Does Increased Evaporative Water Loss Cause Hypermetabolism in Burned Patients?

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IN a cold environment, man, like other homeotherms, attempts to limit heat loss by reducing perspiration and increasing cutaneous vasoconstriction. Below a point termed "the critical environmental temperature," these heat-conserving measures become insufficient to maintain core temperature. Only when this "cooling state" is reached does a compensatory rise in heat production (i.e., metabolic rate) occur.[8]

It is well documented that, when exposed, extensively burned patients have a greatly increased evaporative water loss and, therefore, an increased evaporative heat loss. It is also well documented that such individuals have an increased metabolic rate which correlates to some extent with their evaporative losses.[5] A widely accepted hypothesis is that the two phenomena are causally related; i.e., the heat lost by evaporation from an extensive burn is so great that, like a man in an environment below his critical temperature, the burned patient is forced to compensate by increasing his metabolic rate. Explicit proof of this hypothesis, however, is not well documented.

Frequently cited as supporting this hypothesis are studies in which blockage of evaporation by application of a waterproof plastic film to the burn resulted in a concurrent reduction in metabolic rate.[9,11] These studies were reported for one burned rat and one burned patient, respectively. Unfortunately, the actual data describing the one patient's reduction in metabolic rate were not included in the publication. Other studies cited in support of this hypothesis offer evidence which is indirect and obtained from experimental animals.[2,7]

The present study reappraises the hypothesis that increased evaporative heat loss is a major cause of hypermetabolism in burns. This was done by reducing evaporative water loss in burned human patients and observing the effect on metabolic rate.

Materials and Methods

Twelve patients (Table 1) with thermal burns varying from 17.0 to 67.5% of body surface area were studied. On two consecutive days, simultaneous determinations of rate of oxygen consumption and rate of insensible weight loss were made in each patient after equilibration under the following conditions:

1. On one day, the burned areas were covered with Sulfamylon cream * and a

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* An antibacterial preparation containing 10% alpha-amino-p-toluenesulfonamide acetate; manufactured by Winthrop Laboratories, New York, New York.

water-impermeable, thin, clear film** for a period of 12 hours before measurement of oxygen consumption and insensible weight loss.

2. On the other day, the burns were covered only with Sulfamylon cream during the 12 hours prior to oxygen consumption and insensible weight loss determinations.

The order of treatment was randomized and measurements were made over a 4-hour period (7:30 to 11:30 a.m.). Rectal temperature was monitored throughout the 12-hour equilibration period and the 4-hour study period.

All experiments were conducted with patients supine and at rest in a small quiet room with low illumination. Ambient temperatures were 24–28° C. with an average variation of 0.8° C. between consecutive studies on a single patient. Relative humidity ranged from 29 to 57% with an average variation of 3.0% between consecutive experiments on a single patient. All patients ate a small breakfast one hour before the study.

Oxygen consumption was measured for 5 to 6 minutes, employing a closed circuit oxygen-rebreathing system with a 9-liter spirometer. Except for a few instances, two determinations of oxygen consumption, 1 to 2 hours apart, were made on each patient and averaged. The CO_2 absorber was regularly replaced and the spirometer calibrated with a 120-liter Tissot gasometer. The patient was fitted with a modified U. S. Army M-17 CBR mask which provided a more comfortable and leak-free system than the usual mouthpiece and nose clip. The presence of leaks was detected by applying a 225 Gm. weight to the spirometer bell during an experiment and noting changes in the slope of the spirogram after removing the weight. No change in slope indicated a leak-free system. Caloric production was calculated based on an as-

** Saran Wrap—manufactured by Dow Chemical Company, Midland, Michigan.

TABLE 1. *Characteristics of Patients, and the Effects of Waterproof Dressing on Evaporative Water Loss, Evaporative Heat Loss, and Metabolic Rate.*

				Burns Exposed			Burns Covered		
				Evaporative Loss			Evaporative Loss		
Patient	Body Surface Area M^2	Per Cent Body Surface Burned Total/Full-Thickness	Postburn Days Studied	Gm./M^2/Hr.	Kcal./M^2/Hr.	Metabolic Rate Kcal./M^2/Hr.	Gm./M^2/Hr.	Kcal./M^2/Hr.	Metabolic Rate Kcal./M^2/Hr.
1	1.85	67.5/1.0	13–14	53	31	85	31	18	81
2	1.92	60.0/28.5	5– 6	63	36	62	18	10	62
3	1.94	51.0/5.0	18–19	50	29	68	11	7	64
4	2.11	46.0/0.0	19–20	54	31	53	15	9	55
5	1.97	40.5/18.0	3– 4	38	22	53	18	10	50
6	1.67	40.0/3.0	13–14	40	23	57	14	8	61
7	1.64	37.0/25.0	18–19	29	17	57	21	12	57
8	2.00	36.0/14.0	19–20	43	25	56	13	7	60
9	1.91	25.5/26.5	14–15	47	27	71	24	14	65
10	2.08	35.0/0.0	12–13	38	22	59	36	21	51
11	1.78	30.0/0.0	13–14	21	12	49	21	12	49
12	2.06	17.0/0.0	7– 8	56	32	57	30	17	62

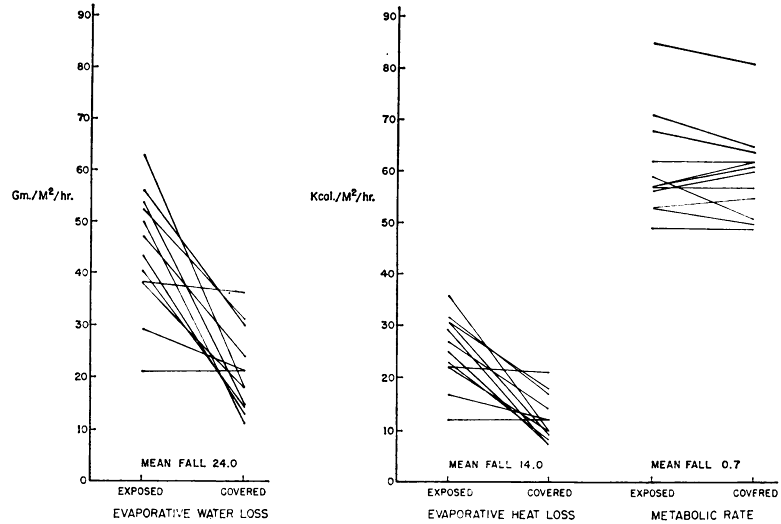

FIG. 1. Effects of waterproof dressing on evaporative water loss, evaporative heat loss, and metabolic rate in burned patients.

sumed RQ of 0.85 with a caloric equivalent of 4.862 kcal. per liter O_2 consumed.[3]

Insensible weight loss, assumed equal to evaporative water loss, was monitored for four hours on a Brookline * metabolic scale (accuracy ±3.0 Gm.). The correction for CO_2 excreted in excess of O_2 intake has been determined by previous studies to be within the range of error of our balance and negligible. Urine, oral and intravenous fluids were kept on the scale during the study period in sealed containers to eliminate evaporative loss from all sources except the patient. Evaporative heat loss was calculated from evaporative water loss, the body losing 0.58 kcal./Gm. of water evaporated from its surface.[5] After calculation, all results were rounded to the nearest whole number.

Results

Table 1 depicts results obtained and characteristics of the 12 patients studied. Total burn ranged from 17.0 to 67.5% of body surface area. All patients were men between 19 and 46 years of age.

* Brookline Instrument Company, Brookline, Massachusetts.

Both evaporative water loss and evaporative heat loss fell significantly ($t = 5.6684$, $p < 0.001$) after application of the impermeable film (Fig. 1). The mean decline was 24.0 Gm./M^2/hr. and 14.0 kcal./M^2/hr., respectively.

The metabolic rates during the period of exposure ranged from 19 to 109% (mean 50%) above basal. With burns covered, metabolic rates were 19 to 100% (mean 46%) above basal. Metabolic rate declined a mean of 0.7 kcal./M^2/hr. after application of the film. The difference between metabolic rates under the two conditions (see accompanying figure) was not statistically significant ($t = 0.572$, $0.6 > p > 0.5$).

During the period of burn coverage, body temperatures averaged 0.5° F. higher than during the period of exposure.

Discussion

There is no reason to believe that Sulfamylon on the burn was the cause of sustained hypermetabolism after the application of Saran wrap. There was no significant difference between the increased metabolic rates of this group of patients and those of another comparable group treated in this unit by simple exposure prior to the availability of Sulfamylon.[5]

In this investigation, a 12-hour reduction of evaporation, a major route of heat loss, did not reduce heat production. This suggests several things:

1. That the relationship between metabolic rate and evaporative cooling in the burned patient is not as clearly defined as has been concluded from previous studies which utilized similar technics for reducing evaporation in a few individuals. While forms of topical burn therapy which diminish evaporative water loss may ameliorate problems of fluid replacement, it is not necessarily true that under ordinary clinical conditions an equivalent reduction in metabolic rate occurs as a consequence.

2. When exposed and treated with Sulfamylon under the usual conditions prevailing on our ward, patients were in a zone of thermal neutrality, i.e., within a range of environmental conditions in which heat loss was not a stimulus to hypermetabolism. Had they been in a "cooling state" when exposed (as is a normal man in an environment below his critical temperature), the expected response to the waterproof covering would have been a decline in metabolic rate due to decreased heat loss.[8] The fact that no patients were shivering and none had subnormal rectal temperatures when exposed confirms this suggestion.

3. Increase in metabolic rate was primarily stimulated by mechanisms other than evaporative cooling. While there is no evidence of thyroid hyperactivity,[4] prolonged increases of norepinephrine and epinephrine secretion have been recorded in burned patients and may be responsible for hypermetabolism.[6] In addition, a burned patient is continually subjected to varying degrees of sepsis and pain, both of which tend to elevate heat production. Other types of physiological insult such as peritonitis (often referred to as a "peritoneal burn"), can give rise to hypermetabolism without evidence or invocation of increased heat loss as its cause.[4]

4. Under the conditions of this study, increased evaporation did not cause the hypermetabolism observed, the "effect" (hypermetabolism) persisting after the "cause" (increased evaporation) was removed. Perhaps, therefore, increased evaporative heat loss of burned patients should be more properly considered a convenient route of loss for heat which would otherwise require dissipation by other routes to keep body temperature near normal. This concept is confirmed by an observation made during the present study. Blockage of evaporative heat loss resulted in an increase in body temperature; this in turn would tend to increase heat loss by all three remaining routes, radiation, conduction, and convection. Body temperature is an indicator of equilibrium between heat production and loss.[10] It is only logical, therefore, that a rise in body temperature would accompany blockage of any major route of heat loss if heat production remained unchanged.

Normal men can be forced to raise their metabolic rates by exposure to sufficiently chilling conditions. So too it is possible that burned patients may be placed in a "cooling state" by exposure, for example, to flows of cold air. This may explain the decline in metabolic rate associated with a change from cool and wet to warm and dry environmental air flows previously reported in burned patients.[1]

The possibility exists that in response to prolonged evaporative cooling, nonshivering thermogenesis or some other mode of heat production may be evoked which, while not reversed by a 12-hour period of reduced evaporation, might be arrested by longer periods. While purely speculative, and not supported by previous experience with prolonged use of occlusive dressings, this hypothesis is not ruled out by the present study and is currently under investigation.

Obviously, the conclusions of this study are not necessarily applicable to patients not comparable to the group reported in terms of age, burn size, environmental conditions, time post burn, and method of treatment. The cases reported are, however, representative of the vast majority of patients treated on our wards.

Summary and Conclusions

It is widely accepted that increased heat production (i.e., hypermetabolism) in burned patients is generated primarily in compensation for heat lost due to increased evaporation from the burned surface. To test this hypothesis, 12 patients with extensive thermal burns were subjected on consecutive days to two 12-hour test periods during which they were treated either by exposure, or by applying a thin, clinging, waterproof film to their burns. All patients had Sulfamylon cream applied to their burns prior to each test; all underwent simultaneous measurement of metabolic rate and rate of insensible weight loss at the end of each test period. Application of waterproof film was associated with a marked reduction in insensible weight loss (which is equivalent to evaporative water loss) but no significant change in the elevated metabolic rate. This indicates that in the group studied increased metabolic rate was primarily stimulated by mechanisms other than evaporative cooling.

Acknowledgment

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