J. Hyg., Camb. (1965), **63**, 25
Printed in Great Britain

Hospital infections and hospital hygiene at Malmö General Hospital

1. The incidence of staphylococcal infections during three years

By CARL ERICSON and INGMAR JUHLIN
Institute of Clinical Bacteriology (University of Lund)
General Hospital, Malmö, Sweden

(*Received* 26 *June* 1964)

The problems of hospital infections have been reviewed most thoroughly by Williams, Blowers, Garrod & Shooter (1960) and the current views on the epidemiology and prevention of such infections were recently discussed at an international symposium in London (Williams & Shooter, 1963). Among those who have had an active interest in this field, there is general agreement on some basic principles regarding the control of hospital infections. At many large hospitals Infection Control Committees have been established. There are, however, comparatively few reports (Howe, 1956; Hitchcock *et al.* 1958; Jensen, 1962) on the effects of a broadly designed preventive programme upon the incidence of hospital infections, and there are still many hospitals without any coherent hygiene programme other than the general instructions issued by official national authorities.

The primary object of this study is to assess the validity of the hygiene programme of our own hospital. We feel that our experience might be stimulating to others.

The first part of this work deals with the incidence of hospital infections and the changes in this incidence in the 3 years of active preventive work. In the second part (Juhlin & Ericson, 1965) the various hygienic measures will be discussed in the light of the results presented in the first part.

MATERIALS AND METHODS

At this hospital there is no continuous record of hospital infections. However, as persons with primary staphylococcal infections are usually treated as outpatients, the number of purulent infections with *Staphylococcus aureus* among inpatients may, with some limitations, be regarded as an expression of the frequency of hospital infections.

This investigation deals with the purulent staphylococcal lesions in eight departments in the years 1960–62. Examples of purulent lesions are furuncles, carbuncles, wound abscesses, decubital infections and septicaemia. Pulmonary and urinary infections and cases of otitis media have been excluded, on the assumption that they would largely have been acquired outside the hospital.

Only the identity of the first culture of a particular strain of *Staph. aureus* from each patient has been included in this study.

The departments which have been studied are: Long-Term Diseases, Internal Chest Diseases, Internal Medicine, Obstetrics and Gynaecology, General Surgery, Chest Surgery, Plastic Surgery and Orthopaedics. Interest in taking bacteriological specimens does not seem to have diminished in these departments during the 3 years under investigation. No great changes have been made in their architecture or organization.

Identification and classification of Staphylococcus aureus *strains*

Typing with bacteriophages has been performed according to the standard international method (Blair & Williams, 1961). For the identification of strains we have also used the antibiogram (disk sensitivity method, H. Ericsson (Ericsson, Högman & Wickman, 1954; Ericsson & Swartz-Malmberg, 1959), with a sulphonamide, benzyl penicillin, streptomycin, tetracyclin, chloramphenicol, erythromycin, kanamycin), and the Tween 80 esterase test (Sierra, 1957). In the course of typing, subcultures have been made on water-blue agar (Ericson, 1962) in order to disclose mixtures of strains.

The methods for primary isolation and typing have remained unchanged in the period under investigation.

For the purpose of this study, the various strains of *Staph. aureus* have been divided into three classes:

(1) '*Virginal*' *strains*. These were resistant to two at most of the antibiotics mentioned above. The results of phage typing were heterogenous, and there are no indications that any of these strains has been truly epidemic at this hospital.

(2) '*Multiple-resistant*' *strains*. These were resistant to more than two antibiotics and did not belong to the '80/81' group (see below). Like the strains in the '80/81' group nearly all of these strains have been epidemic (in some cases rather endemic) at this hospital. Most of them have been lysed by phages belonging to group III (e.g. 7/47/54/75), but a large proportion have been non-typable with phages at 1000 × RTD (Routine Test Dilution).

(3) '80/81' *strains*. On phage typing, these strains were lysed by phages belonging to the '80/81' group (Parker & Jevons, 1963). Most of these strains were resistant to sulphonamides, penicillin, and streptomycin. The strains which were lysed by the same phages, but were more sensitive to antibiotics, have been placed in the virginal group.

This classification was easily carried out without doubtful decisions. Its significance will be discussed below.

Estimation of the incidence of infection

The incidence of infection is usually described as a percentage of the number of admittances or operations. In this investigation we have used a different basis for the determination of this frequency. As the chief purpose of this study is to note any changes in incidence which may have occurred, and to correlate such changes with preventive hygienic measures, it has been important to exclude as far as possible the influence of non-hygienic factors upon the incidence of infection Such factors are: (1) the mean number of beds available during each period,

(2) the extent to which the beds have been occupied, and (3) the mean duration per patient of the period in hospital.

The number of admittances reflects all these factors. The number of infections may, crudely, be simply correlated with the first two factors: the bed capacity and occupancy rate. The effects of the third factor, however, are more complicated. We have preferred to neglect the influence of this factor by correlating the infection numbers during different periods only with the bed capacity and occupancy rate.

This has been done as follows. The number of infections in each department has been noted semi-annually. This number has been related to an occupancy rate of 100 % of the maximum mean number of beds available during any of the six half-year periods. For each department and each half-year, a multiplication factor has been calculated according to the following formula:

$$\frac{100 \times \text{maximum bed capacity}}{\text{occupancy rate} \times \text{bed capacity}}.$$

RESULTS

Two terms will be used in describing the incidence of infection:

The 'infection rate' is the absolute number of purulent infections in a department as a percentage of the number of patients cared for during a certain period of time.

The 'relative infection number' is the absolute number of infections in a department multiplied by the above-mentioned factor.

In Table 1, the annual infection rates in the 3 years under investigation are listed for the eight departments. The relative importance of staphylococcal infections is strikingly different amongst the eight departments. In one respect, however, all

Table 1. *Infection rates* (Staphylococcus aureus) *of eight departments* 1960–62

Departments	Annual infection rates (%) 1960	1961	1962
Long-term diseases	15·78	5·96	3·80
Internal chest diseases	11·17	8·67	2·15
Internal medicine	1·39	0·62	0·98
Obstetrics and gynaecology	0·48	0·26	0·29
General surgery	1·41	1·54	1·11
Chest surgery	10·49	10·76	4·07
Plastic surgery	7·04	10·12	6·53
Orthopaedics	4·69	4·08	3·99
All eight departments	2·27	1·76	1·46

departments are alike, in showing lower infection rates in 1962 than in 1960. If all these departments are treated as one unit, the infection rate shows a steady decline from 1960 to 1962. The reduction is 22·5 % between 1960 and 1961, and 17·0 % from 1961 to 1962. If the infection frequency is described in terms of relative infection numbers, the reduction is 19·6 % in the first period, and 21·4 % in the last period.

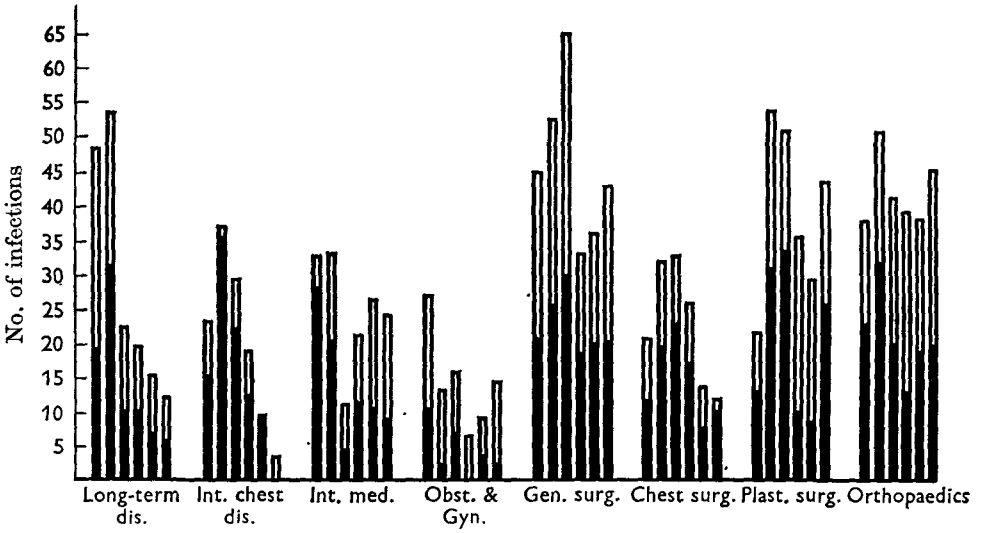

Fig. 1. Relative infection numbers of eight departments, semi-annually from 1. i. 1960 to 31. xii. 1962. For each department, every staple represents one half-year. The upper parts of the staples represent infections with virginal strains, and the filled lower parts infections with multiple-resistant strains and '80/81' strains.

Table 2. *Relative infection numbers of eight departments during two consecutive 18-month periods, and differences between the results from the two periods*

Departments	Classes of *Staph. aureus* strains	Relative infection numbers: 1. i. 60–30. vi. 61	Relative infection numbers: 1. vii. 61–31. xii. 62	Difference (%)
Long-term diseases	Virginal	63·6	23·5	−63·1
	Multiple-R + '80/81'	60·6	23·4	−61·4
	All	124·2	46·9	−62·2
Internal chest diseases	Virginal	16·6	9·9	−40·4
	Multiple-R + '80/81'	73·1	22·0	−69·9
	All	89·7	31·9	−64·4
Internal medicine	Virginal	24·1	40·8	+69·3
	Multiple-R + '80/81'	52·8	30·7	−41·9
	All	76·9	71·5	− 7·0
Obstetrics and gynaecology	Virginal	36·3	24·5	−32·5
	Multiple-R + '80/81'	19·7	5·9	−70·1
	All	56·0	30·4	−45·7
General surgery	Virginal	86·4	53·5	−38·3
	Multiple-R + '80/81'	75·9	58·5	−22·9
	All	162·3	111·8	−31·1
Chest surgery	Virginal	31·2	16·3	−47·8
	Multiple-R + '80/81'	54·2	34·8	−35·8
	All	85·4	51·1	−40·2
Plastic surgery	Virginal	48·8	64·8	+32·8
	Multiple-R + '80/81'	77·8	43·4	−43·9
	All	126·2	108·2	−14·3
Orthopaedics	Virginal	55·2	71·6	+29·7
	Multiple-R + '80/81'	73·8	50·5	−31·6
	All	129·0	122·1	− 5·3

https://doi.org/10.1017/S0022172400044934 Published online by Cambridge University Press

In Fig. 1, the relative infection numbers of the eight departments have been calculated semi-annually. The top parts of the staples represent infections with 'virginal' strains, while the filled lower parts represent infections with '80/81' strains + 'multiple-resistant' strains. In all departments there is a marked drop in the relative infection numbers during the first or second half of 1961. This reduction is most pronounced amongst the infections with non-virginal strains.

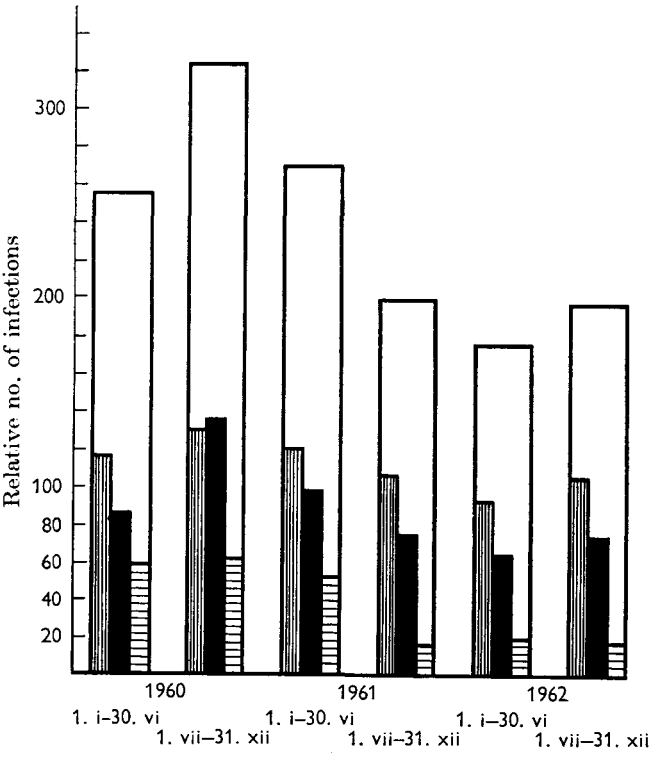

Fig. 2. Relative infection numbers of eight departments taken together. Semi-annual registration from 1. i. 1960 to 31. xii. 1962. Large staples: all infections with *Staph. aureus*. Small staples: Vertical stripes: infections with virginal strains. Black: infections with multiple-resistant strains. Horizontal stripes: infections with '80/81' strains.

In Fig. 2 this tendency may be seen even more clearly. Here, the semi-annual relative infection numbers have been summated, so that the eight departments are treated as one unit. The large staples represent all staphylococcal infections. Within each staple there are three smaller ones, which represent, from left to right, infections with 'virginal' strains, 'multiple-resistant' strains, and '80/81' strains. It is to be noted that the relative infection numbers during the last three half-yearly periods form a plateau that is lower than the corresponding numbers for any of the first three periods. From the small staples it is seen that the general reduction in the middle of 1961 was effected by a reduction in all kinds of staphylococcal infections, although the decrease in the number of infections with '80/81' strains is most evident.

https://doi.org/10.1017/S0022172400044934 Published online by Cambridge University Press

In Table 2, the relative infection numbers for each department have been calculated for two periods each of 1·5 years. It is found that in every department the relative infection numbers for the second period are lower than those for the first period. In some departments there is an increase in infections with 'virginal' strains, but this is always compensated by a decrease in infections with 'non-virginal' strains.

Table 3. *Relative infection numbers of eight departments taken together during two consecutive* 18*-month periods, and differences between the results from the two periods*

Classes of *Staph. aureus* strains	Relative infection numbers 1. i. 60–30. vi. 61 (No.)	(%)	1. vii. 61–31. xii. 62 (No.)	(%)	Difference (%)
Virginal	362·2	42·6	304·7	53·1	−15·9
Multiple-R	318·7	37·5	212·4	37·0	−33·3
'80/81'	168·8	19·9	56·8	9·9	−66·4
All	849·7	—	573·9	—	−32·5

In Table 3, the corresponding figures are given for the eight departments treated as one unit, and the infections are divided into three categories with respect to the different classes of staphylococci. The proportion of each category of staphylococci found in the total sum of infections is also presented here. The reduction in infections with 'multiple-resistant' strains has kept pace with the general reduction in infections (about one-third), while the relative reduction of infections with '80/81' strains has been twice as great. In consequence, the proportion of infection caused by 'virginal' strains has increased.

DISCUSSION

The object of this investigation is to test the effectiveness of the hygienic measures which have been undertaken throughout the hospital. The material ought properly to include infections from departments which are representative of the various kinds of specialized modern hospital care, and on this basis, the departments of Paediatrics, Urology, and Infectious Diseases should also have been included. However, the first has been virtually free from staphylococcal hospital infections, the second has been reorganized during the period under investigation and, in the third department, special hygienic precautions make it unsuitable for comparison with the rest of the hospital.

If conclusions as to the efficiency of a general hygienic programme are to be drawn from the total extent of infection, a successful outcome must be demonstrated in at least a majority of the departments. It is evident from this investigation that, although proportions may vary considerably, all the departments had less staphylococcal infections during the second half of the 3-year period (Table 2).

It is seen from Table 1 and Fig. 1 that the reduction has been most pronounced and definite in departments with a high initial incidence of infection. Only one

department, Plastic Surgery, deviates from the low general plateau during the last three half-yearly periods. During the second half of 1962 a sharp rise occurred in the relative number of 'non-virginal' strains. It is impossible to state the cause of this, but the number of carriers of 'multiple-resistant' strains among the staff was unusually high at that time.

It is doubtful whether one should use mathematical statistics to examine the probability that the observed reduction is purely a chance phenomenon. In view of the multiplicity of factors which may have operated in these circumstances, we prefer to base an opinion on the epidemiological evidence presented.

If all departments are taken together, it is notable that the reduction in infections with 'virginal' strains is much less distinct than the reduction in infections with 'non-virginal' strains, especially with '80/81' strains. This may have several explanations.

The fact that the reduction of infections with 'virginal' strains has been smaller than the average is most easily explained on the assumption that this group includes a number of infections acquired outside the hospital.

Infections caused by patients' 'own' strains, but appearing within the hospital probably belong to this group, as well as infections with strains which have been transferred to the patients by droplet infection. The only serious attempt to block this route of infection has been the wearing of surgical masks by the operating staff.

Table 4. *The distribution of* Staphylococcus aureus *strains from various sources into different classes. Material collected in Malmö* 1960–62

	Virginal		Multiple-R		'80/81'		Total
Origin	No.	(%)	No.	(%)	No.	(%)	No.
Infections in in-patients	509	47·6	390	36·4	171	16·0	1070
Infections in out-patients	169	76·8	3	1·4	48	21·8	220
Carriers among hospital staff	167	81·9	30	14·7	7	3·4	204
Carriers outside the hospital	57	100·0	0	—	0	—	57

These assumptions are founded on several reports from other hospitals (Finland, Hirsch & Wallmark, 1960; Hinton & Orr, 1957; Koch, Lepley, Schroeder & Smith, 1959; Parker & Jevons, 1963; Rountree, 1963; Vogelsang & Haaland, 1959; Vogelsang & Iversen, 1959–60) and also on Winblad's studies at this hospital (Winblad, 1960*a*, *b*). These results agree with those of a number of recent investigations on various populations, both at this hospital and in the city of Malmö, summarized in Table 4. It may be noted that 'virginal' strains were dominant in all groups except in-patients, and that almost all 'multiple-resistant' strains occurred inside the hospital only. Strains belonging to the '80/81' group, however, were rather common also in infections among out-patients (although probably

not as common as it seems. Bacteriological examination is requested much more often in cases of furunculosis than in other types of out-patient infection).

There is a striking discrepancy between the distribution of strains carried by the hospital staff and the strains found in the patients' infections. However, it may be mentioned that 'non-virginal' strains were carried by the staff members in wards with high infection rates more often than in other wards.

As for the '80/81' strains, doctors and nursing staff have for many years been instructed to regard the occurrence of such strains within their departments as a danger signal. Patients infected with such strains have been isolated, when possible, and carriers of such strains have been treated with antibacterial nasal creams. This may explain why infection with this group of staphylococci has decreased more than the average. On the other hand, the special warnings for '80/81' strains had already been issued before 1960.

On the basis of this information, it seems reasonable to accept the assumption that there has occurred at this hospital a real reduction in the number of staphylococcal infections during the course of 1961, and that the causes of the reduction may be found amongst such preventive measures as limit the transmission and multiplication of staphylococci within the wards.

SUMMARY

The incidence of purulent staphylococcal infections at a large Swedish university hospital was followed during 3 years and has been described as an expression of the incidence of hospital infections.

A marked decrease in the relative number of infections was found. The decrease was most evident among infections with '80/81' strains and other antibiotic resistant hospital strains and was parallel in all the departments investigated. This is taken as an evidence for the assumption that the lowering of the amount of staphylococcal infections was brought about by a factor that was active throughout the hospital, probably some hygienic preventive measure.

REFERENCES

BLAIR, J. E. & WILLIAMS, R. E. O. (1961). Phage typing of staphylococci. *Bull. World Hlth Org.* **24**, 771.

ERICSON, C. (1962). Differentiation of staphylococci on water blue agar. *Acta path. microbiol. scand.* (Suppl. 154).

ERICSSON, H., HÖGMAN, C. & WICKMAN, K. (1954). A paper disc method for determination of bacterial sensitivity to chemotherapeutic and antibiotic agents. *Scand. J. clin. Lab. Invest.* **6**. (Suppl.), 11.

ERICSSON, H. & SWARTZ-MALMBERG, G. (1959). Determination of bacterial sensitivity in vitro and its clinical evaluation. *Antibiotics Chemother.* **6**, 41.

FINLAND, M., HIRSCH, H. A. & WALLMARK, G. (1960). Pathogenic staphylococci isolated at Boston City Hospital in 1958. Phage types and antibiotic susceptibility. *Arch. intern. Med.* **105**, 383.

HINTON, N. A. & ORR, J. H. (1957). Studies on the incidence and distribution of antibiotic-resistant staphylococci. *J. Lab. clin. Med.* **49**, 566.

HITCHCOCK, C. R., HARDER, H., PANUSKA, M., COLLINS, M., HELFMAN, L., MIGAKO, H. & BASCOM, J. (1958). Control of surgical infections at the Minneapolis General Hospital. *Surgery*, **44**, 492.

HOWE, C. W. (1956). Prevention and control of postoperative wound infections owing to Staphylococcus aureus. *New Engl. J. Med.* **255**, 787.

JENSEN, K. (1962). Årsrapport til Københavns Kommunes Hospitalsvaensens Centraludvalg til Bekaempelse af Hospitalsinfektioner. Juni.

JUHLIN, I. & ERICSON, C. (1965). Hospital infections and hospital hygiene at Malmö General Hospital. II. Hygienic measures and their correlation with the incidence of infection. *J. Hyg., Camb.*, **63**, 35.

KOCH, M., LEPLEY JR, D., SCHROEDER, C. M. & SMITH, M. B. (1959). Study of staphylococcic infections occurring on a surgical service. *J. Amer. med. Ass.* **169**, 99.

PARKER, M. T. & JEVONS, P. M. (1963). Hospital strains of staphylococci. In *Infection in Hospitals*, p. 55. Ed. R. E. O. Williams and R. A. Shooter, Oxford: Blackwell Scientific publications.

ROUNTREE, P. M. (1963). Hospital strains of *Staphylococcus aureus*. In *Infection in Hospitals*, p. 67. Ed. R. E. O. Williams and R. A. Shooter, Oxford: Blackwell Scientific publications.

SIERRA, G. (1957). A simple method for the detection of lipolytic activity of micro-organisms and some observations on the influence of the contact between cells and fatty substrates. *Antonie van Leuwenhoek*, **23**, 15.

WILLIAMS, R. E. O., BLOWERS, R., GARROD, L. P. & SHOOTER, R. A. (1960). *Hospital Infection*. London: Lloyd-Luke (Medical Books) Ltd.

WILLIAMS, R. E. O. & SHOOTER, R. A. (ed.) (1963). *Infection in Hospitals*. Oxford: Blackwell Scientific publications.

WINBLAD, S. (1960*a*). The distribution of *Staphylococcus aureus* in hospital infections and epidemics related to special phagetypes. *Acta path. microbiol. scand.* **50**, 64.

WINBLAD, S. (1960*b*). Nosokomiala infektioner. V. Terapiresistensen hos nosokomiala *Staph. aureus*-stammar. *Nord. Med.* **63**, 57.

VOGELSANG, TH.M. & HAALAND, H. (1959). Studies of pathogenic staphylococci in the upper respiratory tract of members of hospital staff. 2. *Acta path. microbiol. scand.* **45**, 77.

VOGELSANG, TH.M. & IVERSEN, P. F. (1959/60). Staphylococcal studies in a hospital for chronic diseases. *Acta univ. Bergens.* (ser. med.), no. 1.