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Primary Excision and Grafting of Large Burns *

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EARLY excision of large areas of deep burning, followed by immediate grafting, is not a new idea.[14] To remove dead tissue and close the wound is a well tried surgical principle, and its value in reducing the healing time of burns has been shown by Ross [15] and London.[12] Until recently, however, surgeons have rightly hesitated to embark on very large operations during the stage of shock that follows burns without being sure that the patient's blood volume was normal and could be kept so.

During the last few years the management of shock in severely burned patients has been made easier by blood volume measurement every eight or 24 hours using labelled red cells. Combined with physical signs, and hematocrit and urine output estimations, this has ensured greater accuracy in keeping the patient's blood volume near normal. It is not surprising to find that shock is now less lethal and that the survival time of fatal cases has been prolonged.

But despite these improvements, mortality figures have not improved. There can be little doubt that infection has now taken first place among the causes of death in burned patients who have a chance of survival, and the majority of fatalities are in the first three weeks. It is therefore reasonable to tackle the factors which predispose to invasive infection, and two of these are the size of the open wound and the presence of dead tissue.[8]

Aim and Rationale

The aim of primary excision and grafting was to close as much of the wound as possible before it became infected. Pyrexia, malaise and red cell destruction in severely burned patients often subside after grafting, and when the size of the wound becomes less than 5 per cent of the body surface they usually disappear. Morbidity and mortality might, therefore, be reduced by earlier wound closure. Subsidiary aims were to decrease fluid loss from the burn, to forestall the period of natural slough separation with its associated immobilization and uncomfortable dressings, to limit protein loss and tissue wasting, to improve appetite and morale, and to shorten the healing time. These were reasonable expectations.

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TABLE 1. *Details of Patients Studied*

Case No.	Age	Sex	Total Burn	w.s.l.	Burn to Opn. Hrs.	Burn to Opn. Days	Area Excised	Excision to Graft (days)	Area Grafted (controls)	Blood Loss at Opn. (mls.)	Duration of Opn. (hrs., mins.)	Take of Graft Initial	Take of Graft Final	Homografts Used At 1st Opn.	Homografts Used Later	Healing Time Till <5%	Healing Time Till <2%	Mortality Probability	Died	Survival Time (days)
Pilot Trial																				
1	75	F	10	9	8	—	9	0	—	550	1.35	70	70	—	—	4	—	0.6	D	5
2	7	F	18	10	5	—	10	0	—	870	1.30	93	87	—	—	5	5	0.0	—	—
3	20	F	13	11	6	—	11	0	—	1,590	1.30	87	87	—	—	4	4	0.0	—	—
4	13	M	12	12	4	—	12	0	—	1,100	1.45	90	90	—	—	6	6	0.0	—	—
5	4	M	15	12	6	—	12	0	—	980	2.00	88	88	—	—	4	4	0.0	—	—
6	9	F	20	13	10	—	13	0	—	2,600	2.35	70	70	—	—	32	32	0.0	—	—
7	9	F	17	15	7	—	12	0	—	1,600	1.55	70	33	—	—	31	51	0.0	—	—
8	6	F	24	18	—	5	12	0	—	2,550	1.40	80	80	—	—	24	41	0.1	—	—
9	5	F	25	25	7	—	18	0	—	1,465	1.55	85	85	—	—	28	32	0.1	—	—
10	7	F	50	40	9	—	20	0	—	555	1.30	95	90	—	—	—	—	0.5	D	22
11	5	F	55	52	8	—	15	0	—	1,300	1.20	80	80	—	—	—	—	0.6	D	16
12	7	F	63	60	9	—	18	0	—	1,400	1.50	80	70	H	—	59	c.200	0.8	—	—
Controlled Trial (Controls)																				
13	50	M	12	8	—	23	—	—	8	—	—	90	90	—	—	27	27	0.1	—	—
14	15	M	16	8	—	27	—	—	8	—	—	100	100	—	—	32	32	0.0	—	—
15	4	F	13	11	—	19	—	—	11	—	—	90	90	—	—	23	23	0.0	—	—
16	11	F	16	15	—	18	—	—	14	—	—	95	95	—	—	23	23	0.0	—	—
17	44	M	18	16	—	28	—	—	15	—	—	90	90	—	—	32	52	0.1	—	—
18	25	M	30	20	—	24	—	—	12	—	—	98	98	—	—	44	54	0.2	—	—
19	10	F	35	27	—	25	—	—	20	—	—	45	45	—	—	54	54	0.2	—	—
20	12	F	40	35	—	17	—	—	11	—	—	35	35	—	—	67	110	0.3	—	—
21	10	F	36	36	—	18	—	—	16	—	—	90	90	—	—	41	51	0.2	—	—
22	11	F	40	39	—	18	—	—	30	—	—	55	55	H	—	46	67	0.3	—	—
23	1	F	60	54	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7	D	17 hrs.
Controlled Trial (Primary Excision Cases)																				
24	20	F	13	8	7	—	8	0	—	550	1.25	90	90	—	—	5	5	0.0	—	—
25	14	F	20	9	7	—	9	0	—	1,490	1.50	70	70	—	—	34	61	0.0	—	—
26	52	M	11	10	5	—	10	0	—	390	1.43	80	80	—	—	4	22	0.1	—	—
27	12	M	25	14	18	—	13	0	—	1,324	—	90	60	—	—	19	19	0.1	—	—
28	10	F	18	15	8	—	15	0	—	1,190	1.37	70	90	—	—	23	23	0.0	—	—
29	2	F	28	18	6	—	14	0	—	755	1.45	95	90	—	—	26	38	0.1	—	—
30	17	F	28	25	8	—	14	0	—	—	—	90	17	—	—	61	81	0.1	—	—
31	46	M	33	25	9	—	20	0	—	2,700	2.10	—	—	—	—	—	—	0.6	D	3
32	39	F	30	27	14	—	22	0	—	2,860	—	80	40	—	—	43	57	0.3	—	—
33	25	F	40	35	12	—	25	0	—	3,510	2.00	80	80	—	—	51	73	0.4	—	—
34	7	F	45	36	7	—	18	0	—	1,100	1.20	76	55	—	—	63	83	0.4	—	—
35	17	F	48	37	10	—	18	0	—	3,500	2.05	90	20	H	—	—	—	0.5	D	23
36	8	F	50	47	10	—	20	0	—	600	1.20	85	10	—	H	99	134	0.5	—	—
Experimental Period (Excision and Grafting at Different Times)																				
37	15	F	15	10	6	—	10	5	—	715	—	85	70	—	—	14	40	0.0	—	—
38	6	F	18	16	7	—	15	5	—	340	1.35	90	80	—	—	22	30	0.0	—	—
39	4	F	25	20	—	3	9	7	—	530	0.45	20	40	—	—	45	59	0.1	—	—
40	5	F	25	20	—	1	18	0	—	855	1.45	95	95	—	—	16	26	0.1	—	—
41	48	M	33	20	11	—	15	4	—	680	2.00	85	85	—	—	22	43	0.6	—	—
42	7	F	24	21	—	1	15	11	—	630	0.38	80	80	—	—	30	72	0.1	—	—
43	6	F	25	22	23	—	22	6	—	1,700	1.20	85	50	—	—	65	75	0.1	—	—

TABLE 1.—*Continued*

44	5	F	30	25	23	—	21	6	—	—	500	0.32	85	80	—	—	22	39	0.1	—	D	—	—
45	53	F	31	25	8	—	15	0	—	—	2,990	2.15	40	40	—	—	—	—	0.6	—	D	—	5
46	6	F	32	26	7	—	15	5	—	—	520	0.40	85	85	—	—	38	38	0.1	—	—	—	—
47	3	M	38	30	14	—	15	5	—	—	210	0.40	80	80	—	—	—	—	0.3	—	D	—	16
48	9	F	38	34	—	7	20	3	—	—	915	0.55	70	70	—	—	—	—	0.3	—	D	—	19
49	20	F	65	35	12	—	14	6	—	—	1,460	1.00	—	—	—	—	—	—	0.9	—	D	—	18
50	4	F	41	40	—	8	6	16	—	—	445	—	75	75	—	—	H	104	0.3	—	—	—	—
51	8	F	55	50	6	—	30	0	—	—	550	2.00	80	50	H	—	—	53	0.6	—	—	—	—
52	2	F	61	55	10	—	25	5	—	—	480	0.50	—	—	H	—	—	—	0.7	—	D	—	5
53	7	F	65	60	—	4	35	4	—	—	—	2.00	—	—	H	—	—	—	0.8	—	D	—	13
Controlled Trial (Continued)—Controls																							
54	7	M	55	45	—	27	—	—	40	—	—	—	95	95	H	—	48	69	0.6	—	—	—	—
55	11	M	65	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.8	—	D	—	3
56	4	F	62	60	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7	—	D	—	24
Controlled Trial (Continued)—Primary Excision Cases																							
57	14	F	41	35	19	—	24	0	—	—	1,800	2.00	85	85	H	—	—	—	0.3	—	D	—	13
58	7	F	65	60	—	2	23	1	—	—	600	—	—	—	—	—	—	—	0.8	—	D	—	7
59	5	F	72	65	11	—	20	—	—	—	320	1.00	—	—	—	—	—	—	0.9	—	D	—	2

The cases have been arranged in increasing order of full-thickness skin loss within each trial. The trials (pilot trial, controlled trial, experimental period and continuation of controlled trial) are in chronological order as described in the text.
Total area burned, whole skin loss (w.s.l.), and areas excised and grafted are measured in percentage of body surface.
Healing times are in days until less than 5 per cent and 2 per cent remained unhealed.

Possible disadvantages of the method were also apparent. Making a large fresh wound might open up avenues for overwhelming invasive infection. In addition, the risks added to the shock stage by surgery might outweigh the risks avoided by early excision and closure. Again, it was conceivable that the stress of early operation, which is a second big injury, might somehow break down the body's natural defense mechanisms against infection.[1, 2]

As soon as it was considered safe to try large primary excisions, it was necessary to choose which procedure was most likely to be successful. Should immediate excision and grafting be carried out within a few hours of injury, or would it be better to excise a larger area of dead tissue, and delay grafting it until a few days later? Would four days with a freshly excised open wound increase the risks of septicemia and excessive fluid loss more than a smaller area of debridement with immediate closure? Or was greater benefit to be expected from excision performed in a practically clean field on the first day than from the same operation in a more contaminated field on the fourth day? If immediate operation was better, was this advantage offset by the increased risks of operation in the shock stage? Were risks simply being transferred from the second two weeks to the first two days?

There was little evidence to answer these questions, but our choice of immediate excision and grafting as soon as the patient was resuscitated was based on the following reasoning. Since our aim was to prevent infection, it seemed appropriate to close the wound as soon as possible, and preferably before the surface of the burn was colonized with pathogenic bacteria. Moreover, from our experience of patients transported from a distance and then excised, we were impressed with the greater fitness of badly burned patients to withstand added trauma immediately after

blood volume restoration than one to four days later. We considered it more important to reduce the size of the open wound by excision *and grafting* than to excise a larger area of slough if that meant leaving the wound open. Moreover, it seemed likely that operation with an interval of dressings or exposure before grafting would lead to some graft failure due to infection, and this would probably be less if grafts were applied at once. While we recognized the importance of dead tissue as a reservoir of infection, steps to make the wound smaller without delay seemed more important to us. Furthermore, by starting grafting as early as possible we hoped to reduce the healing time. In making this our first choice we recognized, of course, that other alternatives might also be worth exploration.

Selection of Cases

Throughout this investigation each patient was given the treatment which seemed to offer him the greatest personal benefit. Only when there seemed no indication that early or delayed grafting was superior to the other was treatment allotted in a random manner; and even then the patient was removed from the trial if his welfare required a change in treatment.

The study, which has taken over four years, has been run partly as a controlled trial, comparing primary excision and immediate grafting with grafting in the third week, and partly as an investigation of other procedures such as primary excision with delayed grafting, delayed excision and grafting, and different methods of applying grafts. Details of the cases are given in Table 1.

a) From September to December 1954 a *pilot trial* of excision and grafting of large burns on the day of injury was carried out so that small cases could be done first and technic could be developed, and to find out if the method was practical and comfortable for the patient. Twelve cases were excised and grafted, and the results were sufficiently encouraging to plan a controlled trial.

b) In this controlled trial (January 1955 to February 1957), the cases were selected by one of us (D.J. or J.C.) as suitable for the trial if the whole skin loss was definite, sufficiently extensive and its limits defined. After they were accepted for the trial on the ground that they could be treated equally well by either method, they were allotted at once to "immediate excision and grafting" or to "grafting at 2 to 3 weeks" in a random manner.

The cases in the trial were placed in one of six groups according to age and area of whole skin loss (w.s.l.). The grouping is shown in Table 2 and was as follows: Patients under 55 years of age, Group I—8 to 15% w.s.l., Group II—16 to 30% w.s.l., and Group III—over 30% w.s.l.: the same whole skin loss grouping was used for patients over 55 years (Groups IV to VI). Patients with less than 8% w.s.l. were not included as we have been convinced for some years of the advantages of primary excision in these cases.

This trial contained 13 patients under 55 years excised and grafted on the day of burning, and 11 patients unexcised, and grafted at 2–3 weeks.

c) From March 1957 to March 1958 the controlled trial was interrupted to try other technics which might secure a better take of grafts. During this period selected extensive burns were excised and grafted, without controls, at different times after burning, and with grafts applied at varying periods after excision and in different ways (as sheets, postage stamps and with and without dressings). There were 17 cases in this group.

d) With the experience gained during the previous year (c) the controlled trial was restarted in March 1958 and continued for a year. Three cases were excised, two of them primarily, and there were three controls.

Operative Management and Technic

The primary excision operations in the pilot and controlled trials (a and b) were performed after restoration of the patient's blood volume and as soon as operating theatre and blood were available. The time varied from four to 18 hours after injury, the average being a little over nine hours. In burns of more than about 30 per cent total area, the preoperative blood volume was only accepted as normal after confirmation with a blood volume estimation.

Although the general aim was to operate as soon as possible, delay was sometimes caused by late admission, blood volume measurements or the need to wait for operating facilities.

General anesthesia was used; fluids by mouth were stopped at least four hours before operation, and preferably longer.

During the majority of operations swab weighing was carried out and the transfusion controlled by reference to the measured blood loss. Tourniquets were used on the limbs where possible, and hemostasis was controlled by diathermy coagulation and suitable positioning of the patient and the table. Latterly, "cutting diathermy" was used for incising the skin and this was successful in reducing the blood loss.

Excision was sometimes performed with a scalpel, sometimes by repeated "slices" with a Humby knife excising tangential sheets of skin and fat, and sometimes by dissecting the burn and subjacent fat off the deep fascia. The nipples and subjacent fat were usually not excised, even when diagnosed as necrotic. Sometimes the degree of excision was a little in excess of the grafts available, but usually the excised area was all covered with grafts, sometimes with excess to store. Grafts were applied in sheets, except when alternate strips of autograft and homograft were used, and secured with dressings.

In these operations the aim was to graft as much as the patient would tolerate while keeping the duration of the operation below one and one-half to two hours.

Hematocrit estimations were measured hourly before and after operation, and postoperative blood volume estimations were carried out whenever there was uncertainty and anxiety about the blood volume.

The initial dressing of the grafts was at four days, except in a few cases where the donor areas were intimately mixed with the areas grafted, and these were dressed at eight to ten days.

TABLE 2. *The Grouping of Patients in the Controlled Trial of Primary Excision and Immediate Grafting*

	Under 55 yrs.	Over 55 yrs.
8–15% w.s.l.	Group I (9 cases)	Group IV (nil)
16–30% w.s.l.	Group II (7 cases)	Group V (nil)
Over 30% w.s.l.	Group III (8 cases)	Group VI (nil)

Results

Since the aim of the study was to note the effect of early closure of the burn wound on infection and mortality, the degree of success in closing the wound is described first and the effect on infection and mortality is reported subsequently.

Under each of these headings two comparisons are made:

a) *The Controlled Trial.* The controlled trial cases are used to compare the results of primary excision and immediate grafting with grafting at two to three weeks after injury.

b) *The Comparison of Primary and Delayed Grafting.* All the cases of primary excision and immediate grafting are compared with the cases in which grafting was delayed for several days. The latter group consisted of burns treated by delayed excision and grafting, or by primary excision and delayed grafting: these alternative technics were tried in the hope of securing a better take of grafts with less failure due to hemorrhage.

Other criteria of the value of primary excision and immediate grafting which are examined are the amount of blood loss, the number of grafting operations required and the effect on the general condition of the patient.

Closure of the Wound. An analysis of the cases, grouped according to the amount of whole skin loss, is given in Table 3.

TABLE 3. *Wound Closure and Healing Time*

	Groups for Comparison	No. of Cases	Mean Total Area of w.s.l., %	Mean Area Grafted at First Grafting Operation	Mean Area Successfully Grafted at First Grafting Operation	Mean Time of Grafting Operation: Days Since Injury	Mean Healing Time in Days Till 5% w.s.l.	Mean Healing Time in Days Till 2% w.s.l.
Group I 8–15% w.s.l.	Primary excision controlled trial:							
	Unexcised cases	4	10	10	9	22	26	26
	Excised cases	5	11	10	8	0	17	26
	All primary excision and graft cases	11	12	11	9	0	15	21
	Delayed excision or graft cases	1	10	10	8.5	5	14	40
Group II 16–30% w.s.l.	Primary excision controlled trial:							
	Unexcised cases	3	21	16	12	26	43	53
	Excised cases	3	23	13	11	0	43	59
	All primary excision and graft cases	5	22	14	12	0	36	50
	Delayed excision or graft cases	8	21	16	13	5	33	48
Group III Over 30% w.s.l.	Primary excision controlled trial:							
	Unexcised cases	3	37	19	10	18	51	76
	Excised cases	3	39	18	14	0	71	97
	All primary excision and graft cases	5	45	20	16	0	62	109
	Delayed excision or graft cases	—	—	—	—	—	—	—

All surface area estimations are measured in percentage of body surface (i.e., columns 2, 3 and 4).
All fatal cases are omitted.
Details of cases in the Controlled Trial and the Comparison of Primary and Delayed Grafting are given separately in the three Groups according to total area of whole skin loss (w.s.l.).

a) *The Controlled Trial.* (Primary excision and immediate grafting compared with grafting at two to three weeks.) If the figures for the Controlled Trial are studied, it will be seen that the total extent of deep burning in the excised and unexcised cases is comparable within each Group. So also is the area of whole skin loss grafted at the first operation, and the area of successful take. The important difference is that this degree of successful closure was effected on the day of injury in the excised cases, and only about three weeks later in the unexcised. The average amounts by which the excised burns were made smaller on the first day were 8, 11 and 14% of the body surface in the three Groups.

Final healing times have not been compared because they were not known in a number of cases, the patients having been sent away for convalescence before healing was complete. Instead, the healing time has been measured by the number of days until the wound was reduced to 5 per cent and then 2 per cent of the body surface. These figures are also given in Table 3. In no Group did it take a shorter time for the excised cases to reach the stage of only 2 per cent still unhealed. The early gain in securing skin cover by primary grafting was later lost.

There seemed little doubt that this loss of advantage was related to graft failure. Sometimes there were scattered small areas of graft failure which took a long time to heal; less often extensive destruction of grafts occurred in the second week, after they had appeared to be established during the first week. Graft failure was diagnosed clinically as attributable to hemorrhage and infection with equal frequency. The degree of failure due to hemorrhage was only 5 to 15 per cent of the graft. The extensive failures (25 to 75%) were all associated with (and undoubtedly often caused by) profuse bacterial colonization; in some cases, however, the bacterial colonization was probably a consequence of graft failure due to other causes.

The mean graft take during the first and second weeks is shown in Table 4. (It is the first and better graft assessment which has been used in Table 3.) The deterioration in the mean graft take in the excised series is striking, and it was caused principally by four cases in which apparently sound grafts were largely lost.

The most striking of these was a girl of 17 with a 28% burn, 25% being full-thickness skin loss (Case 35. Fig. 5a–d). Eight hours after injury areas of deep burning on the thighs and buttocks amounting to 14% were excised; the thighs were covered with split skin grafts. At the first dressing on the 6th day the grafts on both thighs were 90% successful; on the 9th day the left thigh was still 90% take and the right 80%. On the 18th day the take of grafts on the left thigh was 25% and on the right 5%. The bacteria isolated from the burns were *Staph. aureus, Ps. pyocyanea* and coliform bacilli. Group A hemolytic streptococci (*Streptococcus pyogenes*), the chief bacterial cause of graft failure in smaller burns, were not found. Such dissolution of apparently established grafts, two weeks after application, is very uncommon in our experience.

b) Comparison of Primary and Delayed grafting. Table 3 also gives the results of all the primary excision and grafting cases for comparison with the delayed excision and delayed grafting cases (fatal cases excluded). Only in Group II are there sufficient numbers for comparison, and here the two series are comparable in size. In the delayed series the mean time of excision was the day after admission and grafting was usually four days later. The two operations were associated with a slightly larger area of successful graft but the healing time was not appreciably different.

Infection

The cases have also been studied bacteriologically to see whether wound infection was reduced by primary excision and grafting, whether avenues were opened to invasive infection, and whether the serious failure of some of the primary grafts was attributable to particular organisms.

The patients were receiving the prophylactic care recommended by Colebrook,[6] including local penicillin cream under dressings and the use of a plenum-ventilated dressing station; the lack of ward isolation facilities and an increase in the number of patients admitted to the hospital, however, limited our success in the control of cross infection.

TABLE 4. *Assessment of Mean Graft Take During First 2 Weeks after Grafting (Range of Graft Take Indicated in Brackets)*

	The Controlled Trial	
	Excised	Unexcised
Number of patients	12	10
Take of graft assessed on 6th day	83%(70–95%)	78%(35–98%)
Take of graft assessed on 11th day	56%(5–90%)	84%(10–95%)

Swabs taken from burns on admission, at all changes of dressings and at operations were examined by the methods described elsewhere.[7] Blood cultures were taken after preparation of the skin with 1 per cent iodine in alcohol, or occasionally from indwelling venous catheters; direct platings on blood agar were examined after overnight incubation, and cultures in cooked meat broth were subcultured on the first, second, seventh, fourteenth and twenty-first days to blood agar for aerobic and anaerobic culture.

a) The Controlled Trial. *Degree of Wound Infection.* Where grafting on the day of injury was permanently successful, there was a reduction in the area of burn colonized by bacteria by up to 14 per cent of the body surface; the size of the reservoir of infection was made correspondingly smaller, and the portal of entry narrowed. On the other hand, no reduction could be shown in the varieties or numbers of pathogenic organisms on swabs taken from the remaining areas of burn. This result was not unexpected, and agrees, for example, with the finding in this Unit of *Ps. pyocyanea* in most burns of more than 10 per cent and almost all burns of more than 15 per cent body area.[13] The incidence of *Ps. pyocyanea* could be reduced by inclusion of polymyxin in the prophylactic cream,[7] but this was not done during the trials reported here.

Colonization with *Ps. pyocyanea* and coliform bacilli was almost invariable in excised and un-

TABLE 5. *Blood Culture Results*

	Number of Patients Studied	Number of Patients who had Bl. Cultures	Pts. with Positive Bl. Culture Any Time	Patients with Positive Blood Culture with Pathogen Any Time	Patients with Positive Blood Culture with Pathogen First 3 Weeks
The Controlled Trial:					
Unexcised cases	11	2	2	0	0
Excised cases	13	3	2	2	0
All Primary Excision and immediate graft cases	28	7	6	4	2
Delayed Excision or delayed graft cases	17	8	6	6	6

Fatal cases are included. Organisms described as pathogens include *Staph. aureus*, *Strep. viridans*, haemolytic streptococci, *Ps. pyocyanea*, Proteus and coliform bacilli. Nonpathogenic organisms include micrococci and aerobic spore-bearers. The delayed excision or delayed grafting cases were sometimes grafted with postage-stamp grafts and often exposed.

excised series: all the excised cases picked up *Ps. pyocyanea* between the first and twelfth day (mean 7th day), and nine of ten unexcised cases picked up the same organisms between the fourth and eighteenth days (mean 9th day). Nine of 12 (75%) of the excised cases picked up Group A β-hemolytic streptococci at some time during healing, compared with six of ten (60%) of the unexcised cases. Group A β-hemolytic streptococci were associated with graft failure following one primary grafting operation, and Group C hemolytic streptococci with another: Group A and C streptococci were not present in relation to any of the first operations of unexcised cases. During the period of the trial there were several severe ward infections with Group A hemolytic streptococci, and this accounts for the large proportion of cases which were infected with this organism at some period during their time in hospital. In our experience Group A hemolytic streptococci usually cause a serious degree of graft failure, but Group C streptococci are less likely to do so.

Degree of Bacterial Invasion. Serious bacterial invasion through the extensive excision wound was recognized from the start as a possible complication which could be made more likely by the presence of adjacent unexcised slough or by graft failure.

In view of discomfort to the patient and because superficial veins are few and precious in extensively burned children, we did not feel that frequent routine blood cultures were justified. However, they were made whenever a bloodstream infection was seriously considered on clinical grounds unless there was no available superficial vein. All the patients who had blood taken for culture had general illness compatible with serious bloodstream infection.

Table 5 shows that in the controlled trial no positive blood cultures with pathogenic organisms were found in the three weeks following injury in the unexcised or excised series. Two of 28 primarily excised and grafted cases, however, had a positive blood culture with pathogenic organisms in the first three weeks: one child died from a *Staph. aureus* and *Ps. pyocyanea* septicemia with pulmonary atelectasis 16 days after her accident, and three days after her second grafting operation; the other, the only primary excision and graft case to be exposed, had septicemia with *Staph. aureus* and micrococci in the blood culture on the twenty-first day, but recovered.

Infection as a Cause of Late Graft Failure. Study of the four excised cases in

TABLE 6. *Pathogenic Organisms and Percentage Graft Take in One of the Cases of Late Graft Failure*

Date of Dressing	6th Day	9th Day	12th Day	18th Day
Left thigh				
% take	90%	90%	No estimate (no appreciable change)	25%
Organisms	Coliform bacilli +++	No swab	Coliform bacilli + *Staph. aureus* ++	Coliform bacilli +++ *Staph. aureus* ++ *Ps. pyocyanea* +
Right thigh				
% take	90%	80%	No estimate (no appreciable change)	5%
Organisms	Coliform bacilli +++	No swab	Coliform bacilli +++ *Staph. aureus* +++ *Ps. pyocyanea* +	Coliform bacilli +++ *Staph. aureus* ++ *Ps. pyocyanea* +

which late graft failure was serious has shown no definite bacterial cause for the failure, the flora being similar to other cases in which grafts remained intact. Table 6 shows the bacteriological findings from swabs taken at dressings, and the assessment of graft take in the case of late graft failure described above (Case 35. Fig. 5a–d).

Most of the excised and unexcised cases, irrespective of their initial graft take or subsequent progress, developed heavy growths of *Staph. aureus* and Gram-negative bacilli, and late graft failure could not be attributed to coincident added infection with these organisms alone. From a study of all the cases, this graft failure cannot be attributed to any particular organisms, though heavy colonization with Gram-negative organisms, especially *Ps. pyocyanea*, is a factor common to them all.

b) Comparison of Primary and Delayed Grafting. *Degree of Wound Infection.* The bacterial colonization of the wound when excision was delayed, or when primary excision was followed by delayed grafting, was very similar to that in both groups of the controlled trial.

Of the 18 cases in this group all but one case (a patient who died on the second day) picked up *Ps. pyocyanea* between the second and thirteenth days (mean 8th day). Nine of eighteen (50%) picked up Group A β-hemolytic streptococci at some time during healing, and this organism was associated with some degree of graft failure on two occasions.

Degree of Bacterial Invasion. The results of blood culture examinations from the delayed excision and delayed grafting cases are given in Table 5. Superficially it would appear that the incidence of septicemia with these procedures is greater than with primary excision and immediate grafting or with grafting at two to three weeks, but two factors must be considered in the interpretation of these results. The first is that blood cultures have been taken more frequently during the last two years when delayed excision or grafting have been practiced: secondly, these delayed cases have been more extensive than the primary excision and grafting cases they are compared with. (The mean total size of burn was 40 per cent of the body surface for the delayed cases, compared with 30 per cent for the primary excision and immediate grafting series.) These two factors would explain in part the apparent increased incidence in septicemias, but part of it may be real.

TABLE 7. *Expected and Actual Mortality**

	Number of Patients	Expected Mortality	Actual Mortality
The Controlled Trial:			
Unexcised cases	11	2.1	1
Excised cases	13	3.1	2
All Primary Excision and Immediate Graft cases	28	7.3	7
Delayed Excision or Delayed Graft cases	17	6.2	7

* Using the Mortality Probability Grid of Bull & Fisher (1954).

Late Graft Failure. Of ten delayed excisions and grafts there were no cases of serious late graft failure similar to the four in the primary excision series. On the other hand the final mean graft take (72%) was not much better than the final assessment for the primary excision cases (68%). [The initial assessment of graft take for all the cases of primary excision and immediate grafting was 83%.]

Mortality

The expected and actual mortality for the groups under consideration are given in Table 7, the expected mortality being calculated from the figures of Bull and Fisher.[4]

a) The Controlled Trial. The actual mortality is slightly lower than the expected in both the unexcised and the excised series, and this is still true when all the primary excision and graft cases are considered together. On these figures it is not possible to claim a reduced mortality due to primary excision and immediate grafting. On the other hand, after 28 cases, the procedure as practiced seems safe, and neither impressions nor figures suggest an increased mortality due to treatment.

b) Comparison of Primary and Delayed Grafting. No significant difference in mortality can be demonstrated for the two methods, though the results of primary excision and immediate grafting tend to be the better.

c) A third assessment of mortality results is of interest, though the cases are not strictly comparable. First, primary excision and immediate graft cases were selected which satisfied two criteria: they had a mortality probability of 0.2 to 0.6 (that is, they had a chance of dying but the burn was small enough to be likely to benefit from the procedure); *and* they had more than 2 per cent of microcytes present in the head of a blood film taken on admission (this is a factor associated with increased blood destruction and higher mortality).[17] In this group of six excised patients, the expected mortality was 3.0 and the actual deaths numbered three, although the presence of over 2 per cent microcytes would have led one to expect more fatalities. Of 12 similar cases not primarily excised and grafted, the expected mortality was 6.0 and the actual deaths nine, which may well be nearer the expected figure for such severe selected cases.

Causes of Death. The causes of death are given in Table 8. They show that infection and lung complications are the common lethal conditions, as they are when extensive burns are grafted at 2 to 3 weeks.

Assessment of Mortality Results. The following points are of assistance in evaluating the mortality results:

1. The cases selected for primary excision had burns which were predominantly whole skin loss, a factor associated with increased mortality. For this reason the expected mortality of all the cases in the study, excised and controls, was probably

TABLE 8. *Causes of Death*

	Case No. (see Table 1)	Age	Total Area of Burn (%)	Survival Time (days)	Cause of Death
The Controlled Trial:					
Unexcised cases	23	1	60	< 1	Congestive atelectasis and pulmonary oedema
Excised cases	35	17	48	23	Bilateral bronchopneumonia and lung abscess
	31	46	33	3	Temporal glioma
All Primary Excision and Immediate Graft cases	11	5	55	16	Septicemia (*Ps. pyocyanea* and *Staph. aureus*) and pulmonary atelectasis
	35	17	48	23	Bilateral bronchopneumonia and lung abscess
	57	14	41	13	Asphyxia from aspiration of vomit and hemorrhagic pyelonephritis
	1	75	10	5	Asphyxia from aspiration of vomit (aged 75, ankylosed hip)
	10	7	50	22	Cardiac arrest (2nd operation, 22nd day)
	31	46	33	3	Temporal glioma
Delayed Excisions or Delayed Graft cases	48	9	38	19	Septicaemia (*E. coli*), bilateral bronchopneumonia
	53	7	65	13	Septicaemia (*Staph. aureus*)
	59	5	72	2	Septicaemia (*Staph. aureus* and Klebsiella) and congestive atelectasis
	49	20	65	18	Acute dilatation of stomach and Septicaemia (*Staph. aureus*)
	52	2	60	5	Staphylococcal colitis, pulmonary atelectasis and hypokalemia
	58	7	65	7	Renal failure due to acute tubular necrosis
	45	53	31	5	Renal failure due to acute tubular necrosis
	47	3	38	17	Cause unknown—high temperature post-transfusion jaundice and ileus

higher than that given; but this source of error should not affect the controlled trial.

2. Reduction in mortality figures can only be expected if the procedure is practiced on patients with a chance of dying. This refers to people under 29 years with burns of more than 22 per cent, and older people with smaller burns.[4] It is the older people with small burns who might be expected to profit most, because it is easier to close their smaller wounds completely: in our experience, however, other serious complicating disease usually prevented this. In the younger patients the difficulty

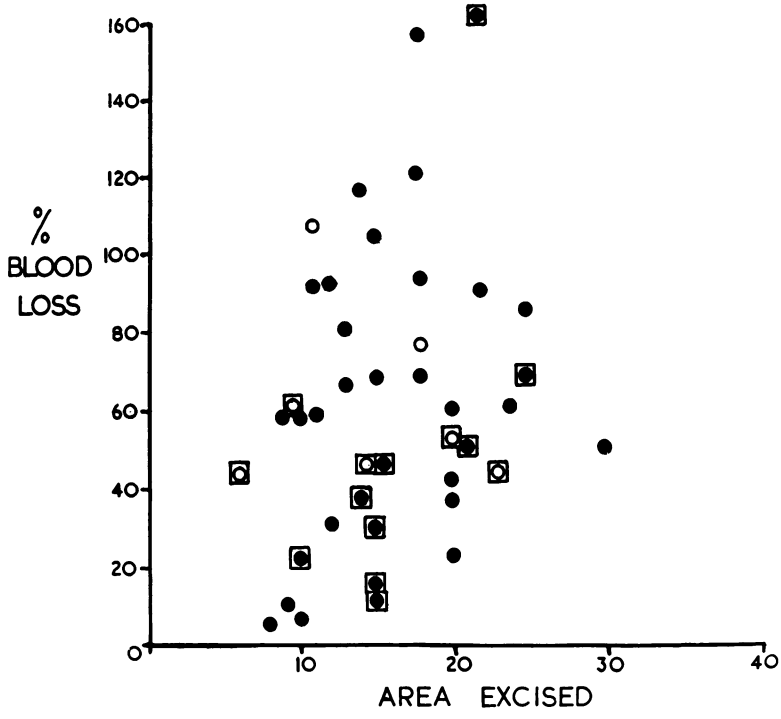

FIG. 1. Blood loss during operation, as measured by swab weighing, is recorded as a percentage of the average normal blood volume for the patient's height. ● Excision and grafting within 24 hours. ○ Excision and grafting after 24 hours. □ Grafts not cut at excision operation.

was to excise and graft sufficient burn to close completely the large wounds present in children with a chance of dying.

3. *If we suppose* that the mean wound closure actually obtained (8% in Group I, 11% in Group II and 14% in Group III—see Table 3) was secured without increased risk of any kind, a theoretical "*expected mortality after partial wound closure*" can be calculated. This would be 0.9 (instead of 3.1) for the controlled trial excised cases, and 2.7 (instead of 7.3) for all the primary excision and graft cases. The actual mortality (Table 7) was more than twice this forecast. This rather dubious way of looking at the results suggests that one might have hoped to save four lives by the 28 primary excisions if one was not inflicting some injury at the same time.

4. This raises the question of whether successful excision and grafting of half a deep burn has the effect of reducing the risks to those of a wound half the original size.

In the past we have been impressed by the negligible upset to *a fit patient* of taking split skin grafts from the whole of both thighs and legs (about 20% of the body surface). The blood loss from this procedure in an adult is about 500 ml.: the hematocrit may rise 2 to 3 per cent. Apart from the discomfort the procedure is a minor one, in no way comparable to a burn of similar extent. Such impressions obtained from a fit homograft donor may not be applicable to a severely burned child.

The results of this study should, in fact, be looked upon as the results of incomplete primary excision and only moderately successful skin grafting.

Other Results

Further negative findings were the absence of a lower pulse and temperature during the first fortnight in excised cases, and actually a slightly higher average number of operations required for each case,

which was probably not a significant finding.

The tendency to anemia during the first three weeks was not less in the primary excision and graft cases. This was probably due to excision being only partial and to postoperative oozing.

There is some evidence to support the idea that excision of the burned capillaries lessens the colloid requirement for the treatment of shock. In burns of 25 per cent and less, in which more than half the burn was excised, the amount of colloid and blood given for shock treatment (excluding blood given to replace operative blood loss) was less than in a similar unexcised group (9/13 excised cases had less than one plasma volume of colloid and blood for every 10% burned, in contrast to 0/5 unexcised cases; all the latter had more than this amount).

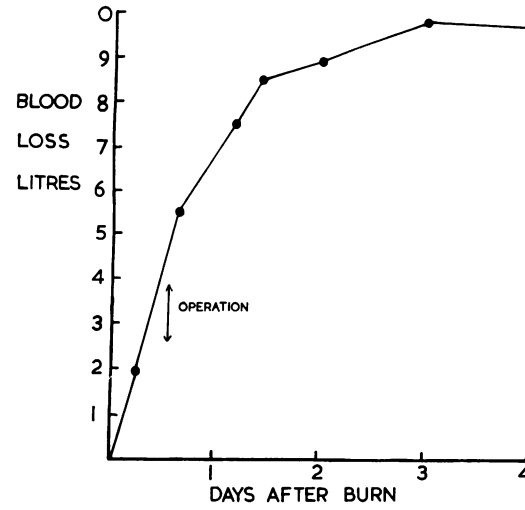

FIG. 2 (*Case 49*). Age 20 years. 65 per cent burn. Primary excision of 14 per cent of body surface 12 hours after injury. Blood loss over first four days measured by red cell volume studies.

Blood Loss During and After Operations

Blood loss during operation, measured by swab-weighing, was often considerable,

TABLE 9. *Blood Loss in Relation to Excision and Grafting*

Case No.	Age	Area Burned: Total Area	Area Burned: Whole Skin Loss	Operation: Area Excised	Operation: Burn to Operation (hours)	Operation: Operation to 2nd RBCV Estimation (hours)	Blood Loss (% of Normal Blood Volume): 1. Preop. Blood Loss	2. Operation Blood Loss by Swab-weighing	3. Other Blood Loss	Total Blood Loss
Group I										
27	12	25	14	13	18	20	0	66	10	66
28	10	18	15	15	8	16	18	68	0	65
Group II										
41	48	33	20	15	11	18	0	12	18	27
30	17	28	25	14	—	—	30	—	—	—
46	6	32	26	15	7	20	24	46	0	51
47	3	38	30	15	14	26	3	13	10	26
Group III										
49	20	65	35	14	12	4	35	38	50	123
—					12	15	35	38	97	170
—					12	24	35	38	112	185
34	7	45	36	18	7	19	21	68	91	180
36	8	50	47	20	10	15	14	42	55	111
51	8	55	50	30	6	6	11	52	0	54
—					6	20	11	52	49	112
52	2	60	55	25	10	14	20	68	62	150
57	7	65	60	23	2 days	4	67	44	19	130
59	5	72	65	20	20	3	38	23	37	98

The cases are arranged in three Groups by the total area of whole skin loss.
All area measurements are percentages of total body surface.
Blood loss has been estimated by repeated red cell volume studies:

(1) *Preoperative blood loss* = $\frac{\text{expected RBCV from height} - \text{found RBCV} + \text{red cells transfused}}{\text{40 (Normal venous hematocrit)}}$. Found RBCV estimated by ^{32}P or ^{51}Cr. Normal blood volume is derived from table for average normal red cell volume for height (Topley & Jackson[16]). Red cells transfused—1 pint or 500 ml. bottled blood = 170 ml. red cells.

(2) *Operation blood loss on swabs*—see Figure 1.

(3) *Later blood loss* = $\frac{\text{preoperative RBCV} - \text{post-op. RBCV} + \text{red cells transfused}}{\text{40 (Normal venous hematocrit)}}$.

Other blood loss = later blood loss − blood loss on swabs.

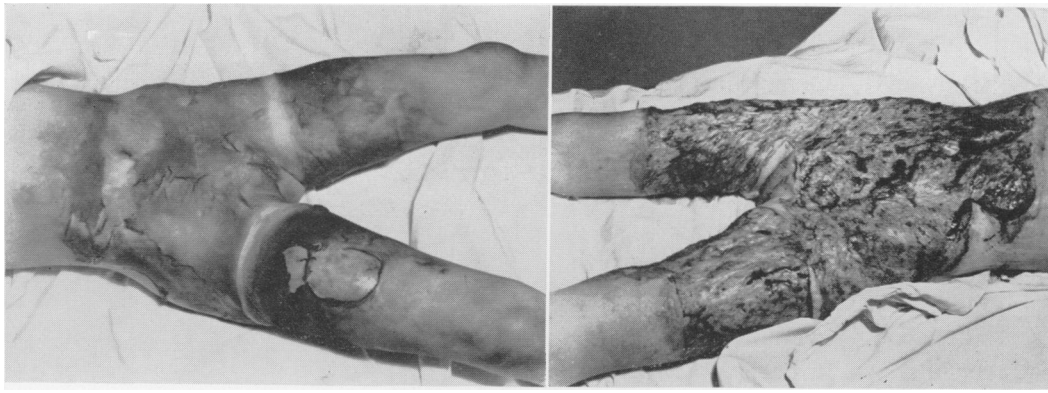

FIG. 3A, B (*Case 38*). Primary excision of 15 per cent of the body surface, with grafting on the 5th day. 90 per cent take of graft.

and sometimes more than 100 per cent of the normal blood volume (Fig. 1 and Table 9). It was not grossly different, however, from the loss when similar areas were grafted two or three weeks after injury.[16]

Blood loss in the two days after operation was also sufficient to be clinically important, requiring whole blood transfusion to avoid oligemia. This loss, estimated by red cell volume studies shortly before and at varying times after the excision, is also shown in Table 9. With burns of less than 30 per cent of the body surface, postoperative blood loss was small, but with burns of more than 30 per cent, loss during the first 24 hours after operation ranged from a negligible amount to 112 per cent of the normal total circulating red cells. In most patients the major loss occurred within the first 12 hours after operation, but in a few cases it continued for 48 hours. One such case is shown in Figure 2.

The detection of clinically important postoperative hemorrhage was not always easy. Some patients showed visible blood-staining of the dressings and in many this oozing was apparent when dressings were removed. In one child (Case 51) who was grafted and left exposed, visible oozing of blood continued for 12 hours after operation, and the loss, weighed on swabs, accounted for the red cell loss from the circulation during this 12-hour period. But in others red cell volume studies measured considerably greater blood loss than was suspected from the degree of oozing. Some cases showed a sharply falling hematocrit when this was measured hourly, and this

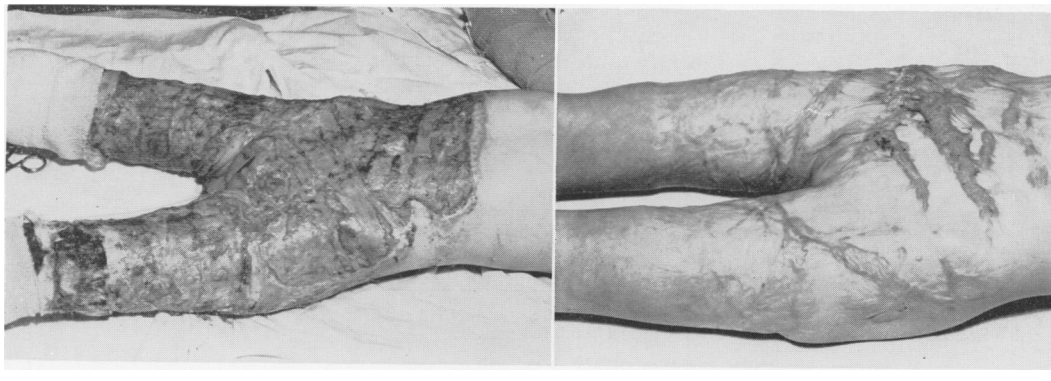

FIGURE 3C, D.

is another useful indication of the replacement required (*vide infra,* Case histories: Case 35).

In addition to hemorrhage at operation and postoperative oozing, there is an unexplained red cell disappearance in patients with burns involving more than 20 per cent of the body surface.[16] This loss may be contributed to by stasis, hemorrhage and a hemolytic anemia. It rarely exceeds 40 per cent of the blood volume and is not the main factor contributing to postoperative blood loss in Table 9, but it has to be appreciated in postoperative assessment. Repeated red cell volume studies measure the total loss from all these factors, and are a great help in blood transfusion management before and after operation. Without careful assessment of blood loss and its replacement by transfusion, the risks of oligemia alone may outweigh all possible advantages of primary excision. The evidence presented here suggests that with swab-weighing, repeated hematocrits and carefully timed red cell volume studies, circulatory collapse can be rare, and operative and postoperative morbidity low. So far there have been no operation deaths, and one death within 48 hours of operation due to congestive atelectasis and septicemia (Case 59). In Case 45, which had a survival time of five days, severe postoperative oozing and oligemia may have contributed with other factors, such as hemoglobinuria, to death from renal failure.

Case Histories

The following case histories are given to illustrate, pictorially and in detail, the type of case submitted to primary excision and some of the complications mentioned above. (All area measurements are given as percentages of the body surface.)

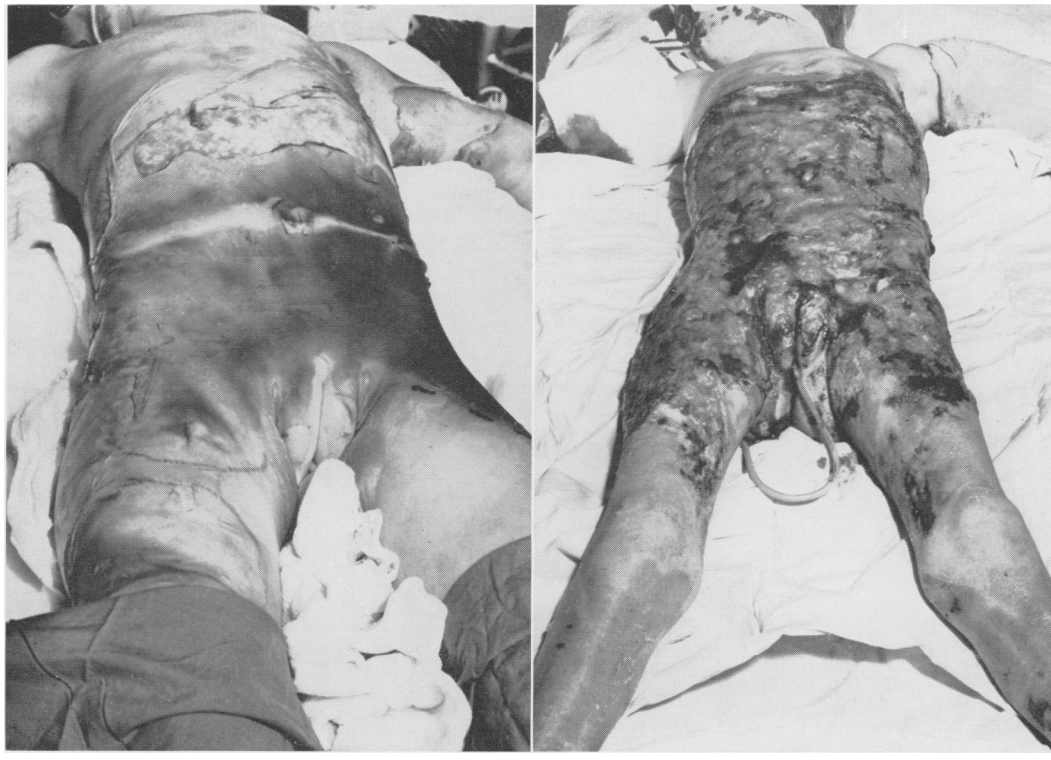

FIG. 4A, C (*Case 46*). Primary excision of 15 per cent of the body surface, with grafting on the 5th day. 85 per cent take of graft.

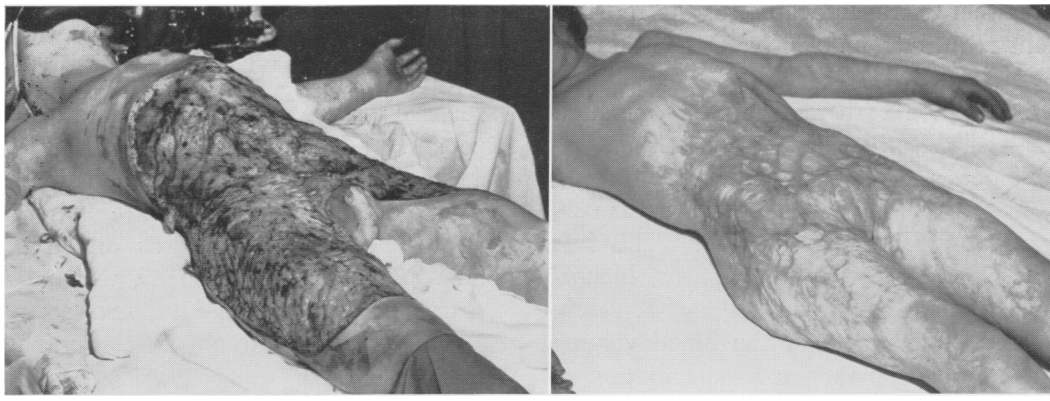

FIGURE 4B, D.

Case 38 (Fig. 3a–d) is one of the smaller burns in the study, being just large enough to fall into Group II. This girl, aged 6, was trying to light a gas fire when it exploded and set her clothes alight. She received an 18% burn of abdomen, thighs and buttocks, 16% being full thickness loss (Fig. 3a). 6½ hours after burning, and after correction of oligemia, 15% was excised on her abdomen and thighs (Fig. 3b). 340 ml. of blood were lost and replaced, and colloid infusion was continued. Five days later split skin grafts were applied to the defect, and the take on the 8th day was 90% (Fig. 3c). After a further small graft on the 22nd day, the burns healed. She is back at school without any disability beyond irritation of the hypertrophic scars (Fig. 3d).

Case 46 (Fig. 4a–d) illustrates primary excision and delayed grafting in one of the larger Group II cases. This girl, aged 6, received a 32% burn when her crepe silk dress caught alight as she reached up to the mantelpiece: she ran out into the street and the flames were put out by a neighbor. 26% of the body surface was full thickness skin loss (Fig. 4a). After resuscitation, and seven hours after the injury, 15% on the front of the abdomen and thighs was excised, for the most part down to deep fascia (Fig. 4b). 520 ml. of blood was lost and replaced while colloid therapy was continued. On the 5th day postage stamp grafts were applied with an 85% take (Fig. 4c). After two further operations the wound was reduced to less than 2% by the 38th day. She has returned to school without appreciable disability (Fig. 4d).

Case 35 (Fig. 5a–d) was one of the cases of late graft failure, a complication which almost certainly cost her her life. This married woman, aged 17, while convalescent from a therapeutic abortion, set her nightdress alight, receiving a 48% burn, 37% being full thickness loss (Fig. 5a). Ten hours after the accident 18% of the deeply burned skin was excised. 3½ liters of blood were lost and replaced during the operation which lasted 2 hours. Alternate strips of autograft and

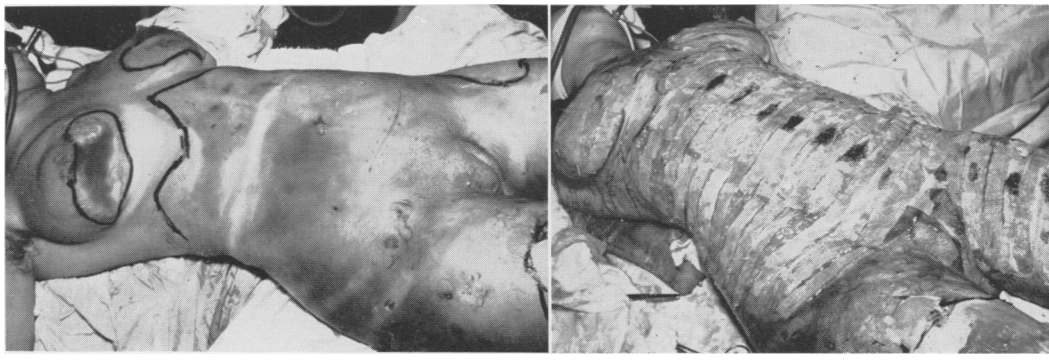

FIG. 5A, B (*Case 35*). Primary excision of 18 per cent of the body surface, with immediate grafting with alternate strips of auto- and homograft. 90 per cent take of graft in the first week became less than 20 per cent in the second week.

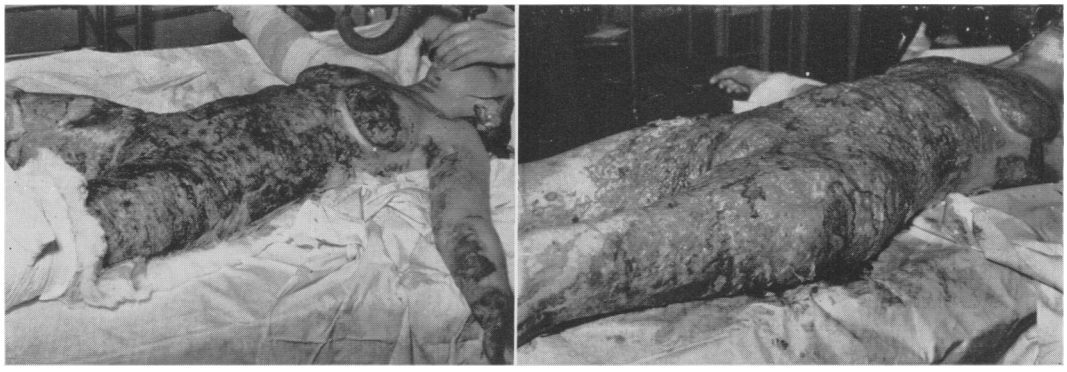

FIGURE 5C, D.

homograft were used (Fig. 5b). Postoperative oozing was considerable; it was accompanied by a sharp fall in the hematocrit, and required a further transfusion of 1,700 ml. of blood. The success of the graft was estimated at 95% on the fourth day, 90% on the seventh day (Fig. 5c); on the eleventh day it was clearly not more than 20% (Fig. 5d). On the tenth day there was x-ray confirmation of bilateral basal bronchopneumonia. A second grafting operation was performed on the 21st day, but she died two days later. Autopsy confirmed bilateral bronchopneumonia with lung abscess.

Case 10 (Fig. 6a–d) illustrates one of the indications for primary excision and grafting—an extensive very deep burn in which the slough will clearly not separate for a long time. The deep burns on the limbs should have been excised and grafted at 7–10 days on the evidence of the great depth of burning seen at primary excision. This girl, aged 7, set her clothes alight while playing beside an unguarded fire. She received a 50% burn, 40% being full thickness skin loss (Fig. 6a). Excision of the burn on her chest was indicated because respiration was seriously embarrassed by the constricting eschar. After resuscitation, 20% of the body surface was excised and grafted 9 hours after burning (Fig. 6b). 550 ml. of blood were lost and replaced, and shock treatment was continued postoperatively. The grafts were 95% successful on the 5th day (Fig. 6c), and 90% on the 11th day. Unfortunately, in spite of the great depth of burning which was confirmed at operation on the first day, the second operation was delayed until the 22nd day in the hope that the sloughs would separate. Since the full depth of subcutaneous tissue was involved separation was delayed, and further excision was necessary (Fig. 6d). During excision cardiac arrest occurred, and in spite of cardiac massage the patient died.

Case 51 (Fig. 7a–g) shows a Group III case treated with postage stamp grafts and exposure—a combination which leads to excessive crusting. This feature, and the considerable postoperative oozing, were responsible for the poor success of

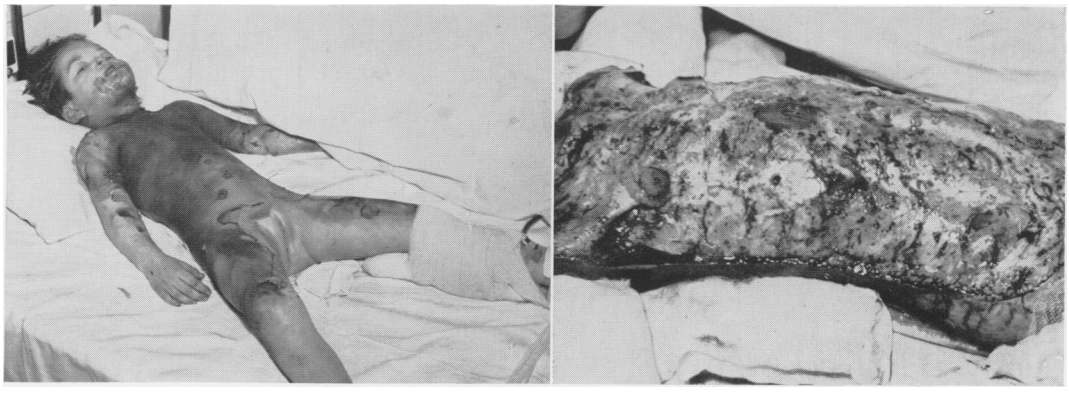

FIG. 6A, B. (*Case 10*).Primary excision and grafting of 20 per cent of the body surface, with 90 per cent take of graft.

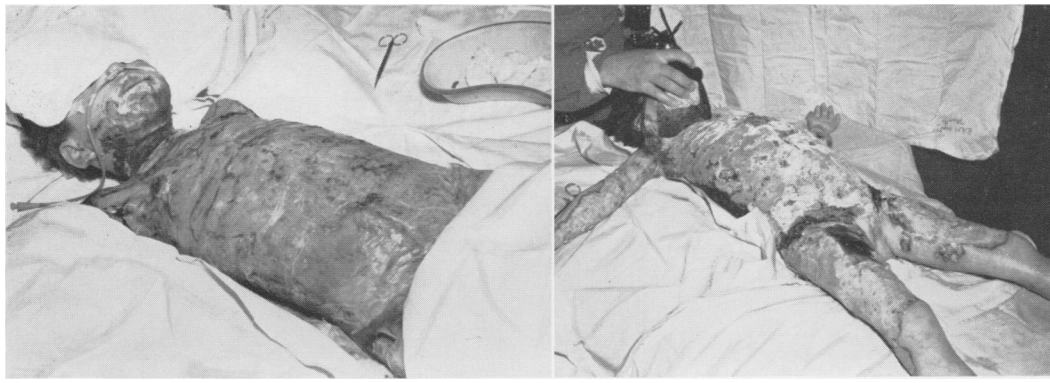

FIGURE 6C, D.

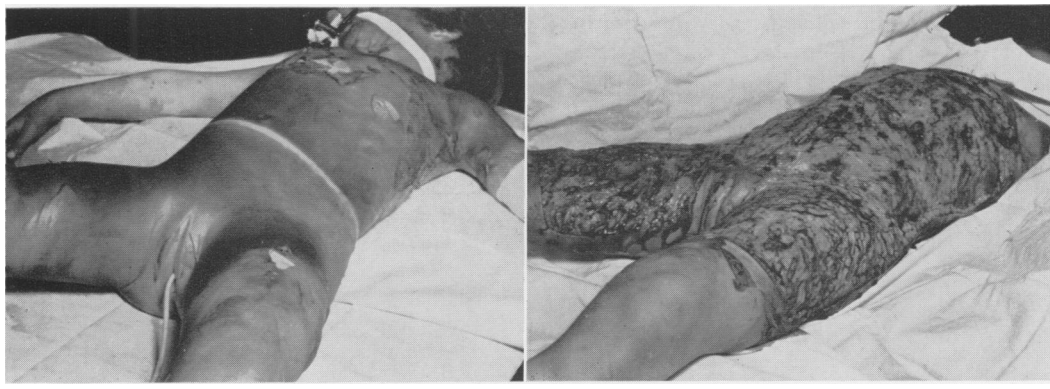

FIG. 7A, B (*Case 51*). Primary excision of 30 per cent of the body surface with immediate autografting. About 3 per cent on the thighs were covered with stored homografts. The graft take was only 50 per cent due to postoperative oozing and crusting.

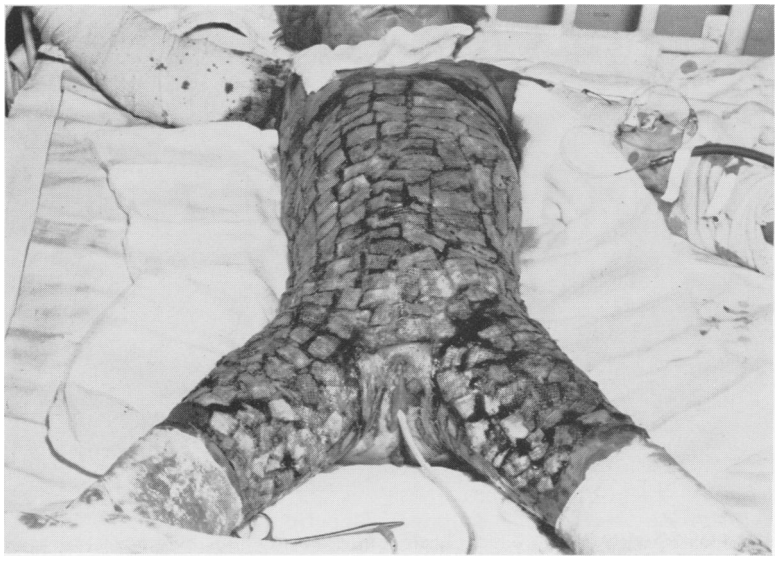

FIGURE 7C.

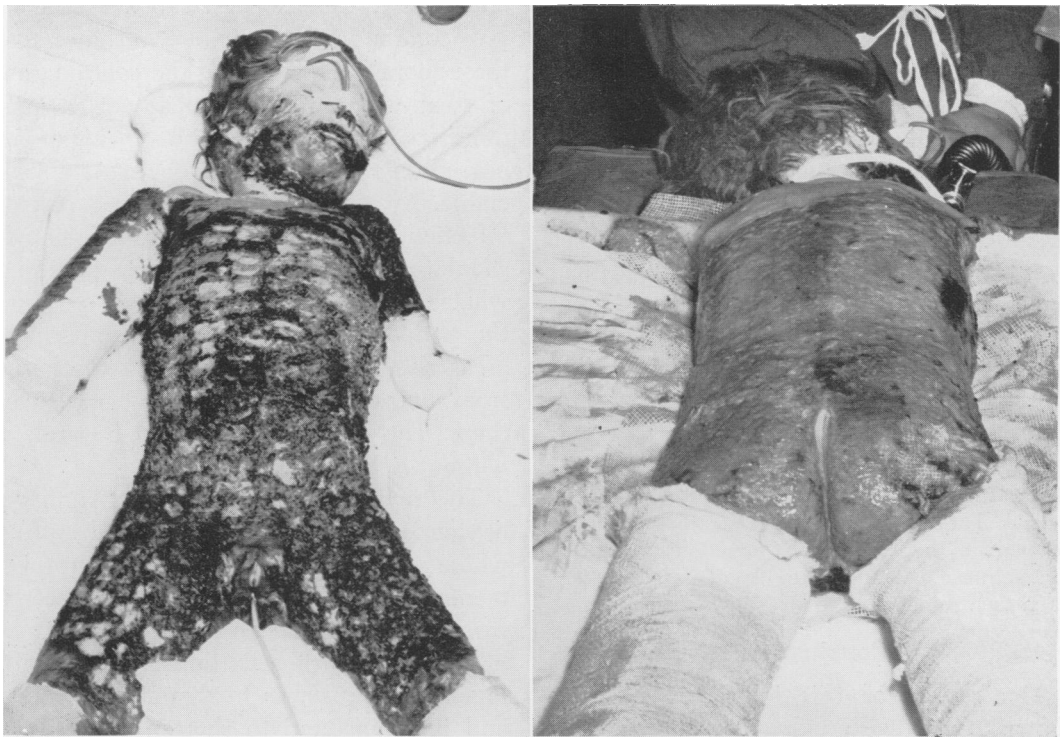

FIGURE 7D, E.

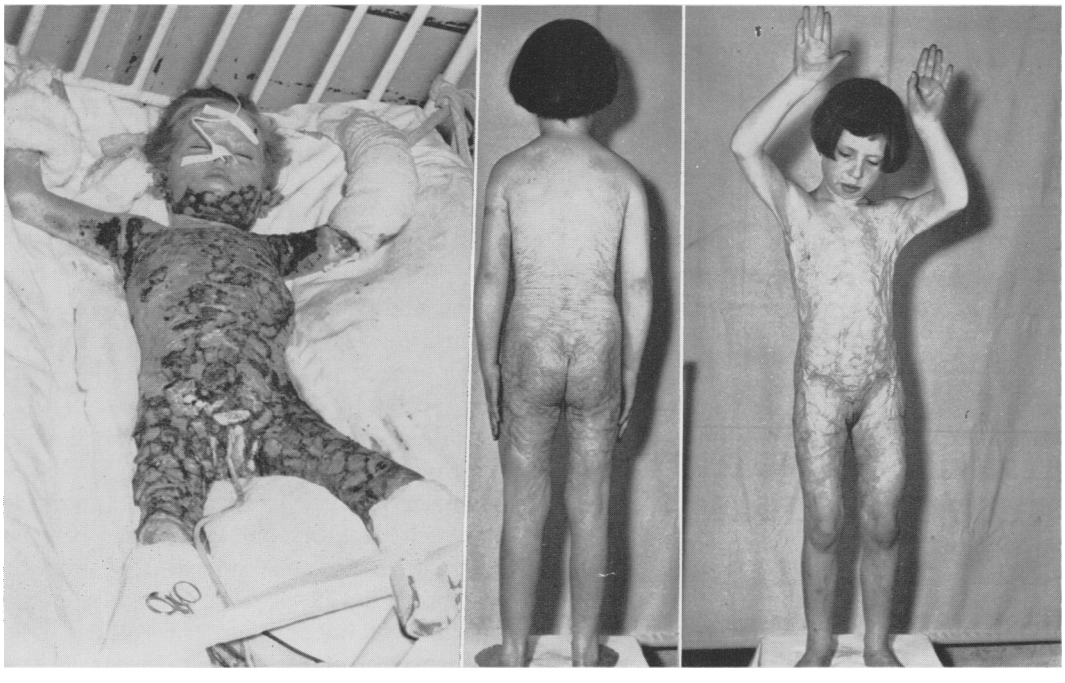

FIGURE 7F, G.

primary grafting. This girl, aged 8, set alight to her dress from an unguarded coal fire while her mother was out at work. She received a 55% burn, 50% being full thickness loss (Fig. 7a). Six hours after injury, and after resuscitation, 30% on the front of the trunk and thighs was excised (Fig. 7b) and covered with postage stamp grafts (Fig. 7c). 550 ml. of blood were lost and replaced during the operation which lasted two hours. Postoperative bleeding, which was considerable, was made up by transfusion: this, and the crusting which followed exposure (Fig. 7d) accounted for the poor take of graft which was only about 50%. Grafting of the back (Fig. 7e) on the 19th day was almost completely successful (95%), and in spite of a *Staph. aureus* septicemia on the 33rd day, which was treated with Vancomycin, completion of grafting on the front of the trunk and thighs on the 35th day was 90% successful (Fig. 7f). She was discharged from hospital on the 82nd day. Correction of axillary contractures should restore almost full function (Fig. 7g).

Conclusions

The results of this investigation have shown that, with adequate safeguards, excision and grafting of 20 to 30 per cent of the body surface can be carried out on the day of injury without increased risk to the patient. On average, two-thirds of the grafted area remained permanently healed so that the aim of the procedure, to make the wound smaller at once, was achieved with safety to a moderate degree.

In the smaller cases which were almost entirely deep the natural process of slough separation was forestalled, and the management of a discharging open wound with all its unpleasantness was avoided.

In addition, the dangers of the method have been assessed. They are latent oligemia, hidden red cell destruction due to extensive burns, serious postoperative oozing due to an ill-understood tendency to bleed, and infection of the excised area from adjacent unexcised burn if it is not grafted at once.

The safety precautions which are required to meet these dangers are the availability of red cell volume estimations to check the blood volume pre- and postoperatively; the use of swab-weighing to give continuous measurement of blood loss throughout operation; and the continuation of swab-weighing and hematocrit estimations postoperatively with the patient nursed on mackintoshes if oozing is appreciable. Awareness of the increased risk of infection from adjacent unexcised slough should influence the surgeon in planning what areas to excise: in whatever position the patient is going to lie, the uppermost areas should be excised so that discharge from unexcised burn does not run over them. The excised area should be grafted without delay.

The investigation has also set a target or standard of amounts excised and grafted which must be beaten if dramatic improvements in clinical results are to be expected from this procedure.

The aim of primarily excising and grafting large burns was to diminish mortality and infection, and to shorten the healing time. None of these three favorable results has been conclusively demonstrated. This may be because the numbers in the controlled trial are too small. In burns of less than 30 per cent whole skin loss some shortening of the healing time is shown when the figure for *all* primary excision cases is compared with the unexcised cases of the controlled trial. Isolated excised cases were spectacularly successful, but so were some controls.

Indications for Extensive Primary Excision and Grafting. There is no doubt that extensive excision and grafting carried out as an emergency procedure in the shock stage calls for greater experience and is considerably more trouble than delayed grafting in the third week. Since it has so far been impossible to show an improvement in mortality and morbidity over an adequate series, the procedure cannot be recommended at present as an advance in *routine* treatment. On the other hand, neither does it mean that the procedure should be abandoned, especially in envi-

ronments such as a new hospital where the chances of infection can be substantially reduced. Already it is possible to see three or four indications for the procedure, and these may be extended as the remaining problems are solved.

The strongest indication is the extensive burn involving most of the subcutaneous tissue as well as the full thickness of the skin (Fig. 6a–d). Active excision of slough in this type of case is called for because natural slough separation will not occur for about six weeks. Such cases are not difficult to diagnose, and diagnosis of the very deep degree of burning can be confirmed during primary excision on the first day by the depth of red fat. Although some additional strain is put upon the child on the first day, she will never be so fit for operation again.

The second indication is a burn of up to 15 to 20 per cent, all full thickness skin loss, providing the distribution is suitable. Such cases are likely to have a slightly shorter healing time without the distress of natural slough separation. The procedure in burns of this size has not been associated with postoperative oozing or serious blood destruction in our experience, and the whole area is small enough to excise and close primarily with less risk of infection. The application of the procedure to these cases is simply an extension of our previous indications to larger burns.

The third indication is a deep, encircling and constricting burn of the whole trunk which grossly limits thoracic and abdominal breathing. The common practice of longitudinal incision to relieve this gives negligible relief compared with excision of the burn on the front of the trunk.

Clarkson and Greenwell put forward another possible indication for early excision: [5] it is the presence of pyemia or a strongly positive blood culture. As yet we have no evidence that the incidence of septicemia is reduced by primary excision and grafting; it is difficult to see why excision should be more valuable in treating septicemia except, perhaps, by reducing the size of the reservoir from which the blood stream becomes reinfected. Massive reinfection from the burn slough is probably responsible for the frequent failure of chemotherapy in the treatment of septicemia in burned patients even when the organism is sensitive to the drug used.[11]

Primary excision and grafting is still a possible method of treatment in experienced hands, but in so far as the risks require further investigation, it should probably only be practiced where facilities for investigation are available.

Problems Calling for Further Research

1. How to Excise and Graft Larger Areas. To excise only part of a large deep burn is an incomplete application of the basic principle of removing dead tissue and closing the wound. We have continually tried to graft more, using homografts when necessary. By a two-stage procedure, excising on one day and grafting four days later, we have not appreciably increased the area grafted, and this procedure is possibly associated with a greater risk of septicemia.

The large excision and grafting operations in our hands have usually taken one and one-half to two hours, and at the end of this period the anesthetist has sometimes advised termination owing to the patient's condition. This is in spite of controlled blood replacement throughout the operation and moderately light anesthesia to preserve vasomotor compensation.

Sometimes the decision not to proceed has been the surgeon's: to do so would have meant turning the patient, and to graft both sides of the trunk often means a poor graft take on one side.

We have not used artificial hypotension. Neither have we used intentional hypothermia; a natural fall of body temperature to about 95° F. during operation is not unusual in these cases due to exposure.

The problem of how to excise and graft more burn with safety, either by doing it more quickly or continuing longer, remains.

2. How to Secure a Better Graft Take. A mean graft take of 70 per cent is poor and clearly inadequate. Possible contributing factors which may be relevant are:

a) *Increased Cortisone Activity.* Billingham, Krohn and Medawar[3] have shown that skin grafts in rabbits treated with a daily subcutaneous injection of cortisone, had weaker primary union to the graft-bed than controls, and that at primary inspection the grafts had more often slipped from their original positions. Although increased cortisone secretion follows all major operations and even severe infection, the degree of it following severe burns may make it a significant cause of graft failure after primary excision.[9, 10]

b) *Other Substances Retarding Healing.* Lawrence[10] has shown that several substances influence the uptake of sulfate by the skin without detectably reducing respiration or epithelial cell migration; this may influence graft take since chondroitin sulfate plays a part in the "ground substance" of most tissues.

Cortisone is one of these substances, and the filtrate from cultures of Groups A and C streptococci, and from Proteus and *Ps. pyocyanea* have a similar effect. These organisms are known causes of graft failure.

An inhibition of sulfate uptake by the skin has also been caused by growing it in serum from patients with burns of more than 25 per cent of the body surface during the first week; this effect disappeared two to three weeks after burning.

c) *Inadequate Excision of Fat.* Although inadequate excision would account for the failure of grafts, we were convinced at the time and are still confident that all *dead* fat was excised in these cases.

It is possible, however, that in the presence of profuse bacterial colonization, subcutaneous fat which is usually a good surface for grafts, ceases to be a viable bed for them.

d) *Postoperative Oozing.* In spite of good hemostasis before applying the grafts, postoperative oozing was the commonest cause of graft failure. It may have been a reaction to the cooling and vasoconstriction which accompanies prolonged exposure during anesthesia, but these factors would operate during delayed grafting operations as well. Other possible causes are being investigated.

Summary

1. The aim of primary excision and grafting of large burns is presented, together with the reasons for completing the operation as soon after injury as possible.

2. The selection of cases and the conduct of the investigation are described.

3. Practical points in the operative management and technic are detailed.

4. The results of the investigation are measured by three criteria, the rate and degree of wound closure, the degree of infection, and mortality. Under each of these headings two comparisons are made: the first (the controlled trial) compares primary excision and immediate grafting with grafting two to three weeks after injury: the second compares the average results of all the primary excision and immediate grafting cases with cases which were excised early and grafted several days later.

The causes of death of fatal cases are recorded, and also the effect of primary excision and grafting on the patient's pulse and temperature, tendency to anemia, and colloid requirements for shock.

5. Blood loss during and after operation is dealt with in some detail because its correct assessment and replacement are essential for the patient's safety.

6. Five case histories are recorded to show the type of case treated, and some of the indications and complications of the method are illustrated.

7. The conclusions include a critical assessment of the results, the present indications for using the method, and difficulties which still call for further research.

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