OBSERVATIONS ON 'HOSPITAL INFECTION' IN A PLASTIC SURGERY WARD

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(With 1 Chart in the text)

Following the discovery by F. Griffith (1934) of the agglutinative types of *Streptococcus pyogenes*, hospital infection has been studied in otorhinological wards by Okell & Elliott (1936), in scarlet fever wards by Brown & Allison (1937), and in general wards and children's wards by Keevil & Camps (1937), and more recently by Wright (1940).

All of these investigations have been chiefly concerned with streptococcal infections of the upper respiratory passages, dust and air probably being the chief vehicle whereby the streptococci spread.

Hospital infection by *Staphylococcus aureus* has been recently studied by Elliott, Gillespie & Holland (1941) and, in operating threatres, by Devenish & Miles (1939).

Among war wounds in surgical wards, evidence of hospital infection was reported by Miles *et al.* (1940) who emphasized the importance of contact spread as distinct from air-borne infection. Unlike the upper respiratory passages, wounds do not filter the bacteria out of large volumes of air.

In many surgical wards, opportunities for contact infection are numerous. This is especially true of plastic surgery wards, in which many superficial wounds and burns are treated and frequently dressed.

For practical purposes of prevention of hospital infection, it seems more profitable to disclose channels of infection in order to block them rather than to await an exact evaluation of the importance of each. To this end, and not because sepsis was causing undue anxiety at the time, the bacteria in wounds and throats in one of the wards of a Maxillo-Facial Unit were studied from 13 November 1940 until the end of April 1941.

The greatest help and co-operation was received from the surgeons in charge of patients and from the nursing staff and the hospital authorities.

The ward consisted of two sections containing eleven and twelve beds respectively for female patients, and two containing sixteen beds each for male patients.

The cases treated in the ward included burns of all kinds, multiple superficial air-raid wounds, fractured mandibles, plastic reconstructions of all parts of the body surface, and a few minor conditions such as hare lips and cleft palates.

BACTERIOLOGICAL METHODS

Samples taken from wounds and throats with throat swabs were plated on 5% blood agar plates, which were incubated overnight anaerobically in McIntosh and Fildes jars. Next morning the plates were searched for haemolytic streptococci, and then incubated for another 24 hr. aerobically to allow other bacteria to develop.

Strains of streptococci which produced a soluble haemolysin were sent to Dr F. Griffith, who very kindly typed upwards of 300 strains from the one ward.

Haemolytic streptococci claimed chief attention, as they are the best indicators of spread of infection from one case to another.

A good method of isolating haemolytic streptococci in the presence of swarming bacilli like *Proteus* was devised by Mr J. K. Butcher. A blood-agar plate is inoculated from a swab in the usual manner. The surface of the plate is then flooded with melted agar at 40–42° C., as suggested by Fry (1932). When the agar has set, its surface is flooded with absolute alcohol or methylated spirit for 30 sec. The spirit is then drained off and the plate dried for a short while in the incubator with its lid open. The lid is then closed, and incubation continued for 24 hr. *Proteus* does not swarm over the surface, as it does in Fry's method, and streptococcal colonies, easily recognized by their zones of haemolysis, can be picked through the agar with a straight wire or a Pasteur pipette.

DISTRIBUTION OF HAEMOLYTIC STREPTOCOCCI

Table 1 shows a summary of the distribution of haemolytic streptococci among the cases examined, both male and female.

Of all wounds swabbed 65% yielded haemolytic streptococci at one time or another. Of these, over a third acquired their streptococci while in the ward, and about a quarter were infected with *Streptococcus pyogenes* on admission, most of them coming from other hospitals. The origin of the haemolytic streptococcal infections of the rest could not be determined either because swabs were not taken early enough or because the patients were already in the ward when the survey started.

The majority of the streptococcal infections were revealed only by bacteriological examination, and not by clinical ill effects.

The infections listed in Table 1 as acquired in the ward were all due to types of streptococci known to be in the ward at the time when the infection was first observed.

Fifteen of the twenty-eight hospital infections due to *S. pyogenes* were due to streptococci of two types, '13' and '4/24', the spread of each of which deserves separate consideration (see Chart).

Since the preparation of this paper, the value of the method of isolating haemolytic streptococci devised by Mr J. K. Butcher has been confirmed by Major Francis in a paper in the *Lancet*, 1941, 9 August, p. 159. The method was demonstrated by me before the Association of Clinical Pathologists in Cambridge on 19 July 1941.

Type 13 streptococci were present in three wounds when the survey started, and subsequently infected twelve more wounds and three throats, two of them not sore, the third developing an acute follicular tonsillitis. In addition, type 13 streptococci were obtained from three finger lesions among nurses and two on the hands of surgeons.

Only one of the wound-infections was associated with serious illness. This was the case of a man with a badly lacerated arm and fractured ulna. For 13 days after admission, his wound remained free from haemolytic streptococci. On 5. ii. 41 his temperature rose to 101° F., he became evidently ill, his arm swelled and became very painful, and for the first time a rich growth of type 13 streptococci was obtained from it. He remained ill with a high irregular pyrexia until 24. iii. 41, when an operation was performed to drain a collection of pus which had formed around the broken bone. This pus contained large numbers of type 13 streptococci. It seems reasonable to associate this man's severe illness with the streptococcal infection. He was the only patient in the series of type 13 infections whose infection coincided with any local or general illness that could be described as severe.

Table 1. *Summary of the incidence of haemolytic streptococci of Lancefield's Groups A, C, G and F in a plastic surgery ward during six months*

	Male	Female	Total
1. Number of patients	102	41	143
2. Patients yielding H.S. at one time or another	70	24	94
3. Patients acquiring H.S. in the ward	38	8	38
4. Patients infected with H.S. before admission	18	7	25
5. Patients with H.S. infections of unknown origin	32	9	41
6. Wounds remaining free from H.S. on repeated swabbing	17	8	25
7. Trivial lesions free from H.S. and swabbed once only	17	10	27

H.S. = Haemolytic streptococci of group A, C, G or F.

At the time when this patient became infected, he and two other men, both suffering from burns of the hands, were daily using arm baths, which may well have been the vehicles of infection. At this time, the cleaning of arm baths was, in the bacteriological sense, questionable.

It is not possible to say with certainty how any of the type 13 infections were acquired. Many possible channels were available.

The scarcity of type 13 throat infections, of which there were three only, and the occurrence during December and January, when most of these infections were observed, of three finger lesions among nurses and two among surgeons suggests that some form of contact infection rather than contamination from the air may have been responsible.

Eleven further wounds acquired type 13 streptococci while under observation, all of them yielding one or more negative swabs at earlier swabbings. Four of them were burns.

A probable twelfth case, a woman with a burned arm, was not examined until the sixth day after her admission, by which time type 13 streptococci were abundantly present.

Since the survey ended, three further wounds in the ward, all of which were free from haemolytic streptococci when first examined, have been found infected with type 13 streptococci. These three cases are of interest because, together with one of the eleven cases referred to above, they were the only four failures in an extensive series of Thiersch grafts performed by Mr Rainsford Mowlem (1941), by a technique described by him in which the graft is laid down on a layer of sulphanilamide powder.

Type 4/24 streptococci (agglutinated by sera against both type 4 and type 24) were not found in the ward before 13. i. 41. On 12. i. 41 ten men burned on the face and hands in a bomb incident were admitted. The burns of five of them, who had all been treated in another hospital, were found to be heavily infected with type 4/24 streptococci when first examined, within 48 hr. of admission. Another man, burned in another incident elsewhere on 12. i. 41, was admitted at once. The burns on his face also rapidly became infected with streptococci of the same type.

Within a short time the throats of these six patients, all of them suffering from first and second degree facial burns, became heavily charged with streptococci of the same type, which were presumably in consequence generously sprayed into the ward air.

Type 4/24 subsequently infected eighteen throats and four wounds in the ward. Three of the wounds were facial wounds, largely exposed to the ward air. The fourth was an excised wound of the anterior chest wall. This distribution contrasts with that of type 13 streptococci which were spreading in the ward at the same time, but which infected twelve wounds at least, and only three throats.

The type 4/24 streptococci did no serious damage. All of the burn cases healed very quickly and soon lost their streptococci. Four of them suffered from discharging ears, the pus from which yielded streptococci of the same type. Of the eighteen throat infections, only three produced sore throats. One of these was in a nurse.

Type 25. Streptococci of this type gave rise to four hospital infections of wounds, four throat infections, one of them associated with a sore throat, and one known admission infection.

One day in January, during a class in practical bacteriology held for some of the nurses engaged in doing dressings in the ward, two nurses were found to be heavy throat carriers of type 25 streptococci. Part of the afternoon's exercise was throat swabbing; part, the preparation of cultures from fingers by rubbing the index finger of the right hand over the surface of a blood-agar plate. Both of the nurses who were heavy throat carriers were carrying streptococci of the same type on their fingers.

Type 11. Of this type, there were found four 'admission strains', two 'hospital wound infection strains', both from patients with burns; two 'throat strains' and two strains from wounds the source of infection of which was not known. Type 11 streptococci in this ward did little or no demonstrable harm.

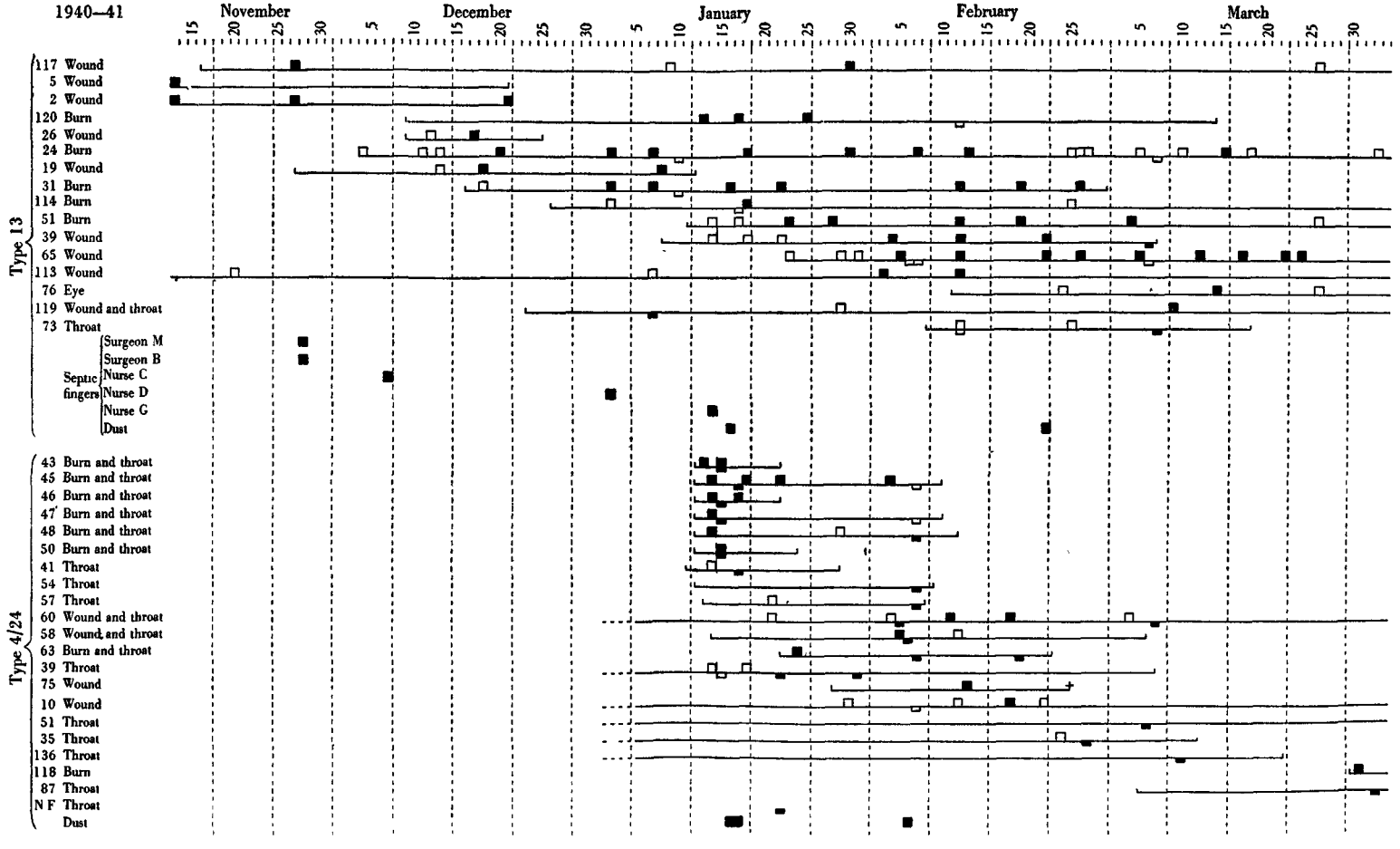

Chart 1. In this chart two wound-and-throat epidemics due to haemolytic streptococci belonging to types 13 and 4/24 are shown. The method of recording was devised by Prof. A. A. Miles (Miles *et al.* 1940). Each horizontal line represents the stay of a patient in the ward, from his admission (left-hand end of line) to his discharge (right-hand end of line). Wound swabs are indicated by squares drawn above the line, white squares representing swabs which did not yield streptococci of the types under consideration, black squares indicating occasions when streptococci of those types were obtained. Black and white rectangles drawn below the line refer to throat swabs.

Type 27. Streptococci of this type gave rise to two hospital infections of wounds.

The other types encountered do not deserve special mention. They are recorded, together with those already discussed, in Table 2.

Table 2. *Distribution of haemolytic streptococci according to Griffith's types (including Lancefield's groups C, G and F)*

								B						Group		
Type ...	... 4/24	13	25	11	27	8	28	3264	12	14	22	2	30	?	C	G	F
Admission	1	1	1	4	3	.	2	2	4	.	1	.		2	1	.	.
Acquired	4	12	4	2	2	3	3	1	1	.	.	.	.	.	2	1	.
Throats	18	3	4	2	1	2	1	2	.	.	1	1	1	9	3	4	.
Fingers	.	5	2	.	.		.		.	.	.	.	.	1	.	.	.
Air	3	2	1	2	.	1	.	.	.	.	.	1	.	9	.	.	.
Wound infections of unknown source	7	2	3	2	3	1	1	2	1	2	.	.	.	14	2	4	1
Total	33	25	15	12	9	7	7	7	6	2	2	2	1	35	8	9	1

Admission: infections present on admission to the ward.
Acquired: infections acquired in the ward.
Throats includes throats of patients and of staff, whether sore or not.
Fingers. includes six finger lesions and two apparently clean fingers of nurses taking part in dressings.
?: strains which belonged to no known type.

BACTERIA OTHER THAN *STREPTOCOCCUS PYOGENES*

Staphylococcus aureus

Staphylococci are not very useful indicators of the paths of hospital infection because few wounds (in a plastic surgery ward) are free from them and because the paucity of agglutinative types limits the tracing of the sources of infection.

Of 115 wounds in the present survey, 100 (86%) yielded *S. aureus* as identified on colonial and morphological appearance. Of thirty-seven strains tested, thirty-three were coagulase positive.

No serious staphylococcal disease was seen. Minor damage attributable to staphylococci included three boils on nurses' arms, one septic finger on a nurse, suppuration in three incisions made for the extraction of bone grafts from the iliac crest, and eight infections of tube pedicles. Four of the infected tube pedicles and one of the iliac crest incisions yielded *Streptococcus pyogenes* as well as *Staphylococcus aureus*.

Pseudomonas pyocyanea (*Bacillus pyocyaneus*)

Pseudomonas pyocyanea, probably because its green colour makes its presence obvious, has a reputation for spreading easily from one wound to another 'if ward technique is faulty'. The evidence of this investigation suggests that *Ps. pyocyanea* deserves this reputation no more than does *Streptococcus pyogenes* (in this ward, for example, type 13).

Pseudomonas pyocyanea was present with *Streptococcus pyogenes* and *Staphylococcus aureus* together in four wounds, with *Streptococcus pyogenes*

alone in another four, with *Staphylococcus aureus* alone in three, from one of which *Streptococcus pyogenes* had disappeared. The twelfth wound which yielded *Pseudomonas pyocyanea* did so at first in pure culture, *Staphylococcus aureus* appearing later. No evidence was obtained that *Pseudomonas pyocyanea*, when it colonizes a wound, displaces the pyogenic cocci.

Pseudomonas pyocyanea was obtained altogether from twelve wounds and one throat.

Proteus

Proteus was obtained from twenty wounds. The species were not determined. Six of these twenty wounds were certainly, and three more probably, admitted with their *Proteus* infections established. Six were acquired in the ward, and the source of five others could not be determined.

Diphtheroid bacilli

Diphtheroid bacilli of various kinds were present in a big majority of the wounds. Hospital infection with diphtheroid bacilli is undoubtedly common. In this series, it was recorded in seven cases, but probably occurred in many others.

Bacteriology of multiple wounds on one patient

The flora of multiple burns on one patient usually became uniform in a few days, especially if the patient has been given baths. In the absence of bath treatment, multiple wounds of smaller areas than the average burn and therefore easily dressed by a forceps technique have kept their individual floras over periods of many weeks.

That one wound on a patient can be heavily infected with *Streptococcus pyogenes* while another wound on the same patient remains free from such infection over a long period indicates that cross infection of wounds is not inevitable and that the absence of a specific kind of microbe from a wound does not necessarily depend on the general immunity of the patient.

Haemolytic streptococci in throats

The throats of patients were not swabbed regularly. On three occasions, in January, February and March, the throats of most of the male patients were swabbed. The result is shown in Table 3.

If all carriers of type 4/24, which was introduced on five burn cases on 12. i. 41, are omitted, the percentages of positives in the February and March groups come nearer that of the January group, showing that the very high rates obtained in February and March were largely due to the presence of streptococci of this one type.

Sore throats were not unduly common. Eleven were recorded among patients and two among nurses. These figures may be incomplete, for there may have been cases which escaped the notice of the bacteriologist.

Of fifteen patients suffering from facial burns, ten became throat carriers yielding profuse cultures of haemolytic streptococci.

Table 3. *Result of swabbing throats of male patients on three occasions in January, February and March*

Date of swabbing	10. i. 41	12. ii. 41	10. iii. 41
No. of throats examined	24	27	35
No. yielding H.S.	4	10	10
% yielding H.S.	16·7	37·0	28·5
% yielding H.S., omitting infections with type 4/24	16·7	11·1	20·0
Types of H.S. present (no. of cases in brackets)	B 3264 (1)	4/24 (7)	4/24 (3)
	13 (1)	25 (1)	13 (2)
	8 (1)	11 (1)	25 (1)
	Group C (1)	2 (1)	Group G (3)
			Group C (1)

SULPHANILAMIDE

At about the time when this investigation started, sulphanilamide powder was introduced into the ward as an almost routine local application to all wounds. In spite of this, the spread of streptococcal infection continued and about 65% of the wounds remained infected with haemolytic streptococci.

Colebrook & Francis (1941) have described a method of removing haemolytic streptococci from wounds by the local application of sulphanilamide powder. In the present investigation, no evidence bearing on this has been obtained, for two reasons. In the first place, the wounds described by Colebrook & Francis were shallow wounds with skin loss, and a granulating surface. Most wounds of this kind in the present survey were treated by early Thiersch grafting on top of a layer of sulphanilamide powder, by the technique described by Mowlem (1941). In this technique, the granulations of the wound are removed, and when bleeding has been controlled sulphanilamide powder is massaged into the area to be grafted. The graft is then laid on top of the sulphanilamide, pressure is applied, and the usual dressing put on. When the dressing is taken down in 7 days' time, the graft has usually taken, but haemolytic streptococci can in most cases still be grown easily from the wound.

The second probable reason why Colebrook & Francis' observation has not been confirmed is that the technique which they describe was not in any case followed in detail. Colebrook & Francis emphasize that the wound should first be cleaned for a few days by treatment with saline and eusol, the powder should then be applied and covered with saline-moistened gauze and a piece of sterile jaconet to retain the moisture. Had this technique been followed more meticulously, one or two wounds which retained their streptococci might have lost them.

DISCUSSION

The type 13 streptococcus wound epidemic described shows clearly that a strain of streptococci may do little damage to most wounds which it infects and yet lead to severe trouble in one or two. It follows that measures designed

to prevent hospital infection of wounds must be aimed at all infections, regardless of their apparent severity.

Small wounds, and wounds which are already infected, must be protected if only to prevent their becoming reservoirs of infection.

Septic fingers and hands among nurses seriously interfere with the work of a busy surgical ward and introduce a risk to wounds. The three finger lesions among nurses described in connexion with the type 13 wound epidemic occurred before the middle of January, and before measures had been taken to prevent such lesions from developing.

This is not the place in which to discuss the measures which may be taken to block obvious channels by which infection undoubtedly passes from one wound to another; but it is permissible to point out that a bacteriologist working in a surgical ward and its sterilizing room may easily find and expose such channels.

One important question regarding wound infection concerns the relative importance of air-borne infection and contact infection. It seems probable that the risks of droplet infection from unguarded throats and of contact infection from unguarded fingers are greater than that of bacteria falling from the air. In the course of an experiment on the effect of treating floors and bedding with paraffin oils, 109 blood-agar plates were exposed each for 15 min. between the hours of 7.0 a.m. and 10.0 p.m. in the ward in which the present investigation was conducted. The aggregate exposure of 1 sq. ft. of medium for 2·08 hr. led to the development of 17,000 colonies, thirteen of which were colonies of *Streptococcus pyogenes*, which indicates that this organism was falling from the ward air at about the rate of 6 per sq. ft. per hr.

Staphylococcus aureus was not much more frequent. It would appear from this that the risk of infection from the air is not very great for a small wound which is not exposed for many minutes to the air. The true magnitude of the risk depends, of course, on the size of inoculum required to infect a wound, and on this point there is no information.

All possible precautions against the risk from dust and air-borne bacteria should be taken, whatever the magnitude of the risk.

It is worth pointing out that patients suffering from facial burns may rapidly become throat carriers, and may thereby contribute a large share to the infection of the dust of the ward.

Summary

Over a period of 6 months, wounds and throats in a plastic surgery ward were swabbed. Haemolytic streptococci obtained from them were typed by the late Dr F. Griffith and his staff at the M.R.C. Streptococcal Research Laboratory. 65% or more of the wounds in the ward were found to be infected with *Streptococcus pyogenes*, but relatively few suffered severe damage as a result of their infection.

About a quarter of the cases admitted to the ward acquired streptococcal wound infections while in the ward. Two wound and throat epidemics, one due to type 13 and one to type 4/24 streptococci are described.

This investigation was carried out for the Medical Research Council.

My thanks are due to Mr Rainsford Mowlem and the staff of his ward for their constant help, interest and co-operation, and for allowing me at all times access to the ward and the patients in it; to Prof. Paterson Ross for his interest, advice and help, and to Prof. L. P. Garrod for the hospitality of his laboratory and for many kindnesses. The work would not have been possible without the kind assistance of the late Dr F. Griffith and his staff at the Research Laboratory for Streptococcal Infections.

Mr J. K. Butcher gave me valued assistance in the preparation of media and with much of the bench work.

My thanks are also due to the Medical Superintendent of Hill End Hospital.

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