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Staphylococcus aureus in Antarctica: carriage and attempted eradication

By S. J. KRIKLER

Department of Bacteriology, University of Aberdeen Medical School, Foresterhill, Aberdeen AB9 2ZD

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SUMMARY

The carriage of *Staphylococcus aureus* was studied in a group of 28 men living in a totally isolated environment for a year. Initially, nasal, axillary and perineal swabs were taken at weekly intervals, but from week 24 throat swabs were taken from known nasal carriers. Several attempts were made during the study to eradicate *S. aureus*. Eight subjects consistently carried their own phage type throughout the study, despite the application of antibacterial agents. In three subjects strains were isolated late in the study of a phage type which had either not been isolated before in this study, or had not been found for a prolonged period. Nine of the 12 nasal carriers also yielded *S. aureus* from the throat. It is apparent that following attempted eradication, *S. aureus* may seem to disappear, only to reappear some time later; 'eradication' in this case would be an erroneous appellation.

INTRODUCTION

This study was conducted at Halley Base, Antarctica during 1983. The aims of the study were to observe the carriage of *Staphylococcus aureus* in an isolated community, and to monitor the effects on this of topical antibacterial therapy. There have been many previous attempts to eradicate nasal carriage of *S. aureus* (Wheat, Kohler & White, 1981), but whatever method used, and however successful it seems to have been initially, when the subjects have been followed up a significant proportion of them have been recolonized by *S. aureus*. Unless specimens are taken from all the contacts of every subject, it is very difficult to postulate the origin of the apparent re-acquisition. In a small group it is practical to swab all the members, and if the group is totally isolated for a long enough period, all potential contacts are swabbed. An Antarctic base provides just such a group; small enough to make it practical to swab everyone, large enough to give useful data and totally isolated for approximately 9 months. In addition, as the investigator is living in close contact with the other subjects, compliance can be encouraged and monitored more easily than in more conventional studies.

The first bacteriological studies in Antarctica were performed by Ekelöf in 1908 (quoted by McLean, 1918) and Atkinson (Scott, 1913) on Scott's second expedition, but this work was purely concerned with bacteria in the environment. The first study to take advantage of the unique circumstances of an Antarctic base to study

human flora was by McLean (1919). Only four subjects were studied and his laboratory conditions were very primitive. No useful data was produced until Sladen (1953) studied staphylococcal carriage in two groups of winterers. Since then studies on staphylococcal carriage have been performed by other British workers (Williams, 1969; Hadley, 1981), Australians (Cameron, 1970), and Russians (Tashpulatov & Petrosov, 1973).

Other studies have been performed on isolated men in space flights and space flight simulators for relatively short periods (Carmichael & Taylor, 1977; Taylor & Zaloguev, 1976) and in submarines (Morris & Fallon, 1973) for longer periods. In none of these studies has the effect of interfering with the bacterial flora been studied.

The group in the present study consisted of 28 men who were in total physical isolation from all other human contact from the beginning of March to the end of December 1983; there were no human visitors or new supplies during this period. There were two bases approximately ten miles apart; subjects 1–15 wintered on the old base, subjects 16–28 wintered on the new base. The two groups were for the most part separate, but there was some contact throughout the year; the investigator visited the new base each week to take specimens, and one or two members of the new base visited the old base for mechanical parts on average less often than once a week. It was very unusual for anyone to stay overnight. Two courses of antibacterial therapy were given to all subjects, whether or not *S. aureus* had been isolated from them previously. Two further courses were given to known carriers.

MATERIALS AND METHODS

General

Laboratory work was carried out in the old base surgery, which was not normally visited by any other base members. The worktop temperature varied from 9 °C to 18 °C, averaging approx. 13 °C. There was no still for water, so tap water (from melted snow) was filtered and passed through an Elgastat ion-exchange column. All plates, slopes and broth were incubated before use, and the few unsterile items discarded.

Specimens

Specimens were collected with sterile, disposable cotton-tipped swabs at weekly intervals from the first week of isolation. Initially swabs were taken from three sites (nose, axilla and perineum), but from week 24 onwards throat swabs were taken from known nasal carriers. For nasal and throat specimens the swab was used dry, but for the axilla and perineum it was first moistened with sterile nutrient broth.

Subjects on the new base were swabbed on the same day as the old base subjects whenever the weather allowed travel between the bases; this was possible on most occasions, and only on weeks 22–24 were swabs not taken due to the weather. One person was on night/fire watch each week on each base, so some subjects occasionally escaped being swabbed. In addition, some people went out on field trips and were not then available.

Nasal, throat and axillary specimens were inoculated on to plain agar, perineal specimens were inoculated on to MacConkey agar. Cultures were incubated at 37 °C. After 24 h they were removed and allowed to stand at room temperature overnight.

Some subjects were found to be persistent nasal carriers of *Proteus* species; their nasal swabs were applied to two Petri dishes, one containing plain agar, the other containing MacConkey agar. Where *Proteus* spp. had swarmed over plates which did not already have parallel cultures on MacConkey agar, staphylococcal colonies which could be seen under the engulfing layer of *Proteus* spp. were subcultured on to MacConkey agar and grown for 24 h at 37 °C.

Organisms were identified by colonial appearance, Gram's stain and coagulase production. Strains of *S. aureus* were tested for antibiotic sensitivity using Multodiscs (Oxoid) and stored on plain agar slopes in sterile plastic bijou containers at 4 °C.

At the end of the year the storage cultures were returned to the UK at 4 °C and taken to the stapylococcal reference laboratory at Colindale for phage typing.

Eradication attempts

(1) In weeks 4 and 5 all subjects were asked to apply Naseptin ointment (ICI) to the nasal vestibule four times daily. The course lasted for 10 days; subjects were next swabbed on week 6.

(2) The course was repeated in weeks 18 and 19, but with the addition of washing with Hibiscrub (ICI), and subjects were also asked to dust themselves and their towels and bedding with Savlon talc (ICI).

(3) In weeks 31 and 32 all subjects who had yielded a positive swab on any of the preceding 4 weeks were asked to apply polynoxylin (Anaflex, Geistlich) cream to the nasal vestibule four times daily. Swabs were not taken during this course.

(4) In week 34 or week 37, each nasal carrier was asked to apply Naseptin again. Throat and nose swabs were taken during this course.

Phage typing

Cultures were typed at the Central Public Health Laboratory at Colindale using the procedure based on that of Blair & Williams (1961). Phages were applied at routine test dilution (RTD) and 100 × RTD. The 23 phages of the 1974 International Basic Set (Report 1975) were used, and in addition four experimental phages were applied to each plate. The RTD plate received phages D16, 47A, 27 and 33. The 100 × RTD plate received phages 88A, 90, 83C and 932.

Once all the strains which had revived had been typed the results were reviewed. Strains which had been typed on different days and whose relationship was uncertain were retyped together.

RESULTS AND DISCUSSION

General

A total of 2667 swabs was cultured, and 304 of the 340 cultures which yielded *S. aureus* were successfully revived. Tables 1 and 2 show details of carriage in four carriers. *S. aureus* was never grown from any of the swabs taken from subjects 1,

Table 1. *Subjects 4 and 6*

Specimens baked

Subject	Site	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4	Nose	—	—		Naseptin		—	N1	—	N1	N1	?1	?1	N1	N1	N1	?1	—	Naseptin		—
	Axilla	—	—				—	—	—	—	—	—	—	—	—	—	—	—	and		—
	Perineum	—	—				—	—	—	—	—	—	—	—	—	—	—	—	Hibiscrub		—
6	Nose	?3	?3				—	—	—	—	—	—	—	—	—	—	—	—	and Savlon		—
	Axilla	—	—				—	—	—	—	—	—	—	—	—	—	—	—	talc		—
	Perineum	—	—				—	—	—	—	—	—	—	—	—	—	—	—			—

Stuck at new base

Subject	Site	Week 21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
4	Nose		—	N1	N1	N1	N1	N1	N1	N1	N1	Poly-		N1	N1	—	N1	N1	Field	N1	Night	N1
	Throat				X1	X+N1	—	—	—	N1	N1	noxylin		—	—	N1	—	N1		N1		N1
	Axilla		—	—	—	—	—	—	—	—	—			—	—	—	—	—		—		—
	Perineum		—	—	—	—	—	—	—	—	—			—	—	—	—	—		—		—
6	Nose		—	—	—	—	—	—	—	—	—			—	Naseptin Field	—	—	—	—	Night	—	H3 (H3)
	Axilla		—	—	—	—	—	—	—	—	—			—		—	—	—	—		—	—
	Perineum		—	—	—	—	—	—	—	—	—			—		—	—	—	—		—	—

Letter refers to phage type. Number refers to antibiotic sensitivity.

(1) Nasal, axillary and perineal swabs were taken from all subjects at weekly intervals from the first week of isolation.

(2) Throat swabs were taken from known nasal carriers from week 24 onwards.

(3) Subjects 1–15 wintered on the old base. Subjects 16–28 wintered on the new base.

(4) One person was on night/fire watch on each week on each base, and so occasionally missed being swabbed.

(5) Towards the end of the study, some subjects were on field trips, and were then not available to be swabbed.

(6) All subjects applied Naseptin (ICI) ointment to the anterior nares for 10 days in weeks 4 and 5. All subjects on the new base repeated this course in weeks 7 and 8.

(7) In weeks 18 and 19, all subjects were asked to repeat this course, but with the addition of whole-body shower bathing with Hibiscrub (ICI) and dusting of fomites with Savlon (ICI) talc.

(8) All known carriers were asked to apply a similar course of Polynoxylin (Anaflex, Geistlich) to the anterior nares in weeks 31 and 32.

(9) Starting in week 34 or 37, all known carriers were asked to apply another course of Naseptin. Swabs continued to be taken during this course. This was the first time that swabs were taken during treatment.

	Phage types (experimental phages in brackets)		Antibiotic sensitivities	
Strain	Lysis at RTD	Lysis at RTD × 100	Penicillin	Cotrimoxazole
A	94/96/(47A/27/33)		1 R	R
B	94/96		2 R	S
C	29/52+	29/52/80/81+	3 S	R
D	NT	83A/85/(90/932)	4 S	S
E	29	29		
F	6/47/53/54		N.B. All strains sensitive to cloxacillin, erythromycin, fusidic acid, lincomycin and neomycin	
G	NT	29/47/54/75/77/85/81		
*G	NT	75/77/85/81	?, *S. aureus* isolated but culture contaminated or failed to revive	
H	29/52/81+	29/52/80/42E/81/(932)		
N	NT	NT	—, *S. aureus* not isolated	
X	NT	6/47/54/75/77/84/(88A/90/932)		

Table 2. *Subjects 16 and 23*

Subject	Site	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
16	Nose	Fallen	C2	?2	Naseptin		C2	Naseptin		?2	C2	?2	C2	?2	?2	?2	?2	?2	Naseptin		C2
	Axilla	agar	—	—			—			—	—	—	—	—	—	—	—	—	and		—
	Perineum		—	—			—			—	—	—	—	—	—	—	—	—	Hibiscrub		—
23	Nose		—	—			?2			—	—	—	—	—	—	—	—	—	and Savlon		—
	Axilla		—	—			—			—	—	—	—	—	—	—	—	—	talc		—
	Perineum		—	—			—			—	—	—	—	—	—	—	—	—			—

Subject	Site	Week 21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
16	Nose	C2	Bad		C2	C2	C2	C2	C2	?2	C2	Poly-		C2	Field	—	Field	C2	C2	C2	C2	C2
	Throat		weather		C2	C2	C2	C2	C2	?2	C2	noxylin		C2		—		C2	C2	C2	C2	C2
	Axilla	X2			C2	—	—	—	—	—	—			—		—		—	—	—	—	—
	Perineum	—			—	—	—	—	—	—	—			—		—		—	—	—	—	—
															Naseptin							
23	Nose	—			F1	F1	F1	—	—	—	—			—	G1	G1	Field	G1	—	G1	—	—
	Throat						F1											—	—	—	—	—
	Axilla	—			—	—	—	—	—	—	—			—	—	—		—	—	—	—	—
	Perineum	—			—	—	—	—	—	—	—			—	—	—		—	—	—	—	—
																		Naseptin				

Letter refers to phage type. Number refers to antibiotic sensitivity. For notes see Table 1.

2, 3, 5, 8, 11, 14, 18 or 19. It was only isolated from one swab from subjects 7, 15, 20 and 27.

All the specimens taken from the new base in week 1 were lost for technical reasons, as were the specimens from the old base in week 3. The weather interfered with collection of specimens in weeks 21, 22 and 23.

Nasal carriage

The simple classification by Gould & McKillop (1954) of carriers into persistent, intermittent and occasional is, of course, complicated in this study by the administration of antibacterial agents. Gould & McKillop defined a persistent carrier as one in whom the same phage type was isolated in more than 90% of swabbings. Only subjects 13 and 16 fall into this category, but six other subjects consistently carried the same phage type throughout the year, although it was isolated in fewer than 90% of swabbings (Table 4). Furthermore, no other subject regularly carried the same phage type as any of these six until weeks 21 and 24 – when the type carried by subject 16 was acquired by subjects 25 and 26 respectively, – and week 34 – when the type carried by subject 28 was acquired by subject 23. This implies that, certainly up until week 20, these subjects were harbouring their own strain even when it was not isolated from any of the swabs taken. The term 'consistent carrier' has been used for these subjects. Their lower carriage coefficients must, at least in part, be due to the effects of the various eradication attempts, and the consistent carriers clearly fall into the same group as persistent carriers in terms of their carrying behaviour.

Seven subjects carried *S. aureus* on more than one occasion, and are classified as intermittent rather than consistent carriers. Subject 6 will be discussed in the section on eradication attempts. The remaining subjects, 10, 17, 23, 24, 25 and 26, fall into two categories, those in whom a change in carrier status was clearly related temporally to antibacterial treatment and those in whom the change seems more likely to have been spontaneous.

Apart from subject 23, the other five intermittent carriers only carried a phage type which was also carried by one of the consistent carriers.

Subjects 17, 25 and 26 fall into the first category. Both subjects 17 and 26 carried on several occasions before the second eradication attempt in weeks 18 and 19, but two different phage types were isolated from each of them during this period. Following this eradication attempt, subject 17 ceased carrying for the remainder of the study, while both subjects 25 and 26 acquired the phage type which had consistently been carried by subject 16. Up until this time, subject 25 had never been a carrier, and one must wonder if he had been protected by another species which had been removed or significantly suppressed by the treatment, as suggested by Martin & White (1968).

Subjects 10, 23 and 24 seem to fit better with Gould & McKillop's intermittent carrier, i.e. periods of carriage spontaneously alternating with periods of non-carriage, usually of the same phage type. No positive swab was obtained from subject 10 from week 2 until week 25, and thereafter only 9 out of 14 nasal swabs were positive. All but one of the cultures were successfully revived, and they were all indistinguishable.

In week 24 subject 23 was found to be carrying a phage type which had not been

Table 3. *Throat carriage*

Subject	Site	Week 24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
4	Nose	N	N	N	N	N	N	N	Poly-		N	N	—	N	N	Field	N	Night	N
	Throat	X	X&N	—	—	—	N	N	noxylin		—	—	N	—	N		N		N
												Naseptin							
9	Nose	A	?	A	A	A	—	—			A	A	A	—	—	—	A	A	A
	Throat	A	A	A	A	?	A	A			A	A	A	—	A	A	A	A	A
												Naseptin							
10	Nose	—	N	—	—	N	N	N			—	—	N	N	N	-	N	N	N
	Throat							—							—	—	—	—	—
															Naseptin				
12	Nose	B	C	B	?	A	B	B			B	Field	B	B	B	—	B	B	B
	Throat	—	—	—	—	—	—	—			—		—	—	—	—	—	—	—
															Naseptin				
13	Nose	N	N	N	N	N	?	N			N	N	N	—	N	N	N	N	N
	Throat	—	—	N	—	—	—	N			N	N	—	—	N	—	N	N	N
												Naseptin							
16	Nose	C	C	C	C	C	?	C			C	Field	—	Field	C	C	C	C	C
	Throat	C	—	—	—	—	—	—			C		—		C	C	C	C	C
												Naseptin							
21	Nose	D	D	D	D	D	D	D			D	D	D	Field	—	D	—	—	—
	Throat	—	D	D	—	D	D	D			D	—	—		—	—	D	—	D
												Naseptin							
22	Nose	E	E	E	—	E	—	Night			E	E	—	E	E	E	E	E	E
	Throat	—	E	E	E	—	E		—		—	E	—	—	E	—	—	—	
												Naseptin							
23	Nose	F	F	F	—	—	—	—			—	G	G	Field	G	—	G	?	—
	Throat			—											—	—	—	—	—
															Naseptin				
25	Nose	C	C	C	C	C	C	—			C	Field	Night	CC	—	C	C	C	
	Throat					C	C	—			—			—	—	C	—	C	C
															Naseptin				
26	Nose	C	C	C	C	—	C	C			C	C	Refused						
	Throat				—	—	—	—			C	-							
28	Nose	G	G	G	G	G	G	G			G	G	G	—	G	G	Night	G	G
	Throat		—	—	—	G	—	G			—	—	G	—	—	—		—	G
													Naseptin						

For notes see Table 1.

Table 4. *Frequency of positive nasal swabs in the 'consistent carriers'*

Subject	Frequency	(%)
4	23/31	(74%)
9	20/32	(62·5%)
12	26/31	(84%)
13	30/33	(91%)
16	27/28	(96%)
21	22/28	(79%)
22	23/29	(79%)
28	22/27	(81%)

For notes see Table 1.

seen before. His nasal swabs again yielded this type in the following 2 weeks, but it then spontaneously disappeared. In week 34 he was carrying the type consistently carried by subject 28, and this type was found on 3 of the 6 swabs that were taken in the remainder of the study.

Subject 24 only yielded positive swabs in 6 successive weeks. In each of these weeks he had a positive nasal swab; although none of these cultures revived, the original cultures showed two different antibiotic sensitivities. During this time, 3 of the 12 skin swabs taken were also positive, and each one grew an *S. aureus* with a different antibiotic sensitivity. Throughout the rest of the study, both before and after this period, he did not yield a single positive swab. The reason for this short period of carriage is not obvious. It may have been due to a temporary change in his innate immunity, although over such a short period this seems unlikely, particularly as he remained physically well throughout. Alternatively, it may have been due to a temporary change in the balance of his endogenous microflora. It may be of relevance that the first positive swab was taken 3 weeks after he finished a course of Naseptin.

S. aureus was not grown from 9 of the remaining 13 subjects on any occasion, and 4 had only one positive swab, only one of which was a nasal swab. These single positives may represent contamination, although the fact that in three of them, including the nasal swab, the isolate was obtained before the first eradication attempt may also be an indication of successful eradication.

The finding that between 9 and 13 out of 28 subjects never carried (12 out of 28 if one considers only nasal swabs) is in marked contrast to that of Hadley (1981), all of whose subjects were nasal carriers at some time. That this is a genuine difference between the two groups may be evidenced by the different frequencies of infection in the two groups. Seven out of his 13 subjects suffered from staphylococcal septic lesions compared with no case of sepsis in the present study. Whether this reflects a lower resistance in his subjects, or a more virulent group of organisms that happened to be sharing that base during that winter, is not possible to state. However, 5 of the septic lesions in Hadley's study were caused by the same strain, which was also carried by one subject throughout and acquired by 8 others, at least 2 of whom were persistent carriers of this strain by the end of the study.

Sladen (1953) failed to isolate *S. aureus* from 2 out of his 7 subjects on any occasion, and only isolated it once from 2 of the others in his first year. In the

second year he again failed to isolate *S. aureus* from 2 of his 7 subjects. The findings of the present study are consistent with these findings, although it must be said that Sladen's materials and facilities were somewhat more primitive.

In the present study, 8 out of 28 subjects (*c.* 29 %) were consistent nasal carriers, 6 (*c.* 21 %) were intermittent nasal carriers, 1 (*c.* 4 %) was an occasional carrier and 12 (*c.* 42 %) were non-carriers. One subject (no. 6) does not fit any of these categories, as will be discussed below.

Skin carriage

It was intended from the outset to study not only the patterns of nasal carriage, but also the patterns of skin carriage. The only studies of skin carriage during prolonged periods of isolation are two of the previous Antarctic studies (Williams, 1969; Cameron, 1970). In both these studies, samples were taken only at monthly intervals, and neither found any significant degree of skin carriage.

Seventeen (1 %) of the 1700 skin swabs in the present study were positive. Seven subjects only had 1 positive skin swab, 2 subjects had 3 positive swabs each and 1 had 4. Subject 24 had 6 positive nose swabs on 6 weeks in succession; on 3 of those weeks he also had a positive skin swab. He had no positive skin or nose swab throughout the rest of the study.

Noble (1969) found that in a non-hospital population of adults, 3·5 % were perineal carriers, and only 1·5 % were axillary carriers. In a group of 28 subjects, 3·5 % represents less than one subject and it is not therefore surprising that none of the subjects in this study was a regular skin carrier. The most frequent skin carrier was subject 26, in whom 4 out of 46 skin swabs yielded *S. aureus*, always of a different type from that present in his nose. Isolates from 4 skin swabs obtained from other nasal carriers were also distinct from the type carried in the nose, and in 3 subjects, a single positive skin swab was the only positive swab throughout the study. It seems likely, therefore, that most of the *S. aureus* on the skin were transient organisms and there was no resident carrier.

Throat carriage

The original design of the study did not include throat swabs, but after the failure of the attempts at eradication, speculation as to the possible sites at which organisms might be persisting led to a wider search for *S. aureus*. It was reasoned that, as the skin and fomites had been treated, organisms were more likely to persist at 'internal' rather than 'external' sites. Samples were being collected from the anterior nares; perhaps organisms were present more posteriorly, on the turbinates, in the nasopharynx, or in the oropharynx. It was felt that weekly swabs from the nasopharynx might be more than some subjects would tolerate, so throat swabs seemed a safer source of samples. These were taken from week 24 until the end of the study on week 41, and only from known nasal carriers (Table 3).

Relatively little work has been done on throat carriage of *S. aureus*, and reported carriage rates vary considerably; *S. aureus* is isolated more frequently from the throat in pathological conditions such as tonsillitis (McAuliffe & Leask, 1941), glandular fever and streptococcal pharyngitis (Campbell, 1948), and in association with throat symptoms in industrial workers (Christensen *et al.* 1977), but this probably represents infection or superinfection rather than true carriage.

Rates found in normal adult populations have varied from 2 % (Masters *et al.*

1958) to as high as 45% (Vogelsang, 1958), but the consensus appears to put it at around or a little under 10% except in the Scandinavian studies, where much higher rates seem to have been found. The variation in frequency of throat carriage with age seems to be similar to that with nasal carriage (Vogelsang, 1951; Masters *et al.* 1958; Noble, Valkenburg & Wolters, 1967; Armstrong-Esther & Smith, 1976).

There is a positive correlation between nasal carriage and throat carriage (Campbell, 1948; Solberg, 1965; Armstrong-Esther & Smith, 1976), i.e. *S. aureus* is more frequently isolated from the throats of nasal carriers and vice versa, but this does not explain the differences found in the various studies, as their rates of nasal carriage were comparable. Several of the studies show that *S. aureus* can be isolated from the throats of people who are not nasal carriers, and when both sites in the same subject are colonized it may not always be by the same phage type; Solberg (1965) found different phage types in 16 of 100 nasal carriers. Henning *et al.* (1979) found different strains in 50% of the pairs (i.e. positive nose and throat swabs from the same subject) of swabs from the surgical staff, and in 15% of the pairs from other subjects. Several authors suggest that there is a tendency for organisms from the nose to infect the throat.

The only studies in which throat swabs have been taken over a prolonged period are three previous studies conducted in the Antarctic. McLean (1919) swabbed four subjects at approximately monthly intervals over a 9 month period; he did not isolate *S. aureus* from any of them after the first two swabbings, and only one throat swab yielded *S. aureus*.

Sladen (1953) studied two separate groups of men over two winters. Swabs were taken irregularly at intervals averaging less frequent than monthly, and he had problems in reviving several cultures. Nevertheless, at least one of his subjects consistently carried phage type 3C in his nose, and type 52+ in his throat.

Cameron (1970) studied carriage of *S. aureus* in a group of 27 men during an Antarctic winter. Like Sladen, he only took nose swabs irregularly at approximately monthly intervals, and throat swabs were only taken on four occasions. Fifteen of 27 subjects were nasal carriers at some time. *S. aureus* was isolated at least once from the throat of 11 of these men, and in 4 of them a strain was found in the throat which differed from that found in the nose. There were 3 men from whom *S. aureus* was only isolated from the throat.

That the throat might be a site of carriage independent from the nose seems likely in view of the findings of Sladen (1953), Cameron (1970) and Henning *et al.* (1979) that some people appear to be throat carriers but not nasal carriers, and that in some people who carry *S. aureus* at both sites the strains from the two sites are different (Solberg, 1965; Henning *et al.* 1967). The present study tends to confirm this view, both by the finding in subject 4 of different phage types and also by the persistence in the throat despite apparent eradication or at least suppression in the nose of several subjects.

There was a marked individual variability in the frequency of carriage in the throat: *S. aureus* was isolated from the throat of subject 9 on 15 out of 16 occasions, and from the throats of subjects 4, 13, 16, 21 and 25 on 50% of occasions or more. In contrast, *S. aureus* was never isolated from the throats of subjects 10, 12 and 23.

In one subject (no. 9), the fact that the nose remained clear for 2 weeks after

the organisms were isolated from the throat might indicate that the failure of eradication was due to the nose being recolonized from the throat. In 14 studies in which eradication of nasal carriage was attempted with a variety of topical treatments, the percentage of subjects yielding positive nasal swabs during the study was 17·5%, and it was much higher during the follow-up period (Wheat, Kohler & White, 1981). Throat carriage has not previously been postulated as a possible reason for the failure of eradication from the nose.

It was unfortunate in this study that throat swabs were only taken from known nasal carriers, but in the circumstances it was felt wiser to keep the investigations which some people might find unpleasant down to a minimum. As it was, from week 35 onwards subject 26 refused to cooperate any further.

No reference has been found in the literature to the effect on throat carriage of interfering with the nasal flora.

Clearly, the relationship between nose and throat carriage is poorly understood, and further longitudinal studies are required. A study of this size can only raise questions and provide a basis for future investigations.

Eradication attempts

It had been hoped that total eradication of *S. aureus* might be achieved. This has proved extremely difficult in other studies (Wheat, Kohler & White, 1981). In some studies the phage type found at follow-up has been different from the subject's original type; it is then not unreasonable to suggest that the eradication was successful, but the subject has since been colonized by a new strain. However, when the phage type is the same as in the original type it is not possible to say whether the organism was truly eradicated, and subsequently re-acquired, or whether it never was eradicated, merely suppressed. In the present study the reappearance of the same phage type some time after its apparent eradication would, if no other subject were carrying that type, imply that the therapy had only suppressed and not eradicated.

Naseptin has been shown to be effective in the reduction of nasal carriage of *S. aureus* (Henderson & Williams, 1961; Rountree *et al.* 1962), so it was thought possible that some, or even most, nasal carriers would no longer carry after the application of this ointment. If the skin was a site of resident carriage in any subject, it was hoped that washing with chlorhexidine and dusting with medicated talc might remove the organisms from the skin. In case these treatments failed, an alternative agent was available. Polynoxylin has been used less widely as a topical nasal cream than Naseptin, but it has been shown to have a high *in vitro* activity against *S. aureus* (Blenkharn, 1985).

The first attempt at eradication was made in weeks 4 and 5; all subjects on both bases were asked to apply Naseptin (ICI) ointment. The following week (week 6) none of the subjects on the old base had a positive swab. On the new base, subjects 16, 17 and 22 all had positive nasal swabs. It was thought possible that the ointment had frozen in transit which had in some way affected its efficacy, although no such effect could be demonstrated on base by *in vitro* testing. The course was repeated on the new base in weeks 7 and 8 with Naseptin which had been prevented from freezing in transit. Subject 16 had a positive nasal swab in week 9, but there was no other positive nasal swab on the new base in that week.

By week 16 there were 11 positive nasal swabs, so in weeks 18 and 19 a second attempt at eradication was made; all subjects were asked to apply Naseptin again, but in addition to wash and shower with Hibiscrub (ICI), and to dust bedding and towels with Savlon talc (ICI). In week 20 subjects 9, 16, 21, 22 and 28 all had positive nasal swabs.

In week 29, 11 subjects were still carrying *S. aureus*, so in weeks 31 and 32 a course of polynoxylin (Anaflex, Geistlich) cream was given to all carriers. No effect on carriage could be seen. During all the attempts at eradication so far, no swab had been taken during the treatment. In week 34 or week 37 each carrier was asked to apply Naseptin ointment to the nose again, but during this course swabs were taken. In every carrier the nasal swab became negative either during or on the first occasion after the course, but in nine carriers it was again positive on the following week. Subject 21 remained negative until 2 weeks after the course was stopped.

Subject 9 lost the organism from his nose and throat following the treatment. It returned to his throat the next week, but it was not isolated from his nose again until 2 weeks after that.

In subject 10, eradication may have occurred following the first course of treatment. The strain which was found in week 25 was indistinguishable from that which he carried initially, but it was also indistinguishable from the strains carried consistently by subjects 4 and 13, so he may have been reinfected.

Subject 6 (Table 1) was a nasal carrier on the two occasions that swabs were taken before the first eradication attempt. Following the course of topical Naseptin he appeared to have been cleared, and for the next 35 weeks *S. aureus* was not grown from any of his swabs. On week 41, the last week of isolation, a *S. aureus* was grown from his nasal swab of a phage type not previously seen. The cultures from his first two swabs failed to revive, but they were of an unusual antibiotic sensitivity, and the same as the final culture. On the following week, although the isolation had ended, a swab was taken from this subject and the same strain was obtained. It appears therefore that this strain had been present throughout the study and had somehow escaped detection. No throat swab was taken from this subject, so it is not possible to state that the organism did not persist there, or indeed at any other site not swabbed in this subject. One cannot exclude the even less likely possibility that this strain was resident for 35 weeks in another subject at some protected site. A similar phenomenon occurred with subject 23 when in weeks 24–26 he was found to be carrying a strain which had not been seen before during the study.

As there was no significant skin carriage in these two subjects, or indeed in any other subject, it is unlikely that failure of eradication was due to persistence of organisms on the skin, but in addition the chlorhexidine washes would have significantly reduced the number of organisms of *S. aureus* on the skin (Seeberg, Lindberg & Bergman, 1981), although it has been estimated that as many as 20% of skin bacteria are protected by follicles, crevices and lipids (Selwyn & Ellis, 1972).

Intraleukocytic sequestration of *S. aureus* has been put forward as a possible explanation for persistent peritonitis in continuous ambulatory peritoneal dialysis (Buggy, Schaberg & Swartz, 1984). Although this applies to patients in whom the

immune response may not be normal, perhaps a similar process could have occurred in these cases. Whatever the cause, these findings show that it is never possible to claim with confidence that eradication has been achieved when *S. aureus* has not been isolated from a nasal swab even for several months ater a course of therapy. It is therefore suggested with caution that successful eradication seemed to have been achieved in weeks 18 and 19 in subject 17, and possibly also in subject 24, as for the remainder of the study neither of these subjects yielded *S. aureus* from any swab.

Lindbrom & Laurell (1967) found that administration of Naseptin cream and Soframycin (framycetin, gramicidin and metaoxidrine) spray 'did not materially reduce the proportion of persistent carriers', and their reduction in overall carriage rates was therefore due to eradication (or suppression) in intermittent carriers. In the present study the consistent carriers were remarkably unaffected by the various agents used, except for subject 6, who may have been a 'dormant' persistent carrier (Table 1). Of the 6 intermittent carriers, whilst *S. aureus* may have been eradicated from 2 by the treatment, in 2 subjects (25 and 26) consistent carriage of a particular phage type followed application of treatment.

Inhibition of *S. aureus* by other strains of the same species is well recognized (Aly, Shinefield & Maibach, 1982), but it also occurs with other species (Martin & White, 1968) and it may be that in the case of subject 25 the treatment given in weeks 18 and 19 allowed the strain of *S. aureus* carried by subject 16 to colonize an ecological niche vacated by a protective organism.

It seems, then, that topical application of antibacterial agents is not only an uncertain way to eradicate *S. aureus*, but may have a counterproductive effect. All the isolates in this study were shown to be sensitive to neomycin by the disk method, so drug resistance is not the explanation.

It would have been interesting to have attempted to eradicate *S. aureus* using other agents, either systemic antibiotics or an agent such as rifampicin, which has been shown to be effective in eradicating this species for longer periods than many other agents (Wheat *et al.* 1983; McAnally, Lewis & Brown, 1984).

Transfer of organisms

One advantage of the circumstances of this study is that samples can be collected from all the contacts of every subject. This allows an assessment of the degree to which organisms may be transferred between individuals, and might be able to demonstrate the presence of a disseminator and the tendency of his fellow winterers to acquire his strain. In a study of this size one would be lucky to obtain clear evidence as to the relative importance in the transfer of strains of factors in the organism (Kay, 1963) and factors in the host (Hoeksma & Winkler, 1963; Noble, Valkenberg & Wolters, 1967; Noble, 1974; Kinsman, McKenna & Noble, 1983), but the evidence might be produced by several such studies.

Each of the consistent carriers continued to carry the same type throughout the study, although subject 12 was found to be carrying a different phage type on two occasions. Subjects 17, 23, 25 and 26 did acquire strains of the same phage types as those carried by consistent carriers, although only in the latter two subjects did the new strain persist up to the end of the study. Dispersal of *S. aureus* is proportional to the degree of skin contamination (Noble & Davies, 1965), and as

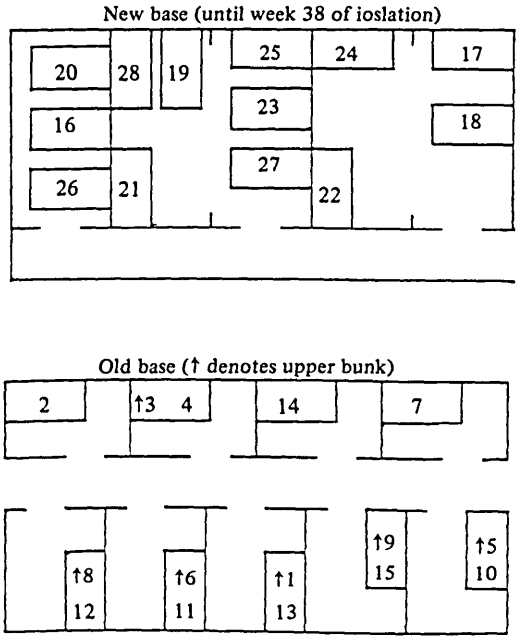

Fig. 1. Sleeping arrangements. All but three subjects on the old base shared two-bunk rooms. Subjects on the new base (under construction) slept in the unfinished office block until week 37 of isolation when the dormitory block was completed.

none of the subjects in this study was a heavy skin carrier it is not surprising that there was so little transfer.

Figure 1 shows the sleeping arrangements on both bases. As it happened, on the old base each consistent or intermittent carrier shared a room with a subject from whom *S. aureus* was never isolated, with the exception of subject 9 who shared with subject 15, from whom a positive nasal swab was obtained in week 1. This isolate had a different antibiotic sensitivity from the strain consistently carried by subject 9.

There is some relationship between the sleeping arrangements and some of the cases of transfer which occurred on the new base. Subject 17 slept in the same room as subject 22, whose strain he carried in weeks 13, 15 and 16, and possibly on other occasions during that period, and subject 23 slept in the same room as subject 28, whose strain he carried from week 34 onwards.

The fact that all the cases of transfer occurred on the new base may be a reflection of the primitive conditions in which the men lived for most of the period of the study.

Rountree & Beard (1962) felt that fomites were a possible source of infection, but this was disputed by Howe (1963) and Gonzaga *et al.* (1964). Finch, Price & Hawksworth (1978) showed that, in a domestic environment, *S. aureus* was only present on fomites in low amounts. As *S. aureus* has to be present in high amounts for it to be acquired from bedding (Gonzaga *et al.* 1964), and as there was no skin carrier in this study, fomites seem an unlikely reservoir of organisms.

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Of the Antarctic studies, Sladen (1953) considered that fomites were an unimportant reservoir of organisms, but Hadley (1981) suggested that fomites might be significant. As skin swabs were not taken in either of these two studies, it is possible that both were correct; if Hadley's subjects included a heavy skin carrier, his bedding may have been a source of disseminated organisms. The unimportance of fomites is suggested in this study by the fact that on the old base each of the men who shared a room with a consistent or intermittent carrier never once yielded a positive swab except subject 15, who had a positive nasal swab in week 1 of a different antibiotic sensitivity from that of his room-mate, subject 9.

It might be argued that even though fomites were not capable of transmitting organisms to others, they might be a source of reinfection following antibacterial treatment. The likelihood of this was reduced by the dusting of towels and bedding with Savlon talc during the second eradication attempt in weeks 18 and 19.

Typing of strains

Phage typing proved adequate to identify most of the strains isolated; 6 of the 10 distinct types obtained during the study were typable at RTD. Three were phage group I, one was phage group III, and two were phage group V. The two in group V gave different patterns of lysis with the experimental phages which were applied to the RTD plate. Three of the four types which were not lysed by any of the phages at RTD were typable at 100 × RTD, and they all belonged to phage group III. Although the patterns of lysis of all the group III types were distinct, the experimental phages applied to the 100 × RTD plates were useful in further distinguishing them. The strains from subjects 4, 10 and 13 were not lysed with any of the phages used at RTD or 100 × RTD. Non-typable strains were also isolated from the axillary swabs of subject 26 in weeks 9 and 12, and from the perineal swab of subject 20 in week 21. The non-typable strains found on the skin were of a different antibiotic sensitivity to the strains isolated from the nasal swabs.

Factors determining carrier status

It is a perennial feature of studies of staphylococcal carriage that some subjects are persistent carriers while others are non-carriers. Since the carriage rate in the newborn is high (Cunliffe, 1949) the subsequent loss of a resident population in some individuals is likely to be due to the acquisition of a relative immunity to *S. aureus*. The design of the present study did not include the investigation of the relationship between carrier status and the presence of anti-staphylococcal antibodies; work is currently being undertaken in similar populations to determine the presence and nature of this relationship.

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