JCI The Journal of Clinical Investigation

CUTANEOUS RESPIRATION IN MAN: *V. The Rate of Carbon Dioxide Elimination and Oxygen Absorption in Subjects with Diseases of the Skin*

A. Carlton Ernstene, Marie C. Volk

J Clin Invest. 1932;11(2):377-382. https://doi.org/10.1172/JCI100419.

CUTANEOUS RESPIRATION IN MAN

V. The Rate of Carbon Dioxide Elimination and Oxygen Absorption in Subjects with Diseases of the Skin [1]

By A. CARLTON ERNSTENE and MARIE C. VOLK

(From the Medical Research Laboratories, Beth Israel Hospital, and the Department of Medicine, Harvard Medical School, Boston)

(Received for publication October 19, 1931)

A suitable method for measuring the rate of cutaneous respiration in man has been developed by Shaw and his associates (1, 2), and normal standards for carbon dioxide elimination and oxygen absorption have been established (3). The present communication deals with an investigation of the rate of cutaneous exchange of carbon dioxide and oxygen in subjects with various pathologic conditions of the skin.

METHOD OF STUDY

The apparatus and technical procedure were the same as those employed in preceding studies on the rate of cutaneous respiration in normal individuals (2, 3). In brief, the total amounts of carbon dioxide eliminated and oxygen absorbed through the skin of the entire arm in a period of three hours were measured, and the results were expressed in terms of cubic centimeters per hour per square meter of skin surface. The relative humidity of the air in the plethysmograph enclosing the arm was kept at the saturation point by means of a moist woolen stocking worn on the arm. The temperature of the air in contact with the skin varied between 26° C. and 31° C. in different experiments but was maintained practically constant during individual experiments by regulating the temperature of the room. All measurements were made with the room temperature between 20° C. and 25° C. In order to compare the results in patients with skin diseases with the rate of cutaneous respiration in normal subjects, all final quantities were transposed by interpolation to the value they would have had if the temperature of the air in the plethysmograph had been 27° C. The manner of making this correction has been described previously (3).

RESULTS

The rate of cutaneous respiration was measured on three or more occasions in twelve subjects with pathologic conditions of the skin, the

[1] This investigation was aided by a grant from the DeLamar Mobile Research Fund of Harvard University.

observations on each individual being made on successive days whenever possible. Only patients presenting diffuse lesions involving a large part of the upper extremity were selected for the experiments. Five subjects had psoriasis, two had eczema, and one each had erythema multiforme, dermatitis venenata, scleroderma, exfoliative dermatitis, and seborrheic dermatitis. In two patients with psoriasis, additional measurements of the rate of cutaneous respiration were made after the lesions had disappeared. A summary of the observations is presented in Tables 1 and 2.

In general, the rate of cutaneous respiration tended to be somewhat elevated. In only one subject was the rate of carbon dioxide elimination lower than 130 cc. per hour per square meter of skin surface, while in 25 of 38 normal individuals the rate was less than 130 cc. per hour (3). In 6 of the 12 patients with skin disease the rate of carbon dioxide elimination was 150 cc. per hour per square meter of skin surface or higher, while a rate of 150 cc. or more was recorded in only two normal subjects. In three patients with skin disease the rate of carbon dioxide elimination was higher than in any of the normal subjects. The rate of carbon dioxide excretion tended to vary directly with the severity of the pathologic process, the two highest rates being observed in the two patients presenting the most diffuse lesions and the greatest degree of accompanying inflammation. The average rate of carbon dioxide elimination for the entire group of patients with skin disease was 162 cc. per hour per square meter of skin surface, as compared with an average rate of 120 cc. in normal subjects.

The effect of pathologic conditions of the skin on the rate of oxygen absorption was somewhat less evident than the effect on carbon dioxide elimination. In 8 of the 12 subjects the rate of oxygen absorption was 100 cc. or more per hour per square meter of skin surface, while rates of this magnitude were recorded in only 12 of 38 normal subjects (3). In only one patient with skin disease, however, was the rate of oxygen absorption higher than observed in any normal subject. The relationship between the rate of oxygen absorption and the severity of the pathologic process was less apparent than in the case of carbon dioxide elimination. The average rate of oxygen absorption in the patients with skin disease was 110 cc. per hour per square meter of skin surface, as compared with an average of 88 cc. in normal subjects.

A tendency toward slightly elevated values for the respiratory quotient of cutaneous respiration was noted in the patients with pathologic conditions of the skin. In 5 of the 12 subjects the respiratory quotient was 1.6 or higher, while values of this magnitude were recorded in only 9 of 38 normal individuals (3). In only one patient with skin disease, however, was the respiratory quotient higher than the highest observed normal value. The average value for respiratory quotient in the patients with skin disease was 1.5 as compared with an average value of 1.4 in normal individuals.

TABLE 1

The rate of cutaneous respiration in subjects with pathologic conditions of the skin

Subject	Sex	Age	Diagnosis	CO_2 excreted*	O_2 absorbed*	Respiratory quotient	Temperature in plethysmograph		
							Experiment 1	Experiment 2	Experiment 3
		years		*cc.*	*cc.*		° *C.*	° *C.*	° *C.*
39..	M	14	Seborrheic dermatitis, severe	266	192	1.4	29.8	26.6	29.2
40..	M	40	Exfoliative dermatitis	225	107	2.1	27.3	28.8	28.2
41..	F	30	Psoriasis, moderately severe	179	139	1.3	29.2	29.8	29.6
42..	M	58	Dermatitis venenata, moderately severe	165	100	1.7	27.4	27.2	28.6
43..	M	32	Psoriasis, severe	157	90	1.7	30.0	28.8	27.3
44..	F	18	Eczema, mild	150	123	1.2	26.7	27.2	27.2
45..	F	42	Scleroderma, moderately advanced	147	119	1.2	28.0	26.7	30.6
46..	F	15	Eczema, moderately severe	137	106	1.3	29.0	26.0	27.4
47..	F	29	Psoriasis, moderately severe	134	83	1.6	27.7	29.4	29.0
48..	F	49	Psoriasis, mild	134	87	1.5	29.6	29.2	30.1
49..	F	32	Erythema multiforme, subsiding	132	70	1.9	31.0	28.4	28.8
50..	F	42	Psoriasis, mild	118	101	1.3	26.2	28.0	29.3
Average.....				162	110	1.5			

* Calculated in cubic centimeters per hour per square meter of skin surface at 27° C. Each figure for carbon dioxide elimination and oxygen absorption represents the corrected average rate.

TABLE 2

The rate of cutaneous respiration before and after the disappearance of skin lesions

Subject	Diagnosis	CO_2 excreted*		O_2 absorbed*		Respiratory quotient	
		Before	After	Before	After	Before	After
		cc.	*cc.*	*cc.*	*cc.*		
43...	Psoriasis, severe	157	131	90	81	1.8	1.6
47...	Psoriasis, moderately severe	134	134	83	93	1.6	1.4

* Calculated in cubic centimeters per hour per square meter of skin surface at 27° C. Each figure for carbon dioxide elimination and oxygen absorption represents the corrected average rate.

The temperature in the plethysmograph during the measurements made before disappearance of the skin lesions is given in Table 1. The temperature in the plethysmograph during the measurements made after the disappearance of the lesions was as follows: subject 43, first experiment 28.1° C., second experiment 29.3° C.; Subject 47, first experiment 26.0° C., second experiment 28.5° C.

In the two patients with psoriasis in whom further measurements of the rate of cutaneous respiration were made after the lesions had disappeared, no striking changes were observed (Table 2).

DISCUSSION

Cutaneous respiration is the result of two distinct processes: (1) the metabolism of the skin, and (2) the passage of carbon dioxide out of the blood by diffusion through the skin (1, 4). In contrast to the dual origin of the carbon dioxide eliminated through the skin, all of the oxygen absorbed by the skin probably is utilized in tissue oxidation (4).

The rate at which the skin absorbs oxygen from the air is influenced not only by the metabolic rate of the skin but also by the oxygen tension of the air and of the blood (4). With a constant oxygen tension of the air, the rate of oxygen absorption is increased by an increase in the metabolic rate of the skin or by a decrease in the oxygen tension of the blood. In individuals with widespread lesions of the skin and accompanying inflammatory changes, a diminished oxygen tension of the blood would hardly be expected. The tendency toward an increased rate of oxygen absorption in these subjects probably is due, therefore, to an increase in the metabolic rate of the skin.

Increased cutaneous elimination of carbon dioxide may be due to an increase in the metabolic rate of the skin or to an increase in the amount of carbon dioxide escaping from the blood by diffusion through the skin. An increase in the amount of carbon dioxide escaping from the blood by diffusion through the skin is dependent on an increase in the carbon dioxide tension of the blood. Since, in individuals with skin disease, there is no apparent cause for an appreciable increase in the carbon dioxide tension of the blood, the increased rate of carbon dioxide elimination in these subjects is probably due to an increase in the metabolic rate of the skin.

The tendency toward elevation of the respiratory quotient of cutaneous gas exchange in subjects with pathologic conditions of the skin could be the result of an actual qualitative change in skin metabolism. On the other hand, if cutaneous metabolism remained qualitatively constant but increased in rate, the respiratory quotient would be elevated in the event that a larger part of the excess carbon dioxide were eliminated through the skin than by way of the blood. That such an occurrence is possible is indicated by the following considerations. The carbon dioxide tension of the air is practically zero, and the difference between this tension and the carbon dioxide tension of the skin is much greater than the difference between the carbon dioxide tension of the blood and of the skin (4). It is probable, therefore, that practically all of the carbon dioxide formed in the superficial layers of the skin is excreted directly into the air and that, of the carbon dioxide formed in the deeper layers, a larger part

is eliminated by excretion through the skin than by way of the blood stream. Similarly, in the event of increased production of carbon dioxide, all of this gas formed in the superficial layers of the skin would still be excreted directly into the air and a proportionately larger part of the excess formed in the deeper layers of the skin probably would be eliminated by cutaneous excretion. It is commonly assumed, furthermore, that carbon dioxide diffuses through living tissue at a greater rate than does oxygen. An increased tension of carbon dioxide in the tissues might therefore cause an appreciable increase in the rate of carbon dioxide elimination through the skin, while a corresponding decrease in the tension of oxygen in the tissues might have much less effect on the rate of cutaneous absorption of oxygen. Because of these considerations, we believe that the elevated respiratory quotient of cutaneous gas exchange in subjects with pathologic conditions of the skin results from the increased rate of cutaneous metabolism in these individuals rather than from qualitative changes in the metabolic processes of the skin.

The fact that no significant change in the rate of cutaneous respiration was recorded in the two subjects in whom additional measurements were made after the skin lesions had disappeared (Table 2) is not in harmony with the observed relationship between the rate of carbon dioxide elimination and the severity of the skin lesions. The reason for this conflict is not apparent.

The patient with scleroderma presented diffuse, board-like infiltration of the skin of the entire upper extremity. It was rather surprising, therefore, that the rate of cutaneous respiration was as high as actually observed. It is quite possible that the vascular changes present in scleroderma interfere with the exchange of carbon dioxide and oxygen between the tissues and the blood, and that, in consequence, a larger proportion of gaseous exchange than normal takes place by diffusion between the tissues and the atmosphere in order to meet the metabolic needs of the skin. The fact that the average respiratory quotient in our patient was 1.2 indicates, however, that the metabolic processes of the skin were not the sole source of the carbon dioxide eliminated and that carbon dioxide was still passing out of the blood by diffusion through the skin.

SUMMARY

1. Repeated measurements were made of the rate of cutaneous respiration in twelve subjects with pathologic conditions of the skin. Five patients had psoriasis, two had eczema, and one each had erythema multiforme, dermatitis venenata, scleroderma, exfoliative dermatitis, and seborrheic dermatitis.

2. The rate of cutaneous respiration tended to be elevated in these subjects.

3. The average rate of carbon dioxide elimination was 162 cc. per hour per square meter of skin surface as compared with an average rate of 120 cc. in normal subjects.

4. The average rate of oxygen absorption was 110 cc. per hour per square meter of skin surface as compared with an average rate of 88 cc. in normal subjects.

5. The average value for the respiratory quotient of cutaneous gas exchange was 1.5 as compared with an average value of 1.4 in normal individuals.

6. The results of the investigation indicate that the metabolic rate of the skin is increased in subjects with widespread cutaneous lesions.

BIBLIOGRAPHY

1. Shaw, L. A., Messer, A. C., and Weiss, S., Am. J. Physiol., 1929, xc, 107. Cutaneous Respiration in Man. I. Factors Affecting the Rate of Carbon Dioxide Elimination and Oxygen Absorption.
2. Shaw, L. A., and Messer, A. C., Am. J. Physiol., 1930, xcv, 13. Cutaneous Respiration in Man. II. The Effect of Temperature and of Relative Humidity upon the Rate of Carbon Dioxide Elimination and Oxygen Absorption.
3. Ernstene, A. C., and Volk, M. C., J. Clin. Invest., 1932, xi, 363. Cutaneous Respiration in Man. IV. The Rate of Carbon Dioxide Elimination and Oxygen Absorption in Normal Subjects.
4. Shaw, L. A., and Messer, A. C., Am. J. Physiol., 1931, xcviii, 93. Cutaneous Respiration in Man. III. The Permeability of the Skin to Carbon Dioxide and Oxygen as Affected by Altering their Tension in the Air Surrounding the Skin.