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THE IRRADIANCE DEPENDENCY OF EXPOSURE TIME AS A FACTOR
IN DETERMINING THE SEVERITY OF RADIANT THERMAL BURNS

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ABSTRACT

The effects of six exposure times (0.5, 1.0, 3.0, 5.0, 10.0 and 30.0 sec.) in the production of burns on bare porcine skin by radiant exposures of 5 cal/cm² and 16 cal/cm² were investigated. The 5 cal/cm² exposure is most injurious at the shortest exposure time, and damage from it decreases as exposure time increases. On the other hand, 16 cal/cm² exposures are more destructive with 5.0 and 10.0 sec. exposure times than with longer or shorter times. The importance of this change in time-intensity relationships in predicting injury on the basis of exposure and exposure time is pointed out.

INTRODUCTION

Previous investigators in this laboratory have demonstrated that, in the production of mild burns, increasing the time of exposure necessitates an increase in the total energy delivered in order to obtain an equal effect (1, 2, 3, 4). For example, to produce a 2+ burn on bare porcine skin with a 30.0 sec. exposure requires nearly twice as much total energy as is necessary when the exposure is only 0.3 sec. However, with higher irradiances and with exposure times between 0.5 sec. and 15.0 sec., it was found that a given total radiant exposure did not always have its most damaging effect at the shorter exposure times (1).

The measurable depth of damage is not always a good criterion of the severity of a burn because one burn may produce edema with a consequently greater width of injury while another may shrivel the dermis and thereby decrease the width of the destroyed area. Thus, the same measurable depth of damage may at one time represent a burn only part way through the dermis and, at another, one which is a full thickness loss (5, 6). The shrivelling effect is most likely to occur with the higher irradiances, and this could possibly account for the "less depth of damage" at shorter exposure times.

With the aid of special histological techniques the junction between damaged and normal dermal tissue can now be determined more accurately than has been possible in the past (7). The use of these methods, plus some criterion of injury not based solely on the measurable width of the damaged zone, could help to determine whether or not the effect of exposure time is variable depending on the rate of delivery of the radiant energy. Such information is necessary before predictions of injury can be based on radiant

dose and exposure time. This experiment was designed to display any differences between a relatively low radiant exposure and a relatively high radiant exposure in the effects of varying exposure time.

METHODS

Young Chester White pigs, anesthetized with intraperitoneal Dial in Urea-urethane (Ciba) in doses of 70 mgm/Kg were the experimental animals. The hair was clipped from the sides, and the skin was washed. The heat source was a modified 24 inch Army carbon arc searchlight (2, 8).

Six exposure times, 0.5, 1.0, 3.0, 5.0, 10.0, and 30.0 seconds, and two levels of radiant exposure, 5 cal/cm² and 16 cal/cm², were used. These twelve treatments were randomly assigned to exposure sites on the sides of an animal and the treatment block was replicated 12 times to give a total of 144 burns. Eighteen to 24 hours following burning the exposed areas were biopsied. The specimens were placed in formalin and were later stained by Hinshaw's Method I (7).

Microscopic assessment of the burns included both a measurement of the depth of damage, with the aid of a ruled ocular, and an estimate of the percentage of normal dermis remaining beneath the damaged area. The central, most severely injured portion of the burned area was used for both the measurement and the estimate. Each biopsy included undamaged skin on both sides of the burn so that the normal thickness of the dermis could be determined for any particular area. Because the dermis is not a plane overlying the fat but rather consists of peaks and valleys, the thickness of the dermis is not perfectly uniform. For this reason an exact estimate of the percentage depth of a burn is neither possible nor

meaningful. Percentage estimates of injury, therefore, were tabulated as full thickness, between half thickness and full thickness, or less than half of the full thickness of the dermis without an attempt to use a more elaborate grading system. The milder burns, produced by 5.0 cal/cm^2 , were recorded as displaying either partial or complete epidermal damage. When they involved dermis, the depth of damage was measured with a ruled ocular. Because little distortion of the tissues results from mild burns (5) this measurement is valid for comparing the severity of such injuries.

RESULTS

The results from microscopic assessment of the 5 cal/cm^2 burn are given in Table I. It is readily apparent that at this exposure level the severity of the injury decreases as exposure time increases. This demonstrates in another manner the observations made previously (1, 2, 3, 4, 9) that increasing the exposure time necessitates an increase in the total energy delivered in order to produce burns of equal severity.

Table II contains the results from microscopic assessment of the 16 cal/cm^2 burns. Contrary to the 5 cal/cm^2 burns, the most severe injury does not result from the shortest exposure time. The estimates of the percentage of full thickness dermal damage are essentially the same for the 0.5 sec. and 30.0 sec. exposure times, but the energy has been most destructive at 5.0 sec. and 10.0 sec. Half of the exposures have resulted in full thickness damage at these latter times.

TABLE I
MICROSCOPIC ASSESSMENT OF INJURIES RESULTING FROM
RADIANT EXPOSURES OF 5 CAL/CM².

Exposure Time (sec)	Epidermal Damage	Depth of Dermal Damage in Millimeters
0.5	12C*	0.03, 0.8, 0.1, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.3, 0.3, 0.4
1.0	12C	0, 0.08, 0.08, 0.08, 0.08, 0.1, 0.1, 0.2, 0.2, 0.3, 0.3, 0.3
3.0	1 P** 11C	Eleven without dermal damage 0.08
5.0	1 P 11C	All twelve without dermal damage
10.0	6 P 6 C	All twelve without dermal damage
30.0	8 P 4 C	All twelve without dermal damage

* Complete Epidermal Damage

** Partial Epidermal Damage

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TABLE II

MICROSCOPIC ASSESSMENT OF INJURIES RESULTING FROM RADIANT EXPOSURES OF 16 CAL/CM².

Exposure Time (sec)	Depth of Dermal Damage In Millimeters	Damage Less Than Half Full Thickness	Damage Half Full Thickness or more	Full Thickness Damage
0.5	0.5, 0.5, 0.6, 0.8, 0.8, 0.8, 0.9, 0.9, 1.1, 1.2, 1.4, 1.4	1	9	2
1.0	0.5, 0.6, 0.8, 0.8, 0.8, 0.9, 0.9, 1.1, 1.1, 1.2, 2.0, 2.2	3	6	3
3.0	0.9, 0.9, 1.0, 1.2, 1.2, 1.2, 1.4, 1.5, 1.5, 1.8, 2.3, 2.3	0	8	4
5.0	0.8, 1.1, 1.1, 1.1, 1.1, 1.1, 1.5, 1.8, 2.2, 2.2, 2.3, 2.3	1	5	6
10.0	0.8, 0.9, 0.9, 1.2, 1.2, 1.2, 1.5, 1.5, 1.5, 1.8, 2.9, 3.2	0	6	6
30.0	0.3, 0.6, 0.6, 0.8, 0.8, 1.1, 1.2, 1.2, 1.2, 1.4, 2.0, 2.2	2	8	2

DISCUSSION

The effect of a given quantity of radiant thermal energy depends on the exposure time, but the most effective exposure time for one dose is not necessarily the most effective for another. The nearly linear relationship between radiant exposure and exposure time in the production of mild burns can be expressed as:

$$Q_c = A t^\alpha$$

where Q_c is the median effective exposure for a 2+ burn, t is the exposure time, A is the value of Q_c where t is equal to unity, and α is an experimentally determined scaling factor (3, 4, 9). This relationship has been checked over the range of exposure times used in the present experiment. However, when higher irradiances are used to produce more severe burns the factor of exposure time works differently so that a given radiant exposure does not produce maximum damage at the shortest time. Davis (1) has reasoned that for a given total exposure a high irradiance, which will cause an abstraction of heat by the production of a steam bleb, might be less damaging than a lower irradiance which causes no such diversion of the energy. This seems to be the most likely explanation of the results obtained here and is further confirmed by the observation that many of the short exposure burns show a microscopic picture of shrivelled, dehydrated tissue.

With the limited information now at hand it is only possible to speculate on the irradiance dependent nature of exposure time in the production of burns. A radiant exposure of 16 cal/cm² causes a moderately severe burn with a 0.5 sec. exposure time. With this same radiant exposure,

damage increases as exposure time increases, over a limited range, and beyond this damage again is less. The 5 cal/cm² burn produces its most severe injury with the shortest exposure time used in this experiment, but one wonders what the result would be if this same exposure could be delivered in a much shorter time. Would it then produce a still greater injury, or would the damage be less? For any given radiant exposure there is some exposure time at which maximum damage will result, and it is at least possible that injury may be lessened by decreasing as well as by increasing the exposure time.

The experimental data presented here indicate that the most effective exposure time for the greater of two radiant exposures tested is considerably longer than that for the smaller one. Predictions of injury based on exposure time and total radiant exposure can be accurate only if such variations in time-intensity relationships are considered.

BIBLIOGRAPHY

1. Perkins, J. B., Kingsley, H. D., and Pearse, H. E., A Study of Radiant Energy Burns: The Effect of Exposure Time and Intensity, Univ. of Roch. Atomic Energy Project Report, UR-217, (1952).
2. Lyon, J. L., Davis, T. P., and Pearse, H. E., Studies of Flash Burns: The Relation of Thermal Energy Applied and Exposure Time to Burn Severity, Univ. of Roch. Atomic Energy Project Report, UR-394, (1955).
3. Mixter, G. Jr., Univ. of Roch. Atomic Energy Project Report, UR-440, (1955). (Classified).
4. Davis, T. P., Hinshaw, J. R., and Pearse, H. E., A Comparison of the Effects on Bare Porcine Skin of Radiant Energy Delivered in the Forms of Square and Simulated Field Pulses, Univ. of Roch. Atomic Energy Project Report, UR-418, (1955).
5. Hinshaw, J. R., Some Effects of Superimposing Two Radiant Energy Thermal Burns On Bare Porcine Skin, Part I, Part II, Part III, Univ. of Roch. Atomic Energy Project Report, UR-433, (1956).
6. Hinshaw, J. R., Bales, H. W., and Pearse, H. E., The Relationship Between Surface Grade and Depth of Damage of Burns Produced by Radiant Thermal Energy, Univ. of Roch. Atomic Energy Project Report, UR-440, (1956).
7. Hinshaw, J. R., and Pearse, H. E., Histological Techniques for the Differential Staining of Burned and Normal Tissues, Univ. of Roch. Atomic Energy Project Report, UR-449, (1956).
8. Davis, T. P., Krolak, L. J., Blakney, R. M., and Pearse, H. E., Modification of the Carbon Arc Searchlight for Producing Experimental Flash Burns, J.O.S.A., 44: 766-769, (1954).
9. Mixter, G. Jr., The Empirical Relation Between Time and Intensity of Applied Thermal Energy in Production of 2+ Burns in Pigs, Univ. of Roch. Atomic Energy Project Report, UR-316, (1954).