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Carriage of *Staphylococcus aureus* in random samples of a normal population*

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INTRODUCTION

Although a great many studies have been carried out on the nose and throat carriage of staphylococci, few investigators have had the opportunity of studying an unselected population. In a comprehensive review of staphylococcus carriage, Williams (1963) lists 15 published investigations on non-hospital populations; of these 10 were on populations selected by age or occupation, e.g. medical students, undergraduates or armed forces personnel, two were on patients attending their general practitioners or out-patient departments and three were on persons selected in an unspecified manner from the general population.

During the course of a survey on the incidence and prevalence of rheumatic fever and rheumatoid arthritis under the direction of one of us (H. A. V.), the opportunity arose of studying staphylococcal carriage in a randomly selected sample of a population. This paper describes the findings.

The population sampled was that of three villages about 3 km. apart in a rural environment but close to the industrial town of Eindhoven in the southern part of the Netherlands. As the total population of the three villages was of the order of 15,000 people, it was not possible to sample all individuals. In the Netherlands, however, a complete register of all persons residing in an area is maintained at the municipal offices; from this register it was possible, by the use of random number tables, to select true random samples from the population. The municipal register gives not merely the names but also the addresses, ages, family size, religion and other details. It was therefore possible to contact each person and to send them a letter explaining the nature of the survey, and subsequently to send a card asking them to attend at a local clinic at a specific time.

The persons to be seen each month were drawn as separate random samples, rejecting from the sample population only those drawn previously and those under 6 years of age. Thus each month's respondents constituted a separate random sample of the population. As all respondents were seen twice, each monthly sample consisted of about 120 persons seen for the first time, plus 120 seen for the second time. The initial response to the invitation cards was of the order of 75% and by

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making home visits the completion rate was brought to about 95%. In addition to the sample population the entire inhabitants of two old people's homes were examined on one occasion only, in a separate study. Some of these people were, of course, included in the random samples.

METHODS

Cotton-tipped swabs were used to obtain the samples; dry swabs were used for throat samples, but swabs moistened with broth were used on the forearm and for nasal swabs. The fingers were sampled by rubbing the finger tips directly on the agar plate. All cultures were made on 5% sheep blood agar. Since the primary interest in the throat swabs lay in the isolation of β-haemolytic streptococci, these swabs were inoculated on agar and then into blood broth for enrichment and the plates incubated anaerobically; all other plates were incubated aerobically. Antibiotic sensitivity was determined using the disk method. Most of the phage-typing was very kindly done for us at the Central Public Health Laboratory, England, by Dr M. T. Parker.

In assessing the results, any swab giving no growth has been omitted on the grounds of faulty technique. Only respondents from whom at least one full set of data was obtained have been included in the analyses.

Respondents were asked the following questions:

(1) Have you a skin infection at this moment; if so have you been to your doctor about it; if 'yes', which doctor?

(2) Have you been in hospital in the last 6 months?

(3) Has anyone at home been in hospital in the last 6 months?

(4) Have you been to an out-patient department in the last 6 months?

(5) Has anyone at home been to an out-patient department in the last 6 months?

(6) Have you had penicillin in the last 6 months?

Respondents were allowed to answer 'yes' or 'no' or 'uncertain'. In analysing these results 'uncertain' has been counted as 'no'.

The word staphylococcus is used throughout this paper to mean the coagulase positive *Staphylococcus aureus*.

RESULTS

Nose and throat carriage

In no part of the survey was any clear difference in carriage seen between the male and female respondents and the results have accordingly been pooled. Table 1 shows the age composition of the population, the sample population drawn for the months November to May and the percentage of persons from whom adequate data were obtained. The total number of respondents seen in this survey was approximately 7·5% of the population.

The distribution of staphylococcus carriage by age is shown in Table 2. In general there was a decrease in the rate of carriage of both nasal and throat staphylococci with increasing age; this trend was also apparent when the figures were

analysed month by month. The figures for the old people's homes are slightly higher than might have been expected on the basis of the normal population, but some cross-infection was obvious in one of the homes, five of the people carrying the same staphylococcus. Although the age trend was quite consistent for each of the three villages, there were differences between the villages in the carriage of penicillin resistant staphylococci and it is possible that these reflect differences in

Table 1. *Age distribution of the populations*

Age group	Total population	Sample population in percentages	Percentage from whom adequate data were obtained
6–9	1445	7·1	89
10–14	1593	8·0	95
15–19	1303	8·4	94
20–29	2184	8·0	94
30–39	1734	7·4	99
40–49	1155	8·9	92
50–59	914	8·3	88
60–69	618	6·3	88
70+	555	6·7	92
Total	11501	7·8	93
Old people's homes			
65–69	27	100	93
70+	163	100	96

Table 2. *Distribution of staphylococcus carriage by age*

(These results are based on the first visit only.)

		Percentage carriers		
Age group	Total no.	Nose carriers	Throat carriers	Nose and throat carriers†
6–9	92	33	14	7
10–14	121	42	13	7
15–19	103	37	13	4
20–29	166	27	13	6
30–39	127	29	6	2
40–49	95	28	8	4
50–59	67	25	3	2
60–69	34	0	3	0
70+	34	15	3	0
Old people's homes				
65–69	25	28*	4	4
70+	157	18*	3	1

* Some 'cross-infection' was obvious in one of the homes.

† Overall a total of 51 pairs of nose and throat staphylococci were available for comparison: in 36 (71 %) of the pairs the strains were identical on the basis of phage-typing.

the prescribing patterns of the local general practitioners. The differences are not statistically significant however (10 % > P > 5 %, χ^2 = 3·6).

Because each monthly sample was a separate random sample from the population, it was possible to use the figures as a measure of the intersample variation (Table 3). There was considerable variation from month to month in nasal carriage but these monthly variations were no greater than the variations between the sample of people seen for the first time each month and those seen for the second time each month, i.e. the differences within months were statistically as large as those between months (F = 1·08, n_1 = 5, n_2 = 6, P > 20 %). This would seem to rule out any possibility of seasonal variation, for differences between months should then be greater than those within months. The mean carrier rate for any one sample was 29 % with a standard deviation of 7 %.

Table 3. *Monthly variation in carriage rates*

	Respondents seen each month					
	For 1st time			For 2nd time		
		Percentage			Percentage	
Month	Total	Nasal carrier	Throat carrier	Total	Nasal carrier	Throat carrier
December 1964	124	26	19	116	33	11
January 1965	119	40	9	119	34	10
February 1965	117	19	9	117	30	9
March 1965	119	31	8	119	39	8
April 1965	118	30	7	118	21	9
May 1965	120	27	4	112	20	1

Because the respondents were seen twice, a comparison of carriage over a month was possible. The percentage of carriers at the first and second sample was the same (29%). The total nasal carrier rate, that is those who carried staphylococci at either one or both visits, was 41·2 % with a standard deviation of 6·3 %. No differences in frequency of acquisition or loss of the staphylococci were seen in respect of age or sex of the respondents; there was a suggestion that staphylococci resistant to penicillin were more 'mobile' than those sensitive to penicillin but the differences are not statistically significant.

Carriage on skin

On one occasion the mid-anterior forearm of 201 respondents was swabbed; nine of the swabs yielded *Staph. aureus* but only one of these yielded more than six colonies on the agar plate. Seven of the nine were nasal carriers and the other two were throat carriers. In a total of 476 respondents the fingers were sampled by rubbing on an agar plate. Thirteen per cent of the 120 nasal carriers yielded more than six colonies of staphylococci from the fingers compared with 4 % of the 356 non-carriers (P < 0·1 %, χ^2 = 18·1). Phage-typing showed that in 20 of the 21 pairs of nose and finger staphylococci the strains were the same, indicating that many of the staphylococci acquired on the hands were of nasal origin.

Results from the questionnaire

From the questionnaire the number of respondents having skin disease, penicillin therapy, etc., was compared with the total carrier rate, but although there was a suggestion that carriers of staphylococci had a higher skin disease rate, none of these differences is statistically significant using the χ^2 test (Table 4). However, respondents carrying penicillin-resistant staphylococci in the nose had skin diseases more frequently than those who were non-carriers. Thus 18% of the 67 nasal carriers of resistant staphylococci had skin disease compared with 7% of the 178 who carried a sensitive strain and 9% of the 587 non-carriers. The difference in the incidence of skin disease between the carriers of resistant and sensitive strains is significant between the 1 and 0·1% levels ($\chi^2 = 8{\cdot}5$).

Table 4. *Staphylococcus carriage in relation to questionnaire*

	Nose		Throat	
	Non-carriers	Carriers	Non-carriers	Carriers
	Percentage giving positive answer to questions			
(1) Presence of skin infection	9	10	9	13
(2) Hospitalization, Self	4	3	3	6
(3) Hospitalization, Family	15	12	14	16
(4) Outpatient visit, Self	12	11	12	13
(5) Outpatient visit, Family	25	28	27	24
(6) Penicillin therapy	4	4	4	1
Total number of persons from whom adequate data were obtained	587	245	750	82

Table 5. *Family carriage of staphylococci*

Secondary case	Index case: Non-carrier	Index case: Carrier	Total
Non-carrier	54	17	71
Carrier	23	19	42
Total	77	36	113

The index case was the first respondent seen in each pair.
The excess of double carriers is significant between the 5% and 2% levels.

Family analysis

In a random sample from a population where the family size is large, some families yield no respondents whilst other families contribute more than one member. This makes it possible to analyse carriage within families by taking the first family member as the index case, irrespective of age, etc., and the next member as the secondary case. As shown in Table 5 there was a significant excess of carriers in the families of carriers. This might be expected if the staphylococci carried were

the same in each of the pairs but this was not the case, for of the 19 pairs of double carriers, only seven pairs carried the same strain. On this basis one might postulate some genetic susceptibility to nasal carriage of staphylococci, for if simple environmental exposure were involved, i.e. if cross-infection occurred between the family members, one would expect the nasal strains to be the same in both respondents.

DISCUSSION

The fact that each of the monthly samples was a separate random sample from the population enabled an estimate to be made of the variation to be expected in the nasal carrier rate of a population. The various carrier rates ranged from 19 to 40 % with a mean of 29 % and a standard deviation of 7 %. On the basis of these figures derived from a rural population having only normal hospital contact one might predict that 'normal' carrier rates for nasal staphylococci derived from a single swabbing would lie within the range 15–43 % and this effectively covers the range given by Williams (1963). In a population with an age bias, such as undergraduates, we might expect a biased carrier rate, for some effect of age was apparent in these investigations. Clearly care is needed before describing a particular population as having an abnormally high or low carrier rate. When the results for the two swabbings are added together the carrier rate is higher (41 %) but there is still a considerable standard deviation (6 %) giving an 'expected' range of 29–53 %.

Analysis of carriage within families suggested that there might be some family predisposition to carry staphylococci. That this predisposition was not simply a reflexion of exposure to some common reservoir was suggested by the fact that in 12 of the 19 pairs of strains the staphylococci were of different phage types. Hoeksma & Winkler (1963) in a study of the nasal flora of 32 pairs of identical and 35 pairs of single sex, non-identical twins concluded that: 'The degree of similarity of the nasal flora of both partners of identical twins was much higher than for non-identical twins pointing definitely to genetic influences on the resistance of the nasal mucosa.' The present work supplements these observations and supports the view that genetic influence plays some part in determining nasal carriage of staphylococci.

It is perhaps surprising not to have been able to draw some positive conclusions on the influence of penicillin therapy and stay in hospital on the carrier rates of staphylococci. Patients discharged from hospital may retain their staphylococci for long periods (Noble *et al.* 1964) and other surveys have demonstrated clear effects of hospitalization or antibiotic therapy (Galbraith, 1960; McDonald *et al.* 1960). In this series spread of staphylococci from one person to another may have blurred the picture. An instance of spread was encountered in which two respondents carried an identical, typically 'hospital' staphylococcus (phage type 83A, resistant to penicillin, tetracycline, streptomycin and sulphonamides). One respondent had been a hospital inpatient but the other denied all hospital contact. The apparent anomaly was explained when it was discovered that the second respondent did the housework of the woman who had been in hospital; she had presumably acquired her nasal staphylococcus from her employer. Only 10 of the

respondents carried staphylococci resistant to tetracycline, but these ten people had not been in hospital or received penicillin therapy more often than had carriers of tetracycline-sensitive staphylococci.

SUMMARY

Nose, throat and finger carriage of *Staphylococcus aureus* was investigated in a series of random samples from a normal European population.

No evidence for a seasonal trend in carriage was found but the intersample variation between successive random samples was obtained. The mean nasal carrier rate was 29 % with a standard deviation of 7 %.

No association was found between nasal or throat carriage of staphylococci and stay in hospital or antibiotic therapy but respondents with penicillin-resistant staphylococci in the nose had skin infections more frequently than those with penicillin-sensitive strains.

Evidence was obtained for a family, perhaps genetic, 'predisposition' to carry staphylococci in the nose.

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