT) between test reaction and surrounding normal skin	
		Left	Right	Left	Right	Left	Right
1	J. G.	May fly Flaxseed	Aspergillus House dust Fusarium	4+ 2+	3+ 2+ -	+2.88 +2.16	+2.48 +1.68 +0.08
2	M. H.	Alternaria Fusarium Hormodendrum	Phoma Short ragweed	1+ - 1+	- 1+	+0.88 +0.24 +0.72	+0.08 +0.40
3	G. C.	Giant ragweed Sycamore Short ragweed	Honeybee Tragacanth	3+ 1+ 4+	1+ - -	+2.08 0 +2.48	+0.16 +0.08
4	R. R.	Giant ragweed May fly House dust	Pigweed House fly Short ragweed	4+ 4+ 1+	- 4+ 3+	+2.32 +2.40 0	0 +2.16 +0.96
5	A. R.	Giant ragweed May fly Birch	Short ragweed Sycamore Aspergillus- Fumigatus	3+ - -	3+ - 1+	+1.20 +0.64 +0.40	+1.84 +0.80 +0.88
6	D. V.	May fly Ash	House fly Alternaria	4+ +	4+ 1+	+2.00 +0.40	+1.76 +0.24
7	V. W.	Short ragweed Honeybee Pyrethrum	Russian thistle Annual sage Lamb's quarter	2+ 2+ 2+	- 2+ ±	+1.68 +1.20 +1.04	0 +0.96 0
8	L. B.	May fly Mosquito Honeybee	House fly Ant pupa	4+ 3+ 2+	2+ 1+	+2.88 +2.64 +1.44	+1.44 +0.08
9	R. B.	May fly Orris root Maple	Short ragweed Ash Phoma	2+ 1+ 2+	1+ - -	+0.64 +0.24 +0.24	+0.40 +0.40 +0.16
10	C. J.	May fly House dust House fly	Ant pupa Honeybee Mosquito	4+ 4+ 3+	3+ 3+ 2+	+2.48 +2.48 +2.24	+2.48 +2.48 +1.68

this was difficult to determine (Fig. 3). Temperature difference of 4+ reactions ranged from 1.76 to 2.28° C. with a mean of 2.38° C.; temperature difference of 3+ reactions ranged from 0.96 to 2.64° C. with a mean of 2.04° C.; temperature difference of 2+ reactions ranged from 0.24 to 2.16° C. with a mean of 1.29° C. The small temperature difference recorded between 4+ and 3+ reactions was probably due to the difficulty in evaluating the skin reactions clinically. Temperature differences of negative skin reactions ranged from 0 to 0.80° C.

Atopic dermatitis

Temperature differences between areas of predilection and surrounding skin in patients with atopic dermatitis, as compared to normal and control atopic subjects, are shown in Tables V, VI, and VII. In Group 1, the normal control group (Table V), the mean temperature difference was 0.48° C. at the neck,

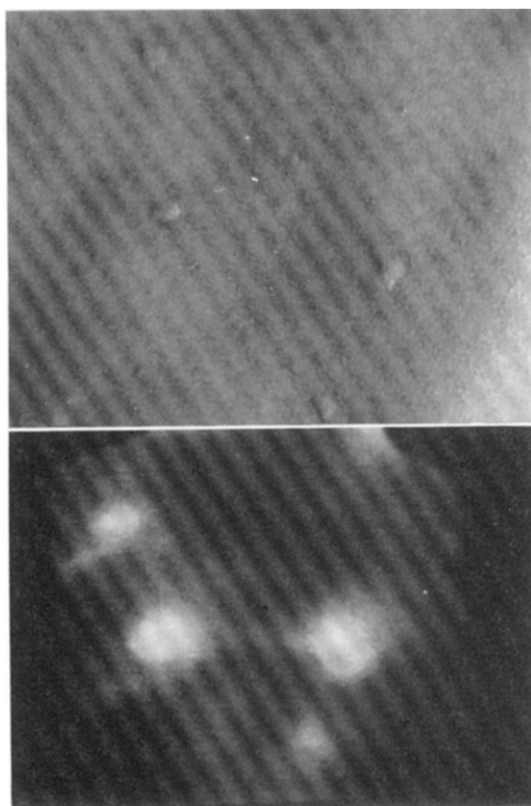


FIG. 3. Duplicate dark skin reactions to allergens in Patient R. R. **Top**, Ordinary photograph of skin test reactions in dark-skinned patient. **Bottom**, Thermogram of same skin test reaction. Visual inspection revealed wheals but not erythema. The infrared emission over those wheals varied. A difference of 1.44° C. was recorded.

0.99° C. at the left antecubital fossa, 1.28° C. at the left popliteal fossa, and 1.25° C. at the right popliteal fossa. In Group 2, the atopic group without atopic dermatitis (Table VI), the mean temperature difference was 0.93° C. at the neck, 1.15° C. at the left antecubital fossa, 1.44° C. at the left popliteal fossa, and 1.43° C. at the right popliteal fossa. In Group 3, the atopic dermatitis group (Table VII), the mean temperature difference was 1.99° C. at the neck, 2.18° C. at the left antecubital fossa, 2.55° C. at the left popliteal fossa, and 2.67° C. at the right popliteal fossa in active atopic dermatitis subgroup. In the healed normal skin and healed lichenified atopic dermatitis subgroups, the respective mean temperature differences were 1.76 and 1.32° C. at the neck, 1.67 and 2.17° C. at the left antecubital fossa, 1.72 and 1.88° C. at the left popliteal fossa, and 1.40 and 1.78° C. at the right popliteal fossa. The mean temperature differences are summarized in Table VIII. In general, there was a trend toward an increase in skin temperature at areas of predilection in both active and healed atopic dermatitis and in atopic subjects as compared to normal individuals (Fig. 4).

TABLE V. Normal subjects

No.	Patient	Sex	Age	ΔT between neck and surrounding skin	ΔT between antecubital fossa and surrounding normal skin	ΔT between popliteal fossae and surrounding skin	
						Left	Right
1	R. S.	Male	41	0.56	0.16	0.32	0.64
2	J. W.	Female	29	0.40	0.88	1.12	0.96
3	M. G.	Female	40	0.72	1.32	1.08	0.60
4	M. M.	Female	25	0.72	1.20	1.80	1.80
5	M. B.	Female	27	0.12	1.80	1.92	1.80
6	K. C.	Female	4	0.36	0.60	1.44	1.68
Mean				0.48	0.99	1.28	1.25

TABLE VI. Atopic subjects without atopic dermatitis

No.	Patient	Sex	Age	ΔT between neck and surrounding skin	ΔT between antecubital fossa and surrounding normal skin	ΔT between popliteal fossae and surrounding skin	
						Left	Right
1	C. D.	Male	25	0.84	1.20	2.16	1.92
2	C. P.	Female	30	0.80	1.44	1.20	1.32
3	J. L.	Male	24	1.20	0.36	1.44	0.84
4	B. J.	Female	18	0.72	1.32	1.32	1.08
5	P. F.	Female	26	1.20	0.72	0.72	1.32
6	T. M.	Male	24	1.44	1.44	1.80	1.44
7	G. K.	Female	3	0.12	1.20	1.08	1.08
8	G. N.	Male	23	0.84	1.56	0.96	0.72
9	D. T.	Female	14	1.08	1.08	1.80	1.92
10	M. T.	Female	34	1.08	0.96	1.56	1.68
11	R. S.	Male	22	0.96	1.32	2.40	2.40
Mean				0.93	1.15	1.49	1.43

Nasal challenge

There was only slight variability among subjects in respect to the severity of symptoms, appearance of turbinates, and thermograms following the nasal challenge (Table IX). Immediately after exposure, sneezing and lacrimation began, but the turbinates appeared normal. In 3 minutes some edema of the nasal turbinates was evident, and by 5 to 10 minutes this was maximal. Changes of nasal mucosa, ethmoidal sinus areas, and maxillary sinus areas were reflected as areas of increased surface temperature on the thermograms of all 6 test subjects. Symptoms, appearance of turbinates, and thermograms correlated well except that changes in the thermogram seemed to last longer and could still be detected even though nasal symptoms were minimal and appearance of the turbinates had returned to normal (Fig. 5).

DISCUSSION

There have been several reports in which thermography has been used in the general study of skin reactivity. Thermographic studies of the depth and degree of burns and frostbite injuries^{7, 8} and wound healing⁹ have been carried out. Bränemark and associates¹⁰ used thermography for evaluation of patch

TABLE VII. Atopic dermatitis group

Subgroup	No.	Patient	Sex	Age	ΔT of neck with sur- rounding skin	ΔT of ante- cubital fossa with sur- rounding skin	ΔT of popliteal fossae with surrounding skin	
							Left	Right
Active dermatitis	1	D. A.	Female	18	3.60	3.20	3.52	3.60
	2	C. B.*	Female	4	—	—	3.48	3.60
	3	G. M.	Male	4	2.04	3.00	2.76	2.28
	4	S. T.	Male	7	2.00	1.60	2.00	3.44
	5	K. S.	Male	7	2.52	—	2.16	2.40
	6	K. H.	Female	10	1.20	2.04	1.56	1.08
	7	L. S.	Female	2	0.60	1.08	2.40	2.28
Mean					1.99	2.18	2.55	2.67
Healed normal skin	1	C. G.	Female	8	2.52	1.32	1.80	1.92
	2	T. L.	Male	7	2.00	2.48	2.56	2.22
	3	D. H.	Female	2	0.60	1.08	0.96	0.60
	4	D. T.	Male	7	1.92	1.80	1.56	0.84
Mean					1.76	1.67	1.72	1.40
Healed dry skin	1	S. M.	Male	4	1.20	2.52	2.88	3.00
	2	L. N.	Female	20	1.92	2.80	2.00	1.60
	3	D. K.	Male	7	1.56	—	2.28	2.16
	4	M. O.	Female	14	0.72	1.32	0.36	0.36
	5	C. B.*	Female	4	1.20	2.04		
Mean					1.32	2.17	1.88	1.78

*Acute dermatitis only at popliteal fossae; other areas were healed dry skin.

TABLE VIII. Mean temperature difference (ΔT)

Group	No. cases	Neck	Antecubital fossa	Popliteal fossae	
				Left	Right
1 Normal	6	0.48	0.99	1.28	1.25
2 Atopic	11	0.93*	1.15†	1.49†	1.43†
3 Atopic dermatitis subgroups					
1. Active dermatitis	7‡	1.99§	2.18	2.55¶	2.67§
2. Healed normal skin	4	1.76¶	1.67**	1.72††	1.40‡‡
3. Healed dry lichenified skin	5	1.32‡	2.17*	1.88††	1.78§§

*p < 0.02, Significant.

†p < 0.50, Not significant.

‡ One patient in this subgroup was also included in Subgroup 3.

§p < 0.005, Significant.

||p < 0.050, Significant.

¶p < 0.01, Significant.

**p < 0.20, Not significant.

††p < 0.30, Not significant.

‡‡p < 0.80, Not significant.

§§p < 0.40, Not significant.

test and tuberculin reactions. Kaufman and Sulzberger¹¹ used infrared thermometry for evaluating immediate skin reactions in darkly pigmented subjects. Their method involved direct measurement of skin temperatures on tested areas. Our technique of infrared thermography has the advantage over infrared

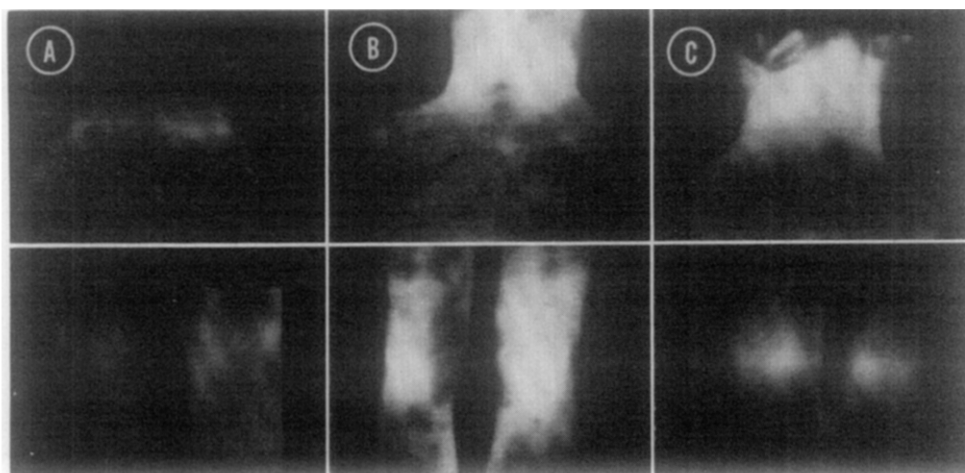


FIG. 4. Top 3 pictures, posterior neck; bottom 3 pictures, popliteal fossae. **A**, Normal subject. **B**, Active dermatitis showing markedly increased heat in neck and popliteal fossae. **C**, Healed inactive dermatitis showing increased heat in neck and popliteal fossae.

TABLE IX. Nasal findings following insufflation of ragweed pollen extract in sensitive subjects

Time (min.)	Symptoms	Appearance of turbinates
Immediate	Lacrimation and sneezing	Normal
3	Rhinorrhea and stuffy nose	Mildly swollen, clear discharge
5	Prominent	Markedly swollen, copious discharge
10	Less prominent	Swollen, less secretion
15	Less prominent	Less swollen
20	Less prominent	Normal
30	Very little	Normal

thermometry of providing pictorial recordings which can be qualitatively read with the naked eye or quantitatively assessed with the densitometer. Moreover, the instrument is sensitive in detecting small differences in temperature in reactions which give the same gross appearance. It is clear that thermography has clinical usefulness for reading immediate skin reactions in dark-skinned patients in whom clinical evaluation is exceedingly difficult.

Altered vascular reactivity in patients with atopic dermatitis is well known.^{2, 12, 13, 15, 16} Observations have been based on changes in skin color and temperature in response to pharmacologic agents or an altered environment. Temperatures of the antecubital and popliteal fossae in patients with atopic dermatitis or with atopy other than dermatitis (namely, bronchial asthma, hay fever, and urticaria) have demonstrated less than normal vasoconstriction in a cold environment and more rapid vasodilation in a warm environment.² In our study, under normal environmental conditions atopic individuals had a tendency toward increased temperature recordings at areas of predilection over the normal control population. As can be seen from Table VIII, certain



FIG. 5. Left, control; middle, 5 minutes; right, 30 minutes. Nasal mucosa response to ragweed challenge in Patient T. M. In 5 minutes the nasal mucosa and surrounding paranasal sinus areas showed markedly increased heat. Changes remained on the thermogram for 30 minutes.

differences were not statistically significant. Areas of predilection in normal subjects were warmer than the surrounding skin. This may explain why these areas are involved more in atopic dermatitis. It is interesting to note that individuals with atopic dermatitis demonstrated increased temperature at areas of predilection even though the gross appearance of the skin was normal. This would suggest that increased vascular reactivity persisted even in the absence of dermatitis. The periods that these areas had remained free from dermatitis varied from months to several years.

In nasal challenge with antigen, thermography detected changes in the nasal mucosa and paranasal sinus mucosa reflected as areas of increased surface temperature. Changes were detected in the maxillary and ethmoidal sinuses but not the frontal sinuses, probably because of the ease with which the insufflated antigen entered the former. It is clear that thermographic changes remained despite the normal appearance of the nasal turbinates. We were also able to detect changes in the paranasal sinuses which cannot be detected on physical examination. The paranasal sinus mucosa is an anatomic continuation of the nasal mucosa and would be expected to respond to antigen challenge in the same fashion as the nasal mucosa. This was demonstrated thermographically.

Thermography appears applicable to several areas of clinical allergy. The instrument is easy to operate and requires little technical skill. It is sensitive and is able to detect such subtle changes as slight alterations in temperature of the skin or underlying structures, such as the sinuses.

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