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FLASH BURN STUDIES:

LIMITATIONS OF A 2+ MEDIAN EFFECTIVE EXPOSURE SCALING LAW

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ABSTRACT

The data pertinent to the estimation of median effective exposures for 2+ burns (2+ EE₅₀) in University of Rochester Atomic Energy Project reports concerned with bare porcine skin burns caused by square pulses of radiant thermal energy are surveyed. A critical study is made of the "scaling factor," α , and of the simple equation relating energy required to produce a 2+ burn to time of exposure:

$$Q_c = A T^\alpha$$

Although a single scaling factor can be determined, at best it represents only a rough estimate of the relationship between radiant exposure and exposure time in the production of 2+ burns.

INTRODUCTION

A number of reports from the University of Rochester Atomic Energy Project Flash Burn Section have dealt with the production of 2+ burns on bare porcine skin. The 2+ burn is defined as one which, 24 hours after the injury is produced, has a patchy white surface (1), and it represents a degree of severity just greater than erythema alone. Although microscopic examination of these burns often shows either transepidermal necrosis or separation of the epidermis from the dermis, the designation, "2+," is based on surface assessment alone. This injury is somewhat comparable to a very mild second degree burn in humans, and it is for this reason that much attention has been directed toward determining the factors which influence the production of these burns.

Because the amount of energy necessary to cause a 2+ burn increases as exposure time increases (2), it would be quite useful if some theoretically predictable relationship between these two factors could be demonstrated. Mixter (3), by adding his own data to that from earlier University of Rochester reports, attempted to do this. From his compilation he suggested the possibility of the equation:

$$Q_c = A t^{\alpha} \quad \text{(Equation 1)}$$

where Q_c is the radiant exposure (cal/cm²) which will produce burns at least as severe as 2+ in half the exposures but will cause burns less severe than 2+ in the other half, t is the exposure time in seconds, α is the experimentally determined "scaling factor," and A is the value of Q_c for a one second exposure time. Three subsequent experiments (4, 5, 6) have been so designed that a scaling factor might be determined from their data. However, as noted in one of these reports (6), the exposure times investigated are so

far apart that it is not justifiable to draw conclusions concerning the times between them.

The experimentally determined scaling factor has varied from one experiment to another, and for this reason it has been thought advisable to determine a factor which best fits all University of Rochester Flash Burn data. In pursuing this object it became evident that we should point out some reasons for the variation and also the consequent limited usefulness of any scaling factor for a 2+ burn.

PROCEDURE

The data from the University of Rochester Atomic Energy reports on 2+ burns produced on bare porcine skin by radiant thermal energy were collected and tabulated. Only those data to which the Litchfield and Wilcoxon (7) method of graphic analysis could legitimately be applied were included, and only burns produced by square wave pulses of energy from the modified carbon arc (8) were considered. Since the time of publication of the earlier reports, the calibration of the heat source has been corrected (9), and the data affected by this were adjusted accordingly.

RESULTS

In Table I the radiant exposures (cal/cm^2) which produce a 2+, or more severe, burn in 50% of the exposures and a less severe burn in the other 50% (median effective exposures or $2+ EE_{50}$) are listed for 13 different exposure times ranging from 0.1 second to 30.0 seconds. The 95% confidence limits for the median effective exposures, the number of burns which could be used to determine the median effective exposures, and the source

TABLE I

COMPILATION OF DATA ON $2+ EE_{50}$ (MEDIAN EFFECTIVE EXPOSURE FOR
2+ BURNS) UNIVERSITY OF ROCHESTER ATOMIC ENERGY PROJECT REPORTS

I Time (sec)	II Q $2+ EE_{50}$ (cal/cm ²)	III Q 95% Confi- dence Limits	IV Total No. of Burns	V Data Source
0.1	2.6	2.2 - 2.9	87	UR-217
0.25	2.5	2.3 - 2.7	105	394
0.3	3.3	3.0 - 3.6	64	418
	2.8	2.6 - 2.9	185	217
	2.5	2.3 - 2.8	144	433
	3.0	2.8 - 3.2	64	438
0.5	2.6	2.4 - 2.8	105	394
	3.0	2.8 - 3.2	68	336
1.0	3.7	3.6 - 3.8	101	316
	3.8	3.7 - 3.9	182	217
	3.6	3.1 - 4.3	88	394
1.5	4.1	3.9 - 4.2	60	316
2.0	4.2	4.0 - 4.5	120	394
	4.4	4.2 - 4.6	60	316
3.0	4.2	4.0 - 4.4	80	418
	4.8	4.5 - 5.2	60	316
	4.1	3.8 - 4.4	63	438
4.0	6.3	5.7 - 6.8	24	316
	4.9	4.7 - 5.1	60	384
	4.8	4.4 - 5.0	196	217
	4.2	4.0 - 4.5	105	394
9.0	6.4	5.9 - 6.9	69	217
10.0	6.7	6.2 - 7.3	30	316
	5.5	5.1 - 5.9	105	394
25.0	7.7	7.3 - 8.2	24	316
30.0	6.3	5.8 - 6.8	80	418
	6.7	6.3 - 7.0	61	438

of these data are also included. At eight of the exposure times two or more determinations of the 2+ EE₅₀ are available.

Figure 1 is a logarithmic plot of the median effective exposures against exposure time. The three lines on this figure represent these equations:

Line A. $Q_c = 3.73 t^{0.224}$, the corrected scaling equation of Ref. (3)

Line B. $Q_c = 3.7 t^{0.15}$, the scaling equation derived from data in Ref. (4)

Line C. $Q_c = 3.56 t^{0.196}$, the scaling equation which best fits the weighted data (method of Snedecor (10)) of Table I

Thus, if we attempt to select a single scaling factor from all of our pertinent data to represent the relationship between exposure time and radiant exposure for the 2+ burn, this exponent would be 0.196.

DISCUSSION

The scatter of the points demonstrates that no one line can provide a really good fit to all the data plotted in Figure 1. No single value for the scaling factor is satisfactory if we are to use a simple scaling law of the form $Q_c = A t$ to predict injury from radiant thermal burns. Hinshaw (11) has suggested that the scaling factor might be written $0.15 < \alpha < 0.25$, and this is a reasonable way of approaching the injury prediction problem for times other than one second. An interval rather than a single value for A would also be appropriate.

Different experiments done under the same conditions of exposure, but on different dates and by different investigators, usually yield different values for the 2+ EE₅₀. Sometimes there is even no overlap of 95%

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Figure 1
Logarithmic plot of median effective exposure for 2+ burns against
exposure time. See text for explanation of Lines A, B and C.

confidence limits (see the 0.5 and 10.0 second data in Table I). Two conclusions thus become immediately apparent. Any single scaling factor for the 2+ EE₅₀ can at best be a rough estimate of the relationship between exposure time and radiant exposure. In addition, each experiment must contain its own control since the data from one cannot be used as the control for another.

Other limitations of a scaling factor should also be pointed out. There is no justification for assuming that a smooth curve fitted to the points which have been investigated represents what happens between these points. The legitimate use of such a curve is almost always limited to suggesting a useful hypothesis to be tested by further experimentation. There is also no justification for assuming that the scaling factor for exposure times ranging between, for example, 0.3 and 3.0 seconds, should be the same as that for times from 3.0 to 30.0 seconds.

SUMMARY AND CONCLUSIONS

1. No single value for the scaling factor, α , in the equation $Q_c = A t^\alpha$ allows a good prediction of Q_c for 2+ bare skin burns over the whole range of times investigated in this laboratory.
2. Equations relating widely separated data points, such as those presented in this paper, are best employed only to suggest hypotheses to be tested in further experiments.
3. Each experiment of the type examined here must contain its own controls since the data from one cannot legitimately be used as the control for another.

BIBLIOGRAPHY

1. Perkins, J. B., Pearse, H. E., and Kingsley, H. D., Studies on Flash Burns: The Relation of the Time and Intensity of Applied Thermal Energy to the Severity of Burns, 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., 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).
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. Mixter, G., Jr., The Sub-Fabric Flash Burn: Effects of Fabric Weight, Reflectance and Transmittance on Cutaneous Burns of Swine under Simulated Field Pulses of Thermal Energy, Univ. of Roch. Atomic Energy Project Report, UR-400, (1955). Classified.
6. Bales, H. W., Hinshaw, J. R., and Pearse, H. E., A Comparison of the Effects of Radiant Thermal Energy on Bare, Blackened and Whitened Pig Skin, Univ. of Roch. Atomic Energy Project Report, UR-438, (1956).
7. Litchfield, J. T., Jr., and Wilcoxon, F., A Simplified Method of Evaluating Dose-Effect Experiments, J. Pharm. and Thera. 96: 99, (1949).

8. Davis, T. P., Krolak, L. J., and Blakney, R. M., Studies of Flash Burns: The Carbon Arc Source, Univ. of Roch. Atomic Energy Project Report, UR-226, (1952).
9. Mixter, G., Jr., Davis, T. P., and Pearse, H. E., The Sub-Fabric Flash Burn: Quantitative Effect on Protectivity of Fabric Reflectance, Fabric Weight and Exposure Time, Univ. of Roch. Atomic Energy Project Report, UR-386, (1955).
10. Snedecor, G. W., Statistical Methods, Iowa State College Press, 4th Edition (1946).
11. Hinshaw, J. R., Letter to Mr. Reynold Greenstone of Technical Operations, Inc., (Nov. 1956).