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THE RELATIONSHIP BETWEEN THE SURFACE APPEARANCE AND DEPTH
OF DAMAGE OF SUBFABRIC AND BARE SKIN BURNS
PRODUCED BY RADIANT THERMAL ENERGY

by

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OF DAMAGE OF SUBFABRIC AND BARE SKIN BURNS

PRODUCED BY RADIANT THERMAL ENERGY

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U N C L A S S I F I E D

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ABSTRACT

In a series of 600 cutaneous burns in swine produced by radiant thermal energy at 0.5 and 5.0 sec. exposure time, the relationship of the surface appearance and the depth of damage of bare skin and subfabric burns was investigated. The fabrics used were a black and a gray sateen weighing 8-9 oz./yd.²

It was found that there is no significant difference in the 1+ burns whether produced on bare skin or beneath fabric, either at 0.5 or 5.0 sec. exposure. However, the 2+ subfabric burns average about 0.1 mm. deeper in dermal damage than the same grade burn of bare skin. Nevertheless, the protection afforded by fabric is found to be nearly the same whether the burns were judged by surface appearance or microscopically by depth of damage.

INTRODUCTION

The surface appearance of burns has been the most widely used criterion in this (1, 2, 3, 4, 5, 6) and other laboratories (7, 8) for the evaluation of the protection afforded by fabrics against radiant energy burns. This method of evaluation is more rapid and less expensive than the laborious process of microscopic examination. However, there are situations in which surface grading does not depict accurately the severity of the burn, as is well known from clinical and laboratory studies of bare skin burns (9, 10).

It has been convenient to express protection as an index which correlates the amount of energy necessary to produce a subfabric burn to that required for the same grade burn in bare skin (4). It was desirable then 1) to determine by microscopic methods any differences between subfabric and bare skin burns, both of which were given the same grade by surface appearance, and 2) to compare the protective indices determined by surface appearance criteria with those found by evaluation of depth of damage.

METHODS

Equipment

A 24 inch carbon arc searchlight, modified as described by Davis et al., provided the radiant energy (11).

The two fabrics used were specially prepared by the Quartermaster Research and Engineering Center, Natick, Massachusetts, by impregnating cotton sateens with carboxymethyl-cellulose and varying quantities of finely divided carbon black. Their characteristics are as follows:

Designation	Weight (oz/yd ²)	Total Reflectance*
Medium Gray	8.2	0.276
Black	9.05	0.035

*Measured by using a reflectometer and Universal spectrophotometer constructed by Krolak and Davis (12).

These fabrics were kept at a relative humidity of 60% for at least 24 hours before burning.

Biological

Chester White and Yorkshire pigs, weighing 8 to 12 kilograms were anesthetized by the intraperitoneal route with Dial in urea-urethane (Ciba) in dosages of 60-70 mgm./kg. of body weight. The hair was closely clipped and the skin gently cleansed prior to burning. The animal was kept in contact with the cloth for at least five seconds following the exposure.

Experimental Design

Burns were produced at five energy levels (cals/cm²) for each of the two fabrics and for bare skin alone. Exposure times were 0.5 and 5.0 sec. The combinations resulting were assigned randomly to 30 areas on the side of each pig. Twenty replications of the 30 combinations were made. An attempt was made to choose energy levels which would produce the same grade of burn an equal number of times for each combination. This was accomplished for the most part, although a greater number of more severe burns were produced with the fabric than on bare skin alone. However, this did not detract from the analysis. The relationship of a given grade of burn as judged by surface appearance to the depth of damage was made without regard to the energy level at which it was produced.

Evaluation

The lesions were graded 24 hours after burning by surface evaluation according to the usual classification in this laboratory (13) as follows:

Grade	Surface Evaluation
1+	Red (erythema)
2+	Patchy white
3+	Uniform white

At this time, the lesions were biopsied, fixed in formalin, and stained by Hinshaw's modification of Verhoef's method (14). The histological sections were graded as to partial and complete epidermal damage and dermal damage measured in increments of tenths of millimeters.

Analysis of data

The median effective exposure or EE_{50} and 95% confidence intervals were estimated by the method of Litchfield and Wilcoxon (15). The median effective exposure (EE_{50}) is the lowest radiant exposure (cal/cm^2) which will produce at least the given grade of burn 50% of the time. The 95% confidence interval defines the limits of radiant exposures which 95% of the time will cover the 50% effective exposure, if the same experiment is repeated.

RESULTS

A. Relationship between Surface Grade and Depth of Damage

The histological gradings of 1+ and 2+ burns are shown in Tables 1 and 2 and Figures 1 and 2 respectively. There is little difference in the 1+ burns whether produced on bare skin or beneath fabric either at 0.5 or 5.0 sec. exposure times. For the most part these burns show complete epidermal damage. A smaller percentage shows either partial epidermal damage or very superficial dermal damage.

Condition of Production	Exposure Time (sec)	No Damage	Epidermal Damage		Dermal Damage (mm.)					Total
			Partial	Complete	0 - 0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	
Bare Skin	0.5		16 (25%)	44 (68%)	5 (8%)					65
Bare Skin	5.0		10 (22%)	30 (65%)	6 (13%)					46
Black Fabric	0.5		6 (15%)	25 (64%)	8 (20%)					39
Black Fabric	5.0		4 (17%)	17 (74%)	1 (4%)	1 (4%)				23
Medium Gray Fabric	0.5	1 (2%)	9 (16%)	37 (66%)	9 (16%)					56
Medium Gray Fabric	5.0	1 (2%)	5 (10%)	36 (77%)	5 (10%)					47

This table shows the depth of damage by the number and percentage (in parentheses) of all 1+ burns produced under the specified conditions.

TABLE I

Condition of Production	Exposure Time (sec)	Epidermal Damage		Dermal Damage (mm.)					Total
		Partial	Complete	0 - 0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	
Bare Skin	0.5		21 (62%)	13 (38%)					34
Bare Skin	5.0	1 (2%)	24 (55%)	15 (29%)	4 (9%)				44
Black Fabric	0.5		7 (15%)	26 (55%)	12 (25%)	2 (5%)			47
Black Fabric	5.0		10 (17%)	19 (32%)	20 (33%)	9 (15%)	1 (2%)	1 (2%)	60
Medium Gray Fabric	0.5		4 (15%)	18 (67%)	5 (18%)				27
Medium Gray Fabric	5.0		7 (18%)	11 (28%)	14 (36%)	7 (18%)			39

This table shows the depth of damage by the number and percentage (in parentheses) of all 2+ burns produced under the specified conditions

TABLE 2

Fig. 1

RELATIONSHIP BETWEEN 1+ BURNS AND DEPTH OF DAMAGE OF RADIANT THERMAL BURNS

RELATIONSHIP BETWEEN 2+ BURNS AND DEPTH OF DAMAGE OF RADIANT THERMAL BURNS

P = PARTIAL EPIDERMAL DAMAGE
C = COMPLETE EPIDERMAL DAMAGE

.1 = 0.0 - 0.1
.2 = 0.1 - 0.2
.3 = 0.2 - 0.3
ETC.

} DERMAL DAMAGE IN mm

At both 0.5 and 5.0 sec. exposure times only 38% of the 2+ burns on bare skin exhibit any dermal damage while 85% of the subfabric burns involve the dermis. Furthermore, the depth of dermal damage of subfabric burns averages about 0.1 mm. deeper than that of the burns of bare skin.

Since it might be possible that more 2+ severe burns were produced than 2+ mild burns, thereby accounting for these differences, the 2+ mild burns are separately tabulated and are shown in Table 3. This possibility is not upheld, however. The differences between the 2+ mild burns on bare skin and beneath fabric are the same as those for all 2+ burns.

It also appears that, as the exposure time is lengthened, the histological damage in 2+ subfabric burns increases. The differences between the 0.5 and 5.0 sec. exposures for 2+ burns produced beneath the black fabric can be explained by a greater number of 2+ severe burns produced at 5.0 sec. However, the difference between the 0.5 and 5.0 sec. exposures for all 2+ burns produced beneath the medium gray fabric cannot be explained in this way and appears to be time dependent.

Condition of Production	Exposure Time (sec)	Epidermal Damage		Dermal Damage (mm.)					Total
		Partial	Complete	0 - 0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	
Bare Skin	0.5		21 (64%)	12 (36%)					33
Bare Skin	5.0	1 (3%)	23 (60%)	11 (30%)	3 (8%)				38
Black Fabric	0.5		6 (25%)	15 (62%)	3 (13%)				24
Black Fabric	5.0		9 (39%)	11 (48%)	2 (9%)	1 (4%)			23
Medium Gray Fabric	0.5		4 (20%)	15 (75%)	1 (5%)				20
Medium Gray Fabric	5.0		7 (29%)	5 (21%)	11 (46%)	1 (4%)			24

This table shows the depth of damage by the number and percentage (in parentheses) of 2+ mild burns produced under the specified conditions.

TABLE 3

B. Comparison of Protective Indices

Tables 4, 5, and 6 show the number and percentage of burns graded by surface appearance for each radiant exposure used. Tables 7, 8, and 9 list the burns as evaluated histologically by depth of damage for each radiant exposure. Tables 10 and 11 give the 50% effective exposure with the 95% confidence interval, required for 2+ burns or dermal damage respectively, for each combination studied. Table 12 lists the protective indices, which are the ratios of the 50% effective exposures of burns produced beneath fabric to those of burns produced in bare skin.

TABLE 12

Fabric	Exposure Time (sec)	Protective Index	
		Grade - 2+	Grade - Dermal Damage
Medium Gray	0.5	1.9	1.7
	5.0	1.2	1.1
Black	0.5	1.4	1.3
	5.0	1.0	0.9

It can be readily seen that, at each exposure time for each fabric, the protective index is nearly the same whether the burns are graded by surface appearance or microscopically by depth of damage.

Radiant Exposure (cal/cm ²)	Exposure Time (sec)	No Burn	1+			2+		
			Mild	Mod	Sev	Mild	Mod	Sev
2.5	0.5		10 (50%)	8 (40%)		1 (5%)	1 (5%)	
2.8	0.5		10 (53%)	7 (37%)		2 (11%)		
3.1	0.5		4 (20%)	10 (50%)		6 (30%)		
3.4	0.5		2 (10%)	6 (30%)	1 (5%)	11 (55%)		
3.8	0.5		1 (5%)	3 (15%)	1 (5%)	12 (60%)	3 (15%)	
4.1	5.0		9 (50%)	8 (44%)		1 (6%)		
4.6	5.0		4 (20%)	10 (50%)	2 (10%)	3 (15%)	1 (5%)	
5.1	5.0		1 (5%)	2 (10%)	6 (30%)	9 (45%)	2 (10%)	
5.7	5.0		1 (5%)	2 (9%)	5 (23%)	11 (50%)	3 (14%)	
6.3	5.0			1 (5%)	3 (15%)	13 (65%)	3 (15%)	

This table shows the number and percentage of burns produced on bare skin with the specified radiant exposure - time combination.

TABLE 4

Radiant Exposure (cal/cm ²)	Exposure Time (sec)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
4.2	0.5	6 (33%)	7 (39%)	3 (17%)		1 (6%)	1 (6%)				
4.7	0.5		10 (53%)	5 (26%)		4 (21%)					
5.2	0.5	1 (5%)	8 (40%)	6 (30%)		2 (10%)	2 (10%)	1 (5%)			
5.8	0.5		3 (15%)	5 (25%)	2 (10%)	6 (30%)	2 (10%)	1 (5%)		1 (5%)	
6.4	0.5	1 (5%)	1 (5%)	7 (35%)	3 (15%)	7 (35%)	1 (5%)				
4.6	5.0	10 (50%)	5 (25%)	3 (15%)	1 (5%)	1 (5%)					
5.1	5.0	3 (16%)	11 (53%)	2 (11%)	1 (5%)	2 (11%)					
5.7	5.0	2 (10%)	2 (10%)	4 (20%)	1 (5%)	6 (30%)	5 (25%)				
6.3	5.0	1 (5%)	5 (26%)	1 (5%)	1 (5%)	8 (42%)	2 (11%)	1 (5%)			
7.0	5.0	2 (10%)	3 (15%)	1 (5%)		6 (30%)	5 (25%)	2 (10%)			1 (5%)

This table shows the number and percentage of burns produced behind medium gray fabric with the specified radiant exposure - time combination.

TABLE 5

Radiant Exposure (cal/cm ²)	Exposure Time (sec)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
3.8	0.5	4 (20%)	8 (40%)	3 (15%)	1 (5%)	3 (15%)	1 (5%)				
4.2	0.5	3 (15%)	5 (25%)	3 (15%)		4 (20%)	5 (25%)				
4.7	0.5	1 (5%)	5 (25%)	6 (30%)	1 (5%)	3 (15%)	3 (15%)	1 (5%)			
5.2	0.5	1 (5%)	3 (15%)	2 (10%)		8 (40%)	2 (10%)	4 (20%)			
5.8	0.5	1 (5%)		1 (5%)	4 (20%)	8 (40%)	5 (25%)	1 (5%)			
4.6	5.0	4 (20%)	7 (35%)	1 (5%)	1 (5%)	5 (25%)	2 (10%)				
5.1	5.0	1 (5%)	3 (14%)		1 (5%)	11 (52%)	3 (14%)	2 (10%)			
5.7	5.0	2 (10%)	2 (10%)	3 (15%)	1 (5%)	4 (20%)	5 (25%)	3 (15%)			
6.3	5.0	1 (6%)	1 (6%)			2 (11%)	9 (50%)	5 (28%)	1 (6%)		
7.0	5.0				1 (5%)		4 (20%)	7 (35%)		5 (25%)	3 (15%)

This table shows the number and percentage of burns produced behind black fabric with the specified radiant exposure - time combination

TABLE 6

TABLE 7

Radiant Exposure (cal/cm ²)	Exposure Time (sec)	Epidermal Damage		Dermal Damage (mm.)		
		Partial	Complete	0-0.1	0.1-0.2	0.2-0.3
2.5	0.5	9 (45%)	11 (55%)			
2.8	0.5	4 (21%)	14 (74%)	1 (5%)		
3.1	0.5	1 (5%)	18 (95%)			
3.4	0.5	1 (5%)	13 (65%)	6 (30%)		
3.8	0.5		7 (35%)	13 (65%)		
4.1	5.0	7 (41%)	10 (59%)			
4.6	5.0	5 (24%)	16 (76%)			
5.1	5.0		18 (90%)	1 (5%)	1 (5%)	
5.7	5.0	1 (5%)	9 (45%)	9 (45%)		1 (5%)
6.3	5.0		6 (30%)	11 (55%)	3 (15%)	

This table shows the number and percentage of burns produced on bare skin with the specified radiant exposure - time combination.

Radiant Exposure (cal/cm ²)	Exposure Time (sec)	No Burn	Epidermal Damage		Dermal Damage (mm)		
			Partial	Complete	0-0.1	0.1-0.2	0.2-0.3
4.2	0.5	2 (12%)	3 (19%)	6 (37%)	4 (25%)	1 (6%)	
4.7	0.5	1 (5%)	3 (16%)	8 (42%)	6 (32%)	1 (5%)	
5.2	0.5		1 (5%)	12 (67%)	3 (17%)	2 (11%)	
5.8	0.5		1 (5%)	8 (40%)	9 (45%)	2 (10%)	
6.4	0.5		1 (6%)	8 (44%)	8 (44%)	1 (6%)	
4.6	5.0	6 (35%)	2 (12%)	8 (47%)	1 (6%)		
5.1	5.0	2 (13%)	2 (13%)	8 (44%)	2 (13%)	1 (7%)	
5.7	5.0	1 (5%)	1 (5%)	8 (45%)	5 (26%)	4 (21%)	
6.3	5.0	1 (5%)	1 (5%)	6 (32%)	4 (21%)	6 (32%)	1 (5%)
7.0	5.0			5 (28%)	4 (22%)	8 (44%)	1 (6%)

This table shows the number and percentage of burns produced behind medium gray fabric with the specified radiant exposure - time combination.

TABLE 8

Radiant Exposure (cal/cm ²)	Exposure Time (sec)	No Burn	Epidermal Damage		Dermal Damage (mm)			
			Partial	Complete	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4
3.8	0.5		4 (24%)	6 (35%)	6 (35%)		1 (6%)	
4.2	0.5	1 (6%)	1 (6%)	8 (44%)	6 (33%)	2 (11%)		
4.7	0.5		2 (11%)	10 (53%)	6 (32%)		1 (5%)	
5.2	0.5	1 (5%)	1 (5%)	3 (16%)	11 (58%)	3 (16%)		
5.8	0.5			7 (37%)	5 (26%)	7 (37%)		
4.6	5.0	1 (6%)	4 (22%)	11 (61%)	1 (6%)	1 (6%)		
5.1	5.0	1 (5%)	2 (10%)	6 (30%)	6 (30%)	3 (15%)	2 (10%)	1 (5%)
5.7	5.0		1 (5%)	6 (32%)	5 (26%)	6 (32%)	1 (5%)	
6.3	5.0			1 (5%)	6 (32%)	8 (42%)	4 (21%)	
7.0	5.0			1 (6%)	1 (6%)	6 (33%)	8 (44%)	2 (11%)

This table shows the number and percentage of burns produced behind black fabric with the specified radiant exposure - time combination.

TABLE 9

TABLE 10

Condition of Production	Exposure Time (sec)	Median Effective Exposure	0.95 Confidence Interval
Bare Skin	0.5	3.3	3.1-3.5
Bare Skin	5.0	5.2	5.0-5.5
Medium Gray	0.5	6.3	5.7-6.9
Medium Gray	5.0	6.2	5.8-6.6
Black	0.5	4.7	4.3-5.1
Black	5.0	5.2	5.0-5.4

This table shows the median effective exposure and 0.95 confidence interval for 2+ burns.

TABLE 11

Condition of Production	Exposure Time (sec)	Median Effective Exposure	0.95 Confidence Interval
Bare Skin	0.5	3.7	3.3-4.0
Bare Skin	5.0	5.8	5.5-6.1
Medium Gray	0.5	6.4	5.4-7.6
Medium Gray	5.0	6.3	5.7-7.1
Black	0.5	4.7	4.3-5.1
Black	5.0	5.2	4.4-6.2

This table shows the median effective exposure and 0.95 confidence interval for burns showing superficial dermal damage.

DISCUSSION

The results clearly show that 2+ subfabric burns are more severe than 2+ burns of bare skin. These differences may well be due to (1) artifactual changes in the surface appearance of subfabric burns, produced by dye or tar transfer, and (2) a change in the rate of delivery of the energy from the cloth to the skin compared to that direct from source to skin.

At the 2+ level these differences are not great, consisting of an increase in the measurable depth of damage of about 0.1 mm. From a clinical viewpoint, such small differences at the superficial dermal level would not change appreciably the healing time or a change in the method of therapy such as grafting or non-grafting. From the practical standpoint the "protective index" of these fabrics is nearly the same whether the burns are graded by surface appearance or microscopically by depth of damage.

SUMMARY AND CONCLUSIONS

1. In a series of 600 burns, the relationship of the surface appearance and the depth of damage was investigated. The burns were produced in bare skin and beneath two sateen fabrics with different reflectances at 0.5 and 5.0 sec. exposure time.
2. There is no significant difference in the 1+ burns whether produced on bare skin, beneath fabric, or at 0.5 and 5.0 sec. exposure times, when evaluated as to depth of damage.
3. 2+ burns produced beneath the fabrics average about 0.1 mm. deeper than those made on bare skin as evaluated histologically.
4. The "protective indices" of the fabrics are nearly the same whether the burns are judged by surface appearance or microscopically by depth of damage.

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