STAPHYLOCOCCUS AUREUS IN THE INFANT UPPER RESPIRATORY TRACT

II. OBSERVATIONS ON DOMICILIARY-DELIVERED BABIES

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(With 3 Figures in the Text)

INTRODUCTION

The initial study (Hurst, 1957) demonstrated that the strains of penicillin resistant *Staphylococcus aureus* which colonize the upper respiratory tract of hospital-born babies are carried for many months. Home-delivered newborns seem less likely to acquire *Staph. aureus* and may have a lower incidence of resistant strains (Cunliffe, 1949; Ludlam, 1953). Observations on babies born at home and phage typing of their cultures promised to provide answers to two interesting questions: (1) Are the penicillin-sensitive strains of the home environment retained for shorter periods, perhaps because they are less adapted to growth on the upper respiratory mucosa? (2) If home-delivered babies do not acquire *Staph. aureus* soon after birth do they do so ultimately or, having passed the age of highest susceptibility, do they remain non-carriers?

METHODS

The group observed consisted of thirty-six babies delivered in homes in the borough of Ealing, Middlesex, between January and March, 1954. Of these, eight were observed only during their first fortnight of life, but twenty-eight were followed until they were between 15 and 25 weeks of age. Both pernasal and throat swabs were collected on three occasions between the third and twelfth days after birth, as well as every 2–4 weeks thereafter. These were inoculated directly on to blood agar plates which were returned to the laboratory by late afternoon. All swabs from each baby were collected by the midwife who attended at delivery.

The bacteriological methods were identical to those used in the first part of the study. One minor change was made in the phage typing, in that phage 71 was now included in the primary routine test dilution set, and phage 44 replaced it in pool *B*. The following code numbers† were used for the phage patterns obtained:

Group I:

IA	52A/79 or 52/52A/79
IB	29/52/52A/73/79 plus other weak reactions
IC	29/52/52A/79
ID	29/52
IE	29/53/79
IF	29/52/52A/79, *B* pool, plus other weak reactions

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† The code employed in this study is not identical to that used in Paper 1 (see p. 299).

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Group II:
- IIA 3B/3C/55 or 3C/55
- IIB 3B/55/71 or 55/71
- IIC 55

Group III:
- IIIA 42E
- IIIB 53, plus other weak reactions (47/77)
- IIIC 70 (weak)
- IIID 6/54/70, plus other weak reactions (7/47/73/75)
- IIIE 6/7/47/53/54/75
- IIIF 47/75
- IIIG 75B

Non-classifiable:
- NC 52/53+

Untypable: UT

RESULTS

Carrier rate during the neonatal period. Of the thirty-six newborn babies observed at birth, twenty-six (72%) acquired *Staph. aureus* in the nose and usually also in the throat during the first fortnight of life. Among the twenty-eight babies who were seen later, eighteen (64%) had been carriers within the first fortnight. The nasal carrier rate remained somewhat higher than the throat carrier rate during the neonatal period, but reached approximately the same level near the end of the month (Table 1 and Fig. 1).

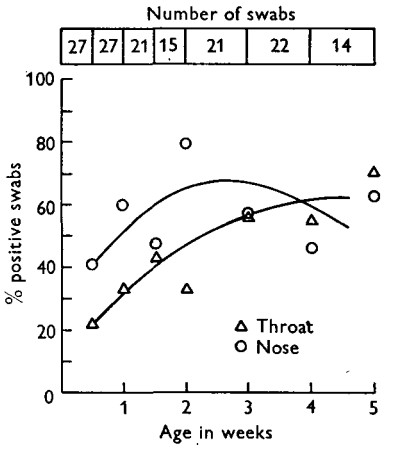

Fig. 1. Incidence of *Staphylococcus aureus* during the neonatal period.

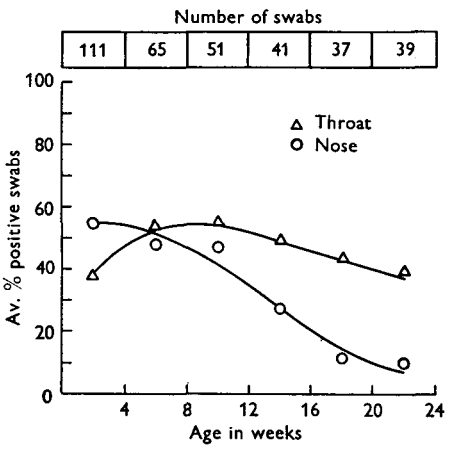

Fig. 2. Incidence of *Staphylococcus aureus* during the first 6 months of life.

Carrier rate during the later months. The nasal carrier rate declined steadily with age (Table 1 and Fig. 2), reaching a level of about 10% by the twentieth week. However, the throat carrier rate continued to increase until about the eighth week, after which it decreased slightly, but did not fall below 40%.

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Table 1. *Age distribution of* Staphylococcus aureus *among twenty-eight babies*

Age in weeks	No. of swabs	Nose cultures positive	Nose cultures %	Throat cultures positive	Throat cultures %
½	27	11	41	6	22
1	27	16	60	9	33
1½	21	10	48	9	43
2	15	12	80	5	33
3	21	12	57	12	57
4	22	10		12	
5	14	9	48	10	54
6	11	5		6	
7	18	7		7	
8	10	4		7	
9	17	8	47	9	55
10	8	2		4	
11	16	10		8	
12	9	1		5	
13	12	6	27	4	47
14	7	2		4	
15	13	2		6	
16	9	2		5	
17	8	0	11	3	43
18	7	1		3	
19	13	1		5	
20	9	1		4	
21	12	1	10	4	39
22	10	2		4	
23	8	0		3	
24	3	1		1	

Carrier behaviour. Examination of the records of the individual babies revealed that the twenty-eight babies who were followed for 15–25 weeks could be classified into three groups:

	Number	%
(*a*) 'early carriers', who acquired *Staph. aureus* within 2 weeks after birth	18	64
(*b*) 'late carriers', who did not acquire it immediately but became carriers within the first 6 weeks of life	5	18
(*c*) 'non-carriers', from whom *Staph. aureus* was cultured never more than once, or who yielded a few colonies intermittently and usually of different phage type on each occasion	5	18

The early carriers tended to follow the same carrier pattern as the hospital-born babies. As judged by phage typing, thirteen carried a single strain throughout the observation period. The other five carried two strains, both of which were acquired during the early weeks of life. As in the hospital-born group, these strains appeared initially in both the nose and throat, but tended to disappear from the nose later while persisting in the throat.

The five late carriers differed from the early carriers in that two of them carried *Staph. aureus* in their throat only throughout the observation period. The other

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three babies acquired it in the nose and throat initially—one continued to carry it in both sites, one ultimately developed negative nasal cultures, and the third lost its staphylococcus from both the nose and throat after the sixteenth week.

Of the five non-carriers, one had negative cultures throughout the 23 weeks of observation, two had positive cultures on only one occasion, the fourth had two positive cultures, but each of different phage type, and the fifth had a total of four intermittently positive cultures containing three different phage types. The strains isolated from the latter four babies were judged to be transients. The upper respiratory flora of the non-carriers did not seem to differ from that of the twenty-three carriers except in the relative absence of *Staph. aureus*.

Penicillin sensitivity and phage types. Penicillin-resistant strains were uncommon among this group of babies. They were present in five of the twenty-three carriers, and occurred as transients in two of the non-carriers.

The distribution of phage types among the twenty-three carriers is shown in Table 2. Phage patterns and penicillin sensitivity, revealed at least fourteen different strains in addition to those which could not be typed. Strains with

Table 2. *Distribution of phage types among twenty-three carriers*

Code	No. of carriers*	%
IA	2	
IA	3	
IB	2	44
IC	2	
IE	1	
IIA	5	
IIB	3	44
IIC	2	
IIIA	1	
IIIB	1	
IIIC	1	22
IIIE	1	
IIIG	1	
Non-classifiable	1	4
Untypable	2	9

* Five babies carried two strains. Penicillin-sensitive strains in italics.

phage patterns of Groups I and II were twice as common as those of Group III. The transient strains, not shown in the table, had phage patterns of IA, *IA*, *ID*, IF, *IIB*, *IIID*, *IIIF*.*

Possible sources of Staph. aureus. Although the study was not designed to determine the source of the babies' staphylococci, the data permitted some consideration of this subject.

To determine whether the positive cultures might be associated with breast feeding, the carrier and feeding records of the babies were compared. Thirteen of the twenty-three carriers were partially or wholly breast fed throughout, so their

* Penicillin-sensitive strains in italics.

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staphylococci might have been derived continuously from the maternal breast. However, several facts indicated that the other ten babies carried staphylococci independently of breast feeding:

(*a*) Four continued to be carriers for many weeks after they were fully weaned from the mother's breast.

(*b*) Two had been artificially fed from birth.

(*c*) Four ceased to be carriers while still being breast fed.

The absence of staphylococci among the five non-carriers was not associated with artificial feeding, for four of them had been breast fed for nearly half of the observation period, and one was breast fed the entire time.

It was considered possible that the carriers could have acquired their staphylococci from the midwives, as suggested by Ludlam (1953). Although the midwives themselves were never swabbed, babies cared for by the same midwife might be expected to carry the same phage type had they obtained their staphylococcus from her. The data, however, contained no indication that the midwives were necessarily responsible for the babies' staphylococci, for in no case did all of the babies swabbed by the same midwife have the same type (Table 3). When two babies delivered by the same midwife had staphylococci with similar phage patterns, these usually were also present among babies cared for by other midwives (e.g. IA, *IIA*, *IIB*). Phage types *IB*, *IIC*, and untypable strains were found only among babies delivered by midwives Sau., Wes. and Mur., respectively. While these strains, therefore, could have been transmitted by these midwives, the association also could have been due to chance because IB and IIC are fairly common phage patterns.

Comparison of staphylococcal carriage by babies born at home with those born in hospital. The incidence of staphylococci among the twenty-eight home-born babies, as compared with that of the thirty-seven hospital-born babies is shown in Table 4. During the first month of life the number of positive nasal and throat swabs was much lower among the home-born babies, the difference being highly significant. Between the fourth and fifth month there still was a considerable difference in the number of positive nasal swabs, also significant. The difference betweeen the number of positive throat swabs, however, was small and not significant.

In relation to age, the nasal and throat carrier rates of the home-born babies seemed to follow the same general trend as those of the hospital-born group. This was particularly true of the nasal carrier rates which declined in nearly even proportion to one another between the fourth and twenty-fourth weeks (Fig. 3). The throat carrier rate of the home-born babies reached its maximum more slowly than that of the hospital-born babies, but both tended to become relatively stable, with only a slight decline after about the eighth week (Fig. 3).

The incidence of penicillin-resistant strains was markedly lower among the home-born babies than among the hospital-born. Whereas 97 % of the thirty-four hospital-born babies were discharged carrying penicillin-resistant strains, only five (18 %) of the twenty-eight babies delivered at home acquired them during the entire neonatal period.

There were fewer carriers of multiple strains among the home-born babies than

Table 3. *Distribution of staphylococcal phage types among babies delivered by the same midwife*

Midwife	Baby no.	Phage types carried	Transient phage types
Ald.	180	*II A*	—
	186	*III C*	—
Btm.	168	*II A*	—
	170	*II B*	—
	175	*II B, N C*	—
	178	IIIB	—
	179	*I A*	—
	185	—	*III D, I A*
Bft.	168	*II A, III A*	—
	174	—	IA
	184	IA, *I A*	—
	190	1A, *II A*	—
Mur.	167	*II A*	—
	176	—	—
	177	—	*III F*
	183	*UT*	—
	195	*UT*	—
Sau.	169	*I B*	—
	172	*IB*	—
	189	*I C*	—
	201	*III G*	—
Svg.	183	*II B*	—
	191	—	IF, *I D, II B*
	192	*I C*	—
Wes.	173	*II C*	—
	187	IA	—
	188	*II C*, IIIE	—
	200	*I E*	—

Penicillin-sensitive strains in italics.

Table 4. *Comparison of incidence of* Staphylococcus aureus *in babies born at home and in hospital*

Age group	Place of birth	No. of swabs	Positive nose swabs		Positive throat swabs	
0–4 weeks	Home	111	61 (55 %)	$\chi^2 = 44{\cdot}17$, $P = < 0{\cdot}001$	41 (37 %)	$\chi^2 = 33{\cdot}94$, $P = < 0{\cdot}001$
	Hospital	111	105 (95 %)		85 (77 %)	
16–24 weeks	Home	76	8 (10 %)	$\chi^2 = 6{\cdot}80$, $P = < 0{\cdot}01$	31 (41 %)	$\chi^2 = 0{\cdot}58$, $P =$ approx. 0·80
	Hospital	85	24 (28 %)		47 (55 %)	

among those hospital-born (Table 5). Two different strains were obtained from only five of the home group, and none carried more than two strains. Of the hospital group, the majority (70 %) carried two or more strains although, as discussed previously, it was not always clear that each baby had acquired all its strains from the hospital.

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Although no absolute comparison can be made between the strains of staphylococci encountered in the two studies, their distribution in the broad phage pattern categories was quite different. The majority of the hospital strains had phage patterns of Group I (74%), Group III (50%) or were untypable(47%), and Group II (6%) were rare. Among the home-born babies, Group II (44%) were more numerous, while Groups I (44%), III (17%), and the untypable strains (9%) were less frequent than among the hospital group.

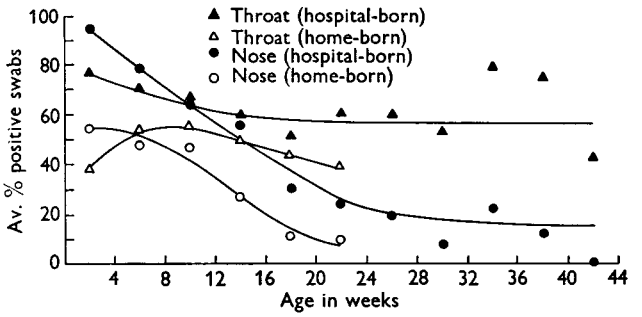

Fig. 3. Comparison of the carrier rates of the home-born and hospital-born groups.

Table 5. *Incidence of multiple-strain carriers among the home and hospital groups*

	Home		Hospital	
	No. of carriers	% of total (23) carriers	No. of carriers	% of total (37) carriers
Two strains	5	22	14	38
More than two strains	0	0	12	32

DISCUSSION

The 72% nasal carrier rate observed during the neonatal period is very similar to that obtained by Ludlam (1953) who found a nasal carrier rate of 59·3% among fifty-four 2-week-old babies born at home. Cunliffe (1949) obtained a nasal carrier rate of only 12·5% for home-born babies aged 2–8 weeks, but it was based on a small group of only eight babies. Neither of these reports demonstrated clearly that the nasal carrier rate continues to be lower than that of hospital-born babies during the later months of the first year. Although Ludlam found the nasal carrier rate among home-born babies to be significantly lower than that of hospital-born babies at the fifth month of age, he did not find any significant difference between such groups at 2 months, nor at 12–24 months. In the present study, the nasal carrier rate of the home-born babies remained significantly lower than that of the hospital-born babies throughout the period of observation. This did not apply to the throat carrier rate which was not significantly lower than that of the hospital-born group after the first month of age. It was first thought that the predominance of throat carriers among the home-born babies late in acquiring their staphylococci might explain the relatively high throat carrier rate after the first month. Examination of the data, however, did not prove this to be a fact.

The babies who acquired their staphylococci early had essentially the same carrier characteristics as those born in hospital, and again demonstrated that after the first few months staphylococci tend to be lost from the nose but retained in the throat. Although the numbers of late carriers and non-carriers was small, they seemed to indicate certain important generalizations:

(*a*) Staphylococci acquired about the end of the first month may colonize only in the throat.

(*b*) Babies who fail to become carriers within the first 2 months are likely to remain non-carriers during their first 6 months, and perhaps longer.

These tendencies are in harmony with those exhibited by the early carriers who have demonstrated that:

(1) the nasal mucosa often seems to become refractory to staphylococci, beginning about the first month,

(2) staphylococci acquired during the first month are more likely to persist in the throat than in the nose,

(3) during later months the throat does not seem to acquire new strains, in addition to those neonatally established.

It may be speculated that if babies could be protected from staphylococcal contact during their first 2 months they would not become carriers until much later in life. Cunliffe (1949) presented data indicating that the nasal carrier rate of children increased only slowly with advancing years.

The lower incidence of penicillin-resistant staphylococci among the home-born babies was as to be expected. Ludlam (1953) also found relatively few penicillin-resistant strains among home-delivered babies. Penicillin-sensitive strains seemed to be carried for as long a period as the penicillin-resistant strains, indicating that penicillin-resistant strains are not particularly adapted to establishment on the mucosa.

The staphylococcal phage patterns of the home-delivered babies, contrasted with those of the hospital group, correlates well with what is known, generally, of strains present in comparable environments in Britain. Williams and co-workers (1953) have found Group III strains to be associated particularly with hospital cross-infections, and Groups I and III most numerous in hospital neonatal infections. It is thought that strains of Group I and III are prevalent in hospitals because a high proportion of them are penicillin-resistant. Group III strains, in particular, seem unstable and most likely to give rise to antibiotic-resistant mutants. Group II strains are least likely to be antibiotic resistant, and are commonly carried in noses of healthy adults (Williams, Rippon & Dowsett, 1953; Barber & Whitehead, 1949; Barbour & Edwards, 1953). It was not surprising therefore to find strains of phage Groups I and III most common among the hospital-born babies, and Group II strains numerous among the home-delivered babies.

SUMMARY

Of thirty-six babies delivered at home 72 % acquired *Staph. aureus* in their noses and throats within their first fortnight of life. The carrier rate among the twenty-eight who were subsequently followed was 65 % during the first fortnight period.

Only 18% acquired penicillin-resistant strains, in contrast to the previously observed hospital-born group, 97% of whom acquired strains resistant to penicillin. Phage typing demonstrated that the home-born babies who acquired *Staph. aureus* during their first fortnight carried the same strains throughout the 15–25 week observation period. As in the hospital-born babies, many of them tended to lose the strains from the nose while retaining them in the throat. Strains having phage patterns of Groups I and II were most common among the home-delivered babies, whereas among the hospital-born babies Groups I, III, or untypable strains were most frequent. There was no evidence that the penicillin sensitive strains acquired from the home are carried for shorter periods than the penicillin-resistant strains of the hospital. Babies failing to acquire *Staph. aureus* within the first fortnight tended either to acquire it in the throat alone, or to remain non-carriers. It is suggested that babies who do not become carriers within the first two months of life are unlikely to do so later.

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