THE EPIDEMIOLOGY OF INFECTION WITH *PSEUDOMONAS PYOCYANEA* IN A BURNS UNIT

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There are many published accounts of hospital infection with *Streptococcus pyogenes* and *Staphylococcus aureus*, and the transfer of these organisms has been followed, respectively, with the aid of serological typing (e.g. Keevil & Camps, 1937; Bradley, 1938) and phage typing (e.g. Barber, Hayhoe & Whitehead, 1949; Rountree & Thomson, 1949; Lowbury, Topley & Hood, 1952). By using Griffith's types, Cruickshank (1935) showed that the same serological type of *Strep. pyogenes* appeared in a number of burns in the same ward, and also in the ward dust.

Much less attention has been paid to the epidemiology of *Pseudomonas pyocyanea* and other Gram-negative bacilli, which are often found in wounds and burns (Medical Research Council, 1941, 1945; Clark, Colebrook, Gibson, Thomson & Foster 1943; Florey, Ross & Turton, 1947; Meleney, 1948). In a burns unit Colebrook and others (Medical Research Council, 1945) isolated *Ps. pyocyanea* more commonly from patients in the wards than from out-patients, and attributed the high frequency in the former to faulty dressing techniques and transmission by dust. Of normal human reservoirs, the skin (particularly of the axilla and perineum) has been cited by Růžička (1898), and the intestine by Ringen & Drake (1952).

Routine local application of polymyxin cream has been shown to reduce the rate of added infection with *Ps. pyocyanea* in burns (Jackson, Lowbury & Topley, 1951). More recently, a controlled trial (Lowbury, 1954) has shown that *Ps. pyocyanea* may be excluded from a proportion of burns by the use of an air-conditioned dressing station with filters, previously described by Bourdillon & Colebrook (1946). Cetrimide solution and some other surgical fluids in bottles with cork stoppers have been found contaminated with *Ps. pyocyanea*, and the routine hospital supply of sterile fluids in screw-cap bottles was followed by a fall in the incidence of *Ps. pyocyanea* in open wounds (Lowbury, 1951*a*). *Ps. pyocyanea*, however, continued to appear on many burns in spite of the removal of this potential reservoir of infection and the use of an air-conditioned dressing station. We therefore made an examination of the environment for other reservoirs and vectors of the organism, and used serological typing of the strains to follow their transmission in the burns wards of this hospital.

RESERVOIRS OF *PSEUDOMONAS PYOCYANEA*

Materials

Most of the samples were taken from patients, staff and environment in the two wards, the dressing station and other rooms of the Burns Unit. A series of stools were kindly examined for *Ps. pyocyanea* by Dr G. T. Cook at the Public Health

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Laboratory, Oxford; most were from patients with gastro-intestinal symptoms, but a small proportion were from healthy people. We obtained also a number of samples from students, from patients attending the Casualty Department, and from patients and staff of other wards.

Methods

Dry swabs with absorbent cotton-wool were used for sampling wet surfaces (e.g. throat, and burns with profuse exudate). For all other surfaces (e.g. furniture, bedclothes, anterior nares, and many burns), the swabs were moistened with 10 % broth saline.

All burns were swabbed on admission to hospital, at every change of dressings and at operations. Those treated by the exposed method were swabbed daily. Nose and throat swabs were taken from all patients on admission, and from patients and staff once a month. For a period of 9 months swabs were taken from the nose of all patients before each dressing, and throat, skin and ear swabs were taken from a proportion of these patients at the same time. Nasopharyngeal swabs were taken from a smaller number of patients at monthly swabbings. Sampling of the environment was done mostly during the winter months, when *Ps. pyocyanea* was present on many burns.

Swabs were examined for *Ps. pyocyanea* by inoculation on 0·1 % cetrimide agar and in cooked meat broth, the latter being subcultured to cetrimide agar after overnight incubation at 37° C. A number of swabs from nose and skin were inoculated into cooked meat broth only. Culture plates were examined by visible light, and under an ultra-violet lamp with a dark glass filter for identification of the fluorescent pigment of *Ps. pyocyanea* (Lowbury, 1951*b*).

Stools examined locally were inoculated on cetrimide agar and into cooked meat broth which was subcultured to cetrimide agar; those examined in Oxford were inoculated on cetrimide agar and deoxycholate citrate agar, and into tetrathionate and selenite F broth enrichment media, which were subcultured to deoxycholate citrate agar and cetrimide agar after overnight incubation.

Floor dust was collected from ward sweepings and approximately 1 g. amounts were inoculated into cooked meat broth, from which loopfuls were transferred to cetrimide agar immediately and again after incubation at 37° C. overnight.

The hands of all the nurses at work in the burns wards were sampled, on two occasions, by rinsing in 100 ml. of nutrient broth, from which a loopful was transferred to cetrimide agar immediately and after incubation.

Air samples (23 cu.ft./min.) were taken with a slit sampler (Bourdillon, Lidwell & Thomas, 1941) on to cetrimide agar plates in the dressing station, the 'plenary' (initial) dressing room and in the wards.

Results

Ps. pyocyanea *in burns*. The incidence of added *Ps. pyocyanea* on the burns of patients admitted during the course of one year (July 1951–June 1952), and the distribution of the organism on different parts of the body, including skin graft

donor areas, are shown in Table 1. Prophylaxis with local polymyxin was not in use during this period.

Table 1. *Regional distribution of added* Ps. pyocyanea *on burns and skin graft donor areas of patients admitted July* 1951–*June* 1952

Site	Added *Ps. pyocyanea*	No added *Ps. pyocyanea*	Total	% added *Ps. pyocyanea*
Arms	100	110	210	48
Hands	5	20	25	20
Legs	97	91	188	52
Feet	9	50	59	15
Trunk	68	67	135	50
Face	28	46	74	38
Scalp	6	6	12	50
Donor areas	75	111	186	40

Areas which could be adequately protected by dressings (feet and hands) acquired the organism less often than the trunk, arms and legs, on which adequate cover was less often attained. Intermediate between these two groups in frequency of added infection were faces, and skin graft donor areas. The former were treated by the exposed method as a routine. The latter produced a large amount of exudate which usually soaked through the dressings when the patient had returned to the ward. The soaked dressing is a likely route by which a burn or donor area may become infected (Colebrook & Hood, 1948). Of the seventy-five donor areas which acquired *Ps. pyocyanea* six were in patients whose burns were free from the organism.

A large proportion of burns colonized by *Ps. pyocyanea* showed a heavy growth of them on culture (see also Jackson *el al.* 1951). Fewer organisms were usually found on faces, but some swabs from these exposed burns also yielded a heavy growth of *Ps. pyocyanea.*

Table 2 shows the association between percentage of the body surface burned and added infection with *Ps. pyocyanea* in the series of patients described in Table 1. Added *Ps. pyocyanea* was found in the majority of patients with burns of more than 10 % of the body surface. By contrast, the majority of burns under 5 % of the body surface remained free from *Ps. pyocyanea.* About one-half of the burns between 5 and 10 % of the body surface picked up the organism.

Table 2. *Added* Ps. pyocyanea *and surface area of burns in patients admitted July* 1951–*June* 1952

Added *Ps. pyocyanea* in burns	Percentage of body surface burned									Total patients
	>50	41–50	31–40	21–30	16–20	11–15	6–10	1–5	<1	
Present	3	4	8	13	8	22	36	42	20	156
Absent	0	1	1	0	0	7	33	83	50	175
Total	3	5	9	13	8	29	69	125	70	331

Ps. pyocyanea *in uninjured parts of the body.* Some data on the distribution of *Ps. pyocyanea* in various parts of the body other than burns are shown in Table 3.

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As the sources and mode of sampling for this table are heterogeneous, quantitative comparison of some of the figures (e.g. hands of nurses, stools, nose and throat) cannot be made. Both patients and staff of the burns wards showed *Ps. pyocyanea* in a proportion of the swabs from nose, throat and skin, but the proportions were higher in patients, and in them the burns also were usually colonized by *Ps. pyocyanea*. The women and children, with burns on the average more severe than those of the men (Colebrook & Colebrook, 1951), showed a higher incidence of *Ps. pyocyanea* in these normal sites.

Swabs from students did not show *Ps. pyocyanea* in the nose, throat and ear, or in the skin of axilla and perineum. Though the number of samples was small, they showed that *Ps. pyocyanea*, unlike *Staph. aureus*, does not commonly appear as a resident organism of these areas in the normal subject. About 3% of the stools from students contained *Ps. pyocyanea*, and the organism was present in a similar proportion of the stools which were examined by the Oxford Public Health Laboratory.

Washings from the hands of nurses working in the burns wards showed that 11/29 (38%) were contaminated with *Ps. pyocyanea*. In addition to these samples from all the nurses on duty, separate samples were taken from the hands of two nurses who had just made the bed of a patient with burns (under dressings) infected with *Ps. pyocyanea*; the hands of both nurses were contaminated with small numbers of the organism.

With few exceptions the swabs from nose, throat, pharynx, skin and ear yielded no more than a scanty growth of *Ps. pyocyanea*. Stools sometimes yielded large numbers; e.g. 9/17 positive swabs from the Oxford series yielded the organism both on direct plating and on subculture from the enrichment medium. The two swabs from students which yielded *Ps. pyocyanea* did so only on subculture from cooked meat broth.

Ps. pyocyanea *in the patients' environment*. Table 4 shows data on the distribution of *Ps. pyocyanea* in the patients' environments. Outstanding features are: (1) the frequency of *Ps. pyocyanea* on the outside of dry bandages over infected burns; (2) the frequency of *Ps. pyocyanea* in the dust; (3) the presence of large numbers of *Ps. pyocyanea* in the air during removal of dressings from an infected burn; (4) the presence of *Ps. pyocyanea* on some bedpans, food trays, toys and wash basins brought to the patients; and (5) the absence of *Ps. pyocyanea* from laundered sheets, blankets, pyjamas and other materials in the linen stores of the wards.

A separate examination of the environment of a patient with burns heavily infected with *Ps. pyocyanea* showed large numbers of *Ps. pyocyanea* on the outside of bandages both where exudate had reached the surface and on apparently dry areas. Smaller numbers were also present on the bandage covering an infected burn in the dressing of which was a layer of nylon derivative (Bull, Squire & Topley, 1948), and on blankets, bedjackets, newspapers, floor, window sills, wash basin, bed, and seven pieces of furniture. A few swabs (from towel, tap, soap tray, radiator and temperature chart) were free from the organism.

Air and dust samples from the plenary dressing room (used for the first dressing of new burns only) were found to be free from *Ps. pyocyanea*. Infants' napkins

Table 3. *Reservoirs of* Ps. pyocyanea: *distribution in uninjured parts of the body*

(*Ps. pyocyanea* from swabs and other samples.)

Source	Nose swab			Throat swab			Nasopharyngeal swab			Skin swab		
	Present	Absent	%+	Present	Absent	%+	Present	Absent	%+	Present	Absent	%+
Burned patients:												
Women and children	99	1346	6·8	46	934	4·7	7	71	9·0	72	304	19·1
Men	51	997	4·9	16	803	1·9	1	71	1·4	12	244	4·7
Nursing staff in burns wards	10	643	1·5	12	534	2·2	—	—	—	6	123	4·6
Patients in other wards	1	94	1·1	—	—	—	—	—	—	2*	80	2·4
Nursing staff in other wards	0	37	0	—	—	—	—	—	—	0	15	0
Students	0	56	0	0	56	0	—	—	—	0†	96	0
Patients attending Casualty Department	0	93	0	—	—	—	—	—	—	—	—	—
Specimens from patients and contacts examined at Oxford Public Health Laboratory	—	—	—	—	—	—	—	—	—	—	—	—

Source	Ear swab			Stool			Hand washings		
	Present	Absent	%+	Present	Absent	%+	Present	Absent	%+
Burned patients:									
Women and children	3	85	3·4	3	12	20	—	—	—
Men	4	75	5·1	—	—	—	—	—	—
Nursing staff in burns wards	—	—	—	—	—	—	11	18	38
Patients in other wards	—	—	—	—	—	—	—	—	—
Nursing staff in other wards	—	—	—	—	—	—	—	—	—
Students	0	56	0	2	62	3·1	—	—	—
Patients attending Casualty Department	—	—	—	—	—	—	—	—	—
Specimens from patients and contacts examined at Oxford Public Health Laboratory	—	—	—	97	2896	3·2	—	—	—

* The two positive results were from perinaeal swabs in a series of twenty-three perinaeal and twenty-three axillary swabs from children.

† Forty-eight swabs from the axilla and forty-eight from the perinaeum.

and sheets from several patients whose burns were heavily colonized with *Ps. pyocyanea* were marked with coloured thread before being sent to the laundry, and were found free from *Ps. pyocyanea* when they returned to the ward.

Table 4. *Reservoirs of* Ps. pyocyanea: *distribution in the environment*

Source	*Ps. pyocyanea* present: Large or moderate numbers	*Ps. pyocyanea* present: Scanty*	*Ps. pyocyanea* absent	% present	Total observations
Outside of bandages					
(1) From cases with *Ps. pyocyanea* in burns	30	69	174	36	273
(2) From cases with no *Ps. pyocyanea* in burns	0	2	29	6·5	31
Total	30	71	203	33	304
Dust					
(1) Burns wards	47	47	6	94	100
(2) Other surgical wards	12	14	4	86	30
(3) Domestic	0	1	22	4	23
Patients' bedclothes					
(1) Patients with *Ps. pyocyanea*	4	11	52	22	67
(2) Patients without *Ps. pyocyanea*	0	0	39	0	39
Total	4	11	91	14	106
Laundered articles (linen, bed-jackets, pyjamas, blankets, etc.)	0	0	57	0	57
Objects brought to patients					
(1) Bedpans	2	0	9	18	11
(2) Wash basins	1	0	16	6	17
(3) Food trays	0	5	23	18	28
(4) Toys	0	3	25	11	28
Air (130 cu.ft.)					
(1) Burns dressing station (during dressing of infected burn)	18		3	86	21
(2) Burns ward at bedmaking	3		8	27	11
(3) Burns ward at rest	1		3	25	4
(4) Plenary dressing room (during dressing of new cases)	0		10	0	10

* Growth in fluid medium only.

SEROLOGICAL TYPES OF *PSEUDOMONAS PYOCYANEA* IN BURNS

Further information on the routes of infection was sought in a study of the serological types of *Ps. pyocyanea* isolated from burns during a period of 5 months.

Materials and methods

Agglutinating sera were prepared in rabbits by immunizing them with strains of *Ps. pyocyanea* which had been typed with sera kindly supplied by Dr R. Christie of Melbourne (see Christie, 1948). The methods used in preparing the sera and their

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agglutination properties and patterns have been described by the authors (Fox & Lowbury, 1953*a*, *b*). The antigens were described, by reference to the sera which caused slide agglutination, as 16 and 17 (flagellar antigens), and 2, 4, 8, 15, 36, 50 and 475 (somatic antigens). Two additional flagellar antigens, suggested by differences in the range of sensitivity to agglutinating sera, were described as 16A and 17A.

Between July 1952 and December 1952, every strain of *Ps. pyocyanea* isolated from the swabs of burns was typed, and for a further period of 10 weeks a proportion of strains from all patients was typed. For a shorter period we also tested *Ps. pyocyanea* isolated from the nose and skin, and from floor dust in the ward. The type result was expressed as a pattern showing all the antigenic components, flagellar and somatic, that could be distinguished by slide agglutination (e.g. 16–15/2, 16A/17–8).

Results

We typed 722 strains (343 from the male ward, 379 from the women's and children's ward), from which thirty-eight different patterns of agglutination could be recognized. A few strains were inagglutinable. Some patterns were common (e.g. 16–15, 16–0, 17–0), but many were rarely found.

Many burns continued to yield *Ps. pyocyanea* for varying periods of time, and we expected that strains with the same agglutination pattern might be found in successive swabs from these burns. In most burns, however, *Ps. pyocyanea* found at different times did not show a constant agglutination pattern, but often varied from one swab to the next in a manner which suggested variation in the agglutinability of the organism rather than displacement of one strain by another. These differences were particularly marked in the case of somatic agglutination.

Table 5. *Flagellar antigens in* Ps. pyocyanea *from successive swabs*

First swabs from 117 burns with *Ps. pyocyanea*		Later swabs with *Ps. pyocyanea* from the same burns, showing the same and different antigens from those found in the first swab							
Flagellar antigen	No. of swabs	16	16A	17	16A/17	16/17A	17A	16A/17A	0
16	48	215	1	2	2	1	0	0	0
16A	1	1	0	1	2	0	0	0	0
17	25	0	0	45	18	0	0	1	0
16A/17	26	2	1	40	28	0	1	2	0
16/17A	0	0	0	0	0	0	0	0	0
17A	1	0	0	1	0	0	1	0	0
16A/17A	12	14	0	1	7	0	4	13	1
0	4	5	1	1	2	0	3	1	7

From the data it seemed that differences in the pattern of O agglutination do not necessarily indicate differences in clone, but that differences in the H antigen may provide a classification of the species into two or perhaps three separate groups. This view is illustrated in Table 5, showing the frequency with which *Ps. pyocyanea* from later swabs showed H antigens the same as and different from those present on the first strains isolated from 117 burns. It can be seen that antigen 16A is usually found in combination with antigen 17, though the latter is often found

alone; and that in series of swabs from the same burn *Ps. pyocyanea* showed sometimes one and sometimes both of these antigens. Antigen 16, on the other hand, never appeared in combination with other flagellar antigens, and series of swabs from burns on which organisms of flagellar type 16 were found usually yielded strains with the same flagellar antigen, though the somatic antigen showed considerable variation from swab to swab. Flagellar types 16 and 16A/17 therefore appeared to be distinct from each other. Flagellar antigen 17A was usually linked with antigen 16A; its presence in all the burns of one patient (sometimes at more than one swabbing) and other characteristics mentioned below suggest the independence of strains showing this antigen from flagellar types 16 and 16A/17.

In support of these hypotheses, we found some variation in somatic agglutination of forty randomly selected colonies from each of four strains of *Ps. pyocyanea*, originally described as 16–0, 16–15/2, 17–0, and 16A/17–15. There was some variation in the appearance of antigen 16A in the strains 17–0 and 16A/17–15, but no variation between these flagellar antigens and antigen 16. These results will be more fully described elsewhere.

In studying the epidemiology of *Ps. pyocyanea* in the burns wards we therefore restricted our attention to the flagellar agglutination, and classified the organisms as flagellar types 16, 16A/17 (including 16A, 17 and 16A/17) and 16A/17A (including 16A/17A and 17A). Table 6 shows the distribution of strains from patients in the two wards in 4-week periods from July to December 1952. The features of interest are (1) predominance of type 16 until October; (2) appearance of type 16A/17 strains in October; (3) from that time predominance of type 16A/17 in the women's and children's ward (F), while type 16 continued to be predominant in the male ward (E); (4) sparsity of type 16A/17A strains.

Table 6. *Distribution of flagellar types of* Ps. pyocyanea *in two burns wards*

	Numbers of burns with *Ps. pyocyanea* of types						
	16		16A/17		16A/17A		
Period (1952)	Ward E	Ward F	Ward E	Ward F	Ward E	Ward F	Totals
16 July–12 Aug.	53	8	0	1	0	3	65
13 Aug.–9 Sept.	41	18	0	0	0	0	59
10 Sept.–7 Oct.	17	13	0	0	0	0	30
8 Oct.–4 Nov.	26	14	11	40	6	2	99
5 Nov.–2 Dec.	84	9	22	57	5	1	178
3 Dec.–30 Dec.	23	8	5	113	2	10	161
Totals	244	70	38	211	13	16	592

Ward E, men; ward F, women.

We studied the data in greater detail, and found that a patient (D.K.) (see Table 7) was admitted to ward F on 9 October with *Ps. pyocyanea* of type 16A/17 on her burns. No other patient in either ward was then carrying this type of *Ps. pyocyanea*, but in a short time it appeared on the burns of a number of other patients in that ward. The burns of a few patients in the male ward (E) also

Table 7. *Spread of a new strain of* Ps. pyocyanea (*type* 16A/17) *through the burns wards*

		Serological type of added *Ps. pyocyanea*					
		16		16A/17		16A/17A	
Period (1952)	Data from	Ward E	Ward F	Ward E	Ward F	Ward E	Ward F
Before admission of new strain (16 July–9 Oct.)	Patients	8 (100 %)	6 (75 %)	0	1 (12·5 %)	0	1 (12·5 %)
	Swabs	107 (100 %)	36 (90 %)	0	1 (2·5 %)	0	3 (7·5 %)
After admission of new strain (10 Oct.–10 Dec.)	Patients	9 (60 %)	7 (27 %)	6 (40 %)	17 (65 %)	0	2 (8 %)
	Swabs	105 (85 %)	26 (16 %)	19 (15 %)	127 (81 %)	0	4 (3 %)

Table 8. *Replacement of* Ps. pyocyanea *present on admission by predominant strain in the ward* (*type* 16) (*Patient J.D., ward E*)

	Serological type of *Ps. pyocyanea* (during 1952) in burns on							
Site of burn	3 Nov. (admission)	9 Nov.	11 Nov.	16 Nov.	24 Nov.	7 Dec.	12 Dec.	18–23 Dec.
Right leg	16A/17A–8	16A–0	16–15	17A–8	16–15	—	—	16–0
Left leg	16A/17A–8	16A/17A–0	—	16–15	16–15	16–15	16–15	16–15
Chest	16A/17A–8	—	16A/17–0	—	—	—	16–15	16–15
Back	16A/17A–8	16A/17A–15/8	—	16–15	16–15	16–15	—	—
Right arm	16A–8	—	16A/17–8	16A/17–0	—	—	16–15	—
Left arm	16A/17A–8		—	—	16A/17–8	—	—	—

acquired *Ps. pyocyanea* of type 16A/17, but in these it was usually displaced by type 16, the resident ward strain.

In another patient (J.D.) (see Table 8) admitted to ward E with *Ps. pyocyanea* in his burn, the strain present on all burns was found to belong to type 16A/17A. This strain, however, was displaced from all but one of the burns by the resident type 16, and temporarily also by a strain of type 16A/17. The colonies of the admission strain (16A/17A) were small and sometimes not detected on culture until plates had been incubated for 48 hr. It seemed likely that such an organism would be displaced by a more rapidly growing one, such as the type 16 or 16A/17 strains. To test this hypothesis we inoculated approximately equal numbers of type 16A/17A and type 16 strains isolated from the patient into nutrient broth, and after incubation inoculated dilutions of the culture on agar plates. Fifty colonies were picked from the culture on these plates and typed by slide agglutination. All the colonies were found to be of type 16. This result might have been expected from the observed capacity of the type 16 strain to grow more rapidly than type 16A/17A. In addition, moreover, the type 16 strain was found to be lysogenic toward type 16A/17A, but was not itself lysed by filtrates of the latter organism.

The most useful fact of epidemiology shown by this study was the difference in the predominant strain of *Ps. pyocyanea* for a period in the two wards. Since all the patients had their dressings and operations (if any) in the same dressing station and theatres, it seems that much of the added infection was occurring in the wards, even in burns covered with apparently adequate dressings.

A NOTE ON THE PROTECTION OF EXPOSED BURNS AGAINST *PSEUDOMONAS PYOCYANEA* WITH POLYMYXIN POWDER

The prophylactic value of local polymyxin cream in burns covered with dressings has been reported (Jackson *et al.* 1951). Burns treated by the exposed method cannot be protected in this way, though they are particularly liable to contamination before a dry coagulum has formed on the surface. All extensive burns in this unit are exposed to such a risk during the period of treatment for shock, whether the burns are subsequently treated by the exposed or the covered method, and a large proportion of such burns become contaminated with *Ps. pyocyanea*.

To find whether the risk of added infection with *Ps. pyocyanea* during this period could be reduced by chemoprophylaxis, we made a controlled trial of a powder containing 1 mg. of polymyxin E and 10,000 units penicillin per gram of lactose. This powder was dusted frequently over the burns of patients with 15% (10% in children) or more of the body surface burned, when their hospital number was odd; the burns of even-numbered patients in the same category were dusted with penicillin powder (10,000 units per gram) as a control. The bacteriology of these burns was studied by the methods summarized above.

Table 9 shows that the proportion of burns which became contaminated with *Ps. pyocyanea* before the first dressing was significantly smaller in the polymyxin-treated series (16/133: 12%) than it was in the controls (35/126: 27·7%). Many of the burns in both series, however, eventually became colonized by *Ps. pyocyanea*.

Table 9. *Controlled trial of polymyxin powder applied to extensive burns before the first dressing*

	Swabs from burns				
	At first dressing		At first dressing or later		
Powder applied	*Ps. pyocyanea* present	% total burns	*Ps. pyocyanea* present	% total burns	Total burns
Polymyxin penicillin mixture	16	12·0	88	66·1	133
Penicillin	35	27·7	103	81·8	126
χ^2	9·17		7·35		—
P	<0·01		<0·01		—

DISCUSSION

Colebrook, Duncan & Ross (1948) found that a combination of prophylactic methods which greatly reduced the incidence of *Strep. pyogenes* in burns wards did not have any similar effect on the incidence of *Staph. aureus* and *Ps. pyocyanea*. In the case of *Staph. aureus*, probably two factors were responsible—the prevalence of penicillin-resistant strains, and the presence of the organism in a large proportion of normal subjects in the nose and on the skin. The studies reported above show that, in respect of the second of these factors, *Ps. pyocyanea* differs from *Staph. aureus*, being carried, like *Strep. pyogenes* (Topley & Wilson, 1946), by a small proportion only of normal subjects. The infected burn or wound is clearly the major reservoir of *Ps. pyocyanea* in the ward, particularly when it is imperfectly covered by dressings. Self-infection (apart from transfer between burns of the same patient) must therefore be of negligible importance compared with cross-infection.

From the evidence it seems likely that the organism is carried to uninfected burns both by airborne particles and by contact. Although, by contrast with Gram-positive bacilli, a large proportion of the organisms in a suspension of *Ps. pyocyanea* have been found to die during the evaporation of their suspending fluid on skin (Ricketts, Squire & Topley, 1951) and on glass (Lowbury & Fox, 1953), enough of them continue to survive on a dried surface to allow a moderate contamination of the air during the removal of dressings, and of the ward dust. Such contamination of the environment is likely to persist for some time and may constitute a minor reservoir of infection, even when the ward is free from infected burns, and when the floor is swept daily (Lowbury, 1950). Burns treated by the exposed method are particularly liable to contamination from this source if effective dust-laying is not practised.

The presence of *Ps. pyocyanea* on the hands of nurses, on objects handled by patients and on the outside of their bandages suggests ways in which the organism may be transferred by contact in the ward; especially to burns which are imperfectly covered or those in which the dressings become soaked with exudate.

Serological typing of the strains of *Ps. pyocyanea* throws some light on the relative importance of the different routes of transfer. Although the patients from both wards were dressed in the same dressing station and grafted in the same

operating theatres, each ward had for a time its own resident strain which spread freely in that ward but hardly at all to the other ward. A similar difference in the serological types of *Proteus* from patients in these two wards has been demonstrated by Cunliffe (personal communication). These findings suggest that most of the added infection with *Ps. pyocyanea* was occurring in the wards, and not during operations or dressings—the latter done in a room supplied with filtered air.

As the routes of transfer of *Ps. pyocyanea* are almost certainly multiple, measures directed towards blocking each of them are needed in an effective campaign against cross-infection. Substantial effects have been demonstrated in trials of dressing in filtered air (Lowbury, 1954), polymyxin cream under dressings (Jackson *et al.* 1951), and, as reported above, with polymyxin dusting powder applied during exposure. These methods should be supported by cubicle isolation, oiling of floors and blankets, sterilization of cutlery and crockery, the use of surgical rubber gloves while attending to shock cases, and other measures to prevent cross-infection. They might be supplemented by further attempts to block known channels of transfer—e.g. by the use of a disinfectant barrier to prevent organisms growing through soaked dressings to uninfected burns or skin-graft donor areas (Lowbury & Hood, 1951). Unsuspected routes of transfer may well come to light if all who attend the patients—nurses, doctors, physiotherapists and others—are vigilant.

Wallace (1949) has advocated treatment of burns by exposure to the air, and claims that with this method organisms will not multiply on the burned surface because it is covered by a dry eschar. In our experience a considerable proportion (38%) of face burns treated by the exposure method became colonized by *Ps. pyocyanea*. A minority of these showed a heavy growth of the organism, but there is evidence that a scanty growth on the outside of an eschar may be associated with a heavy growth underneath. If, however, the pigment pyocyanin is an important factor in causing a delay in local repair (Cruickshank & Lowbury, 1953), contact with a thick layer of cotton-wool soaked with green exudate may contribute to the delay in healing and failure of skin grafts of burns infected with *Ps. pyocyanea*. Further study is required for a satisfactory assessment of the bacteriological evidence for and against the exposure method of treatment.

SUMMARY

A bacteriological study of burned patients and of the staff and environment in a burns unit was made with the purpose of discovering the principal reservoirs and routes of transfer of *Ps. pyocyanea*.

Infected burns appeared to be the most important reservoirs. About 3% of the stools of normal subjects and of patients with intestinal symptoms carried the organism, which was also isolated from the nose, throat, nasopharynx, skin and ear of a small proportion of patients and staff in the burns wards.

The hands of nurses in the wards were often contaminated with *Ps. pyocyanea*, and presented a likely vector in the transfer of the organism by contact—e.g. from the bandages of infected patients, and from furniture and other objects near to their beds.

It was shown by slide agglutination that a new type of *Ps. pyocyanea* admitted to one of the wards spread freely in that ward but hardly at all to the other ward. Since patients from both wards used the same dressing station and operating theatres, it seemed from this finding that a large proportion of the cross-infection occurred in the wards.

Polymyxin dusting powder was shown in a controlled trial to protect exposed burns against contamination by *Ps. pyocyanea*.

These results are discussed in relation to the mechanism of transfer of the organism and the methods of preventing cross-infection. The need to use several methods concurrently is emphasized, since none of those which have been investigated contributes more than a partial effect. Cubicle wards are advocated, since much cross-infection is shown to occur in open wards.

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