Probit Analysis of Burn Mortality in 1,831 Patients:

Comparison with Other Large Series

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Case records of 1,831 patients who were consecutively treated on the Burn Unit at the Medical College of Virginia from 1949 through 1962 are presently undergoing an extensive statistical review. The purpose of this report is to present the results of a probit analysis of these records relating the age of the patient and the extent of the body surface area that was burned to the mortality rate. Weidenfeld [11] showed over 60 years ago that the prognosis for the survival of burn patients could be related to both the extent of the burn and the age of the patients, but it remained for Bull and Squire,[2] and later Bull and Fisher,[3] to define this relationship more fully by using the probit transformation of their mortality data to convert it into linear form and to improve the goodness of fit. This same method has since been used to report mortality data by other authors,[1,7] the most recent report being that by Pruitt *et al.*[9] of a study of a large series of patients (1,100) treated at the Army Surgical Research Unit, Brooke Army Hospital.

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Material and Methods

The Burn Unit of the Medical College of Virginia is responsible for the care of all patients admitted to this institution with thermal injuries. Most of the patients are from Richmond or are referred from the surrounding urban areas. One thousand and forty-nine of the patients whose records are being reviewed were admitted within less than 5 hours after they had sustained their injury, and only 7 per cent of the patients were referred from another hospital where some form of primary treatment had been given.

Until 1956 most patients were treated by a "closed" method of wound care, but since 1958 most burn wounds have been treated by an "open" method. At present, patients are taken to the Burn Unit dressing room immediately after arrival. Here the extent of the injury is determined and expressed as the percentage of the body surface area involved by both second and third degree burns, and immediate resuscitative therapy is started. This includes administering intravenous fluids (modified Evan's formula), tetanus toxoid or antiserum, and prophylactic antibiotics, and cleaning and debriding the burn wound. These resuscitative principles have been unchanged during the time covered by this study. Systemic infections continue to be treated with the "appropriate" antibiotic

TABLE 1. *MCV Clinical Burn Data 1949–1962*

% Total Area Burned	0–4 Yr.			5–14 Yr.			15–39 Yr.			40–44 Yr.			45–64 Yr.			65+ Yr.		
	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort
0–4	107	0	0	59	0	0	121	0	0	27	2	7.4	74	2	2.7	62	11	17.7
5–14	232	3	1.3	86	0	0	167	0	0	27	1	3.7	112	6	5.3	57	23	40.3
15–24	79	3	3.8	56	4	7.1	86	3	3.5	5	0	0	39	12	30.8	21	15	71.4
25–34	31	12	38.7	24	10	41.7	37	10	27.0	11	3	27.3	20	11	55.0	19	19	100.0
35–44	16	11	68.7	23	12	52.2	24	11	45.8	4	4	100.0	8	6	75.0	9	9	100.0
45–54	9	7	77.8	7	5	71.4	18	9	50.0	2	2	100.0	13	13	100.0	6	6	100.0
55–64	11	11	100.0	9	7	77.8	15	12	80.0	2	2	100.0	5	4	80.0	6	6	100.0
65–74	2	2	100.0	4	4	80.0	12	10	83.3	3	3	100.0	5	5	100.0	2	2	100.0
75–84	1	1	100.0	3	3	100.0	9	9	100.0	4	4	100.0	1	1	100.0	2	2	100.0
85–94	3	3	100.0	2	2	100.0	13	13	100.0	0	0	0	4	4	100.0	2	2	100.0
95+	2	2	100.0	2	2	100.0	3	3	100.0	0	0	0	1	1	100.0	4	4	100.0
Totals	493	55	11.1	276	49	17.7	505	80	15.8	85	21	24.7	282	65	23.0	190	99	52.1

Total no. pts.: 1831
Total no. deaths: 369
Mortality: 20.15%

as determined by *in vitro* bacterial culture and sensitivity tests. Every effort is made to obtain a clean burn wound ready for grafting at the earliest possible moment. An increasing number of selected wounds are being treated by primary excision and grafting.

The record of each patient was abstracted at the time of their discharge (either from the hospital or the Out-patient Clinic), and the information was placed on an IBM Source Document designed by Dr. E. I. Evans' coworkers following his death. This information was then transferred to IBM tabulation cards, and the necessary computations were performed by the Clinical Computer Center. All patients dying with a thermal injury have been included, although a certain number probably died due to associated injuries.

The relationship between the extent of the body surface area that was burned, the age of the patient, the race and sex of the patient, and the patient's time of entry into the hospital to the mortality rate has been determined using both standard statistical methods and the probit analysis described by Finney.[4, 5]

Results

Table 1 summarizes the total patient data. Patients are divided into groups according to the percent of the total body surface area involved by second and third degree burns and their age. These groups are comparable to those used by Bull and Fisher except for dividing their 0–14 year-old group into 0–4 years and 5–14 year-old groups, and their 15–44 year-old group into 15–39 and 40–44 year-old groups. The younger age group was subdivided because other authors have reported that the mortality was higher in the 0–4 year-old patients than in the 5–14 year-old pateints. The 15–44 year-old patients were subdivided as shown because a preliminary study of the effect of age[10] by another

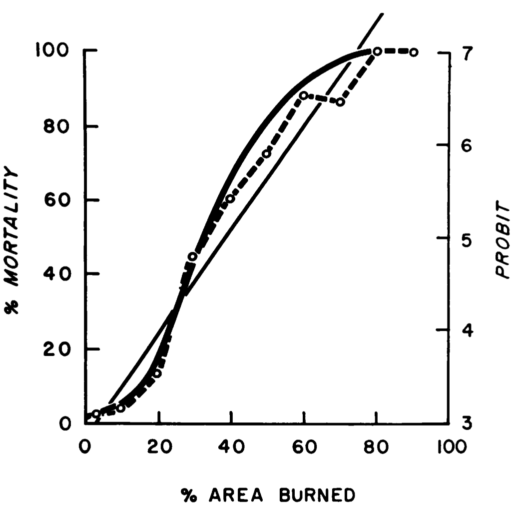

FIG. 1. Probit transformation of MCV mortality data. See text for explanation.

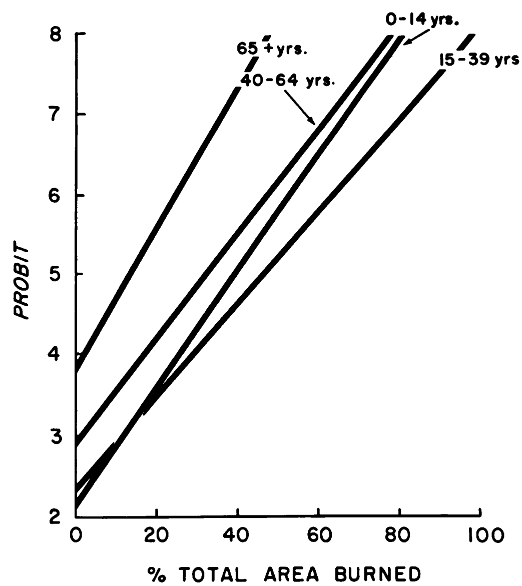

FIG. 2. Mortality probit lines for different age groups related to the total body surface area burned.

analytical technic showed a change in the effect of age on mortality at the age of 40 years. The number of patients dying and the per cent mortality is shown for each group.

Three hundred and sixty-nine patients died, an overall mortality rate of 20.15%. The mortality rate increased both with the patient's age and the percentage of the total body surface area that was burned. No patients survived with a burn involving more than 85% of the total body surface area, and only nine patients survived with a total body surface area burn of 55% or greater. The 15- to 39-year-old patients were the most tolerant of severe burns. Mortality rate was very low for patients less than 45 years of age with 25% or less of body surface area burned, but it became appreciable in older patients with the same amount of burn. As reported by Moyer,[8] these older patients tolerated a burn wound very poorly, and no patient 65 years or older lived with a burn greater than 25% of the total body surface area. Eighteen per cent of this oldest group of patients with 4% (or less) body burns died.

Probit Analysis. The data was next subjected to the probit transformation noted earlier, and the overall results of this analysis are shown in Figure 1. In this figure the dashed line represents a rough plot of mortality rate against per cent of the total body surface area that was burned. The solid sigmoid curve shows the "smoothed" data and the straight line shows the probit transformation of the sigmoid curve. Probit values are given on the right ordinate. The percentage mortality and the probit scale are not linearly related because of differences in their true values. Thus a probit value of 5.0 represents a mortality rate of 50%, but probit values of 3.0 and 7.0, respectively, represent mortality rates of 2% and 98%. The use of this transformation makes it more convenient to fit the straight line to this raw data by the method of least squares in order to obtain an accurate equation to express its slope. This equation in turn can then be used both to verify the fit of other data and to predict the mortality for a given area of burn.

Effect of Age and Severity of Burns

Mortality probit lines for the different age groups of patients are shown in Fig-

TABLE 2. *MCV Clinical Burn Data—3rd Degree 1949–1962*

% 3rd deg. Area Burned	0–4 Yr. No. Pts.	0–4 Yr. No. Deaths	0–4 Yr. % Mort.	5–14 Yr. No. Pts.	5–14 Yr. No. Deaths	5–14 Yr. % Mort.	15–39 Yr. No. Pts.	15–39 Yr. No. Deaths	15–39 Yr. % Mort.	40–44 Yr. No. Pts.	40–44 Yr. No. Deaths	40–44 Yr. % Mort.	45–64 Yr. No. Pts.	45–64 Yr. No. Deaths	45–64 Yr. % Mort.	65+ Yr. No. Pts.	65+ Yr. No. Deaths	65+ Yr. % Mort.
1–4	159	5	3.1	86	0	0	154	1	0.6	31	0	0	95	4	4.2	63	12	19.0
5–14	69	5	7.2	50	3	6.0	76	5	6.6	13	2	15.4	71	12	16.9	53	35	66.0
15–24	21	6	28.6	29	7	24.1	33	8	24.2	5	2	40.0	24	16	66.7	12	12	100.0
25–34	18	12	66.7	21	12	57.1	24	16	66.7	3	3	100.0	11	11	100.0	12	12	100.0
35–44	6	5	83.3	13	9	69.2	9	7	77.8	3	3	100.0	5	5	100.0	8	8	100.0
45–54	11	10	90.9	8	6	75.0	12	8	66.7	3	3	100.0	11	10	90.9	5	5	100.0
55–64	3	3	100.0	4	3	75.0	14	14	100.0	1	1	100.0	2	2	100.0	4	4	100.0
65–74	2	2	100.0	4	4	100.0	8	8	100.0	1	1	100.0	1	1	100.0	1	1	100.0
75–84	1	1	100.0	1	1	100.0	4	4	100.0	4	4	100.0	2	2	100.0	1	1	100.0
85–94	4	4	100.0	3	3	100.0	5	5	100.0	0	0	0	2	2	100.0	2	2	100.0
95+	0	0	0	1	1	100.0	2	2	100.0	0	0	0	0	0	0	3	3	100.0
Totals	294	53	18.0	220	49	22.3	341	78	23.9	64	19	29.7	224	65	29.0	164	95	57.9

Total no pts. with 3rd degree burns: 1307
Total no. deaths with 3rd degree burns: 359
Mortality: 27.5%

ure 2. The slope of each line represents the tolerance of that group of patients to the burn injury. It is obvious that the 15- to 39-year-old age group tolerate the burn somewhat better than any of the other groups, and the 65+ year-old age group show the least tolerance.

It is frequently very difficult or impossible to delineate areas of second degree burn from those with third degree injuries, and it is also very difficult to separate different effects upon the patient. The role of infection in converting areas of deep second-degree injury into full-thickness injuries is also of importance,[6] and, as yet, there is no data available on whether or not the "converted" full-thickness injury has a different effect upon mortality. Most patients have a combination of these two types of burns. Five hundred and twenty-four of 1,931 patients studied had no areas of third degree burn, and only 10 (1.98%) died. Causes of death in these patients with second degree burns were delerium tremens in one patient with a 2% surface area burn; respiratory smoke burn in one 51-year-old patient who died less than 24 hours following admission; pneumonia and acute myocardial failure in an 86-year-old man who had a 4% surface burn and a body temperature of 26.1° C. on admission; aspiration from a feeding tube in a 3-year-old child with a 31% body burn, and bronchopneumonia and sepsis in 39- and 73-year-old males with 45% and 46% deep second burns, respectively. Causes of death in the remaining four patients could not be determined.

As reported earlier[10] this low mortality rate associated with a partial thickness burn is striking, and therefore mortality data for patients with any amount of third degree burn has been determined and is presented in Table 2. The patient groupings are the same as those used in Table 1, but the degree of surface area burn refers to the extent of third degree burn and not to the total body surface area burn. Two

TABLE 3. *Comparison of Probit Equations and LA_{50}'s by Area Burned*

Age (yr.)	Total Area	LA_{50}	3rd Degree	LA_{50}
0–4	$y = 1.824 + 0.0881\,x$	36.1%	$y = 2.944 + 0.0745\,x$	27.6%
5–14	$y = 2.638 + 0.0569\,x$	41.5	$y = 3.044 + 0.0587\,x$	33.3
0–14	$y = 2.131 + 0.0733\,x$	39.1	$y = 2.924 + 0.0673\,x$	30.8
15–39	$y = 2.346 + 0.0574\,x$	46.2	$y = 2.849 + 0.0680\,x$	31.6
15–44	$y = 2.422 + 0.0580\,x$	44.5	$y = 2.876 + 0.0709\,x$	30.0
40–44	$y = 3.131 + 0.0488\,x$	38.3	$y = 2.705 + 0.1125\,x$	20.4
40–64	$y = 2.963 + 0.0638\,x$	31.9	$y = 3.209 + 0.0834\,x$	21.5
45–64	$y = 2.945 + 0.0663\,x$	31.0	$y = 3.310 + 0.0786\,x$	21.5
65+	$y = 3.893 + 0.0864\,x$	12.8	$y = 2.577 + 0.2834\,x$	8.5
Overall	$y = 2.894 + 0.0571\,x$	36.9	$y = 3.344 + 0.0655\,x$	25.3

y = probit; x = % area burned.

groups of patients, aged 5–14 and 40–44, with smaller third degree burns were the only ones with no mortality. If this table is compared to Table 1 it is obvious that the mortality rate increased for each of the groups, and total overall mortality rose to 27.5%. Mortality rates were very high when the area of third degree burn was greater than 25% for the 0–44-year-old age groups, greater than 15% for the 45–64-year-old age groups, and more than 5% for the 65+ year-old age group. Only one patient older than 40 years of age survived a third degree burn wound of greater than 24%.

The severity of this type of wound is again illustrated in Figure 3, showing the mortality probit lines for the major age groups. All lines are shifted to the left, and lines for the two older age groups are steeper than those calculated on the basis of total body surface area burn.

Equations for the mortality probit lines shown in Figures 2 and 3 and the calculated LA_{50} values * for both the amount of total body surface area burn and the amount of third degree burn for the different age groups are given in Table 3. LA_{50} values for the 0–4-year-old age group are lower than those for the 5–14-year-old age group, but the difference in these values is not statistically different at the $p < .05$ level.[5] The effect of the age is more apparent when the LA_{50} value for the patients in the 15–39-year-old age group is compared to that for the 40–44-year-old age group. The LA_{50} value for the total body surface area burn is 46.2% (95% confidence limit range 41–53%) for the 15–39-year-old age group, but this falls to 38.3% for the 40–44-year-old age group. There were too few patients in the latter group to calculate meaningful statistical differences. Difference in the LA_{50} values is even greater for patients in this age group with third degree burns. As expected, LA_{50} values decrease for older patients. The total body surface area burn LA_{50} value range (95% confidence limits) for the 40–64-year-old age group is 24–40%, and for the 45–64-year-old group 23–38%, again illustrating that patients between the ages of 40–44 years tolerate the burn wound in a manner similar to that shown by older patients. It is notable that the difference between the LA_{50} values for both types of burn wounds in the 65+ age group is less than for younger age groups, suggesting that other factors assume a relatively more important role in these patients. Despite the facts that LA_{50} values for the per cent of the body surface area involved by third degree burns were lower, and that

* The percentage of the total body surface area that produces a 50% mortality rate when involved by a thermal injury.

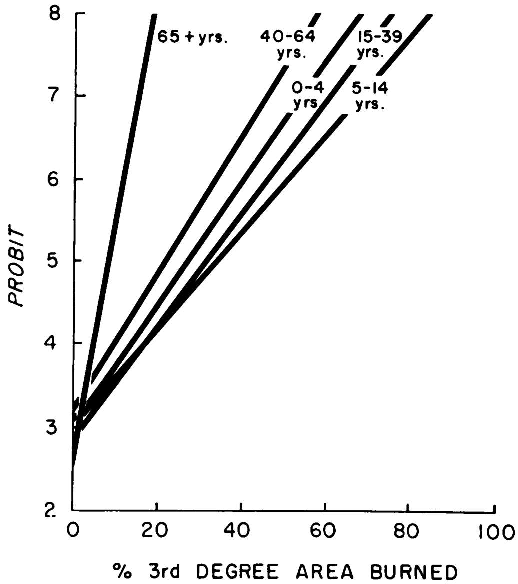

FIG. 3. Probit transformation of data for per cent of body surface area involved by third degree wound.

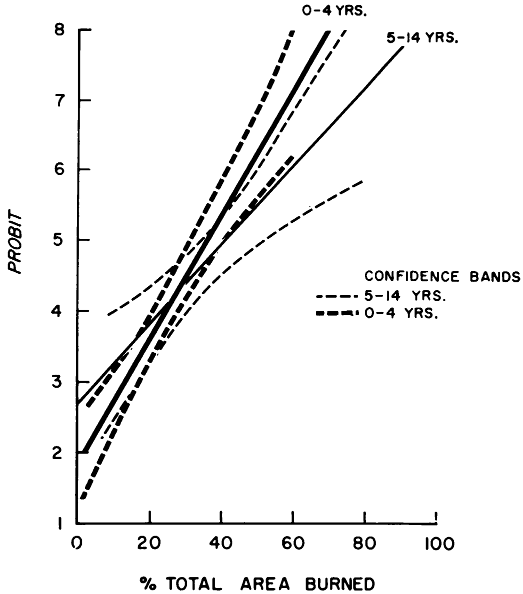

FIG. 4. Mortality probit lines for 0–4- and 5–14-year-old age groups with 95% confidence lines.

patients with second degree injuries had a very low mortality rate, subsequent data that will be presented is based on the per cent of total body surface area burned because previous authors have calculated their data on this basis.

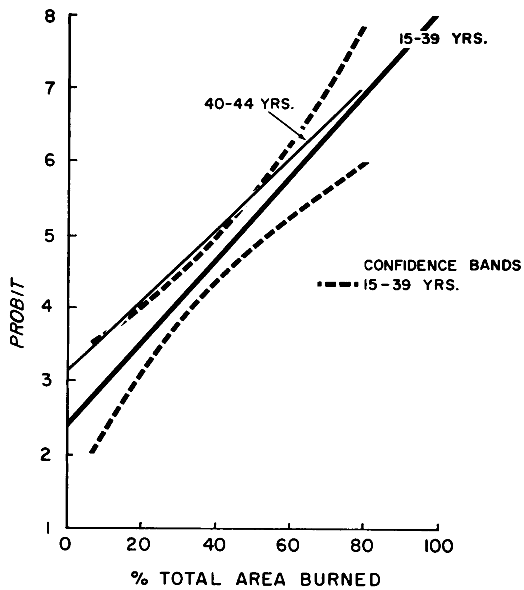

FIG. 5. Mortality probit line with 95% confidence limits for 15–39-year-old age group, and probit lines for 40–44-year-old age group.

Figure 4 shows the mortality probit lines for the 0–4- and 5–14-year-old age groups with their overlaping 95% confidence limit lines, again showing that the response of these two age groups to the burn injury is similar. Figure 5 shows the lines for the 15–39- and 50–44-age groups. This again

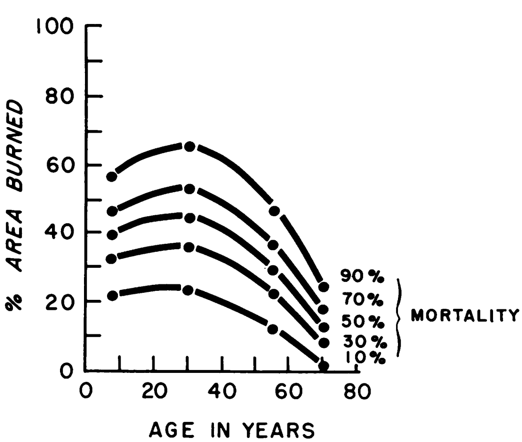

FIG. 6. Mortality contours showing the mortality rates for the different ages and percentage of total body surface burns.

GRID OF APPROXIMATE MORTALITY PROBABILITIES

% Body Area Burned	Age - Yrs.													
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65+
68 or more	1	1	1	1	1	1	1	1	1	1	1	1	1	1
63 - 67	1	1	1	.9	.9	.9	.9	1	1	1	1	1	1	1
58 - 62	1	1	.9	.8	.8	.8	.8	.9	1	1	1	1	1	1
53 - 57	.9	.9	.8	.8	.7	.7	.7	.8	.8	.9	1	1	1	1
48 - 52	.8	.8	.7	.7	.6	.6	.6	.7	.8	.8	.9	1	1	1
43 - 47	.7	.7	.6	.5	.5	.5	.5	.6	.7	.7	.8	.9	1	1
38 - 42	.6	.5	.5	.4	.4	.4	.4	.5	.5	.6	.7	.8	.9	1
33 - 37	.5	.4	.3	.3	.3	.3	.3	.4	.4	.5	.6	.7	.9	1
28 - 32	.4	.3	.2	.2	.2	.2	.2	.3	.3	.4	.5	.6	.7	.9
23 - 27	.2	.2	.1	.1	.1	.1	.1	.2	.2	.3	.3	.5	.6	.8
18 - 22	.1	.1	0	0	0	0	.1	.1	.1	.2	.2	.3	.5	.7
13 - 17	0	0	0	0	0	0	0	0	0	.1	.1	.2	.3	.5
8 - 12	0	0	0	0	0	0	0	0	0	0	0	.1	.2	.3
3 - 7	0	0	0	0	0	0	0	0	0	0	0	0	.1	.2
0 - 2	0	0	0	0	0	0	0	0	0	0	0	0	0	.1

FIG. 7. Mortality grid according to age and per cent of total body surface area burned.

illustrates the changing tolerance to the burn wound that occurs at the age of 40 years. As noted earlier another analytical method (discriminate function analysis) has also been used to determine the effect of age upon mortality, and the same effect was apparent.[10]

Equal mortality contours have been constructed from the mortality rates, and they are shown in Figure 6. The age in years is shown on the abscissa and the per cent of the total body surface area that was burned is on the ordinate. Thirty-year-old patients with a 50% total body surface area burn would therefore be expected to have a mortality rate of approximately 65%, but the same burn in 10-year-old patients would have a mortality rate of approximately 75%. This effect was not shown for younger age groups in data presented by Bull and Fisher, but it was present in data presented by Winterscheid and Merendino [12] and Pruitt *et al.*[9]

Figure 7 is the mortality grid constructed from mortality curves shown in Figure 6. Finer divisions for both age of the patient and per cent of the total body surface area that was burned are used. The numbers in this grid are approximations only, and some patients with a value of 0 would die

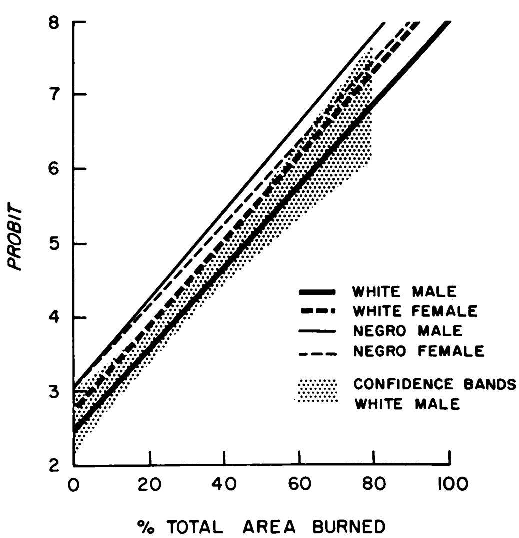

FIG. 8. Mortality probit lines according to race, sex, and per cent of total body surface area burn.

TABLE 4. *Number of Patients and Mortality by Race and Sex*

Age (yr.)	White Males			Negro Males			White Females			Negro Females		
	No. Pts.	Deaths	% Mort.	No. Pts.	Deaths	% Mort.	No. Pts.	Deaths	% Mort.	No. Pts.	Deaths	% Mort
0–4	142	9	6.3	81	7	8.6	125	6	4.8	145	33	22.7
5–14	49	3	6.1	84	13	15.5	44	4	9.1	98	29	29.6
15–39	162	20	12.3	166	27	16.3	65	16	24.6	113	17	15.0
40–64	105	19	18.1	144	38	26.4	46	13	28.3	72	16	22.2
65+	32	10	31.3	77	44	57.1	27	16	59.2	54	29	53.7
Total	490	61	12.4	552	129	23.4	307	55	17.9	482	124	25.7

TABLE 5. *LA_{50}'s by Race and Sex*

Age (yr.)	White Male	Negro Male	White Female	Negro Female
0–4	44.2%	35.9%	36.5%	31.2%
0–14	48.8	37.4	36.4	33.5
15–39	48.8	39.5	46.0	53.7
40–64	39.2	25.2	29.7	25.6
65+	17.4	9.6	16.6	11.9
Overall	44.8	32.5	39.3	35.1

while an occasional patient with a value of 1 would survive. This grid differs from that of Bull and Fisher because it shows a decreased survival in the younger age group although, as noted above, the difference is not statistically significant. It is otherwise remarkably similar to theirs.

Effect of Race and Sex

Seven hundred and ninety-seven (43.5%) of the patients were Caucasians, and 1,042 (56.9%) of the patients were males. An effort was made to determine whether or not the race or sex or both had a significant effect upon mortality rates. Results are summarized in Table 4, with patients divided according to race, sex and age. If total numbers of white patients are compared to total numbers of Negro patients, there is a significant difference in mortality rates ($p < .001$),** but there is no significant difference in overall mortality rates according to sex of the patient, disregarding race.

Data in Table 4 shows that the overall mortality rate for male patients in any age group except for 0–4-year-old white females was less than that for the other patient classifications. In the 0–14-year-old age groups it is significantly lower than the mortality rate for Negro females in the same age groups. White females have the highest mortality rates when the other age groups are compared however.

Relationships between the effect of race and sex of the patient on mortality are best shown by the probit lines for over-all mortality rates for these patients (Fig. 8) and the LA_{50} values for each age group (Table 5). The numeric value for the 95% confidence limits for the white male LA_{50} value is 39 to 56%, widely overlapping the same values as those for the white female (33 to 50%). This is also shown in Figure 8 where the superimposed confidence limits for the white male probit line encompass the probit line for the white female. The respective LA_{50} 95% confidence limits for the probit line for Negro females are 30 to 43%, and for Negro males 31 to 40%. Although there is some overlapping of these limits (and these are not shown in Figure 8) the mean LA_{50} values of these patients are statistically different from those of white males. A statistical comparison of values shown in Table 5 for different age groups shows that the Negro female LA_{50} value is statistically significantly lower than that of the

** Test for significance of difference in proportions.

TABLE 6. *Time of Admission Post Burn*

% Area Burned	2 Hrs.			2–5 Hrs.			6–23 Hrs.			1D–6D			1 Wk.+		
	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.	No. Pts.	No. Deaths	% Mort.
0–24	503	22	4.4	238	17	7.1	104	7	6.7	156	9	5.8	320	11	3.4
25–64	123	77	62.5	112	73	65.2	17	15	88.2	13	8	61.5	2	2	100.0
65+	48	48	100.0	25	23	92.0	2	2	100.0	0	0	0	0	0	0
Total	674	147	21.8	375	115	30.7	123	24	19.5	169	17	10.0	322	13	4.0

TABLE 7. *LA_{50}'s by Time of Admission Post Burn*

Age (yr.)	2 Hr.	2–5 Hr.	6–23 Hr.	1–6 Da.	1 Wk.+
0–4	35.4	41.2		31.7	
15–39	35.8	48.3			
40–64	32.0	28.4	24.2	35.9	
65+	13.7	15.2	21.7*	11.9	
Overall	35.2	37.4	28.9	34.1	36.8

* 50+ yrs.

TABLE 8. *Overall Probit Equations by Time of Admission Post Burn*

Time of Admission	Equation	LA_{50}
2 Hr.	$y = 2.519 + 0.0705\,x$	35.2%
2–5 Hr.	$y = 3.068 + 0.0517\,x$	37.4
6–23 Hr.	$y = 2.608 + 0.0828\,x$	28.9
1–6 Da.	$y = 2.941 + 0.0604\,x$	34.1
1 Wk.+	$y = 2.871 + 0.0578\,x$	36.8

y = probit; x = % area burned.

white male in the 0- to 14-year-old age groups. There is no significant difference in values for other age groups.[5]

There is insufficient data to determine why this racial difference exists, although the lower socio-economic status of the Negro in the population from which these patients were taken may explain this difference.

Mortality Rates by Postburn Time of Admission

The effect of the time of admission to the hospital after the patient is burned upon the mortality rate is shown in Tables 6, 7 and 8. Table 6 shows the per cent mortality for different times of admission in relation to percentage of the total body surface area burned. Mortality rates were low and very similar for patients with a burn of 24% or less of total body surface area. In addition there was very little difference in mortality rates for patients with larger burns, although 15 of 17 patients with 25 to 64% total body surface area burns that were admitted from 6 to 23 hours after injury died. Lowered mortality rate for 491 patients admitted 24 or more hours after injury is due to the fact that only 3% of these patients had the more severe burn wounds. This, plus the fact that only two of 75 patients admitted with burns involving more than 65% of body surface area were admitted after one day, either reflects the immediate referral of more severely burned patients to the Burn Unit without a significant delay in surrounding hospitals or communities or death of these patients prior to admission.

Table 7 lists the LA_{50} values for the same groups that contain sufficient numbers of patients for analysis and that were listed in Table 6. Changes in the LA_{50} values relative to age of the patient are similar to those noted earlier, but there is no significant difference relative to the time of admission to the hospital. The overall probit equations for admitting times are shown in Table 8, and LA_{50} values are very similar. This data shows that the transit time from the place of injury to the Burn Unit is short for the majority of these patients, that the more severe burns are probably sent directly to this Unit, and that those patients with larger burns who are not

TABLE 9. *Survival Time of Fatal Cases 1949–1962*

Mortality Probability from Grid	Period	0–2 Days	3–7 Days	8–21 Days	22 or More Days	Total Cases	Mean Survival (Days)
	1949–1952	1	1	7	5	14	32.1
0–0.4	1953–1957	5	7	8	23	43	31.9
	1958–1962	2	8	21	19	50	21.9
	1949–1952	3	8	13	4	28	11.5
0.5–0.9	1953–1957	6	11	14	6	37	12.2
	1958–1962	9	16	27	13	65	14.6
	1949–1952	16	10	2	1	29	3.9
1.0	1953–1957	11	22	8	3	44	6.7
	1958–1962	11	16	14	4	45	9.7

brought to the unit shortly after burning probably do not survive long enough to be brought there later.

Change in Survival Time in Fatal Cases

An effort has been made to determine whether or not there has been an increase in the survival time of patients dying of the burn wound within the period of time covered by this study. Patients were divided according to mortality probability as determined from Figure 5, and by three nearly equal time periods covered by this study. Table 9 shows this division and the numbers of patients that survived for various times in each of these groups. One hundred and seven patients with a mortality probability of 0 to 0.4 died, and the proportion of cases in each time period studied that survived for 8 or more days is essentially the same. However the mean survival time in this group of patients did decrease from an average of 32.1 days during the first 4 years to 21.9 days during the last 5 years of this study. These patients would all have total body surface area burns of less than 42%, and therefore the change could probably be due to associated injuries, although the information to prove or disprove this assumption is not yet available.

There were 130 patients who died that had a high probability of dying (0.5 to 0.9), and the mean survival time for these patients was essentially unchanged during the time periods covered by this study. The proportion of patients that survived for 8 or more days was also remarkably uniform for each time period.

One hundred and eighteen patients had a mortality probability of 1.0, implying only a minute statistical chance for survival. In the years 1949 through 1952, 55% of these patients died within the first 2 days following injury, but this percentage fell to 25% for the latter two periods. The survival time gradually increased, and whereas only 14% and 25% of the patients seen from 1949 to 1952 and from 1953–1957, respectively, survived for 8 or more days, 40% of the patients seen in 1958–1962 survived for this time. The mean survival time increased from 3.9 days in the first time period to 9.7 days in the latter.

These data would show that, despite other evidence that overall mortality has not decreased, progress has been made in prolonging life of patients with major burns.

Mortality Rate by Year of Admission

The mortality rate was also determined for patients according to year of admission, these being divided into the same time pe-

TABLE 10. *No. of Patients and Mortality by Year of Admission*

Area Burned %	1949–1952 No. Pts.	No. Deaths	% Mort.	1953–1957 No. Pts.	No. Deaths	% Mort.	1958–1962 No. Pts.	No. Deaths	% Mort.
0–4	101	0	0	211	8	3.8	137	6	4.4
5–14	167	6	3.6	238	13	5.5	276	16	5.8
15–24	72	5	6.9	97	13	13.4	114	17	14.9
25–34	31	15	48.4	48	21	43.7	61	29	47.5
35–44	19	6	31.6	27	17	63.0	38	30	78.9
45–54	15	9	60.0	21	17	80.9	18	15	83.3
55–64	19	15	78.9	9	9	100.0	20	18	90.0
65–74	9	7	77.8	8	7	87.5	12	12	100.0
75–84	6	6	100.0	9	9	100.0	5	5	100.0
85–94	3	3	100.0	9	9	100.0	9	9	100.0
95+	5	5	100.0	5	5	100.0	5	5	100.0
Total	447	77	17.2	682	128	18.8	695	162	23.3

TABLE 11. *Probit Equations and LA_{50}'s by Year of Admission*

Years	Equation	LA_{50}
1949–1952	$y = 2.773 + 0.0503\,x$	44.3%
1953–1957	$y = 2.954 + 0.0562\,x$	36.4
1958–1962	$y = 2.898 + 0.0632\,x$	33.2

y = probit; x = area burned

riods used in Table 9. The number of patients, per cent of total body surface area burned, and overall percentage mortality are shown in Table 10. Patients with 0 to 4% total body surface area burns had no mortality until 1953, and since that time only 14 of 348 patients (about 4%) died. Mortality rates for patients with 15 to 24% and 35 to 44% body surface area burns has doubled in the last 10 years covered by this study, and mortality rates for all of the larger surface burns has increased. The overall mortality rate was only 17.2% for the first 4 years covered by this study, but this had risen to 23.3% for the last 5 years.

Table 2 lists the probit equations and the LA_{50} values by the different periods of admission. The LA_{50} value for the first 4 years of the study was 44.3%, but this decreased significantly to 33.2% for the last 5 years.[5] Probit lines and 95% confidence limits for these years are shown in Figure 9. The probit lines themselves lie almost com-

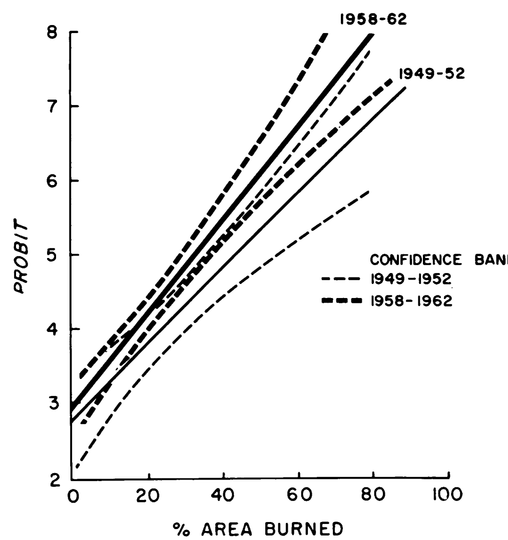

FIG. 9. Mortality probit lines and 95% confidence limits 1949–52 and 1958–62, for the per cent of total body surface area burn.

pletely outside of the confidence limit lines except for burns of less than 20% of total body surface area. These data show that there has been a definite increase in mortality rate and an apparent decrease in the tolerance of patients to a given burn wound.

It is difficult to account for this change using these types of statistical analyses. A compilation of data presented in Table 10 reveals that essentially the same percentage (23.9%, 19.9% and 24.2%) of admis-

TABLE 12. *Comparison of Patients and Mortality*

Age (yr.)	Bull and Fisher			Brooke			MCV		
	No. Pts.	Deaths	% Mort.	No. Pts.	Deaths	% Mort.	No. Pts.	Deaths	% Mort.
0–14	1366	46	3.4	238	43	18.1	769	104	13.5
15–44	967	28	2.9	806*	124	15.4	590	101	17.1
45–64	330	24	7.3	56**	22	39.3	282	65	23.0
65%	144	63	43.7				190	99	52.1
Total	2807	161	5.7	1100	189	17.2	1831	369	20.1

* 15–49 yrs.
** 50 + yrs.

sions during the three periods of time being studied were patients with greater than 25% total body surface area burned, although the mortality rate for these selected patients rose from 61.7% to 73.2% during this time. If the same calculations are carried out relative to the numbers of patients admitted with 15% or more total body surface area burns the same percentage of admissions had burns of this magnitude in both the first 4 years of this study and the last 5 years, although the mortality rate again rose 10 per cent. Therefore the difference in mortality cannot be due to any significant increase in numbers of patients that were admitted to this Burn Unit with larger burns.

However the incidence of the patients in various age groups that were admitted in these different time periods did vary significantly. Patients aged 0 to 14 years decreased progressively from 1949–52 (46%) to 1958–62 (37%), while patients aged 45–64 years increased from 11% to 20% ($p <$ .001).** The incidence of patients in the other age groups remained the same. This shift would therefore affect the overall probit lines and mortality rates calculated according to the year of admission. Differences in these values from the first 4 years to the last 5 years of this study are therefore probably due to a significant increase in the number of older patients and a decrease in the number of younger patients admitted during the latter period. This direct relationship is presently being analyzed using discriminate function analysis.

** Test for significance of difference in proportions.

Discussion

The present study has used the same method of analysis as that of Bull and Fisher[3] and Pruitt *et al.*[9] in order to facilitate comparing mortality rates in large numbers of burn patients treated in three separate burn centers. Certain differences exist in the patient populations, however, and these could account for certain apparent differences in mortality rates. The series reported by Bull and Fisher and the present one were composed of civilian patients treated at different times. Bull and Fisher do not present socio-economic data that could be important in view of the effect of race (or socio-economic status) shown in the present series. Patients comprising the series reported by Pruitt *et al.* (Brooke Army Hospital) were highly selected in that they were either military personnel or dependents, and were drawn from military bases scattered throughout the United States and in some instances foreign countries. In addition a significant number of patients treated at Brooke Army Hospital are transferred (largely by air transport) from other military hospitals after resuscitative therapy has begun. Those patients that died before they were referred, due either to the seriousness of their injury or a delay in transportation facilities, have not been included in their series. These would be further selective processes not in the series of Bull and Fisher or this one.

TABLE 13. *Comparison of Overall Mortality Excluding Area Groups with Less Than 1½% Mortality*

		Bull and Fisher		MCV	
Age (yr.)	Area Excluded	Remaining Pts.	% Mortal.	Remaining Pts.	% Mortal.
0–14	0–14%	187	22.4	285	35.4
15–44	0–14%	97	25.8	248	39.5
45–64	0–4%	87	25.3	282*	23.0
65+	None	144	43.7	190	52.1
Overall		515	29.3	1005	36.1

* No area group excluded.

Brooke Army Medical Center

Age (yr.)	Area Excluded	Remaining Pts.	% Mortal.
0–14	0–10%	158	27.2
15–49	0–10%	605	20.5
50+	0–20%	30	73.3
		793	23.8

Data from these three series relative to mortality rate for different patient age groups is presented in Table 12. The mortality rate for each group reported by Bull and Fisher is much lower than that reported by the Brooke Army Surgical Research Unit or the present series. This table, as noted, does not have strictly comparable age groupings for the Brooke series due to the method by which their data were presented, and their mortality rate for the older patients is therefore not strictly comparable.

Raw mortality rates are strongly influenced by the number of patients within any series with relatively minor or extremely severe burn injuries. Therefore, in order to compare these rates more meaningfully, patients with minor burns having little or no mortality have been excluded, and results are shown in Table 13. It is obvious that a large number of patients reported by Bull and Fisher were admitted to the hospital with minor burns, and only 515, or 18.4% of the total, had burns involving more than 14% of the body surface. Seventy-two per cent of the Brooke series and 55% of this series had more severe burn injuries. The overall mortality rate for more severely burned patients reported by Bull and Fisher increases to 29.3%, somewhat closer to those reported from Brooke Army Hospital and the Medical College of Virginia (MCV). The percentage of patients aged 0 to 14 years and 15 to 44 or 49 years in each series are fairly evenly distributed, and without determining the extent of the total body surface area burn in each series, the MCV mortality rates appear to be significantly higher.

Table 14 compares the LA_{50} values for total body surface area that was burned by age groups for the three series. Both Bull and Fisher and the Brooke Army Hospital

TABLE 14. *Comparison of LA_{50}'s for Total Area Burned by Age Groups*

Age (yr.)	Bull and Fisher	Brooke	MCV
0–14	49.4%	48.5%	39.1%
0–14	49.4%	48.5%	39.1%
15–44	46.4	55.8*	44.5
45–64	27.1	29.0**	31.0
65+	10.1		12.8

* 15–49 yr.
** 50+ yr.

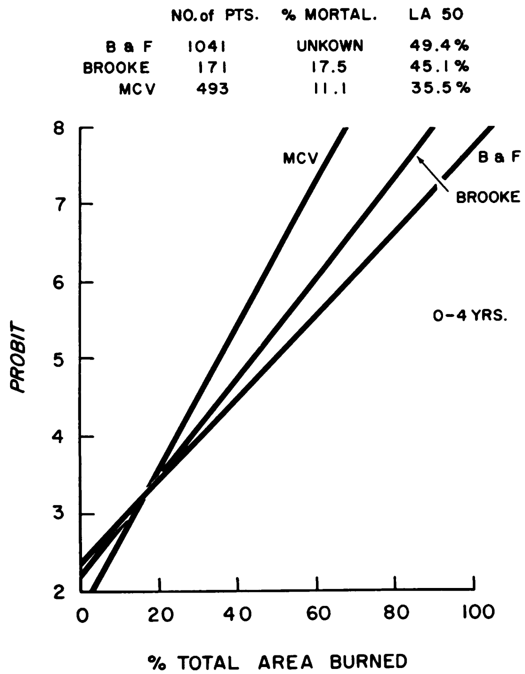

FIG. 10. Mortality probit lines for age group 0–4 years for present series and those reported by Bull and Fisher and Brooke Army Hospital.

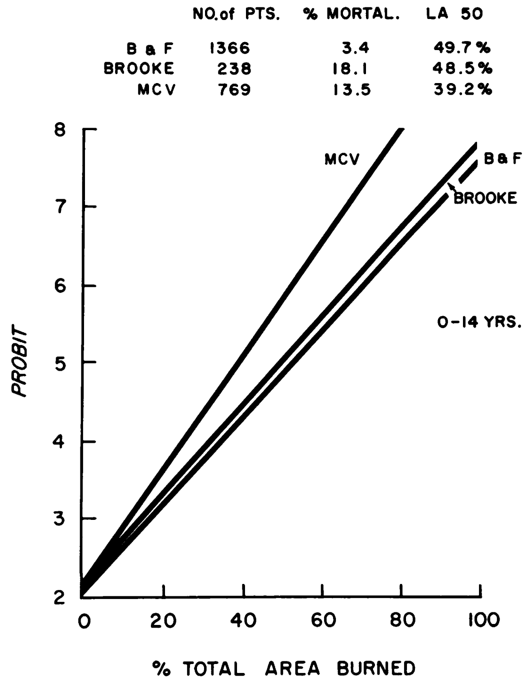

FIG. 11. Mortality probit lines for age group 0–14 years for present series and those reported by Bull and Fisher and Brooke Army Hospital.

series LA_{50} values for the age groups 0 to 14 years were statistically significantly higher than MCV's.

Pruitt *et al.* showed that the mortality rate for the 0- to 4-year-old patients is higher than that for the 5- to 14-year-old patients. Figure 10 shows mortality probit lines for the total body surface area burn for this age group from the three series now being compared. It is obvious that for burns of more than 25 to 30% of the body surface area there is a difference in mortality. As noted earlier in Tables 4 and 5 the 95% confidence limits for the LA_{50} values of patients treated at MCV in the 0 to 4 age group ranged from 31 to 44%, the latter being close to the values reported in the other series. The significantly decreased LA_{50} values for Negro females in this age group, and the overall decreased tolerance to the burn wound shown by Negro patients in this series, could account for the difference in the LA_{50} value. Figure 11 reproduces mortality probit lines for the per cent of total body surface area burned for the 0- to 14-year-old age group, and here the lines representing patients from Bull and Fisher and Brooke Army Hospital lie very close, with a significant decrease in the LA_{50} value being shown again, and for the same reason, for the MCV patients. Therefore patients reported in this series do not show the significantly increased mortality reported by Pruitt *et al.* for the 0- to 4-year-old age group, although the total mortality for these younger patients was higher and the LA_{50} value was lower than with either of the other series.

In addition the Brooke Army Hospital 15- to 49-year-old age group LA_{50} value was significantly higher than that for the 15- to 44-year-old age group from both MCV and Bull and Fisher. This age group encompasses most of the active military personnel. The remaining LA_{50} values are essentially the same.

One of the major conclusions that can be made from these data is that the mortality rate for burned patient has not significantly changed during the 10 years prior to 1962, although there is data showing, as reported by others, that survival time for fatal cases is increasing significantly. The effect of primary excision of the burn wound or newer local and systemic antibiotic and chemotherapeutic agents or both on mortality remains unevaluated at the present time although preliminary reports have been encouraging.[6]

The probit type of analysis has definite limitations, and some of these have been illustrated in the present series. The analysis is limited in the studies quoted by the use of only two factors to determine mortality, these being age of the patient and per cent of total body surface area that was burned. It is obvious that total body surface area burned is not as significant a factor as area of third degree burn, but clinical difficulties in delineating second degree from third degree burns are well known and limit the use of this factor. In addition there are other factors which affect the patient's chance of living or dying. These include pre-existing disease, associated injuries and postinjury complications. This type of information is not available using the probit transformation of raw mortality data, even by grouping patients according to the different complications that occur. A preliminary study of important factors in determining lethality in burn patients has previously been reported,[10] and results have led the authors to believe that a discriminate function type of analysis is more useful than probit analysis. It is hoped that other authors will use this type of analysis so that a better understanding of these various factors can be obtained.

Summary

The present study presents results of a probit analysis of the mortality rate seen in 1,831 burn patients treated between 1949 and 1962 at the Medical College of Virginia Hospital. Differences in mortality rates are related both to age of the patient and to percentage of total body surface area and the third degree surface area burn. In addition an attempt is made to show the effects of race and sex of the patient, time of admission to the hospital following burn injury, and the year of admission on mortality.

Results of this study confirm the relationship existing between expected mortality and age and amount of body surface area burned, but, as shown in Table 9, 107 patients or 29% of those dying had less than 50% chance of dying according to this analysis. This is a large degree of error and the total error in predicting mortality by this method would be higher if patients with a probability of dying of greater than 50%, but who lived, were included. This shows a definite need for a more accurate means to predict burn mortality. There was no effect on mortality according to time of admission to the hospital following the burn. The race of the patient was found to be important, but sex was not.

These data show that progress has been made in prolonging survival time of patients who eventually die, but the overall true mortality rate is unchanged at this hospital and in other reported series.

The LA_{50} value is a useful figure to express tolerance of a patient or a group of patients for burn injury. These values were significantly lower for younger patients treated at the Medical College of Virginia compared to values reported by Bull and Fisher and Pruitt *et al.* The best survival rates for middle aged patients have been reported by Pruitt *et al.* at Brooke Army Hospital.

These data show a striking difference between effects of second- and third-degree burn injuries in that the partial-thickness injury is rarely lethal.

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