HAEMOLYTIC STREPTOCOCCI IN THE DUST OF HOSPITAL WARDS, AND THEIR RELATIONSHIP TO INFECTION

A REPORT TO THE MEDICAL RESEARCH COUNCIL

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(With 3 Figures in the Text)

Increasing attention has recently been paid to the role of dust in the aerial spread of infection. Many micro-organisms, including certain viruses (Edward, 1941), have been shown to resist drying and to remain alive in dust for days, weeks or even months. In investigations of hospital wards certain pathogenic bacteria, including *Str. pyogenes* and *C. diphtheriae*, have been actually demonstrated in the floor dust (White, 1936; Crosbie & Wright, 1941), and it has been repeatedly shown that the bacterial content of the air is enormously increased by floor-sweeping and bed-making which bring about a redispersal of the dust in the air (Thomas & van den Ende, 1941). Methods were therefore sought to diminish the number of dust-borne organisms in the air, and it was found that this could largely be accomplished by the oiling of floors (van den Ende, Lush & Edward, 1940) and by the impregnation of bed-clothes with oil (van den Ende, Edward & Lush, 1941; van den Ende & Thomas, 1941). Before, however, such methods as these are likely to become widely applied in hospitals, further investigation of the part played by dust in producing cross-infection will be necessary.

Though instances of cross-infection due to dust have been described (White, 1936; Cruickshank, 1941), it is not known how frequently they occur, nor what exact significance is to be attached to the demonstration of viable pathogenic bacteria in dust. It was thought that information bearing on the problem could be obtained by examining the dust of a hospital ward at regular intervals over a period of months. Strains of haemolytic streptococci were therefore isolated from the dust, identified serologically, and compared with those present in swabs taken from the patients and staff, in order to determine the source of the organisms in the dust and their relation to cross-infection. Observations were limited to haemolytic streptococci because of the frequency with which they occur and give rise to hospital infections, and the ease with which they can be isolated from dust. They can also be differentiated serologically into groups and types, thus making analysis easier. It is, however, probable that data obtained for haemolytic streptococci are in many respects valid for other pathogenic organisms.

Scope of the investigation and technical methods

The investigation was carried out in the wards of two contrasting types of hospital. Observations were first made in the combined ear, nose and throat and eye ward of an E.M.S. hospital, set up in what had been a mental hospital. An outbreak of streptococcal tonsillitis had occurred previously in the ward, leading to its closure and thorough cleansing and fumigation. The investigation began immediately after it was reopened. The ward was situated on the first floor of a two-story building and consisted of a suite of rooms with four main subdivisions, a main ward for diseases of the ear, nose and throat (E.N.T. ward), a smaller ward for ophthalmological patients (Eye ward), a day room and corridor (see Fig. 1). The whole ward was reserved for adult patients from the Services. Most of them were up and about during the greater part of the day, and they were even allowed occasionally to leave the ward.

The dust was examined at weekly intervals during a period of 26 weeks from June to December 1941. Representative samples of the dust swept up in the morning from each of the four subdivisions of the ward were chosen for testing. Weighed amounts were extracted with broth and dilutions of the latter plated out on horse blood-agar plates containing 1:500,000 gentian violet (Garrod, 1942). The usefulness of this medium for isolating haemolytic streptococci was amply confirmed. Often pure cultures were obtained, and on only one occasion were the plates so overgrown with Gram-negative bacteria that no count was possible. The total number of haemolytic streptococci per gram of dust was estimated. Three colonies, chosen where possible because of differing colonial appearances, were picked off and identified serologically according to group and, in the case of group A streptococci, also according to type, using Griffith's slide agglutination technique (1926, 1934).

Each week on the same day as the dust was sampled, throat swabs were obtained from all the patients and from the medical, nursing and domestic staff. Plates

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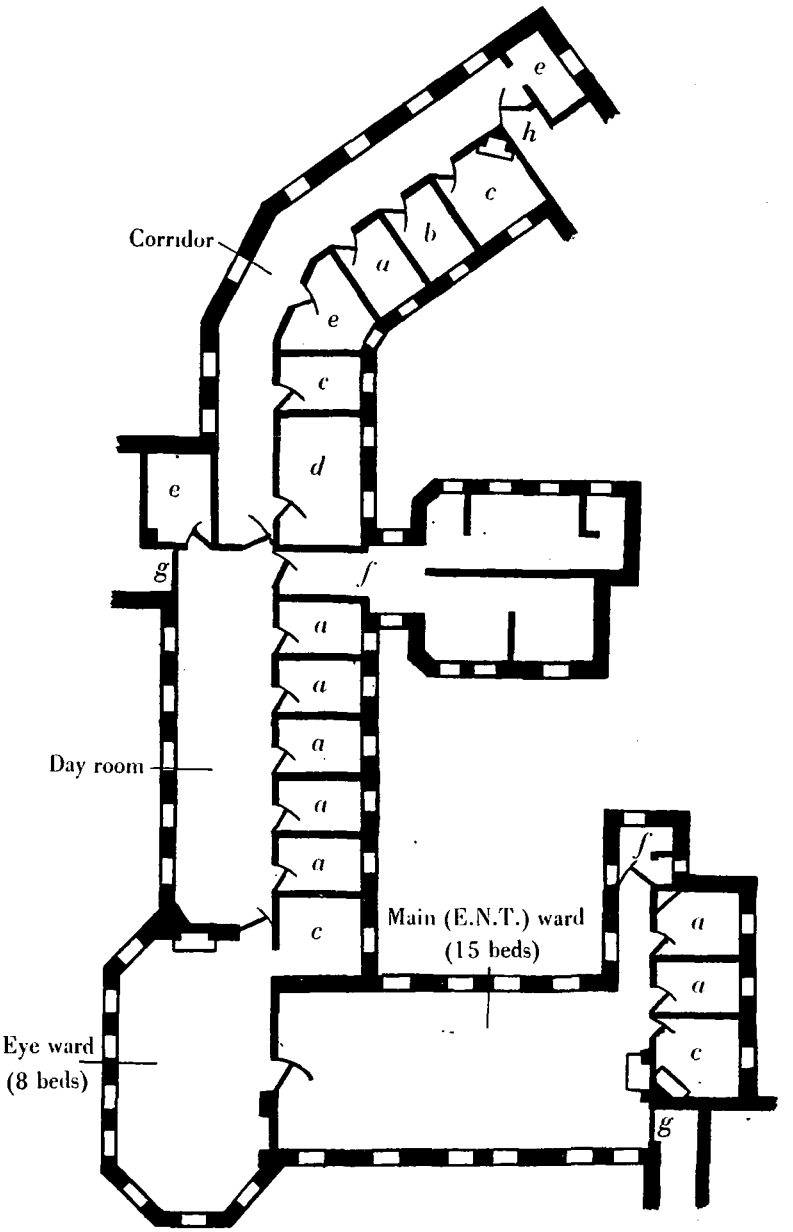

Fig. 1. Plan of combined E.N.T. Eye ward.

Key to Figs. 1 and 2.

a, cubicle; *b*, treatment room; *c*, nurses' room;
d, kitchen; *e*, storeroom; *f*, lavatory, sluice-room or bathroom;
g, locked door leading to another ward; *h*, entrance; *i*, unused room.

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of horse blood-agar were streaked from the swabs, incubated aerobically and examined for haemolytic streptococci. When present, these were grouped and typed. Unfortunately, it has only been subsequently realized that, at least in scarlet-fever patients and their contacts, a greater proportion of positive isolations of haemolytic streptococci can be obtained by, in addition, inoculating a blood-agar plate for anaerobic cultivation and a blood-agar plate containing 1:500,000 gentian violet. Swabs were also examined for haemolytic streptococci from septic lesions, such as otitis media and abscesses.

Several factors made this ward rather unsatisfactory for the investigation, and therefore at the end of six months observations were repeated in the children's ward of another hospital with certain amendments to technique suggested by the previous experience. This hospital had been recently built to a modern design on high ground in the country, and the wards were light and well ventilated. The children's ward was on the ground floor and consisted of a main ward with a solarium at the far end, four single-bed cubicles, a two-bed and a four-bed cubicle, all opening out of a corridor (see Fig. 2). Children between the ages of 5 and 14 years were admitted for either medical or surgical treatment. Occasionally the cubicles were used to nurse adult patients with diseases of the ear, nose and throat.

In this part of the investigation twenty-nine consecutive weekly samples of dust from the main ward, each cubicle and the corridor were examined between January and July 1942. As a routine swabs were taken from the nose as well as from the throat of all patients. Instructions were given for nose and throat swabs to be taken from patients directly they were admitted, but this arrangement did not work perfectly and occasionally the initial swabbing was omitted. Each week a few children were admitted, usually to the four-bed cubicle for tonsillectomy. Admission swabs were examined, but the patients were usually discharged before the next routine weekly swabbing.

Incidence of streptococcal infection

During the investigation in the E.N.T. Eye ward, group A streptococci were isolated from the throats of thirty-two patients and four nursing staff, although the swabs of only fourteen of the patients and none of the nurses contained more than scanty numbers. Unfortunately, on a number of occasions satisfactory cultures were not obtained from the swabs. It is therefore impossible to give accurate figures for the proportion of streptococcal carriers. Nineteen patients apparently acquired a streptococcal infection while in hospital; either an earlier swab was negative or in one case a *Streptococcus* of different serological type was later isolated from an already infected patient. Complete clinical details concerning these patients are not available, but it would appear that about three-quarters of the infections were latent. During the last few weeks of the investigation in this ward there was a small outbreak of both manifest and latent cross-infection due to *Str. pyogenes* type 30. It is therefore probable that if observations had been continued more cross-infections would have been detected. Apart from the examples of

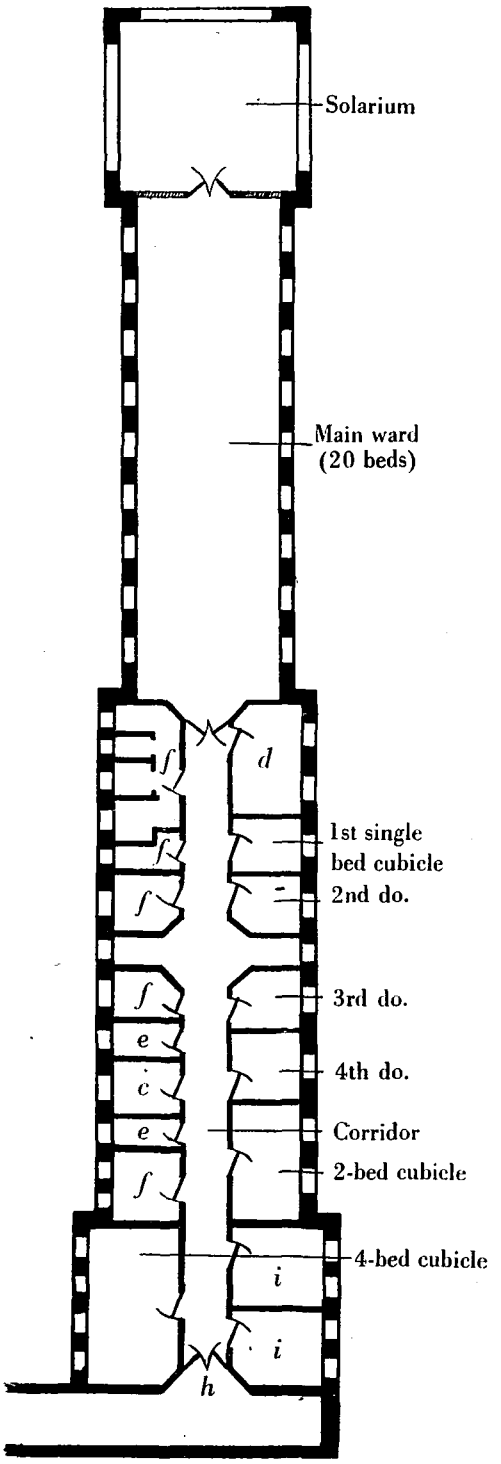

Fig. 2. Plan of children's ward.

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cross-infection included in the figures already mentioned, there were other possible instances in both this ward and the children's ward where patients at their first swabbing, which may have been a few days after admission, were found to be harbouring streptococci of a type known to be producing cross-infection in the ward at the time. On the other hand, it is impossible to exclude the possibility that the figures include a few patients wrongly regarded as being infected in hospital; streptococci may have been scanty in their throats and not have been isolated from the swabs on the first examination.

Swabbing was more effective in the children's ward and figures can be given for the incidence of streptococcal infection. Out of 891 throat swabs from patients from whom satisfactory cultures were obtained, group A haemolytic streptococci were isolated from 139 (15·8 %); similarly among 754 nasal swabs fifty (6·6 %) were positive. The numbers of swabs from which more than only a few streptococci were isolated were much less; the figures were twenty-seven (3·0 %) and forty (5·3 %) for the throat and nose respectively. Among the staff thirteen out of a total of 231 throat swabs (5·6 %) contained haemolytic streptococci, but in only three (1·3 %) were there more than a few. Swabs were received from 258 children and twelve adult patients. From seventy-five of these (27·8 %) group A streptococci were isolated at some time during their stay in hospital, but in only twenty-seven (10·0 %) were the streptococci present in more than scanty numbers. In forty-four instances there was evidence that the patient had become infected while in hospital; either his swabs had been negative initially on one or more occasions, or the streptococci isolated later were of a different serological type from those found earlier. The forty-four cross-infections were observed in thirty-three patients, all children. From one patient in the course of 11 weeks four different types of *Str. pyogenes* were isolated. Attention has been paid to the presence or absence of any clinical manifestations resulting from these hospital cross-infections and reinfections; the results are shown in Table 1. Except for one case of scarlet fever all manifestations were mild and apparently did not increase the patients' stay in hospital. A few of the affected patients were suffering from acute nephritis and acute rheumatism, where superadded streptococcal infection is potentially dangerous, but no worsening of their condition was observed. Most numerous were infections of the nose, causing a slight discharge with little constitutional disturbance. Some nasal infections were very persistent and one patient was discharged with her infection still active after 7 weeks in spite of treatment.

Table 1. *Summary of manifest or latent cross-infections occurring in children's ward*

Clinically manifest:		
Scarlet fever	1	
Sore throat and/or slight pyrexia	3	
Nasal infection and rhinorrhoea	9	
	—	13
Latent (without clinical manifestations):		
Haemolytic streptococci numerous	3	
Haemolytic streptococci scanty	18	
Reinfection (with a different serological type)	10	
	—	31
	Total	44

Haemolytic streptococci in the dust

The results of examining ninety-nine samples of dust from the four subdivisions of the E.N.T. Eye ward are summarized in Table 2. It appears that considerable numbers of haemolytic streptococci are to be found in the dust of such a ward. The mean for the whole ward was just over 300,000 streptococci per gram of dust, though the average figure for the E.N.T. ward was double this. In only three samples were no haemolytic streptococci found (i.e. less than 80 per gram); in another three there were less than 1000 per gram. On ten occasions there were more than 1 million per gram, the highest figure obtained being 8 million per gram in the dust of the E.N.T. ward. The other eighty-three samples contained numbers of streptococci that ranged between 1000 and 1 million per gram.

Rapid fluctuations occurred from week to week in the numbers of streptococci in the dust. There were many instances where there were large numbers one week and only a few the next. For example, the chart (Fig. 3) shows that in the 15th week 2,300,000 streptococci per gram were present in the dust of the E.N.T. ward, and in the next week only 3600 per gram. On another occasion in the Eye ward 1,400,000 streptococci per gram were found one week and less than 80 per gram the

Table 2. *Number of haemolytic streptococci in dust of E.N.T. Eye ward*

		No. of samples containing			
Subdivision of ward	Approx. average no. of HS/g.	Less than 80/g.	More than 80/g. but less than 1000/g.	From 1000/g. to 1 million/g.	More than 1 million/g.
E.N.T. ward	674,000	1	0	20	4
Eye ward	193,000	2	2	19	2
Day room	209,000	0	0	23	2
Corridor	190,000	0	1	21	2
Total for whole ward	—	3	3	83	10
Weighted arithmetic mean	318,000	—	—	—	—

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next. If these results are not wholly attributable to errors of sampling, they suggest a fairly rapid removal of specific bacteria from the dust of a ward by the ordinary domestic procedures of dusting and sweeping, because haemolytic streptococci have been shown to survive for more than 15 weeks in dust that has been artificially infected (van den Ende & Lush, 1943). However, only weekly samples were examined; fuller information might have been obtained by more frequent examinations.

The curve (see Fig. 3) for the numbers of haemolytic streptococci in the dust of the main E.N.T. ward shows a steep rise for the 21st to 24th weeks. This was associated with a small outbreak of cross-infections due to type 30. The numbers fell during the 25th and 26th weeks, although cross-infections were still occurring.

Only a proportion of the streptococci isolated from the dust were group A. The results of grouping 285 strains derived from single colonies are given in Table 3. Cultures on the gentian violet blood-agar plates in a majority of instances contained colonies of more than one group, and as the colonies could not be distinguished from each other morphologically, estimation of the numbers of each group separately on the plate was impossible.

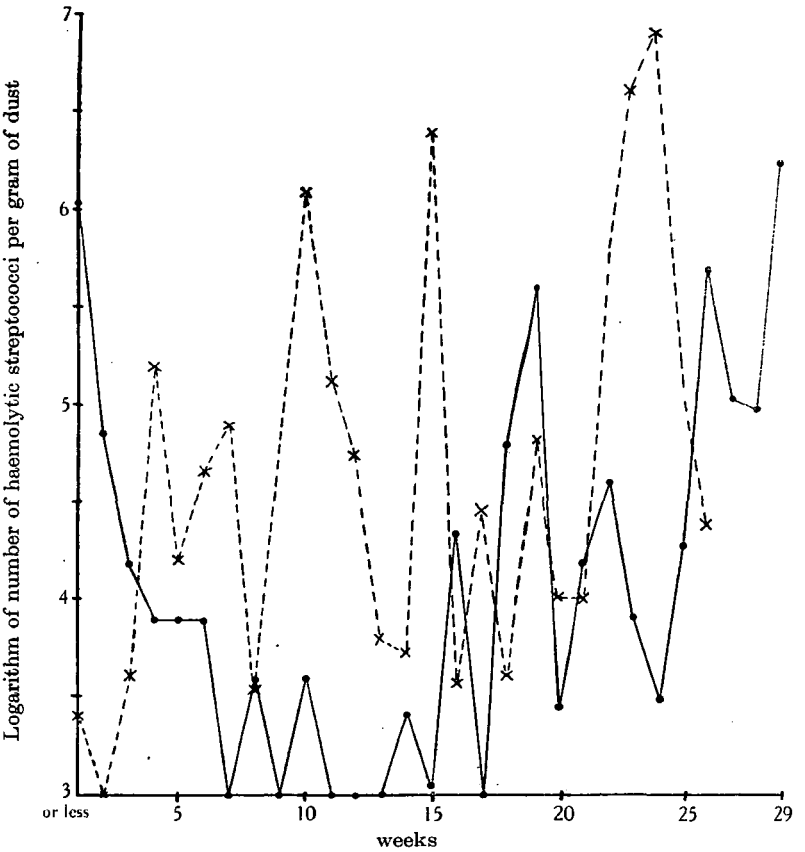

Fig. 3. Chart showing the number of haemolytic streptococci present in the dust of the main children's ward and the main E.N.T. ward.

•——•——• Main ward of children's ward. ×– –×– –× Main (E.N.T.) ward.

Table 3. *Results of grouping haemolytic streptococci isolated from dust of E.N.T. Eye ward*

Group	No. of strains	Percentage of total
A	95	33·3
C	79	27·7
G	38	13·4
Not A, B, C or G	73	25·6

A summary of the results of the examination of the dust of the children's ward is given in Table 4.

For the whole of this ward there was a mean of approximately 250,000 haemolytic streptococci per gram of dust, a figure only slightly less than that found for the E.N.T. Eye ward. From thirteen samples no haemolytic streptococci were isolated (less than 80 per gram), and in a further thirty-nine samples less than 1000 were present per gram. In six samples there were 1 million or more per gram, the greatest number found on any one occasion being 16 million per gram in a single-bed cubicle.

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Table 4. *Average number of haemolytic streptococci in dust of children's ward*

Subdivision of ward	Approx. average no. of HS/g.	No. of samples containing: Less than 80/g.	More than 80/g. but less than 1000/g.	From 1000/g. to 1 million/g.	More than 1 million/g.
Main ward	143,000	0	6	21	2
1st single-bed cubicle	58,000	5	6	18	0
2nd single-bed cubicle	169,000	1	2	25	1
3rd single-bed cubicle	635,000	2	4	22	1
4th single-bed cubicle	329,000	2	3	21	1
2-bed cubicle	36,000	1	8	15	0
4-bed cubicle	539,000	2	6	19	1
Corridor	70,000	0	4	24	0
Total for whole ward	—	13	39	165	6
Weighted arithmetic mean	251,000	—	—	—	—

In the children's ward there were rapid fluctuations from week to week in the total numbers of streptococci in the dust, similar to those noted in the E.N.T. Eye ward. Attention has already been drawn to the marked increase in streptococci in the dust that accompanied a small outbreak of streptococcal infection in the latter ward. This finding can be compared with others in the children's ward made when there was much infection there. There were in that ward most of the time from the 18th to 29th weeks several profuse carriers of streptococci and a number of cross-infections resulted. During the 18th and 19th weeks the number of streptococci in the dust showed some increase but fell again when all the heavily infected patients were isolated in cubicles (see Fig. 3). It rose little in the subsequent weeks though there were again several profuse carriers in the ward. It was only in the 26th and 29th weeks that high figures were recorded. Other factors than the presence of an infected patient in a ward are therefore of importance in determining the number of viable streptococci that collect in the dust. The contrasting circumstances in which the outbreaks took place in the two wards suggest at least some of the factors. Apart from different type of patient, design and routine of ward, the outbreak in the E.N.T. ward occurred in winter and that in the children's ward at the height of summer when ventilation was at its maximum. It is to be noted, nevertheless, that a considerable amount of spread of infection did take place when natural ventilation was very good.

The results of grouping 618 strains of haemolytic streptococci isolated from the dust of the children's ward are given in Table 5. Unfortunately during most of this part of the investigation an antiserum for group G streptococci was not available and the method of extraction was not suitable for the identification of group B.

Table 5. *Results of grouping haemolytic streptococci isolated from dust of children's ward*

Group	No. of strains	Percentage of total
A	489	79·1
C	17	2·8
Not A or C	112	18·1

Occurrence of group C and G streptococci

The relatively high proportion of group C and G strains in the dust of the E.N.T. Eye ward is of interest. It is not clear where they originated and how they got into the dust. Group C streptococci were found in the swabs of three patients and then only in small numbers. When observations were being made in the children's ward an attempt was made to obtain further information by a fuller investigation of all group C strains isolated, including their capacity to ferment sorbitol and trehalose and their agglutination by Griffith's type 7, 20 and 21 antisera. Unfortunately, the number of strains cultured from the dust of this ward was too few for conclusions to be drawn.

Association of group A streptococci in the dust with infection

Group A streptococci can be differentiated serologically into a number of types. Thus further information can be obtained about the origin of the organisms in the dust by comparing the types present with those in the swabs. Nine of the recognized types were encountered during the investigation of the E.N.T. Eye ward, and there were in addition a few strains that could not be typed. Several of the types made more than one appearance in the dust or swabs separated by a number of weeks. The presence in the ward week by week of each type is shown in Table 6. Details regarding each separate appearance of a type are too lengthy to be given here and the findings will therefore be summarized as a whole.

Twice the isolation of a particular type from the dust followed the admission to the ward of a thoat carrier of that type. In the last few weeks of the investigation there was a small outbreak of infection in the ward following the introduction of a type 30 *Streptococcus* by a carrier. The organism was found in the throats of nine other patients, several times in large numbers; it was also present in large numbers in the dust. On five occasions a specific type appeared first in the dust, not being demonstrable then or previously in any of the swabs. On two of these occasions, however, a patient became infected subsequently. On the other hand, there were four instances where cross-infection was found

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Table 6. *Group A streptococci in the swabs and dust of the combined E.N.T. and Eye ward. Findings analysed according to type*

Types	Dust only examined	Week 1	2	3	4	5	6	7	8	No examination made 9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1		–	–	–	–	–	–	–	–		–	–	–	S	–	–	–	–	–	–	–	–	–	–	–	–	–
2		–	–	–	–	–	–	–	–		–	S	–	–	–	–	–	–	–	–	–	–	S	–	–	–	–
4		–	S	–	–	–	–	–	–		D	S	D	S	–	–	–	–	–	–	S	–	–	–	–	–	D
5		–	–	–	–	–	–	–	–		–	–	–	–	–	–	S	–	S	–	–	–	–	–	–	–	–
11		–	–	S	–	S	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	–
12		–	–	–	D	S	D	–	D	–	–	S	–	S	D	S	D	S	D	–	–	–	–	–	S	–	–	S	–
22		–	–	–	–	–	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	D	S	D	S	D	S	D	S	D	S	D
B3264		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	D	–	–	–	D	–	D	S	–
Untypable strains		–	S	D	S	–	–	–	S	–	–	D	–	D	–	–	–	D	–	–	S	D	–	–	S	–	–	–	–	–	D	–	–

S, this type was isolated from the swabs of one or more patients.
D, this type was isolated from the dust of one or more subdivisions of the ward.

Table 7. *Group A streptococci in the swabs and dust of children's ward. Findings analysed according to type*

Types	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	–	–	–	D	S	–	–	D	–	–	–	–	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	D	–
2	–	–	–	–	S	–	–	–	–	–	D	–	D	–	–	–	–	–	–	–	D	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	D	S	–	–	D	–	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	S	–	–	–	–	–	–	–	–	–	–	–	–	D	S	D	S	D	–	–	–	–	–	S	–	–
6	–	–	–	–	–	–	–	–	–	S	–	S	–	S	–	S	–	–	–	–	–	–	–	–	–	S	D	–	–
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	D	S	D	S	D	S	D	–	–	S
11	–	–	–	–	–	–	–	–	–	–	–	–	–	D	–	–	–	–	–	–	–	–	S	D	S	D	S	D	–
12	S	–	S	–	–	S	–	–	–	S	D	S	D	–	D	S	D	S	D	S	–	S	D	S	D	S	D	S	D
14	S	–	S	–	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	D	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	–	–	–	–	S	–	–	D	–	D	–	D	–	–	–	D	–	–	–	–	–	–	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	–	D	–	D	–	–	–	–	S	–	–	–	–	D	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	–	–	–	–	–	–
Imp. 19	S	D	–	D	S	D	–	D	–	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–
R491	–	–	S	D	–	D	S	D	S	D	S	D	–	D	–	–	–	–	–	–	D	S	D	–	D	–	D	–	–
B3264	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	S	–	–	–	S	–
Untypable strains	S	D	–	–	S	D	–	D	S	D	–	–	–	–	–	D	S	–	–	–	–	–	–	–	–	–	–	–	D

S, this type was isolated from the swabs of one or more patients.
D, this type was isolated from the dust of one or more subdivisions of the ward.

to have occurred, although the particular type was not isolated from the dust or from any of the other swabs. On nine occasions streptococci of a specific type were not demonstrable in the dust although they were isolated from one or more carriers among the patients or staff.

A total of twenty types were encountered during the investigation of the children's ward (see Table 7). The distribution of these types in the dust of the various subdivisions of the ward is shown in Table 8. On five occasions the appearance of a particular type in the dust followed the admission and presence in the ward of one or more carriers of that type, although sometimes the organism was isolated only from the dust of subdivisions other than that in which the patient was being nursed. At one week's examination 14 million type 12 streptococci per gram were found in the dust of the four-bed cubicle when it contained two adult patients with heavy streptococcal infections (type 12) of the upper respiratory tract. Many type 8 were also isolated from the dust during a small outbreak due to that type. This followed the admission of a patient with a scarlatiniform rash, not regarded as scarlet fever. Later she became a profuse nose and throat carrier of type 8. Six other patients acquired infections due to this type; all, with one exception, were in beds near each other in the main ward. The exception was a patient in the main ward who became infected at a time when all the known carriers had been isolated in cubicles. Type 8 streptococci were present in the dust. It is to be noted that all those who were infected by the patient admitted with a scarlatiniform rash developed clinically recognizable infections, including one case of scarlet fever. This contrasts with the finding for the whole series that two-thirds of the infections acquired in hospital were latent.

On nine occasions there were in the ward one or more patients whose swabs yielded haemolytic streptococci, although usually in small numbers, without streptococci of that particular type being demonstrable in the dust. During a period of 6 weeks there were in the ward altogether eight patients with infections due to a type 6 *Streptococcus*, three of the patients having acquired their infections in hospital. Yet no type 6 was isolated from the dust. On four occasions patients apparently developed infections while in hospital with a type that was not found in the swabs of other patients or in the dust.

Table 8. *Summary of findings of each type of* Streptococcus pyogenes *in dust of children's ward*

Type of *Streptococcus*	Number of findings of each type of *Streptococcus* in dust: Main ward	1st single cubicle	2nd single cubicle	3rd single cubicle	4th single cubicle	2-bed cubicle	4-bed cubicle	Corridor	Total no. of isolations	No. of sites in which it was found	No. of patients and staff infected
1	1	0	0	0	2	0	0	1	4	3	3
2	1	2	0	0	2	1	0	1	7	5	1
3	2	0	1	0	0	0	0	0	3	2	2
4	0	1	2	1	2	0	0	2	8	5	3
5	0	0	0	0	0	0	0	0	0	0	1
6	0	1	1	1	0	0	0	0	3	3	9
8	2	2	1	2	1	1	2	3	14	8	7
11	3	2	6	3	1	1	2	1	19	8	9
12	7	9	7	8	4	4	6	9	54	8	12
14	0	0	0	0	0	0	0	0	0	0	1
18	0	0	1	0	0	0	0	1	2	2	0
19	0	0	0	0	0	0	0	0	0	0	1
22	0	0	0	0	0	4	0	0	4	1	1
23	0	0	0	0	0	0	0	0	0	0	1
25	0	0	1	0	0	0	0	0	1	1	0
27	0	0	0	3	1	0	1	0	5	3	1
28	0	0	0	0	0	0	0	0	0	0	1
Imp. 19	0	6	7	0	1	2	4	0	20	5	4
R491	9	1	0	5	7	1	6	5	34	7	5
B3264	0	0	0	0	4	2	3	2	11	4	2
Total no. of types found	7	8	9	7	10	8	7	9			
No. of examinations of dust made	29	29	29	28	28	24	28	28			

Twice a *Streptococcus* appeared for the first time in the dust and was found to have given rise to cross-infection at the same week's examination. On fourteen occasions a specific type appeared first in the dust and was not then found in any of the swabs from patients and staff. On two of these occasions one or more patients later had the type in the throat and had apparently acquired the infection in hospital.

DISCUSSION

Observations made in the wards of two hospitals, in each for about 6 months, have shown the almost continuous presence in the dust of haemolytic streptococci. A combined ear, nose and throat and eye ward and a children's ward were chosen for investigation, as it is well recognized that it is in such wards as these that outbreaks of streptococcal infection commonly occur. On an average for the whole period the dust of the former

https://doi.org/10.1017/S0022172400012948 Published online by Cambridge University Press

ward was found to contain approximately 300,000 haemolytic streptococci per gram and that of the latter 250,000 per gram. Three colonies of streptococci grown from each sample of dust were grouped; about 33 % of those from the E.N.T. Eye ward and about 80 % from the children's ward were found to be group A. However, these percentages refer only to the colonies tested and not to the proportion of group A streptococci in the dust itself. In both wards routine weekly swabbing of the patients and staff showed the existence of a considerable amount of hospital cross-infection, though little of it was clinically evident.

Further information has been obtained by typing serologically the strains of group A streptococci isolated. In a number of instances the appearance of a particular type in the dust followed the admission of a patient infected with that type. Sometimes other patients became infected and the numbers of streptococci in the dust mounted. However, their numbers appeared to bear no constant relation to the number and severity of the infection in the ward. On one occasion there were 14 million streptococci per gram of dust in a cubicle containing two heavily infected patients; on another there were only 160,000 per g. under somewhat similar conditions. In the main E.N.T. ward a small outbreak of infection was accompanied by quite a large increase in numbers in the dust, but in the main children's ward many cross-infections occurred when streptococci were scanty in the dust. The factors controlling the numbers of streptococci that collected in the dust can only be guessed at; they are likely to be multiple and to include ward hygiene, amount of ventilation, age of patient, type and degree of infection. It was noted that infection of the dust of one subdivision of a ward is likely to be followed quite rapidly by the finding of a similar organism in the dust elsewhere. On the occasion when two heavily infected patients raised the streptococcal content of the dust of their own cubicle to 14 million per gram, it also rose in other cubicles, in one to 840,000 per gram. Occasionally the particular type of *Streptococcus* has not been demonstrated in the dust of the subdivision where the infected patient was being nursed, but only elsewhere. The failure to detect it, however, may have been due to chance, for only three colonies from each sample were examined serologically.

On a number of occasions streptococci of a particular type were not detected in the dust although there was a carrier in the ward. Usually the carrier had only small numbers of streptococci in his swabs, but sometimes there was more than one infected person. It is, nevertheless, quite likely that in a number of these instances the particular streptococci were present in the dust although undetected. They may have been outnumbered by other types or, as already pointed out, by chance omitted from the colonies submitted to serological identification.

It was frequently noted that a particular type appeared in the dust without being at that time demonstrable in any of the swabs. The manner in which the dust became infected is therefore of some interest. The findings admit of several explanations. First, there may have been a streptococcal carrier among the patients who was not detected by the routine swabbing. By mischance the swabbing of some patient's throat or septic lesion may have been omitted. This was more likely to have occurred in the E.N.T. Eye ward, greater care having been taken to avoid it during the latter part of the investigation. It is more difficult to exclude the possibility that swabbing occasionally failed to reveal the presence of small numbers of haemolytic streptococci. Secondly, the particular streptococci may have been derived from an earlier infection and have persisted alive in the dried state on furniture, the dust of ledges, etc. They may have been absent from the floor dust for weeks until perhaps by chance dusting had redispersed them so that they reached the floor. Thomas & van den Ende (1941), who noted similar findings, suggested that streptococci may survive on blankets and be contributed to the dust by bed-making. Thirdly, the streptococci may have been introduced to the ward by persons entering it other than the patients and staff. Apart from actual infected carriers discharging streptococci from the upper respiratory tract or a septic lesion, the organisms may have been present on their clothing or dust of their shoes. Finally, reference must be made to a certain proportion of strains of group A streptococci which could not be typed. They may have been members of as yet undefined types. If, however, any were members of recognized types but were refractory to identification by the technique used, their existence to some extent complicates the findings.

The third suggestion that the streptococci were introduced by visitors to the ward merits further comment. This would also help to explain the occurrence of cross-infections when there were in the dust no organisms of the type involved or carriers among the other patients and staff. There is some contributory evidence. On three of the five occasions when a particular type appeared initially in the dust of the E.N.T. Eye ward, it was found first in the corridor. Inquiry revealed that in a cubicle opening on to the corridor, dressings were commonly carried out on patients from other wards with infections of the ear, nose and throat. It is not unlikely that it was then that infection of the dust took place. In the children's ward, where the initial appearance of a particular *Streptococcus* was more often in a cubicle, the samples of dust were collected the morning after the weekly visiting day. This fact is of interest, as it is generally recognized that allowing visitors to a ward entails the not inconsiderable risk of the introduction of infection. It has therefore been advocated that, at least in children's wards, visiting should be reduced to a minimum. Such a policy has been found easier to apply when it is made possible for parents to communicate directly, either personally or by telephone, with the sister of the ward regarding the condition of their children.

Wright (1940) investigated the incidence of streptococcal infection in two children's wards and found that 6·1 % of the patients were infected on admission and 18·9 % acquired in hospital infections that were either manifest or latent. In the present investigation it was found that 27·8 % of 270 patients in the children's ward were infected, either on admission or at some time during their stay in hospital. There were thirty-three patients who acquired an infection in hospital; this is 12·2 % of the total, but the latter includes a number of patients who, owing to a stay in hospital of less than a week, were swabbed only once. It is to be noted that this rate of cross-infection occurred in a hospital of modern

design, situated in the country. Moreover, the average number of haemolytic streptococci in the dust of this ward was not significantly less than that found in the other ward investigated, which was a converted mental hospital ward. Improvements in the ordinary hospital design have therefore a limited usefulness in preventing cross-infection, unless they include such radical changes as the providing of cubicles for the majority of patients where they could be nursed by a strict isolation technique. In the wards of neither hospital were special measures employed designed to diminish dispersal of dust in the air, such as damp-dusting or the oiling of floors or bed-clothes.

Less than a third of the hospital infections were clinically evident, and all were mild with the exception of one case of scarlet fever. However, in a ward serious outbreaks of infection probably occur not so much when the barriers to the spread of infection suddenly break down, as when a more virulent strain of organism is introduced. In this investigation the severer effects due to the strain of type 8 *Streptococcus* have already been noted. The occurrence of latent cross-infection due to the spread of relatively avirulent strains probably indicates that channels exist in a ward for the spread of infection, so that conditions are favourable for a serious outbreak if a virulent strain is unfortunately introduced. There is a great need for a satisfactory laboratory test to assess the virulence and invasive power of a strain of *Str. pyogenes*. Such a test would make the search for streptococcal carriers a more useful measure, so that strict measures of isolation could be restricted to known carriers of virulent strains. Failing this, it is necessary to regard evidence of the spread, manifest or latent, of haemolytic streptococci in a ward as a potential danger and to take every precaution to prevent it.

Unfortunately, this investigation has not afforded any conclusive example of a hospital infection conveyed by dust. There is, however, some suggestive evidence such as the occurrence of cross-infections due to a type of *Streptococcus* that was present in the dust but not in the other swabs. On the other hand, similar instances of cross-infection have occurred, and the infecting type has not been found in the dust or the other swabs; transfer of infection must be attributed here to some contaminated article or to a carrier among the visitors to the ward.

SUMMARY

1. A weekly examination for haemolytic streptococci was made of the dust of two hospital wards; observations lasted in each ward for about six months. The wards chosen were a combined ear, nose and throat and eye ward used for adult patients, and a children's ward.

2. It was found that on an average for the whole period the dust of the former ward contained 300,000 haemolytic streptococci per gram and the dust of the latter 250,000 per gram.

3. Representative colonies of haemolytic streptococci grown from each sample of dust were examined serologically to determine their group. About 33 % of those isolated from the E.N.T. Eye ward were group A and about 80 % of those from the children's ward.

4. In order to determine the relationship of the streptococci in the dust to streptococcal infection among patients and staff, throat swabs and swabs from septic lesions were regularly examined.

5. In the children's ward 27·8 % of 270 patients were found to be infected with haemolytic streptococci either on admission or at some time during their stay in hospital. The incidence of infection acquired in hospital was more than 12·2 %. About two-thirds of these infections were latent.

6. Group A streptococci isolated from the dust and swabs were identified serologically according to type. It was noted that the occurrence of a particular type in the dust often resulted from the presence of one or more infected persons in the ward.

7. It was, however, frequently noted that a particular type made its first appearance in the dust when it could not be cultured from any of the swabs. It is possible that these strains were introduced to the ward by visitors, such as patients' relatives and friends or patients from other wards coming for septic dressings.

8. No conclusive example of a hospital cross-infection conveyed by dust was noted.

I wish to thank Dr T. J. Hennelly and Dr D. G. Morgan, Medical Superintendents of the two hospitals, for giving me the facilities to carry out the investigation; also Dr S. T. Crowther and Dr Duncan Davies, and the sisters and nursing staff for their assistance and co-operation. I am especially indebted to Dr V. D. Allison for his helpful advice and criticism.

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(*MS. received for publication* 2. III. 43.—Ed.)