I am indebted to the 48 general practitioners who co-operated in this survey; to Miss A. White, who provided the information on the work of the district nurses; and to the hospital secretaries and matrons for figures of diabetic admissions.

APPENDIX : QUESTIONNAIRE SENT TO G.P.s

Patient's initials.....
 Present age if known
 Sex
 Whether attending a clinic:
 (a) Diabetic clinic
 (b) General medical
 (c) Other
 Whether at present a hospital in-patient:
 (a) General medical ward
 (b) Chest hospital
 (c) Geriatric service
 (d) Mental hospital
 (e) Other
 If no hospital contacts, diagnosis based on
 (a) Previous hospital investigations
 (b) Symptoms and urinary findings
 (c) Blood-sugar examination
 During 1954 how many visits did this patient require:
 (a) Home visits
 (b) Surgery attendances
 Is this patient at present having insulin?
 Number of list patients surveyed
 Number of diabetics found
 Private diabetic patients under your care

Remarks:

If information not available enter O. Signature: _____

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OUTBREAK OF STAPHYLOCOCCAL INFECTION IN A SURGICAL WARD

BY

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Outbreaks of staphylococcal infection in surgical wards are not very uncommon, but they are rarely recorded in print. This is partly because opportunities are not often available for extensive investigation, and in consequence the source of infection can rarely be traced. Nevertheless, the paucity of published records makes more difficult the study of new outbreaks as they occur.

It so happened that the outbreak described in this paper could be investigated in some detail, and, perhaps for this reason, we have been able to indicate a possible way in which infection may have been spread.

Clinical Features

The surgical unit concerned consisted of an operating theatre and a male and a female ward, each containing

25 beds. The wards were large and airy and the beds were spaced approximately 6 feet (1.8 m.) apart. Before May, 1956, sporadic cases of staphylococcal infection had occurred in both wards. On May 2 a wound-book was begun in order that a more reliable measure of the incidence of sepsis could be obtained. Against each patient's name was entered the name of the surgeon, details of the operation, and the condition of the patient's wound during convalescence. Wounds in which pus could be seen were regarded as septic; patients whose operations were through infected areas were excluded in assessing the sepsis rate.

Between May 2 and June 25, 86 clean operations were performed: three of the patients died post-operatively from causes unrelated to sepsis; of the remaining 83 patients, 24 developed sepsis in their wounds (Table I). Most of this

TABLE I.—Sepsis Developing in Clean Wounds, May 2 to June 25, 1956

	No. of Operations	No. Infected	Other Staphylococcal Infections
May 2-6 ..	7	4	
" 7-11 ..	7	4	
" 12-16 ..	8	2	1 chest infection
" 17-21 ..	3	0	
" 22-26 ..	10	0	
" 27-31 ..	12	3	
June 1-5 ..	7	2	1 urinary "
" 6-10 ..	4	3	
" 11-15 ..	9	3	1 chest "
" 16-20 ..	9	2	2 chest, 1 urinary infection, 2 enteritis
" 21-25 ..	7	1	1 chest, 1 urinary infection, 1 enteritis

sepsis was in the male ward, where 18 out of 43 patients became infected as compared with 6 out of 34 women. Six children brought from the children's unit in another part of the hospital to the operating theatre and returned after operation had no septic complications. *Staphylococcus pyogenes* was recovered in culture from 17 of the infected wounds. From two coliform bacilli were grown, and from five no swabs were taken.

Seven of the male patients developed staphylococcal infection of sites other than the operation wound, including five chest infections and three urinary infections. Finally, by June 25 three patients were found to have staphylococcal enteritis, and, because of this and the number of other infections, it was decided to stop operating, and the male ward was closed.

In addition, the male ward contained six patients operated on before May who, before or during May, became infected with staphylococci. Of these six, one had a pelvic abscess, two had infected wounds, two had urinary infections, and three had chest infections. One of these last patients developed an abscess involving most of the upper lobe of the left lung.

Staphylococci Responsible for Infection

The staphylococci isolated from infected wounds were all of a strain of *Staph. pyogenes* resistant to penicillin, streptomycin, and tetracycline, but at first sensitive to chloramphenicol and erythromycin. Later, as a result of treatment, variants resistant to chloramphenicol or erythromycin appeared. Twelve of the 17 staphylococci isolated from lesions were typed by the bacteriophage method and all were found to belong to one type, with the phage-sensitivity pattern 47/53/75/77. Some strains were lysed only by phages 53, 75, and 77, and some by 75 and 77 alone, but all were considered to belong to the same type. There was no correlation between these minor variations in phage-sensitivity pattern and the change in antibiotic sensitivity. Staphylococci that were not tested, but had the same sensitivity to antibiotics, were considered to belong to the same type in view of our failure at that time to find any strain with the same characteristics but belonging to a different phage type. With one exception, all the staphylococci isolated from patients with infective complications belonged to the epidemic type.

In the case of enteritis, chest infection, and urinary infection the staphylococci were plainly acquired in the ward. The source of the staphylococci infecting the wounds was not so clear. The majority of infections were thought on clinical grounds to be theatre infections, an early rise in temperature and pus developing deep in the wound being the main criteria.

Staphylococci in the Operating Theatre

In a report of post-operative wound infection occurring in another unit in this hospital (Shooter, Taylor, Ellis, and Ross, 1956) the opinion was expressed that infection originated from air-borne organisms sucked into the theatre from adjacent wards. There seemed less reason to incriminate air in this case.

There was some suction of air into the theatre from the corridor outside, but this was less than in the unit described before, and the total bacterial air counts in the theatre were substantially lower. Search for staphylococci in the theatre air showed a variety of types to be present. On May 30 50 cu. ft. (1.416 cubic metres) was sampled, and six staphylococcal colonies were recovered, five of which belonged to the epidemic type. Examination of 50 cu. ft. (1.416 cubic metres) of air on June 6 yielded three staphylococcal colonies, none of the epidemic type, and a further examination of 540 cu. ft. (15.29 cubic metres) of air on June 20 yielded 26 staphylococcal colonies, only 2 of the 25 typed being of the epidemic type.

Altogether the 35 staphylococci isolated included 15 different phage types. If the wound infections had been chiefly due to air-borne bacteria the staphylococci cultivated might have been expected to reflect the diversity of types present in the theatre air. The fact that they did not suggested some other source of infection.

A clue to this source was given by the examination of nasal swabs from the theatre team. Swabs were taken from 17 members of the team, including surgeons, nurses, students, and the orderly, and from seven of these swabs *Staph. pyogenes* was recovered. From only one person, however, were staphylococci of the epidemic type isolated. Examination of this individual's movements strongly suggested that he was concerned with infection of the wounds. Of the 45 operations in which he took part 21 resulted in infection. On the other hand, of the 38 patients operated on in his absence, only three became infected, and of these one was infected with coliform bacilli, and the other two may have been ward infections. Furthermore, he had been on leave from May 14 to 27, and during this time, with the exception of the wound infection due to *Bacterium coli*, no patients operated on developed septic wounds.

The surgical members of the unit worked as two teams, and it was possible that infection was the result of some difference in technique or came from some other person. This appeared improbable in view of the failure to detect any other carrier of the appropriate staphylococcus, and was not supported by a more detailed analysis of the wound-book. The team to which the carrier did not belong carried out 29 operations, three of which were followed by sepsis. The other team, with the carrier, performed 54 operations, and 21 of these patients developed infected wounds. However, of these 54 operations, 40 were done in the carrier's presence, and 20 of the 21 infections came in this group. Of the 14 patients operated on in his absence, only one became infected, and that infection was due to *Bact. coli*.

On three occasions the carrier was examined after he had been wearing rubber gloves; his hands were moist, and staphylococci of the epidemic type could be recovered from the fingers and the insides of the gloves. The same finding was recorded after preliminary washing of the hands with soap and water and a scrubbing-brush. In two of these experiments he was dressed in clean surgical uniform and incarcerated in a sterile room for 10 minutes. On neither occasion were staphylococci of the epidemic type

recovered from the air. Such staphylococci were, however, isolated from the air when he was shut in the room in his ordinary clothes. The carrier yielded a heavy growth of staphylococci from his nose on all the occasions on which he was examined; his faeces also yielded numerous staphylococci of the same type.

Staphylococci in the Wards

During this investigation there was less wound sepsis in the female ward than in the male ward, only 6 women out of 34 developing septic wounds, as compared with 18 out of 43 men. There was still, however, a suggestion that the carrier in the theatre was concerned, since of the 15 operations on female patients which he attended four were followed by sepsis, whereas of the 18 when he was absent only two wounds were infected, and in one of these the cause was *Bact. coli* and the other was almost certainly a ward infection. The patients in the female ward were also free from staphylococcal complications.

In the male ward *Staph. pyogenes* was carried in the nose by 7 out of 10 nurses, but only one of the strains was found to be of the epidemic type. This nurse, and the carrier from the surgical team, constituted a source of infection in the ward, but a very much more prolific source was provided by the patients themselves. This applied particularly to the patient with an extensive lung abscess who was present in April and throughout May. During most of the period this elderly man was producing copious sputum which despite treatment contained very large numbers of staphylococci.

Air samples were taken in the ward on May 10, 11, 18, and 22, and June 13 (Table II). In the first samples, other strains besides the epidemic strain were present, but by May 18 the epidemic type was predominant, and it remained so.

TABLE II.—*Staph. pyogenes* in Air Samples Taken in the Male Ward, May 10 to June 13, 1956

Date	Volume of Air Sampled		<i>Staph. pyogenes</i> Colonies	
	cu. ft.	m. ³	No.	Proportion Epidemic Type
May 10 ..	60	1.70	22	4/11
" 11 ..	60	1.70	8	2/5
" 18 ..	125	3.54	29	11/12
" 22 ..	120	3.40	14	7/8
June 13 ..	459	13.00	623*	22/22

* Estimated number on phenylphthalein phosphate plates: coagulase tests done on 158.

In all the samples counts of general bacteria ranged between 19 and 51 colonies per cubic foot (0.028 cubic metre) of air.

Air collected on June 17 in the corridor joining the male and female wards to the operating theatre showed *Staph. pyogenes* to be present. Of 26 strains tested, 10 belonged to the epidemic type.

Further evidence of the large number of staphylococci present in the male ward was given by examination on June 27 of blankets from three patients with staphylococcal enteritis and of eight of the bed curtains. Both blankets and curtains were tested by the sweep-plate technique (see Blowers, Potter, and Wallace, 1955), and all were found to be heavily infected. Of the many staphylococci recovered, 28 were typed, and all but one were of the epidemic strain.

Closure and Cleaning

In view of the sepsis rate and the simultaneous onset of staphylococcal enteritis in three patients, it was decided on June 28 to cease operating, and to clean and, if possible, disinfect the male ward. All the patients were therefore removed, either by discharge or by transfer to isolation in other parts of the hospital. Movable articles in the ward were disinfected by boiling, treating with formalin vapour, or spraying with sodium hypochlorite solution as seemed

most appropriate. The ward itself was most vigorously cleaned by spraying from ceiling to floor with a power-driven spray of sodium hypochlorite solution (0.17%).

No such steps were taken in the female ward. This was partly because of the better record of the ward, and partly because the result of examination of the air on June 27 was reassuring. Altogether 375 cu. ft. (10.62 cubic metres) of air was examined, and, although 16 colonies of *Staph. pyogenes* were isolated, none belonged to the epidemic type. General bacterial counts were also low, averaging 6.6 per cu. ft. (0.028 cubic metre). The decision not to close this ward was justified by the fact that none of the 39 patients operated on before the unit finally closed on August 22 for redecoration developed sepsis due to *Staph. pyogenes*.

Opening of the Male Ward

During the cleaning of the ward the carrier in the surgical team and the nurse who carried the epidemic staphylococcus left the unit. The ward was opened on July 3 and stayed open until August 22. At first, examination showed a great reduction of the staphylococcal and general bacterial population. For example, the count for the latter ranged between 5 and 10 colonies per cu. ft. (0.028 cubic metre) of air on July 3 and 4. Sweep-plates taken from 10 blankets on July 3 and 4 failed to grow any staphylococci. As the ward was reoccupied bacterial counts rose, and the results of sampling for general bacteria in the air showed a steady climb to a maintained level—approximately 16 colonies per cu. ft. (0.028 cubic metre). This climb was accompanied by an increase in the staphylococci in the ward air (Table III), and a return of the epidemic type.

TABLE III.—Colonies of *Staph. pyogenes* Recovered from the Air of the Male Ward After Cleaning

Date	Volume of Air Sampled		<i>Staph. pyogenes</i> Colonies	
	cu. ft.	cu. m.	No.	Epidemic Type
July 3 ..	100	2.83	1	0
" 4 ..	195	5.52	3	0
" 10 ..	195	5.52	5	1
" 31 ..	200	5.66	12	0
Aug. 13 ..	110	3.11	12	3
" 14 ..	75	2.12	29*	26

* Includes 18 colonies from 5 cu. ft. (0.14 cu. m.) when a bed was being made.

There was again little to suggest that the staff were chiefly responsible. Nasal swabs taken from 34 members of the unit on August 9, 10, and 11 failed to yield any staphylococci of the epidemic type.

At first the return of staphylococci to the surgical ward was not accompanied by infection. This freedom was, however, only temporary, and infections occurred on July 27 and August 2, 4, and 7. Two of these—an infection around an indwelling catheter and a septic wound—were caused by the type of staphylococcus previously present in the ward. The other two, an enteritis and a wound infection, were due to a staphylococcus of different type. During this time 47 men underwent clean operations.

On August 22 the ward was closed for painting, which had been previously arranged.

Discussion

Outbreaks of staphylococcal infection have been attributed to a variety of sources. Wells and Wells (1936, 1938) and Hart (1937) suggested the possibility of air-borne infection during operations, and, more recently, Blowers, Mason, Wallace and Walton (1955) and Shooter *et al.* (1956) described wound infections which they thought were due to staphylococci from the air of the operating theatre.

In other cases infection was apparently transmitted to the patients by a single carrier, as in the outbreak described by Devenish and Miles (1939). They drew attention to the frequency with which surgical gloves are punctured at operation, and suggested that infection might be caused by staphylococci squeezed through perforations in the gloves.

A third mode of transmission, recorded more for streptococcal than for staphylococcal infection, is from case to case at the time of wound dressing by way of contaminated fingers and instruments (for example, Miles *et al.*, 1940).

In the present outbreak there seemed little doubt that a proportion of the wounds were infected at the time of operation, and glove punctures may well have been the way in which the carrier in the surgical team infected patients, as normally about a third of the gloves worn by members of the surgical staff of the hospital are found to have perforations after use. In retrospect, direct proof is unobtainable, and the possibility that staphylococci from the carrier found their way into the wound by some other route cannot be excluded.

Though in our opinion there seemed to be good grounds for suspecting that the theatre infections originated from a single person, the position in the ward was considerably more complex. The key to the situation seemed to be the great ability of the epidemic staphylococcus to colonize wounds and lungs and other sites. No reliable method exists for testing in the laboratory the disease-producing potentialities of strains of *Staph. pyogenes*, but there is no doubt that some strains are in fact able to spread more readily than others and are more able to cause infection. Our strain showed considerable versatility in the way in which it caused a variety of infections and while the patients were under treatment became resistant to chloramphenicol or erythromycin. It seemed also to be able to establish itself to the exclusion of other strains of staphylococci which had been present earlier. In consequence, not only was it the only strain to be recovered from wounds by mid-May, but it became increasingly preponderant in the ward air (Table II) and was practically the only strain to be recovered from the ward curtains on June 27.

Some of the ward infections may have originated from the male carrier or the nurse, but these two individuals are less likely to have been the cause of some of the other complications; for instance, chest infections or enteritis. Compared with the patients, the carriers must have contributed only a small proportion of the staphylococci present in the ward, and it is tempting to suggest that the start of the epidemic was the elderly patient with the lung abscess. Once established, new victims maintained the staphylococcal strain. To what extent the extensive spread of the staphylococcus should be attributed to inherent properties and to what extent to the efficiency with which two or more particular carriers were able to spread it must remain unknown.

During this epidemic we were able to examine the air for general bacteria and for staphylococci. General air counts appear to reflect largely the activities of the ward and are not necessarily linked with infection. It is misleading to use them alone as a gauge of the effectiveness of measures designed to prevent the spread of infection. Staphylococcal air counts, on the other hand, particularly when phage-typing is available, may be of more help. We used low counts and the absence of the epidemic type in deciding to keep the female ward open, and when more is known it may be possible to estimate the risk of infection in a ward from the number of pathogenic staphylococci present in the environment, and the extent to which they belong to one phage type known to be responsible for infection. Whether this is so or not must depend, of course, largely on whether the staphylococci are actually transmitted to the patients through the air. Further surveys similar to ours are needed to discover whether high air counts precede the transfer of infection or whether they merely reflect transfer that has already happened by other routes.

Another unanswered question in our survey is why the female ward enjoyed its relative freedom from infection. Women are known to be less liable to post-operative chest infection than men, and during this period there was no patient in the female ward disseminating large numbers of staphylococci. Even so, the absence of the epidemic type

in the air collected on June 27 was surprising, and, taken in conjunction with the low general bacterial count, may represent some other factor such as the effect of differences in light or ventilation which we have not recognized.

Finally, the measures taken to disinfect the male ward appear to have been successful in that for a time they eliminated staphylococci and reduced the incidence of infection. From the information available, it is not possible to tell if the epidemic strain of *Staph. pyogenes* was brought back to the ward by a member of the staff from some other part of the hospital, or was brought in by a patient, or came from some unsuspected hiding-place which had escaped disinfection. This staphylococcus had been isolated from time to time in other parts of the hospital.

Summary

During a period of nine weeks, 24 of 83 patients undergoing clean operations in one surgical unit developed wound sepsis and seven developed other staphylococcal infections. All but one of the staphylococci tested from the wounds and other lesions belonged to one phage type.

In many cases wound sepsis seemed to follow infection acquired in the operating theatre, and there was strong evidence implicating one of the members of the surgical team in these infections.

Some cases of wound infection and most of the other infections seemed to have been acquired in the ward. It is suggested that one patient, who had a staphylococcal lung abscess, may have been responsible for widespread dissemination. The epidemic type was found in large numbers in the air and on bedclothes, curtains, etc.; it was carried by only one member of the nursing staff.

We are greatly indebted to Dr. Radmila Skalova, of the Medical Faculty of the University of Zagreb, Yugoslavia, who, while working with a British Council bursary at the Central Public Health Laboratory, gave much assistance with the bacteriological air sampling.

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The latest *Life Tables* volume of the Registrar-General's *Decennial Supplement for England and Wales, 1951* (H.M.S.O., 3s.), is based on the 1951 census populations and on the mortality experience in England and Wales as a whole during the three years 1950-2. It shows that the expectation of life of a boy at birth has increased by nearly 15 years in the past 40 years; for a girl the increase is more than 16 years. These increases are largely the result of the immense improvement in infant mortality. In 1910-12 120 of every 1,000 boys born and 98 of every 1,000 girls born died before reaching their first birthday; the corresponding figures for 1950-2 were 33 boys and 25 girls. Women have fared better than men in the improvement of longevity. While for women there has been a continued substantial lightening of mortality even beyond the age of 80, for men the improvement has been much less. For men aged 60 the expectation on 1950-2 mortality is about 14½ years, an increase of only three-eighths of a year on the figure 20 years earlier, whereas for women of that age it is 18 years, an increase of 1½ years. Persons living in England have a higher expectation of life than those living in Scotland or Wales. The rural districts show mortality lighter than the national average. Alone of all the major conurbations Greater London experienced lighter mortality than England and Wales as a whole.

CLINICAL AND LABORATORY ASSESSMENTS OF SENNA PREPARATIONS

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The use of standard British pharmacopoeial preparations of senna implicitly assumes that all such preparations will have, for the same dosage, similar laxative effects, and that, subject to individual variation, like effects will be consistently produced by the same dose of the same preparation at different times.

Work directed by one of us (J.W.F.) led to the development of a reliable bioassay procedure, using mice as the test animal (Lou, 1949); and the indications of laxative potency given by this method agree closely with those derived from a physico-chemical method of assay which determines the amount of the glycosides, sennosides A and B, present in different senna preparations (Fairbairn and Michaels, 1950). When applied to standard preparations of senna both these laboratory assay methods strongly suggest that senna pods and different samples of the *B.P.* liquid extract vary widely in potency: indeed, some of the extracts appear to be virtually inert. Further, *B.P.* liquid extract of senna appears to lose potency when kept over a period of time (Fairbairn and Saleh, 1953).

These indications, however, are based on laboratory techniques and need not necessarily apply in clinical practice. Although American workers (Miller and Alexander, 1949) have shown that bioassay results agree with laxative effects in humans, their subjects were normal (unconstipated) individuals. We here describe controlled clinical trials designed to measure the relative laxative potency of various *B.P.* senna preparations in constipated patients in hospital practice and to compare clinical results with the findings of chemical and biological assay. At the same time we have included in the trial a new granular type of senna preparation ("senokot"), for which total retention of the activity of the crude drug, consistency, and stability of potency are claimed (Ryan, 1951). Its laxative efficiency has been favourably assessed by several workers (*Brit. Ency. med. Pract.*, 1956), but no rigorously controlled observations have been reported.