

Some aspects of nasal carriage of staphylococci

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SYNOPSIS The nasal carrier status of 3,736 patients was determined throughout their stay in hospital. The carrier rate on admission, which was highest in patients under 20 years of age, did not appear to vary with season.

The carriage of strains resistant to penicillin increased with the patients' stay in hospital from 13.8% on admission to 20.5% on discharge, and the acquisition of these strains was enhanced by the administration of antibiotics.

Patients discharged from hospital carrying strains of staphylococci acquired in hospital lost them more readily than patients discharged carrying the strain which they had carried on admission, 31% of those discharged carrying strains resistant to penicillin and tetracycline being readmitted carrying these strains compared with 69% of those discharged carrying strains sensitive to these antibiotics.

During investigations of staphylococcal sepsis at St. Bartholomew's Hospital the patients admitted to one medical and three surgical wards were examined for nasal carriage of staphylococci on admission and thereafter at weekly intervals (Shooter, Girling, Matthias, and Williams, 1960; Williams, Noble, Jevons, Lidwell, Shooter, White, Thom, and Taylor, 1962). This extensive material, which was obtained over a period of four years, seemed to offer a chance of filling some of the gaps in our knowledge of the factors relating to staphylococcal nasal carriage, and this paper presents the results of analyses in terms of age, length of stay in hospital, antibiotic treatment, and previous admission to hospital.

METHODS

Nasal swabs were taken from the anterior nares using cotton-tipped swabs which were inoculated on to serum agar plates containing 0.01% phenolphthalein phosphate (Barber and Kuper, 1951). Phosphatase-positive colonies were tested for coagulase and coagulase-positive strains were tested for resistance to antibiotics (penicillin, tetracycline, streptomycin, chloramphenicol, and erythromycin) and were phage typed at the Staphylococcus Reference Laboratory, Colindale. Unless the presence of more than one strain of staphylococcus was suspected, only one colony from each nasal swab was tested for antibiotic sensitivity and phage type.

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Throughout this paper the word 'staphylococcus' is used to mean the coagulase-positive *Staphylococcus aureus* and the term 'carrier' is used for anyone who yielded *Staphylococcus aureus* from a nasal swab. A patient was said to have 'acquired' a staphylococcus if he was a non-carrier on admission and became a carrier subsequently; or if he was a carrier but could be shown by phage typing of the staphylococci to have changed the strain he carried during his stay in hospital. Obvious intermittent carriers were not regarded as 'acquiring' a new strain each time the strain reappeared in the nose. The group of patients regarded as 'non-carriers' on admission to the wards may well have included intermittent carriers from whom we did not isolate a staphylococcus and were consequently regarded as having acquired the staphylococcus while in hospital.

The term 'sepsis' is used to denote any clinically manifest infective condition; 100 of the 206 cases of sepsis were cases of post-operative wound infection and 73 were of chest infections, the remainder being of minor sepsis such as boils.

Altogether the records for 3,736 male patients, some of whom were admitted on more than one occasion to give a total of 4,335 admissions, have been collected. Not all have been included in each analysis, however, since complete records were not available for all patients, owing to the extended nature of the survey.

RESULTS

RELATION OF NASAL CARRIAGE ON ADMISSION TO AGE
On admission to the wards 40.5% of the patients carried staphylococci in the anterior nares. The total

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TABLE I

NASAL CARRIAGE OF STAPHYLOCOCCI IN RELATION TO AGE OF THE PATIENT ON ADMISSION										
Age of patient on admission (yr.)	5-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	All ages
No. of patients	40 ¹	185	266	313	485	686	636	281	33	2,925
Percentage nasal carriers	70	60	41	42.8	39	39.1	36.5	37.2	12	40.5
Percentage patients carrying strains										
S/PT	32.5	41.4	28.5	27	27	28.4	25	23	6	27.4
R/P, S/T	32.5	18	10.3	13	10.7	7.5	9	10.3	6	10.4
R/PT	5	0.6	2.2	2.8	1.3	3.2	2.5	3.9	0	2.5

S/PT = sensitive to penicillin and tetracycline

R/P, S/T = strains resistant to penicillin but sensitive to tetracycline

R/PT = resistant to penicillin and tetracycline

¹There were no patients under 5 years of age. One patient was aged 5 years and the rest evenly distributed over the range 6 to 10 years.

Only four patients were over 90 years of age. None was 100 or over.

staphylococcal carrier rate was considerably higher in the patients under 20 years of age than in the older patients (Table I).

Strains resistant to penicillin and tetracycline were carried by 2.5% of the patients on admission; there was no significant difference in the rate at different ages. On average about 10% of patients carried penicillin-resistant strains on admission, the youngest patients having the highest rates. There was no great difference in the rates over the years 1956 to 1961.

SEASONAL VARIATION IN NASAL CARRIAGE Meteorological data, derived from Air Ministry data for central London, were plotted against the mean monthly carrier rate on admission for a total of 2,646 patients admitted between December 1957 and January 1961. There was no clear correlation of carrier rate with season, nor was this rate correlated with the mean monthly temperature or relative humidity.

Likewise there was no correlation between season and the frequency with which patients in the ward acquired staphylococci (computed as the number of acquisitions per 1,000 patient-days' exposure).

CARRIAGE DURING STAY IN HOSPITAL AND EFFECT OF ANTIBIOTICS Previous work (e.g., Williams *et al.*, 1962) has shown that patients acquire staphylococci

during their stay in hospital. However, this increase in carrier rate is influenced not only by length of stay in hospital but also by antibiotic treatment and the development of a septic lesion and these three factors are inter-related. An attempt to disentangle them is presented in Tables II, III, and IV, which are based on patients undergoing operations from whom two or more nasal swabs were received during their hospital stay.

Those patients who developed sepsis acquired nasal staphylococci more often than those who did not develop sepsis, as did those patients who received antibiotics, whether or not they developed sepsis (Table II).

In Tables III and IV patients who developed sepsis are omitted. There was a steady increase in acquisition rate with length of stay in hospital both for those who received and those who did not receive antibiotics (Table III).

Patients who were not nasal carriers of staphylococci on admission to hospital acquired nasal staphylococci more often than those admitted carrying staphylococci, regardless of antibiotic therapy, although in both groups the incidence was higher among the patients who had had antibiotics.

CARRIAGE OF STAPHYLOCOCCI ON DISCHARGE The total carrier rate at the last routine swabbing before

TABLE II

Length of Time in Hospital	EFFECT OF ANTIBIOTICS ON CHANGE IN CARRIER STATUS IN PATIENTS WITH AND WITHOUT SEPSIS			
	No Antibiotics Given		Antibiotics Given	
	No. of Patients	% Acquiring Nasal Staphylococcus	No. of Patients	% Acquiring Nasal Staphylococcus
Patients developing sepsis ¹				
< 12 days	12	16.7	9	0
> 12 days	67	47.8	118	56.8
Patients not developing sepsis				
< 12 days	287	9.8	62	16.1
> 12 days	412	25.2	257	40.7

¹'Sepsis' includes wounds in which there was visible pus and other clinically recognizable infective complications, usually in the chest, due to any organism.

TABLE III
EFFECT OF LENGTH OF TIME IN HOSPITAL IN RELATION TO CHANGE IN CARRIER STATUS AND ADMINISTRATION OF ANTIBIOTICS IN PATIENTS NOT DEVELOPING SEPSIS

Length of Time in Hospital (days)	No Antibiotics Given		Antibiotics Given	
	No. of Patients	% Acquiring Nasal Staphylococcus	No. of Patients	% Acquiring Nasal Staphylococcus
< 12	287	9.8	62	16.1
12-20	299	20.7	96	22.9
21-30	74	33.7	93	36.6
31-40	27	44.4	30	46.7
> 41	12	41.7	38	73.7

TABLE IV

EFFECT OF ANTIBIOTICS ON CHANGE IN CARRIER STATUS OF PATIENTS EITHER CARRIERS OR NON-CARRIERS ON ADMISSION TO THE WARDS¹

	No Antibiotics Given		Antibiotics Given	
	No. of Patients	% Acquiring Nasal Staphylococcus	No. of Patients	% Acquiring Nasal Staphylococcus
Carriers on admission	141	21.3	79	31.6
Non-carriers on admission	271	27.3	178	41.0

¹All these patients were in hospital for more than 12 days and none of them suffered sepsis

the patients left the ward was 43% (of 4,002 patient discharges). Twenty-two per cent of patients were discharged carrying a penicillin-sensitive strain, 14.5% a strain resistant to penicillin only, and 6% a strain resistant to penicillin and tetracycline. These rates may be compared with 40.5% for carriers on admission, with 27% of the patients carrying sensitive strains, 10.4% carrying strains resistant to penicillin only, and 2.5% resistant to penicillin and tetracycline.

In one of the wards neomycin nasal cream and hexachlorophene soap were used for the control of an outbreak of staphylococcal cross-infection. The period of this treatment has been omitted from the rest of the analysis, but during the treatment period the percentage of patients discharged from the wards as non-carriers was higher than for the other periods (70% of 484 patients). Sixteen per cent were discharged carrying a penicillin-sensitive strain, 9% a

penicillin-resistant strain, and 4.5% a strain resistant to penicillin and tetracycline.

CARRIER STATUS ON READMISSION TO THE WARDS
During the course of the investigation, 374 patients were readmitted to the wards on one or more occasions giving a total of 599 readmissions.

From Table V it can be seen that 62% of the 246 patients who had been discharged as nasal carriers were readmitted carrying the same strain; 14% (34) carried a new strain as determined by phage-typing and antibiotic resistance. In 25 of the 34 patients the new strain and the original strain belonged to different phage groups, thus indicating a complete change of strain rather than a minor change in the pattern of lysis of the initial strain.

Patients who acquired nasal staphylococci in the hospital lost them more readily after discharge than those who were discharged carrying the strain that

TABLE V
CARRIAGE OF STAPHYLOCOCCI ON READMISSION

Carrier Status on Discharge	% Patients Readmitted			Total No. of Patients Observed
	Carrying Same Strain	As Non-carriers	Carrying New Strain	
Discharged carrying strains				
S/PT	68.7	16	15.3	125
R/P, S/T ¹	62	28.2	9.8	92
R/PT	31	45	24	29
Total carriers	61.7	24.4	13.9	246
Non-carriers		84.1	15.9	353

¹R/P, S/T indicates a strain resistant to penicillin but sensitive to tetracycline
The difference between the three groups of carriers is significant between the 1% and 0.1% levels.

TABLE VI

Days from Discharge to Readmission	Patient Discharged Carrying	% Patients Readmitted			Total No. of Patients Observed
		Carrying Same Strain	As Non-carriers	Carrying New Strain	
1-50	'Own' staphylococcus	88.5	9.6	1.9	52
	Hospital-acquired staphylococcus	37	37	26	19
51-150	'Own' staphylococcus	68.4	21.4	10.2	89
	Hospital-acquired staphylococcus	28	39	33	18
> 151	'Own' staphylococcus	56.4	27.3	16.3	55
	Hospital-acquired staphylococcus	15	54	31	13

they had carried on admission (Table VI); not only did more of those who had been discharged carrying a hospital-acquired staphylococcus return as non-carriers but more returned carrying other strains.

Eighty-seven of the patients were admitted three or more times during the course of the investigation. Twenty-eight (32%) never carried staphylococci, 18 (21%) carried the same strain throughout, 11 (13%) carried different strains, and 30 (35%) showed intermittent carriage.

Seventy-three patients lost the strain carried on the first admission during their stay in hospital, becoming either non-carriers or carrying another strain. Thirty-eight (52%) of these patients carried the original strain again at the second admission.

DISCUSSION

Many studies have been carried out on the change in nasal carrier status with time in newborn and young children but there have been few such studies of adolescents and adults. Miller, Galbraith, and Green (1962), in a survey of staphylococcal carriers in patients attending their general practitioners, found that the carrier rate was highest in the age group 5-14 years and had settled to the adult level in the 15-24 age group. The carrier rate in our series was also highest in the patients under 20 years of age but the numbers are not large enough to permit further breakdown.

Since the carrier rate for staphylococci is fairly similar for a number of different countries and climates (Williams, 1963), it is perhaps not surprising that, in common with Miles, Williams, and Clayton-Cooper (1944), we failed to find any relation between the carrier rate and season in Great Britain.

Previous work has indicated that the administration of an antibiotic tends to eliminate the antibiotic-sensitive flora from the nose and allow recolonization with an antibiotic-resistant flora; the emergence of pre-existing antibiotic-resistant bacteria from the original flora seems in comparison to be rare (Barber, 1947; Knight, White, and Martin, 1958). This is confirmed in our series. Of 1,300 patients who were carriers on admission to hospital, 1,092 received no antibiotics; 164 (15%) of these acquired a new staphylococcus. Of the 208 patients receiving antibiotics, 108 (53%) acquired a new staphylococcus as determined by phage-typing (Table VII). No clear evidence of a change in antibiotic sensitivity unaccompanied by a change in phage type was seen. From studies on the airborne staphylococci in the wards to which these patients were admitted it seems likely that between 40 and 50% of the staphylococci inhaled by the patients were resistant to penicillin and so it is not surprising that many of the patients acquired penicillin-resistant staphylococci in the nose.

Goslings and Büchli (1958) in a follow-up study found that patients discharged from hospital carrying

TABLE VII

RELATION OF ANTIBIOTIC THERAPY TO CARRIAGE OF STAPHYLOCOCCI¹

	No Antibiotic Given		Antibiotic Given		
	No. of Patients	% Changing or Acquiring a Nasal Staphylococcus	No. of Patients	% Changing or Acquiring a Nasal Staphylococcus	
				Before Antibiotic	After Antibiotic
Carrier on admission	1,092	15 ²	208	5	47 ³
Non-carrier on admission	1,101	18.5	241	11	33

¹This table is based on all patients from whom two or more swabs were received, except those with sepsis.

²In 38% of these 164 patients the change was to a more resistant strain.

³In 63% of these 98 patients the change was to a more resistant strain.

penicillin-resistant staphylococci lost them and became non-carriers more readily than patients discharged carrying penicillin-sensitive strains. Miller, McDonald, Jevons, and Williams (1962) in a study of Royal Air Force personnel found that penicillin-resistant staphylococci were more readily acquired and more rapidly lost than sensitive strains and these observations have been amply confirmed by our own investigations.

It thus seems that the selective advantage of antibiotic resistance which enables the strain to make a success of colonization in the hospital environment is in some way disadvantageous when the selective agent is removed. This, however, is not true for all strains, for Johnson, Rountree, Smith, Stanley, and Anderson (1960) have shown that hospital strains of staphylococci of phage type 80/81 have spread extensively outside hospital in Australia.

In our studies about half of the patients who appeared to have lost the strain of staphylococcus which they carried on admission to the hospital were subsequently readmitted carrying their original strain. Jarvis and Wigley (1961) reported a similar recolonization of the nose in nurses treated with Neobacrin and Soframycin. This recolonization could have arisen from carriage of the staphylococcus on another body site or from members of a patient's family. In other unpublished studies (Simpson and

Noble) we have found, however, that about 65% of hospital out-patients with staphylococci in the anterior nares also carry staphylococci on either the inferior or middle turbinates or in the post-nasal space.

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