TREATMENT OF BURNS: EXPERIENCES WITH POLYETHYLENE GLYCOL DRESSING*

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The toxicity of hexylene glycol has been described and a relatively high mortality in burns (4·6%) has been ascribed to its use in burn dressings. It was observed that, apart from the narcotic effect of hexylene glycol, the local efficacy of the dressing had been found to be superior to any of a large number used. Moreover, the use of hexylene glycol was peculiar to the Republic of South Africa, owing to conditions of sterilization. In other countries, the manufacturers used a polyethylene glycol mass, with no reported unfavourable side-effects.

A clinical trial of the use of the polyethylene glycol mass impregnating a gauze mesh dressing was undertaken to compare the local efficacy of the dressing and, by comparison under similar conditions, to confirm the toxicity of hexylene glycol and the safety of polyethylene glycol.

An opportunity is also provided to review the results of the treatment of burns in this unit by including a series treated with an antibiotic-impregnated gauze mesh dressing.

The bacteriology of the burn wounds has been studied and correlated with percentage area of the burn, duration in hospital, and anaemia of burns.

MATERIAL AND METHOD

During the period July 1966 - September 1967, 351 cases of burns in non-White children under the age of 12 years were admitted to the burn unit of paediatric surgical wards. The method of management was the same as described originally,[1] with the addition of low molecular dextran solution to the fluids infused, in the cases where this was necessary—i.e. burns over 10% body surface area. The rationale for this has also been described,[2] together with the details of infusion and management.

Patients were admitted with burns involving a surface area of less than 10%, affecting only face, hands and feet, and perineum. Burns under 10% surface area not involving these regions were not admitted to the burn unit. Children admitted for skin graft only are not included in these series.

In the first consecutive 140 cases, the burns were dressed in 112 cases with an antibiotic-impregnated petroleum-gauze mesh. In the subsequent 211 cases, 176 were dressed with a gauze mesh impregnated with an 80% polyethylene glycol mass with no antibiotics.

The regimen practised in the frequency and technique of dressings was the same in both series and has been described previously.[2] Antibiotics were not used as a routine other than urinary and or bowel sulphonamides in cases of perineal burns.

All skin grafts were covered with the respective dressings, which, in turn, were covered by cotton gauze soaked in acriflavine emulsion. These were removed on the 5th day and the area was left open unless some complication ensued. All patients treated thus remained in hospital for a minimum of 14 days after skin graft.

*Date received: 11 September 1968.

Nineteen admissions were of burns already septic on admission, and these were all under 20% body surface area.

The thermal agent in most cases was boiling water or other hot liquids. No more than 35 cases suffered injury by fire.

RESULTS

The average surface area burnt in the total of 351 cases was 13·6%, and the average period of hospitalization was 26·3 days. The period of delays in hospital after wounds had healed, occasioned by defaulting parents, is included in this average. There were 3 deaths, giving a mortality of 0·85% (Table I). Two of these were fire burns. A child of 5 with 75% burns died from shock within hours of delayed admission. One with 33% burns died from staphylococcal septicaemia, with terminal bronchopneumonia, 30 days after admission. The third died 3 days after admission, from bronchopneumonia, having been ill at the time of the accident. These last two deaths were in infants under 2 years old and the percentage burns was 13%.

TABLE I. ANALYSIS OF CASES

Total number of cases	351
Average surface area burnt	13·6%
Average duration of hospitalization	26·3 days
Total number dressed	288
Full-thickness burns	172
Total number of cases skin-grafted	151
Deaths	3 (0·85%)

The maximum period of hospitalization was 153 days and the minimum 3 days.

In the series dressed with hexylene glycol mass, the maximum hospitalization was 113 days. This series is analysed further in Tables II - IV, in comparison with the antibiotic-impregnated tulle.

TABLE II. TYPES OF DRESSING

	Polyethylene glycol dressings	*Antibiotic dressings*
Total number of cases	211	140
Average surface area burnt	12·3%	15%
Average duration of hospitalization	25·6 days	27 days
Total number dressed	176	112
Full-thickness burns	95	77
Total number of skin grafts	83	68
Deaths	2 (0·94%)	1 (0·7%)

In the first series the maximum surviving burn was 80%, and in the second the maximum surviving burn was 65% surface area in 2 cases.

The burns are classified into 4 groups according to the area affected: Group I, less than 10%; group II, 10 - 19%; group III, 20 - 29%; and group IV, 30% or more.

Reference to depth of burn is restricted to superficial

(not requiring skin graft), and deep, where skin coverage was necessary.

Group II constituted the majority of admissions (104) followed by group I (87 admissions). Those in the latter group were admitted only because face, hands or feet or perineum were involved.

The same interesting correlations between area and depth of burn described elsewhere[2] were noted again in this series (Tables III and IV). As the percentage area of the burn increases, so does the incidence of full-thickness loss, and consequently the period of hospitalization is prolonged.

This relationship is the same regardless of whether the dressing used contained antibiotics (Neobacrin-Tulle) or not (Carbonet PEG) (Tables II and III).

A total of 151 cases received skin grafts. Twenty of these operations were carried out in planned stages owing to the large size of the burns. Of the remaining 131 cases grafted, 112 were completely successful at the first attempt, while 19 required a further skin graft. Of these 19, 16 were burns dressed with antibiotic tulle, and 3 dressed with PEG.

Of the 20 cases skin-grafted in planned stages, 8 had been dressed with antibiotic tulle, and 12 with PEG. Full skin coverage was achieved in all cases.

In all wounds where skin graft failed or required to be repeated, *Pseudomonas aeruginosa* and/or *Streptococcus haemolyticus* had been cultured from the burn wound.

Nineteen patients in whom there was some area of full-thickness loss were not grafted owing to the presence of *Ps. aeruginosa* and the small size of the wound. These small areas healed by scarring before the organism was cleared.

Infection

Organisms cultured from the 211 cases of burns dressed with PEG are indicated in Tables III and IV. In 85 cases (40·2%) the burns remained sterile, and almost all of these were in areas of under 20%.

By far the commonest invading organism was *Staphylococcus aureus*, having been cultured in 85 of the cases (40·2%). The next in frequency were *Strep. haemolyticus* in 38 (18%), *B. coli* in 28 (13·4%), *Ps. aeruginosa* in 25 (11·3%) and *B. proteus* in 21 (9·9%).

A significant comparison is seen in the incidence of *Strep. haemolyticus* and *Ps. aeruginosa* in the first series of 140 dressed with antibiotic tulle and in the series of 211 dressed with polyethylene glycol. In the former group of 140 cases there were 54 (39%) positive cultures for *Ps. aeruginosa* and 67 (48%) for *Strep. haemolyticus*, whereas in the latter group of 211 cases there were 25 (11·3%) positive cultures for *Ps. aeruginosa* and 38 (18%) for *Strep. haemolyticus*. There was no incidence of septicaemia due to either organism in either series.

Period of Hospitalization

The significance of the invading organism in respect of period of hospitalization is indicated in Table IV. This is shown in each percentage area group of burns. The larger the area burnt, the higher the incidence of secondary bacterial invasion which occurred and the higher the incidence of full-thickness loss.

Ps. aeruginosa was responsible for the longest stay in hospital, by a considerable margin in all groups. Cases in which this organism was cultured had an average hospitalization of 56·5 days, as compared with the over-all average of 26·3 days.

TABLE III. POLYETHYLENE GLYCOL DRESSINGS: INCIDENCE OF INVASION BY PATHOGENIC BACTERIA IN EACH GROUP

Group	*Aver. % area*	*No. of admissions*	*No. grafted*	*Sterile*	*Ps. aeruginosa*	*Haemolytic strep.*	*Non-haemolytic strep.*	*Staph. aureus*	*Staph. albus*	*B. coli*	*Alcaligines faecalis*	*Proteus*	*Achrom. anitratus*	*Candida albicans*	*Deaths*
I	7·4	87	18 (20%)	49	4	15	1	18	1	7	1	4	2	6	0
II	12·7	104	47 (45%)	35	14	19	2	49	9	13	2	10	8	4	1
III	24·3	11	10 (91%)	1	2	1	0	9	1	4	1	2	1	0	0
IV	41·5	9	8 (89%)	0	5	3	0	9	1	4	0	5	0	1	1
Total	12·3	211	83 (39·3%)	85 (40·2%)	25 (11·3%)	38 (18%)	3 (1·4%)	85 (40·2%)	12 (5·7%)	28 (13·4%)	4 (1·9%)	21 (9·9%)	11 (5·2%)	11 (5·2%)	2 (0·9%)

TABLE IV. SUMMARY OF AVERAGE HOSPITALIZATION INDICATING AVERAGE PERIOD ASSOCIATED WITH EACH ORGANISM CULTURED, SUBDIVIDED INTO EACH GROUP, TOGETHER WITH THE INCIDENCE OF EACH ORGANISM

	Group I		*Group II*		*Group III*		*Group IV*		
Organisms	*No. (%)*	*Average hospitalization (days)*	*No. (%)*	*Average hospitalization (days)*	*No. (%)*	*Average hospitalization (days)*	*No. (%)*	*Average hospitalization (days)*	*Average hospitalization all groups (days)*
Ps. aeruginosa	4 (4·45%)	29	14 (13·4%)	54	2 (18·1%)	40	5 (56%)	103	56·5
Strep. haemolyticus	15 (17%)	22	19 (18·2%)	35·4	1 (9%)	44	3 (33%)	69	42·6
Non-haemolytic streptococcu	1 (1%)	16	2 (2%)	57	—	—	—	—	36·5
Staph. saureus	18 (21%)	26	49 (47%)	34·4	9 (82%)	48·5	9 (100%)	45	38·5
Staph. albus	1 (1%)	32	9 (8·6%)	40	1 (9%)	27	1 (11%)	54	28·2
B. coli	7 (3·8%)	17·5	13 (6·2%)	29	4 (18·1%)	44	4 (28%)	92	45·6
Alcalig. faecalis	1 (1%)	18	2 (1·9%)	39·5	1 (9%)	35	—	—	23·1
B. proteus	4 (4·5%)	21·5	10 (9·5%)	38	2 (18·1%)	45·5	5 (55·5%)	81	46·5
Achrom. anitratus	2 (2·2%)	23·5	8 (7·7%)	59·5	1 (9%)	50	—	—	44·3
Candida albicans	6 (6·4%)	23·5	4 (3·8%)	52·5	—	—	1 (11%)	81	52·3
Sterile	49 (56·3%)	9·9	35 (33·6%)	16·9	1 (9%)	26	—	—	14·3
Total average hospitalization		21·7		41·5		40		75	25·6

TABLE V. COMPOSITE TABLE SUMMARIZING COMBINATIONS OF ORGANISMS CULTURED FROM BURN WOUNDS, IN 211 CASES (SECOND SERIES)

In combination with:	*+ Ps. aeruginosa*				*+ Haemolytic strep.*				*+ Staph. aureus*				*+ B. coli*				*+ Proteus*				*+ C. albicans*			
Groups:	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
Organism *Ps. aeruginosa*	—	65	—	— *1*			*7*				*21*				*9*				*3*				*2*	
Haemolytic strep.	55	61	—	119	20	23	—	— *1*			*20*				*6*				*3*				*2*	
Staph. aureus	29	54	37	103	25	43·6	44	68·6	26·6	27·8	55	— *28*			*19*				*13*				*4*	
B. coli	55	39	110	105	335	38	—	119	31	35·6	49·6	82·6	14	12	—	— *6*			*6*				*2*	
Proteus	—	—	—	114	—	47	—	76	26·5	47	45·5	81	—	45·5	—	92·2	14·6	20·5		— *7*			*0*	
Candida albicans	—	118	—	81	28	10	—	—	—	30·6	—	81	9	44	—	—	—	—	—	—	28	—	—	— *3*

The upper diagonal half indicates the *number of cases* found in combination with each organism, and the lower diagonal half the average *period of hospitalization* of cases where these combinations were found in each group.

In group III, *Staph. aureus, B. coli* and proteus produced a period of hospitalization which was approximately similar to that of *Ps. aeruginosa.* In this group infection was usually mixed. The exceptions in group II, with *Candida albicans, Achromobacteria anitratus* and non-haemolytic streptococcus, are not statistically significant.

Other bacteria prolonging the stay in hospital were *Staph. aureus, B. coli,* proteus and *Achromobacteria anitratus.* Other secondary invaders did not occur frequently enough to be significant. Tetanus was never observed.

Whereas in groups III and IV the size of the burns may be an important factor in prolonging hospitalization, in groups I and II *Ps. aeruginosa* prolonged this period more than any other organism, with average hospitalization of 29 days as compared with the over-all average in group I of 21·7 days; and an average in group II of 54 days in cases with *Ps. aeruginosa,* as compared with the over-all average of 41·5 days. Other significant organisms in these groups of smaller burns were *Strep. haemolyticus* (22 days in group I and 35·4 days in group II); and *Staph. aureus* (26 days in group I and 34·4 days in group II). The only case with *Staph. albus* was one in combination with *Ps. aeruginosa.*

As might be expected, the average period of hospitalization was considerably shorter where the burn wounds remained sterile, and consequently the incidence of full-thickness loss was lowest. In group IV, none remained sterile.

Combinations of Organisms

In view of the findings with the earlier series of 140 cases treated with antibiotic tulle, where a combination of *Strep. haemolyticus* and *Ps. aeruginosa* prolonged hospitalization considerably in excess of that by *Ps. aeruginosa* alone, the various combinations of all the organisms encountered were studied in the latter series of 211 cases dressed with polyethylene glycol.

Table V indicates, in the lower diagonal half, the days in hospital in each group, where the individual organisms were found in company with each of the others, and alone.

The upper diagonal half indicates the number of cases in which each individual organism occurred in company with each of the other organisms. Those organisms occurring with insignificant frequency (Table IV) have been excluded from Table V.

It will be noted that in group IV no organism occurred alone. In group III only *Staph. aureus* occurred singly in 3 cases. Expectedly, *Staph. aureus* was the most frequent companion of the other organisms.

Of the 25 cases where *Ps. aeruginosa* was cultured, 21 had *Staph. aureus* as well. This would account for the apparently high average hospitalization of cases in which *Staph. aureus* was cultured (Table IV). Of the 38 with *Strep. haemolyticus,* 20 were accompanied by *Staph. aureus,* and of the 21 proteus cultures, 13 had *Staph. aureus* in the culture as well. There were 28 positive cultures for *B. coli,* and in 19 of these *Staph. aureus* was also grown.

The average hospitalization in each group with each individual organism was significantly longer when the organism occurred in combination with another organism

than when cultured alone, with the exception of *Ps. aeruginosa*. With this organism the period in hospital was always prolonged. *Ps. aeruginosa* occurred singly in only one patient, with a 16% burn, who remained in hospital 65 days. The identity of the organism accompanying *Ps. aeruginosa* was not significant with regard to prolonging hospitalization.

Excluding *Ps. aeruginosa*, the significant combinations of organisms were *B. coli* with *B. proteus*, and with *Staph. aureus*, in groups II, III and IV; and *Strep. haemolyticus* with *Staph. aureus*, and with *B. coli*, in all groups. *Strep. haemolyticus* cultured alone did not prolong the stay in hospital, indicating a satisfactory response to treatment by ampicillin.

In only 7 cases were *Ps. aeruginosa* and *Strep. haemolyticus* cultured together, out of 176 cases dressed with Carbonet PEG, with an average hospitalization of 68·4 days.

In the series of 112 cases dressed with antibiotic tulle the combination occurred in 39 cases, with an average hospitalization of 57 days.

Anaemia

The criterion for blood transfusion in the Livingstone Hospital Paediatric Burn Unit is a haemoglobin concentration of 10·0 G/100 ml. This is based on the average expected haemoglobin level in non-White children, which is lower than that of Whites.

In the series of 211 cases described, 26 cases demonstrated anaemia requiring blood transfusion, given in preparation for skin graft or to accelerate convalescence. Table VI lists these 26 cases in their groups, indicating length of stay in hospital and the lowest haemoglobin level recorded, together with the stage in hospital at which this level was recorded. The organism cultured from the burn wound is indicated in an attempt to associate the anaemia with a particular organism.

TABLE VI. 26 CASES OF ANAEMIA REQUIRING BLOOD TRANSFUSION

% area burnt	*Lowest haemoglobin (G/100 ml.)*	*No. days after adm.*	*Total hospitalization (days)*	*Organisms cultured*
Group I				
7	9·0	19	55	*Staph. aureus, Ps. aeruginosa*, haemolytic strep., *E. coli*
8	7·8	15	15	*Staph. albus*, haemolytic strep.
9	9·8	1	42	*Staph. aureus*
7	8·8	3	10	Nil
9	9·5	1	22	*C. albicans*
10	9·0	3	13	*Staph. aureus, Ps. aeruginosa*
10	8·0	11	16	*Staph. albus*
Group II				
11	7·0	1	39	*Staph. aureus*, haemolytic strep.
11	9·0	1	47	*Alcal. faecalis*, haemolytic strep., proteus
11	9·0	10	9	Nil
18	9·5	15	38	*Staph. aureus, C. albicans*
13	8·5	1	1 (died)	Nil
18	8·8	1	8	Nil
13	9·5	1	58	Nil
13	9·0	27	36	*Staph. aureus*
13	9·2	1	14	Nil
11	9·5	20	44	
16	9·2	4	36	*Staph. albus*
11	9·5	20	44	*Staph. aureus, C. albicans, E. coli*
19	8·8	1	43+	
Group III				
23	8·7	30	37	*Staph. aureus, E. coli*
21	8·5	1	44+	*Staph. aureus*, haemolytic strep.
23	9·5	20	35	*Staph. aureus, Alc. faecalis*
Group IV				
33	7·5	1	26+	*Staph. aureus* (*Staph. aureus* blood culture)
33	5·0	15	30 (died)	*Staph. aureus, E. coli*, proteus
36	8·6	1	113	*Staph. aureus, Ps. aeruginosa*

Anaemia recorded on the first day may be regarded as having been present at the time the thermal trauma was sustained.

In group I, 3 cases out of 87; in group II, 8 out of 104; in group III, 3 out of 11; and in group IV, 3 out of 9 cases, became anaemic.

Staph. aureus was cultured in 12 of the 26 cases, and appeared to be the only organism which may be regarded as being of any significance. Since *Staph. aureus* was by far the commonest organism throughout the entire series, even this significance is doubtful.

No grossly low haemoglobin leyels were found, with the exception of one case where 5·0 G/100 ml. was recorded, and this on the first day in hospital. It is interesting to note that this child died after 15 days, having suffered a 33% surface area burn with skin loss.

It will be noted that both deaths were in children who had become anaemic, which was probably a contributing factor and also an indication of progress of response to infection.

COMMENT

Water and heat exchanges in patients with burns are never studied in the detail described by Roe *et al.*[3] in the Paediatric Burn Unit at Livingstone Hospital. While the importance of this knowledge is admitted, the formula used here has been adequate, as assessed in the results achieved. Thus, provided cognizance is taken of the potential fluid loss from burns, and the requisite allowances made, e.g. by means of a tested formula, elaborate laboratory measures are not required as a routine, except in very severe burns.

Leape[4] found that in tissues of burnt areas there was a rapid rise by 75% in water content, a parallel increase in solid content by 64% with doubling of tissue albumin content, and a remarkable increase in red cell content by 52%. These profound changes in viable tissues would account for the progression of the trauma to necrosis of this tissue with conversion to full-thickness loss in a wide area, unless these increases and sludging are reversed. This substantiates the rationale of low molecular dextran solutions infused during resuscitation of patients suffering from burns, and repeated after 42 - 48 hours to reverse this state in the tissues. This procedure, described elsewhere,[2] is in routine use in our burn unit, and it may account for the low sepsis rate and the smaller numbers of full-thickness loss, and smaller areas of full-thickness loss in a larger burnt area. Low molecular dextran may also contribute towards the absence of renal shutdown or even appreciable oliguria from this series.

The statement by Kamp and Watts[5] that absorptive dressings are indispensable is questionable, but that other dressings are adherent and promote infection is incorrect. This may be true of some dressings used, but the two used in this series were found to favour healthy granula-

tions permitting early skin graft regardless of the organism cultured, excluding *Ps. aeruginosa* and *Strep. haemolyticus*. There is no statistical evidence of the efficacy of the colloidal silicate dressings used by Kamp and Watts, and length of hospitalization is not indicated. The average stay in hospital in this series may be regarded as entirely acceptable.

The emphasis in our burn unit on wound care rather than the administration of systemic antibiotics is in full agreement with Stone *et al.*,[6] who state that routine antibiotic therapy produces more virulent and refractory infections than if none is given at all. The low incidence of fatal septicaemia in this series is testimony to this statement. However, these authors advocate vigorous toilet to the wound with breach and debridement of all blebs, on admission, followed by the immediate application of a dressing, except to face, neck, axillae and perineum, which are left open. Robinson *et al.*[7] do not advocate vigorous toilet and this has not been carried out in this series, where all areas except hands and feet and circumferential burns were left open initially. One assumes that the areas not dressed by Stone *et al.* healed satisfactorily, as did all wounds in this series not contaminated by *Ps. aeruginosa*. Dressings were applied to burnt areas usually on about the 10th day, to remove eschar and prepare the area for skin graft. This is based on the regimen long in use at Red Cross War Memorial Children's Hospital, Cape Town, and since described elsewhere.[8] The importance of a well-controlled specialized burn unit as described by Barclay,[9] or as in existence at Red Cross and Livingstone Hospitals, must not be overlooked in the control of infection.

Infection of burn wounds by *Ps. aeruginosa* is well recognized[9-12] as the major complication during treatment and, similarly, hitherto as a major cause of death. The presence of this organism has been the only factor significantly retarding the healing process and recovery in burn wounds in this series, but there has been no incident of septicaemia due to this pathogen.

Great advances in combating pyocyaneus invasion have been claimed in recent years, and the most effective appear to have been soframycin,[8] gentamicin[8-12] and silver nitrate.[10-12] In this series it is noteworthy that without these substances there has been no incidence of pseudomonas septicaemia and, more important, the use of Carbonet PEG reduced the incidence of positive swabs from 56 out of 112 cases, when antibiotic tulle was used, to 25 out of 176 cases. The efficacy of soframycin and gentamicin is open to some doubt since our experience is that both of these antibiotics applied locally as a cream are effective for the first 4 - 5 weeks, to be followed by the development of resistant strains.

This aspect is at present under trial in several centres, including Livingstone Hospital, and the outcome will be interesting to note.

Among the adult patients in Livingstone Hospital, where there is no adult burn unit, the use of gauze dressings soaked in silver nitrate ½% has achieved dramatic improvement in results, in keeping with experience elsewhere.[10,11]

It would appear, therefore, that the combination of polyethylene glycol dressings with silver nitrate would further reduce positive swabs of the dreaded *Ps. aeruginosa*. It is proposed to institute trials with this procedure in the near future.

Other organisms of which cognizance should be taken, as deduced from this series, are *Staph. aureus, B. coli, B. proteus* and *Strep. haemolyticus*.

In the absence of pyrexia and local evidence of acute inflammation, local treatment only is necessary, with the exception of *Strep. haemolyticus* infections which are treated very effectively with ampicillin. Apart from this last-mentioned organism and *Ps. aeruginosa*, skin graft should not be delayed on account of bacterial invasion, provided adequate local care is taken.

The comparable hospitalization in cases where *Strep. haemolyticus* was cultured, as compared with other organisms, may be accounted for by the fact that these cases with cultures positive for *Strep. haemolyticus* were the only ones treated with ampicillin. Without this systemic antibiotic the period would probably have been longer.

There seems little doubt that the non-adherent polyethylene glycol dressings are superior to any other used, in the preparation of the area for skin grafting, and the success of this operation is more confidently assured. Hexylene glycol unfortunately was found to have been toxic. No toxicity was observed in any of the patients in this series, and the low mortality rate and relatively short period of hospitalization substantiate this finding.

The polyethylene glycol appears to have a definite inhibitory effect on pathogenic bacteria.

SUMMARY

The results of treatment of 351 cases of burns treated over a period of 15 months are presented. The series is subdivided into 112 dressed with an antibiotic tulle, and 176 dressed with polyethylene glycol tulle. The latter appears to have been the more favourable treatment.

The over-all low mortality in burns treated in the Paediatric Burn Unit at Livingstone Hospital is mentioned, and the effect on hospitalization of infections by a variety of organisms is discussed. The means of combating this infection is reviewed briefly in the light of experience of several other authors.

The complete absence of toxicity of polyethylene glycol used as a dressing is stressed.

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