J. Hyg., Camb. (1962), **60**, 451
Printed in Great Britain

Staphylococcal disease and nasal carriage in the Royal Air Force

By D. L. MILLER,* J. C. McDONALD, M. P. JEVONS and R. E. O. WILLIAMS

Royal Air Force Medical Service and Public Health Laboratory Service

(*Received* 6 *June* 1962)

INTRODUCTION

An analysis of fatal cases of influenza occurring during the epidemic of 1957 (Public Health Laboratory Service, 1958) showed that staphylococcal pneumonia was responsible for many deaths and that 35% of the staphylococci isolated from patients who developed pneumonia outside hospital were resistant to penicillin. This seemed a higher proportion than would be expected in staphylococci from the noses of the general population and suggested that penicillin-resistant staphylococci were more virulent than sensitive ones.

To obtain an estimate of the proportion of resistant strains carried by the general population we surveyed the nasal carriage of staphylococci by new recruits to the Royal Air Force (McDonald, Miller, Jevons & Williams, 1960). Only 14% of the nasal strains isolated were penicillin resistant, but 30% of the strains from septic lesions among recruits were resistant, a proportion similar to that from cases of staphylococcal pneumonia.

Thus in both these situations outside hospital, the strains isolated from septic lesions were more often resistant to pencillin than those isolated from the noses of normal recruits. The present investigation was planned to elucidate the reasons for this difference and to study more closely the relationship of nasal carriage of staphylococci to disease. As this required an extensive prospective survey it seemed worth including other studies on the nasal carriage of staphylococci, such as the importance of the hospital in contributing to the reservoir of antibiotic-resistant organisms in the community, and the extent to which penicillin treatment has encouraged the emergence of resistant strains. The R.A.F. provided an unusual opportunity to study these questions and others related to the effect of service life on nasal carriage and the incidence of disease. As there are considerable differences in the pattern of respiratory illness in new recruits, boy entrants and more seasoned personnel (McDonald, Wilson, Thorburn, Holland & Andrews, 1958), we looked for similar effects in staphylococcal infection.

The survey was carried out between September 1959 and July 1960. In the first part the influence of communal living conditions and of the length of service on staphylococcal carriage and disease was studied in a recruit camp, a school for boy apprentices and a number of operational stations. The penicillin resistance and phage type of nasal and lesion strains were determined in an attempt to detect

* Present address: Central Public Health Laboratory, Colindale Avenue, London, N.W. 9.

differences in the ability of certain strains to spread, to persist, or to cause lesions and also to discover the relationship between nasal carriage and disease in the carrier and his contacts.

In the second part of the investigation the carriage of penicillin-resistant staphylococci was studied in relation to the history of sepsis, hospital admission, penicillin treatment, or the presence of a baby in the household—factors which in our earlier inquiry in new recruits had been associated with the carriage of a high proportion of resistant organisms.

In addition, to provide a background for this study, an analysis was made of service records relating to the incidence of sepsis in the Royal Air Force. The results are reported in the following paper (Miller, 1962).

STUDY POPULATION AND FIELD METHODS

Recruits

At the time of this inquiry most recruits were men aged between 18 and 21 years, who joined the Service from civilian life at R.A.F. Cardington. They were transferred each week, within 7 days of their arrival, to R.A.F. Bridgnorth where they spent 8 weeks undergoing training. At Bridgnorth they were allocated to flights of between 60 and 80 men, and each flight was allotted to billets each of about 20 men. The members of each billet slept, worked and probably spent most of their leisure time together, although there was opportunity also for some contact with men from other billets and flights.

For 7 consecutive weeks all recruits were interviewed on the day of their arrival at Bridgnorth; a total of 2397 men was seen. A nasal swab was taken from each man, using the same swab to sample the anterior parts of both nostrils. 1566 of the 1756 men in the first 5 weekly intakes and 16 men who had meanwhile joined them were interviewed and swabbed again at the end of the 7th week of training. Most of the remaining 190 had been transferred to other training units or flights. Satisfactory cultures were obtained from 2376 men on the first occasion and 1571 on the second. Changes of flight or billet were recorded, but substantial alterations in the composition of the billets were few.

A nasal swab was also taken immediately before and at the end of treatment from all men who received penicillin in the sick-quarters during the course of the study, whether they were in the observed flights or not. In patients who received a single injection of a long-acting penicillin, the end of treatment was defined as one week after injection.

The unit medical officers were asked to collect swabs from the pus of any septic lesions reported to them, if possible before treatment with antibiotics. Records of other septic lesions occurring among the men under observation were extracted from the daily sick reports, which gave details, including the diagnosis, of all men who attended the station sick-quarters. The men were also asked at the second interview whether they had any septic lesions, other than mild acne or small pustules, which they had not reported to a medical officer. Records of admissions to the station sick-quarters or to hospital were obtained from the official weekly returns.

To add to our previous studies on the influence on nasal carriage of a baby in the household we asked about the age and relationship of babies in the men's homes and whether the babies were born at home or in hospital.

Boys

The boy apprentices at R.A.F. Cosford were aged between 15 and 17 years. There were two intakes each year and the boys spent 2 years undergoing apprenticeship training. Their first 6 months were spent in the Initial Training Squadron (I.T.S.) when they had little contact with the other boys. They then dispersed to the four permanent squadrons and to various trade training groups. Each squadron was allotted to billets, most of which accommodated 15–20 boys, though there were a few smaller billets. Boys in each trade training group were spread throughout the four squadrons. Thus there was much more mixing between boys than occurred at Bridgnorth, they lived together for much longer, and new entrants were introduced into the community less frequently.

Each squadron of boys was seen in turn during an afternoon at intervals of one week, and nasal swabs were taken in the same way as at Bridgnorth. Of the 1172 boys in the squadron 1142 were interviewed and swabbed at the outset and 1083 of them again 8 weeks later. The higher lapse rate on the second occasion was mostly accounted for by boys discharged from the Service, posted elsewhere or away on duty. Satisfactory cultures were obtained from all but 6 boys on the first occasion and all but 4 on the second. Swabs were collected from septic lesions by the station medical officers. Records of other septic lesions in the boys under observation were extracted from each boy's medical documents and checked for completeness as at Bridgnorth by personal inquiry at the second interview.

Admissions to the unit hospital and other hospitals were recorded from the daily admission sheet. Boys with injuries and non-infectious conditions were admitted to the main hospital. Boys with infectious diseases were admitted to a separate infectious diseases unit.

The out-patient treatment book and the notes of those admitted to hospital were used to obtain records of antibiotic treatment of the boys.

A newly recruited group of 446 boys composing a new Initial Training Squadron was interviewed the day after arrival at Cosford, and nasal swabs were collected from 439 of them in the same manner as at Bridgnorth; 3 cultures yielded no growth. The same boys were seen and swabbed again 10 days and 17 days later. On the second occasion 444 boys were available and all were swabbed. On the third occasion 439 boys were available, all were swabbed but 1 culture yielded no growth.

Operational stations

Our three studies in operational stations were limited to a few special groups of men. Sixty-one stations throughout the United Kingdom participated in the investigation; 52 were active flying stations and the remaining 9 were maintenance and signal stations.

(1) At 48 stations swabs were taken from septic lesions seen in station sick-quarters before antibiotic treatment.

(2) Thirty-three of the units within easy reach of London were visited and nasal swabs were taken from 1076 men who had been discharged from hospital within the previous 12 months. The type of ward, the hospital and the month of discharge were recorded for each man.

(3) A further 4 stations were visited and nasal swabs were collected from 785 men in order to obtain some idea of the carrier and resistance rates to be found in seasoned and older personnel. The men were not selected by any random sampling method, but were simply those most readily available. There is no certainty that the sample seen was representative but we have no reason to suspect any bias.

R.A.F. hospitals

The staffs at each of 5 R.A.F. hospitals were asked to take a nasal swab from all service personnel admitted or discharged during a 14 day period. They were asked to record on admission whether the man was transferred from another hospital or had been recently discharged. On discharge the type of ward, antibiotic treatment and duration of hospital stay were recorded.

TECHNICAL METHODS

Transport of specimens

Nearly all nasal swabs were plated on 1 % horse serum agar plates immediately after they were taken and incubated overnight in the laboratory. The only exceptions were swabs from septic lesions, nasal swabs from men treated with penicillin at Bridgnorth and from men on operational stations who had been recently discharged from hospital. These swabs were broken off into 5 ml. screw-capped bottles containing Stuart's medium (Moffet, Young & Stuart, 1948). Swabs from hospitals were stabbed into agar buffered at pH 7·2–7·4. All swabs normally reached the laboratory within 48 hr. of collection and on arrival were immediately spread on serum agar plates and incubated overnight.

Isolation of Staphylococcus aureus

Colonies resembling *Staphylococcus aureus* were tested for coagulase production by the slide test in the first instance. Those giving doubtful or negative reactions were tested by the tube method. We use the term *Staph. aureus* or staphylococcus to refer to coagulase-positive strains.

Antibiotic sensitivity

All strains isolated were tested for sensitivity to penicillin. This was determined with paper discs containing 1 unit laid on the surface of the plates used for phage typing. Strains not submitted to phage typing were tested by streaking at right angles to a paper strip impregnated with 5 units per sq.cm. laid on a nutrient agar plate. Any strains in which the results were equivocal were tested for penicillinase production and only penicillinase-producing strains were regarded as resistant. All penicillin-resistant strains were tested for sensitivity to tetracycline, streptomycin, chloramphenicol and erythromycin, by means of Oxoid 'Multodisks'.

Phage typing

All strains isolated at the routine swabbing of a 1 in 5 random sample of men at Bridgnorth and of boys at Cosford and a 1 in 3 sample of the newly recruited boys at Cosford, all staphylococci isolated from lesions and from the nose before and after antibiotic treatment, together with a few other selected groups of strains, were tested for phage type. The following phages were used at routine test dilution and at a concentration 1000 times stronger: 29, 52, 52A, 79, 80, 3A, 3B, 3C, 55, 71, 6, 7, 42E, 47, 53, 54, 75, 77, 187, 42D.

Table 1. *Prevalence of* Staph. aureus *in the nose and in septic lesions*

	First examination				Later examination of same groups			
	No. examined	Carrier rate (%)	Proportion of strains penicillin-resistant (%)		Time after first examination	No. examined	Carrier rate (%)	Proportion of strains penicillin-resistant (%)
New arrivals to R.A.F.								
Boy entrants	436	46	18		7 days	444	49	16
					17 days	438	55	16
Adult recruits	2376	45	15		7 weeks	1571	42	14
Personnel after initial training								
Boy entrants	1136	53	23		8 weeks	1079	61	22
Trained men								
in 4 selected units	785	38	35		—	—	—	—
on admission to hospital	304	30	38	30	29	—	—	—	—
discharged from hospital within 1 year	1076	40		24		—	—	—	—
Septic lesions	268	87	31		—	—	—	—

RESULTS

Carrier rates and proportions of antibiotic-resistant strains

The frequency of isolation of *Staph. aureus* from nasal swabs taken at different times from personnel in various types of unit and the proportions of strains resistant to penicillin are presented in Table 1, with comparable information on swabs from septic lesions. Penicillin-resistance rates for the staphylococci from new arrivals to the R.A.F., whether boy entrants or adult recruits, ranged from 15 to 18%, whereas the rates for boys after their initial training and for various groups of men in operational stations ranged from 23 to 35%. Further swabbing in both recruits and boys showed some fluctuations in carrier rates but resistance rates remained constant.

The carrier rates for men in the 4 operational units and boy entrants after the initial training period were analysed in detail by age and by length of service for

https://doi.org/10.1017/S0022172400020581 Published online by Cambridge University Press

evidence of a rising trend in penicillin resistance, but none was found. The highest rates in both groups were, in fact, in those who were youngest and with the least service.

Of strains isolated from septic lesions, 31 % were penicillin resistant, the same proportion as was found in our previous R.A.F. investigation. The rate was similar for strains from lesions in recruits, boys, and trained men.

Table 2. *Resistance to other antibiotics of penicillin-resistant strains*

	Nasal strains from				
	Recruits and boy entrants	Men on admission to hospital	Men on discharge from hospital	All nasal strains	Lesion strains
No. penicillin resistant strains tested	339	28	63	430	68
No. also resistant to:					
Tetracycline	18	3	6	27 (6 %)	4 (6 %)
Streptomycin	8	2	12 (19 %)	22 (5 %)	3 (4 %)
Chloramphenicol	5	2	3	10 (2 %)	0 (–)
Erythromycin	4	0	0	4 (1 %)	0 (–)
More than one of above*	9	2	6	17 (4 %)	0 (–)

* These are also included under the individual antibiotics.

The resistance to other antibiotics of the penicillin-resistant strains is shown in Table 2. Nasal and lesion strains were similar in this respect; resistance to tetracycline was most frequent and to erythromycin least. There is some evidence in the table that patients discharged from hospital had acquired streptomycin-resistant strains.

Assuming that the penicillin-sensitive strains were also sensitive to the other antibiotics, the resistance rates for all strains of *Staph. aureus* isolated in this investigation were about 1 % for tetracycline and streptomycin and considerably less for chloramphenicol and erythromycin.

Although the proportions of the nasal and lesion staphylococci that fell into each of the three main phage groups were very similar, there were some substantial differences in the distribution of the individual types (Table 3). For example, types 52, 79, 71 and 3C/71 were considerably more frequent in carriers while 52A, 3C/55/71 and 42E were commoner in lesions. Also the proportion of nasal strains belonging to Group IV, or mixed groups or groups that were untypable, was higher than in those from lesions. Penicillin-resistant nasal strains belonged to Group III more often than lesion strains; almost half the resistant strains from lesions belonged to Group I.

Changes in carrier state

The changes that occurred in the nasal carriage of resistant and sensitive organisms between initial and final swabs from recruits and boy entrants are summarized in Table 4. The results presented refer only to persons in the random samples whose strains were phage typed, but those for men and boys not sampled

Table 3. *Phage-type distribution of nasal and lesion strains*

Phage type	All strains		Penicillin-resistant strains	
	Nasal*	Lesion	Nasal*	Lesion
Group I				
29	12	9	3	2
29/52	5	1	0	0
52	11	4	1	0
52A	3	27	2	12
79	15	3	4	3
52A/79	11	16	5	9
80	8	7	2	5
52/52A/80	1	1	0	0
52/80	7	4	1	0
29/52/80	4	8	0	2
Other	7	3	0	1
Total	84 (29 %)	83 (36 %)	18 (31 %)	34 (47 %)
Group II				
71	16	8	7	4
3C/55/71	9	26	0	1
3B	2	3	0	1
3B/71	3	1	0	0
3C	13	14	2	3
3C/55	1	4	0	1
55	12	7	0	0
55/71	6	11	1	1
3C/71	13	4	0	0
3B/3C	2	1	0	0
Other	12	5	2	0
Total	89 (31 %)	84 (36 %)	12 (20 %)	11 (15 %)
Group III				
6/7/47/53/54/75	2	1	1	0
42E	5	13	2	6
53	6	4	3	4
73	3	6	0	0
Other	18	10	10	4
Total	34 (12 %)	34 (15 %)	16 (27 %)	14 (19 %)
Group IV and Mixed	42 (14 %)	17 (7 %)	5 (8 %)	6 (8 %)
Not typable	41 (14 %)	14 (6 %)	8 (14 %)	7 (10 %)
Total	290	232	59	72

* The nasal strains were from recruits and boy apprentices only.

were similar. In the 7–8 week period about a quarter of the non-carriers became carriers and vice versa, but only about half the men who were carriers at the first swabbing had organisms of the same sensitivity and phage type at the end. The carriage of resistant strains appeared less persistent than that of sensitive strains and resistant strains formed a higher proportion of those acquired by non-carriers (30 %) than was expected from their relative prevalence in the noses of the population.

Analysis of changes in carrier state among the new intake of boy entrants between arrival and 17 days later gave very similar results (Table 5). Once again the carriers of resistant strains more frequently became non-carriers (30%) than those with sensitive strains (11%).

Table 4. *Changes in nasal carrier state between first swab and swab taken about 7–8 weeks later*

Random samples of recruits and boy entrants only.

Carrier state at first swab	No. of persons	7–8 weeks later: *Staph. aureus* not isolated (%)	7–8 weeks later: Penicillin-sensitive organisms isolated (%)	7–8 weeks later: Penicillin-resistant organisms isolated (%)
Staph. aureus not isolated	273	74	18	8
Penicillin-sensitive organisms isolated	198	21	77*	3
Penicillin-resistant organisms isolated	44	27	11	61†

* In 103 (68%) of the 152 persons in this group the organisms were of the same phage type.
† In 20 (74%) of the 27 persons in this group the organisms were of the same phage type.

Table 5. *Changes in nasal carrier state beetween swabs taken on arrival and 17 days later in new boy entrants*

Carrier state on arrival	No. of boys	17 days later: *Staph. aureus* not isolated (%)	17 days later: Penicillin-sensitive organisms isolated (%)	17 days later: Penicillin-resistant organisms isolated (%)
Staph. aureus not isolated	230	72	23	6
Penicillin-sensitive organisms isolated	161	11	86	2
Penicillin-resistant organisms isolated	37	30	11	54

Occurrence of sepsis

The occurrence of septic lesions during the 7–8 weeks that elapsed between the initial and final nasal swabs in recruits and boy entrants was studied in relation to the findings from the first swab (Table 6). The sepsis rate was higher in carriers (9·6%) than in non-carriers (5·6%) and the difference statistically significant (S.E. difference = 0·9). In 13 out of 23 persons (57%) known to be carriers before the appearance of a lesion, the phage type isolated from the lesion was the same as that found in the nose. Few subsequently carried a nasal strain of the same type as was found in their lesion who had not carried it before.

We also compared the sepsis rate in carriers of sensitive and resistant strains. In the boy entrants there was no difference but in recruits the rate was higher in carriers of resistant strains (11·6% compared with 6·3%; S.E. difference = 2·6).

https://doi.org/10.1017/S0022172400020581 Published online by Cambridge University Press

Table 6. *Incidence of sepsis in relation to result of initial nasal swab*

	Staph. aureus in initial swab	No. of persons	No. who developed sepsis in following 7 weeks
Boy entrants	Present	600	83 (13·8 %)
	Absent	536	48 (9·0 %)
Recruits	Present	1062	76 (7·2 %)
	Absent	1314	55 (4·2 %)
Both	Present	1662	159 (9·6 %)
	Absent	1850	103 (5·6 %)

The incidence of sepsis was surprisingly high, particularly in the boy entrants and many in both groups had more than one lesion during the period. The proportion with more than one lesion was considerably greater than would have been expected by chance. As shown below, the observed distribution differs significantly from the calculated Poisson distribution ($P < 0{\cdot}001$),

	Number of lesions		
	0	1	2 or more
Observed	2664	240	27
Expected	2651	266	14

Factors leading to a change in carrier rate

Stay in hospital

Nasal swabs were received from 304 men admitted to the 5 selected R.A.F. hospitals during 2 week's study; 92 of the men (30 %) were carrying staphylococci and 28 (30 %) of the strains isolated were resistant to penicillin (Table 7). Only one penicillin-resistant strain was isolated from the three carriers who were transferred from other hospitals or who had last been in hospital within 1 month. The resistance rate was not therefore influenced by recent hospital admission.

Table 7. *Carrier rates and proportion of resistant strains in men on admission to and discharge from hospital*

	No. of persons	Per cent carrying staphylococci	Per cent of staphylococci resistant to penicillin
On admission	304	30	30
On discharge after			
< 2 weeks in hospital	240	32	36
2–4 weeks in hospital	166	34	37·5
> 4 weeks in hospital	60	37	59
Unknown time in hospital	22	27	50
Total discharges	488	33	40

Swabs were received from 448 men discharged from these hospitals in the same 2-week period. 160 men (33 %) were carriers and 64 (40 %) of their strains were resistant. The proportion of resistant strains was only slightly greater than on

admission (difference = 10%, S.E. difference = 6·3); there was little difference in the total carrier rate. The proportion of resistant strains was higher in those from surgical wards (45 %) than in those from medical wards (33 %) (S.E. difference = 8·2) but the total carrier rates were similar.

The longer the stay in hospital the higher was the proportion of resistant strains carried; but the difference was only noticeable in men who had been in hospital more than 4 weeks.

The carrier rate among men on the 33 operational stations swabbed at intervals of up to 1 year after discharge from hospital was 40 %, similar to that found in most groups studied (Table 8). The proportion of strains resistant to penicillin, 24 %, was lower than in men admitted to hospital (although the carrier rate for resistant strains was similar) and also lower than in the sample of 785 men swabbed in 4 operational stations (Table 1). There was little difference between men who had been admitted to R.A.F., other service, and civilian hospitals or between those from medical or surgical wards. There was some evidence of a trend towards a lower proportion of resistant strains with increased time since discharge from hospital.

Table 8. *Carrier rates and proportion of resistant strains in year after discharge from hospital*

Months since discharge	No. of persons	Per cent carrying staphylococci	Per cent of staphylococci resistant to penicillin
< 3	267	43	27
3–5	346	35	27
6–8	231	43	25
9–12	232	41	16
Total	1076	40	24

χ^2 on trend in proportion of resistant strains = 3·11 on 1 D.F. ($0{\cdot}05 < P < 0{\cdot}10$)

It seems, then, that the penicillin-resistant strains acquired in hospital, in any case rather few in number, were not carried for long after discharge.

The nasal carriage was not significantly affected by admission of recruits and boy entrants to station sick-quarters or hospital.

Penicillin treatment

There was a small fall in the staphylococcal carrier rate, but a rise in both the proportion and the number of penicillin-resistant strains isolated from recruits and boys treated with penicillin. Table 9 combines the results from two groups—those swabbed immediately before and after treatment, and those swabbed at the start and end of the survey who happened to be treated at some time. The differences in carrier and resistance rates were most striking between swabs taken shortly before and immediately after treatment, and between the treated and untreated groups on discharge from hospital.

Comparison of the phage types of strains isolated before and after treatment suggested that the rise in resistance rate was due to elimination of the sensitive

strains and recolonization with resistant strains, rather than to a change in the resistance pattern of strains already present (Table 10). Two men who acquired penicillin-resistant strains previously carried sensitive strains of the same type; one carried type 30/55/71 and the other type 52A/79, both reasonably common types.

Table 9. *Carrier rates and proportion of resistant strains before and after penicillin treatment*

	No. of persons	Per cent carrying staphylococci	Per cent of staphylococci resistant to penicillin
Recruits and boys treated on stations during survey			
Initial swab	88	45	22·5
Before treatment	157	43	15
After treatment	157	29	42
Final swab	80	38	32
Men admitted to hospital			
On admission	304	30	30
On discharge			
after penicillin treatment	62	26	62·5
no penicillin treatment	411	34	37

Table 10. *Changes in carrier state following penicillin treatment*

		After treatment				
			Penicillin-sensitive organisms isolated		Penicillin-resistant organisms isolated	
Before treatment	No. of persons	*Staph. aureus* not isolated	Total	Same phage type	Total	Same phage type
Staph. aureus not isolated	90	78 (87 %)	5	—	7	—
Penicillin-sensitive organisms isolated	57	29 (51 %)	21	16	7	2
Penicillin-resistant organisms isolated	10	5 (50 %)	0	0	5	3

Sepsis

Although, as stated earlier, the carrier rates were higher in men who suffered sepsis during the survey than in those who did not, there was no evidence that sepsis led to a change in nasal carrier rate or proportion of penicillin-resistant strains isolated, or in phage type distribution.

Contact with cases of sepsis

Studies which included phage typing of both nasal and lesion strains in billets of recruits and boys where a lesion occurred revealed no evidence that lesions resulted from cross-infection, or that strains spread from lesions to the noses of others in the billet. There was evidence of a higher lesion rate in billets with the

highest proportions of carriers, but this was probably only a reflection of the general observation that carriers are more likely to develop lesions than non-carriers. In billets where a large proportion of the men carried penicillin-resistant staphylococci, the number of lesions was no higher than in billets where the proportion was low.

Contact with infants

In previous studies of recruits we found that men coming from a household with a baby under 2 years old carried a high proportion of resistant staphylococci particularly if the baby had been born in hospital. In this study 18% of the 97 men with a baby in the household carried a resistant strain, that is a higher rate than average for recruits but lower than the rate of 21% observed previously. The mean rate for men from households with a baby born in hospital was the same as when the baby was born at home.

DISCUSSION

Though the rates for nasal carriage of *Staph. aureus* were similar in all groups studied, the proportion of penicillin-resistant strains varied. In adult recruits 15% of the staphylococci were resistant, the same as was found previously (McDonald *et al.* 1960), and in newly recruited boy apprentices the proportion was a little higher (18%); in the older boys and in trained men the rates were considerably higher (23–29%). Recent studies in general practice have shown evidence that the rate rises with age (Miller, Galbraith & Green, 1962). In the present investigation, however, the change appeared to occur very rapidly when recruits moved to operational stations, and we found no association with age or length of service. Hospital studies have shown how rapidly the carrier and resistance rates among newly admitted patients can conform to those prevailing in their new environment (Williams *et al.* 1959), and the intimate living conditions in the service may have a comparable effect.

The proportion of penicillin-resistant strains isolated from septic lesions was similar in recruits, boys and trained men and much the same as was observed in our previous inquiry and in fatal influenzal pneumonias. It did not therefore reflect the varying level of resistance of nasal strains in these populations. Evidence has accumulated in recent years that different phage types vary in their pathogenicity (Williams, 1959; Williams *et al.* 1959; Wesley-James & Alder, 1961), and it is possible that the distribution of the more pathogenic types in recruits and others varied less than is suggested by the difference in carriage rates for all resistant strains. Unfortunately we did not study the phage types of nasal strains from trained men, so no comparison with the recruits was possible. Whatever the reason for the difference in resistance of nasal and lesion strains it is clear that it is not simply a matter of resistant strains being more virulent than sensitive ones. The finding of certain phage types more frequently in lesions than in the nose suggested that they possessed greater virulence. Nearly half the penicillin-resistant lesion strains belonged to phage Group I, which may reflect the dissemination in the community

of hospital epidemic types which in recent years have frequently belonged predominantly to this group (Williams, 1959).

Our finding that non-carriers acquired penicillin-resistant strains more frequently than was expected from their prevalence in the noses of others supports that of Williams *et al.* (1959) among new admissions to a surgical ward. Furthermore, like Goslings & Büchli (1958), we were able to demonstrate that resistant strains were probably more readily discarded than sensitive ones. This suggestion of greater mobility on the part of resistant organisms was also implied in the finding of Gould & McKillop (1954) that a higher proportion of strains from occasional carriers were penicillin-resistant than from persistent carriers. This mobility could explain the failure of resistant strains to supplant the predominantly sensitive flora of the general population rapidly, though they flourish in hospitals where the use of antibiotics exerts a vigorous selective pressure in their favour.

Many workers have shown high carrier rates and frequent identity between lesion and nasal strains in patients with skin sepsis (Atkins & Marks, 1952; Valentine & Hall-Smith, 1952; Tulloch, 1954; Gould & Cruikshank, 1957; Roodyn, 1960*b*). Only in the studies of Atkins & Marks and of Roodyn was there clear evidence that this was due to the nose acting as the reservoir from which sepsis occurred rather than the other way round. Roodyn (1960*b*) showed that some strains of staphylococcus may persist in the same person causing repeated sepsis, and there was evidence among the recruits and boys that some of them suffered repeated lesions more frequently than would have been expected by chance. We found further evidence that nasal carriage predisposed to the development of disease in that 9·6% of the men who were carriers on their first swab developed a septic lesion, compared with 5·6% of those who were non-carriers, and in the frequent identity between the phage types of strains isolated from lesions and those found earlier in the patients' noses. A considerable proportion of those with lesions were not nasal carriers when swabbed, but it is possible that they were carrying staphylococci in other sites, such as the perineum (Hare & Ridley, 1958; Roodyn, 1960*b*).

Our studies of the sleeping quarters showed no evidence of cross-infection as a cause of lesions, nor of transfer of nasal strains. This experience is similar to that of Shooter, Girling, Matthias & Williams (1960) in medical wards and of Goslings & Büchli (1958) and Dowling, Lepper & Jackson (1953) in families. Roodyn (1960*a*) on the other hand was able to demonstrate spread of infection in families but his observations were made over much longer periods than ours.

The rise in the penicillin-resistance rate between admission to and discharge from hospital was considerably less than is found in civilian hospitals. This may have been due to the character of the hospitals rather than of the men admitted, for new recruits who had recently been admitted to civilian hospitals carried resistant strains much more frequently than those who had not (McDonald *et al.* 1960) and had presumably acquired them in hospital. The difference is more probably explained by the relative infrequency of seriously ill patients in R.A.F. hospitals and consequently less use of antibiotics. Goslings & Büchli (1958) have shown that of penicillin-resistant strains carried on discharge from hospital two-thirds are lost within the first 3 months. Few resistant strains were acquired in

R.A.F. hospitals and they were not apparently carried for long after discharge.

It is usually considered that the effect of penicillin treatment is to eliminate sensitive strains allowing either the emergence of resistant strains already present or recolonization by a resistant strain (Cruickshank, 1955; Barber, 1947) and our results support this view. In two men the resistant strain isolated after treatment was of the same phage type as the sensitive one present before; as both were common types this may have been a coincidence, though a somewhat remarkable one.

SUMMARY

1. The nasal carriage of *Staph. aureus* and its relation to disease was studied in new recruits, boy apprentices and trained men of the Royal Air Force.

2. The proportions of *Staph. aureus* that were penicillin-resistant ranged from 15% in new recruits to 29% in trained men. In a school for apprentices the rate in new arrivals was 18%, and 23% for boys after the initial training. We were unable to find when these changes occurred.

3. 31% of strains isolated from septic lesions were penicillin-resistant and the rate was similar in all types of unit. Resistant strains were not apparently more virulent than sensitive strains.

4. About 1% of all strains isolated were resistant to tetracycline and streptomycin and much smaller proportions to chloramphenicol and erythromycin.

5. The phage-group distribution was similar for nasal and lesion strains, but nearly half the penicillin-resistant lesion strains belonged to Group I, and types 52A and 3C/55/71 were much commoner in lesions than in the nose.

6. Penicillin-resistant strains were more readily acquired and more rapidly lost than the sensitive strains.

7. Nasal carriers suffered from septic lesions more frequently than non-carriers, and those with a lesion tended to suffer further lesions. There was no evidence of cross-infection among bedroom contacts.

8. The proportion of penicillin-resistant strains rose from 30 to 40% between admission to and discharge from service hospitals. Resistant strains were not carried for long after discharge.

9. Penicillin treatment resulted in a fall in the total carrier rate and a rise in the resistance rate. Phage type analysis showed that this was mainly due to elimination of sensitive strains and recolonization with resistant strains.

We are greatly indebted to Miss Susan Green for the large amount of work that she did in the laboratory. We should like to thank also many Royal Air Force medical officers for their assistance, in particular Wing Commander E. S. Odbert, Wing Commander M. White, Squadron Leader M. Shearer and Flight Lieutenant A. J. Zuckerman; and the Director-General of the Royal Air Force Medical Services for permission to publish the results.

REFERENCES

ATKINS, J. B. & MARKS, J. (1952). The role of staphylococcal infection in beat disorders of miners. *Brit. J. industr. Med.* **9**, 296.

BARBER, M. (1947). Staphylococcal infection due to penicillin-resistant strains. *Brit. med. J.* **2**, 863.

CRUICKSHANK, R. (1955). Penicillin: the problem of resistance. *Practitioner*, **174**, 53.

DOWLING, H. F., LEPPER, M. H. & JACKSON, G. G. (1953). Observations on the epidemiological spread of antibiotic-resistant staphylococci, with measurements of changes in sensitivity to penicillin and aureomycin. *Amer. J. pub. Hlth*, **43**, 860.

GOSLINGS, W. R. O. & BÜCHLI, K. (1958). Nasal carrier rate of antibiotic-resistant staphylococci. *Arch. intern. Med.* **102**, 691.

GOULD, J. C. & CRUIKSHANK, J. D. (1957). Staphylococcal infection in general practice. *Lancet*, ii, 1157.

GOULD, J. C. & MCKILLOP, E. J. (1954). The carriage of *Staphylococcus pyogenes* var. *aureus* in the human nose. *J. Hyg., Camb.*, **52**, 304.

HARE, R. & RIDLEY, M. (1958). Further studies on the transmission of *Staph. aureus*. *Brit. med. J.* i, 69.

MCDONALD, J. C., WILSON, J. S., THORBURN, W. B., HOLLAND, W. W. & ANDREWS, B. E., (1958). Acute respiratory disease in the R.A.F., 1955–7. *Brit. med. J.* ii, 721.

MCDONALD, J. C., MILLER, D. L., JEVONS, M. P. & WILLIAMS, R. E. O. (1960). Nasal carriers of penicillin-resistant staphylococci in recruits to the Royal Air Force. *Proc. R. Soc. Med.* **53**, 255.

MILLER, D. L. (1962). The incidence of sepsis in the Royal Air Force. *J. Hyg., Camb.*, **60**, 467.

MILLER, D. L., GALBRAITH, N. S. & GREEN, S. (1962). Nasal carriers of penicillin-resistant staphylococci in the general population. *Brit. J. prev. soc. Med.*, **16**, 203.

MOFFET, M., YOUNG, J. L. & STUART, R. D. (1948). Centralised gonococcus culture for dispersed clinics. The value of a new transport medium for gonococci and trichomonas. *Brit. med. J.* ii, 421.

PUBLIC HEALTH LABORATORY SERVICE (1958). Deaths from Asian influenza, 1957. *Brit. med. J.* i, 915.

ROODYN, L. (1960*a*). Epidemiology of staphylococcal infections. *J. Hyg., Camb.*, **58**, 1.

ROODYN, L. (1960*b*). Recurrent staphylococcal infections and the duration of the carrier state. *J. Hyg., Camb.*, **58**, 11.

SHOOTER, R. A., GIRLING, J. A., MATTHIAS, J. Q. & WILLIAMS, R. E. O. (1960). Staphylococcal infection in a medical ward. *Brit. med. J.* i, 1923.

TULLOCH, L. G. (1954). Nasal carriage in staphylococcal skin infections. *Brit. med. J.* ii, 912.

VALENTINE, F. C. O. & HALL-SMITH, S. P. (1952). Superficial staphylococcal infection. *Lancet*, ii, 351.

WESLEY-JAMES, O. & ALDER, V. G. (1961). Staphylococci in septic fingers. *J. clin. Path.* **14**, 96.

WILLIAMS, R. E. O. (1959). Epidemic staphylococci. *Lancet*, i, 190.

WILLIAMS, R. E. O., JEVONS, M. P., SHOOTER, R. A., HUNTER, C. J. W., GIRLING, J. A., GRIFFITHS, J. D. & TAYLOR, G. W. (1959). Nasal staphylococci and sepsis in hospital patients. *Brit. med. J.* ii, 658.