

INCIDENCE AND PENICILLIN SENSITIVITY OF *STAPHYLOCOCCUS AUREUS* IN THE NOSE IN INFANTS AND THEIR MOTHERS

BY G. B. LUDLAM, M.B., CH.B., D.T.M. & H., D.L.O.
Public Health Laboratory Service, Nottingham

Although a good deal is known about the incidence of nasal carriage of *Staphylococcus aureus* in infants in maternity hospitals, little is known of the incidence in infants born at home or in infants after the first few weeks of life. The work described here is an attempt to fill this gap, and at the same time to determine the relation of nasal carriage in the infant to carriage in the mother. In the latter part of the investigation the penicillin sensitivity of the strains isolated was also tested and phage-typing was used in an attempt to solve certain problems.

METHODS

Clinical material. Nasal swabbing was carried out in five Child Welfare Clinics on 530 infants aged 2 weeks to 2 years, although only a small number (57) were swabbed in their second year. The mothers of 488 of these infants were also swabbed. The clinics were visited at irregular intervals and most of the infants and mothers present at the time of the visit were swabbed. In addition to noting the age of the infant a record was kept of whether it had been born in hospital or at home. The sample of the mother-infant population examined may be regarded as representative of those who were regular attenders at the clinics. Examination of random samples of clinic records showed that a high proportion of the mothers were attending with their first or second child. As was to be expected, a higher proportion of the mothers delivered in hospital were primiparae than of those delivered at home.

At the end of the investigation nasal swabs were also cultured from nurses and infants in maternity hospitals C and F and from the mothers of the infants in hospital C. Swabs of the floor dust from the two nurseries in hospital F were also cultured for *Staph. aureus*. In the course of another investigation the Health Department ophthalmic nurse sent in eye and nose swabs from infants born at home and suffering from neonatal eye infections. Nasal swabs were also taken from the mothers. As the results already obtained in this investigation are relevant to the present work they have been included here. This group is referred to hereafter as the 'special home group'.

Cultural technique. The anterior nares and adjacent vestibule of each side were swabbed, and the swab was inoculated on to culture media less than 2 hr. after sampling. At the beginning of the investigation, in 1948-9, swabs were at first cultured in parallel on digest agar and a tellurite agar (Ludlam, 1949). As there appeared to be no significant difference in the results obtained with these two media, the tellurite agar was then used alone; the medium was found more useful for picking out scanty *Staph. aureus* colonies among numerous colonies of other

organisms. When, however, the investigation was continued in 1951 the tellurite agar in use at the time proved unusually inhibitory, and as the cause of this was not immediately apparent the work was continued with digest agar. Cultures were examined after 48 hr. incubation and suspected colonies were tested for coagulase production. After being left for at least 1 week at room temperature the plates were re-examined for any pigmented colonies that might have been overlooked.

Coagulase test. Colonies suspected of being *Staph. aureus* were tested either by the slide coagulase test (Cadness-Graves, Williams, Harper & Miles, 1943) or by inoculating a large loopful from a streak culture into 0.5 ml. of 1/10 rabbit plasma, incubating at 37° C. and examining at 3 and 18–24 hr. for clot formation. Doubtful or negative slide tests were re-examined by the tube method.

Penicillin sensitivity tests. Ninety-nine strains of *Staph. aureus* from babies and 125 from mothers have been tested. A speck of growth from a colony was streaked on an agar plate radially from a disc of filter paper containing 1.5 units of penicillin (Fairbrother & Martyn, 1951). The Oxford staphylococcus was used as a control. The method was checked by streaking any staphylococci giving doubtful results across an agar plate containing a ditch of 10 units of penicillin/ml. agar, and in some cases by testing the organism in serial dilutions of penicillin in broth.

Phage-typing. The Staphylococcus Reference Laboratory carried out phage-typing of a random sample of strains of *Staph. aureus* and also of a number of strains isolated from both the mother and her infant to determine how commonly the infant carried the same type as the mother. The strains isolated from the nurses, babies and dust of hospital F were also phage-typed.

RESULTS

The mothers and infants swabbed were grouped according to whether they were delivered in hospital C, hospital F, or at home. They were also grouped according to the infant's age into 2 weeks–2 months, 2–5 months, 5–12 months and 1–2 years. This grouping gave some samples large enough to have statistical significance.

Nasal carriage rate in infants. The essential findings are summarized in Table 1. It can be seen that there was a steady decline in the incidence of *Staph. aureus* throughout the first year in all three groups, falling to below 30% in all groups in the latter part of the year. Infants born in hospital had a much higher incidence in the first 2 months and in the last half of the year than the infants born at home, but in the 2–5-month period there was not such a clear distinction between the groups. In the first 5 months the incidence in the infants born in hospital F was significantly higher ($P = \text{approx. } 0.02$) than that for infants born in hospital C. The incidence of *Staph. aureus* in the 'special home group' was similar to that in the clinic group born at home. The figures for the second year of life were small, but the low level of the preceding months appeared to be maintained.

Nasal carriage rate in mothers. Table 2 shows that in the first 2 months the mothers delivered in hospital showed a significantly higher incidence of *Staph. aureus* than those delivered at home. After 2 months there was a tendency for the incidence to fall but the three groups showed little difference in incidence among themselves.

Relation of nasal carriage in the infant to nasal carriage in the mother. When the incidence of carriers among mothers of positive and negative infants was compared a statistically significant association between carriage in infant and mother was found in all groups of infants under 1 year old, wherever they were born. This

Table 1. *Incidence of nasal carriage of Staphylococcus aureus in infants under two years old*

Age group	Place of birth	No. of infants examined	No. positive <i>Staph. aureus</i>	% positive <i>Staph. aureus</i>
'Special home group'*		38	20	52.6
2 weeks	Hospital C	57	40	70.2
	Hospital F	29	25	86.2
	Home	54	32	59.3
2 months	Hospital C	78	30	38.5
	Hospital F	46	27	58.7
	Home	64	28	43.8
5 months	Hospital C	57	16	28.1
	Hospital F	31	9	29.0
	Home	57	5	8.7
12-24 months	Hospital C	19	3	25.0
	Hospital F	12	3	15.8
	Home	26	4	15.4

* Infants under 3 weeks old with eye infections (not necessarily staphylococcal infections).

Table 2. *Incidence of nasal carriage of Staphylococcus aureus in mothers of infants under two years old*

Age group of infant	Place of birth of infant	No. of mothers examined	No. positive <i>Staph. aureus</i>	% positive <i>Staph. aureus</i>
'Special home group'		38	34	42.1
2 weeks	Hospital C	46	26	56.5
	Hospital F	25	19	76.0
	Home	47	20	42.5
2 months	Hospital C	68	38	55.9
	Hospital F	43	25	58.1
	Home	57	28	49.1
5 months	Hospital C	57	24	40.9
	Hospital F	31	18	58.1
	Home	57	23	40.4
12-24 months	Hospital C	19	7	36.8
	Hospital F	12	5	41.7
	Home	26	12	46.1

association was most striking in the 2-5 month old group born in hospital F and in the 2 week-2 month old group born at home, but there was little evidence of association in the latter part of the first year (see Table 3). It is interesting to note that in the 'special home group', where an association might have been expected, there was no evidence of association at all.

Incidence of penicillin-sensitive strains in infants. Table 4 summarizes the results of testing for penicillin sensitivity the strains of *Staph. aureus* isolated from infants in the latter part of the investigation. The most remarkable feature of this part of

the investigation was the high incidence of resistant strains in babies born in hospital F, 12 out of 13 and 13 out of 17 strains from infants in the first two age groups being resistant. It can be seen that there was a very much lower incidence in the infants born at home, a difference in incidence which is statistically significant. The incidence in infants born in hospital C occupied an intermediate position.

Table 3. *Relation of nasal carriage rate for Staphylococcus aureus in mother and infant*

Place of birth	Age of infant	Positive infants		Negative infants		χ^2	P
		No.	% mothers positive	No.	% mothers positive		
Hospital C	2 weeks	30	63.3	16	43.7	—	—
	2 months	23	69.6	45	48.8	—	—
	5-12 months	16	56.2	41	36.8	—	—
	Total	69	63.8	102	43.1	6.07	< 0.02
Hospital F	2 weeks	22	77.3	3	66.7	—	—
	2 months	24	75.0	19	36.8	4.78	< 0.05
	5-12 months	9	44.4	23	60.9	—	—
	Total	55	70.9	45	51.1	5.0	< 0.05
Home	2 weeks	26	57.7	21	23.8	3.57	c. 0.06
	2 months	26	57.7	31	41.9	—	—
	5-12 months	5	40.0	52	40.4	—	—
	Total	57	56.4	104	37.5	4.48	< 0.05
'Special home group' 0-3 weeks		20	40.1	18	44.4	—	—

Table 4. *Penicillin sensitivity of strains of Staphylococcus aureus isolated from infants under one year old*

Age group	Place of birth	No. of strains	No. resistant strains	% resistant strains	χ^2	P
'Special home group'		16	4	25.0	—	—
2 weeks	Hospital C	17	5	29.1	60.6	< 0.01
	Hospital F	13	12	92.3		
	Home	11	4	36.4		
2 months	Hospital C	14	6	42.9	2.41	< 0.2
	Hospital F	17	13	76.5		
	Home	11	3	27.3		
5-12 months	Hospital C	7	3	42.9	—	—
	Hospital F	6	3	50.0		
	Home	3	0	0.0		

Penicillin sensitivity of strains isolated from mothers. It can be seen in Table 5 that not only had the infants born in hospital F a high incidence of resistant strains, but 20 out of 28 of the strains isolated from their mothers in the first 5 months after delivery were also penicillin-resistant. This was a very much higher proportion of resistant strains than that found in either mothers delivered in hospital C or mothers delivered at home. This high incidence of resistant strains was still very striking in the second age group (2-5 months) although proportionally they had dropped somewhat. In the later part of the first year, although the hospital F

group still had the highest proportion of resistant strains, the difference was not significant, perhaps because the samples were small. There was no clear difference between the incidence of resistant strains in mothers delivered in hospital C and in those delivered at home.

Table 5. *Penicillin sensitivity of strains of Staphylococcus aureus isolated from mothers with infants under one year old*

Age group of infant	Place of delivery	No. of strains	No. resistant strains	% resistant strains	χ^2	<i>P</i>
'Special home group'		10	1	10	—	—
2 weeks	Hospital C	16	7	43.8	1.31	{ < 0.3 > 0.2
	Hospital F	11	8	72.7		
	Home	10	2	20.0	4.17	< 0.05
2 months	Hospital C	24	3	12.5	—	—
	Hospital F	17	12	70.6	4.89	< 0.05
	Home	13	3	23.1		
5-12 months	Hospital C	11	2	18.2	—	—
	Hospital F	10	4	40.0	2.43	{ < 0.2 > 0.1
	Home	13	1	7.7		

Phage-typing. Phage-typing was done mainly to determine whether the high incidence of penicillin-resistant strains of *Staph. aureus* in the infants born in hospital F was due to infection with a particular type of staphylococcus that had established itself in the hospital environment, but also to see whether the strains found when both mother and child were infected were usually of the same type.

Among 41 typable strains isolated from infants aged 5 months or less there were 22 different phage patterns. This great variety of phage pattern was found in all three groups of infants, whether born in hospital C, hospital F or at home. Although it occurred both among penicillin-sensitive and penicillin-resistant strains it appeared to be rather less pronounced in the resistant strains; thus only 14 phage patterns were found among 24 resistant strains, and the same number were found among 17 sensitive strains. The only common type was type 52A, which occurred 8 times among the penicillin-resistant strains. No other pattern occurred more than twice. Type 52A was particularly common in strains from babies previously born in hospital F, 5 out of 13 strains (all penicillin-resistant) from infants in this group belonging to this type. When investigating the nurseries of hospital F (some months after the clinic babies in question had been born there) phage-type 52A was isolated from the nose of one nurse, from 4 out of 8 infants yielding typable staphylococci, and was found 6 times among 11 typable strains of *Staph. aureus* isolated from the dust of one nursery. All these strains were penicillin-resistant. Barber & Whitehead (1949) found type 52A the predominant type of penicillin-resistant staphylococcus in the General Lying-in Hospital and also found it the second commonest type among penicillin-resistant staphylococci isolated in other institutions. The results obtained by phage-typing strains from the mothers were very similar to those obtained with the infants in the great variety of strains isolated and the failure of any one strain to be predominant.

Strains of *Staph. aureus* isolated from 35 pairs of mothers and children were phage-typed to determine to what extent mother and infant were infected with the same type. The distinction between 'same' and 'different' types was made according to the conventions suggested by Williams & Rippon (1952). Table 6 summarizes the results. The occurrence of the same type in mother and child may be due to the association of mother and child or to infection of mother and child independently with a type of staphylococcus common in their community. Study of the phage-types carried by 37 mothers revealed 23 different types, of which 17 occurred once only and the most frequent only 7 times. In view therefore of the infrequency of most types, it may be assumed that most of the mothers and infants with the same types carried them through association.

Table 6. *Relation of the phage-type of Staphylococcus aureus in the infant to that in the mother. Age of the infants, 5 months or less*

Group	No. of mother-infant pairs with same phage-type of <i>Staph. aureus</i>	No. of mother-infant pairs with different phage-types of <i>Staph. aureus</i>
Delivered in hospital F	5	5
Delivered in hospital C	7	9
Delivered at home	7	2
Total	19	16

Staphylococcus aureus in hospitals C and F. Because infants born some months earlier in hospital C had been found to carry a smaller proportion of penicillin-resistant strains than infants of similar age from hospital F, some investigations were made in both hospitals to see if an explanation could be found.

Table 7. *Incidence and penicillin sensitivity of nasal Staphylococcus aureus in various groups in two hospitals*

Hospital	Group	No. swabbed	Penicillin-resistant <i>Staph. aureus</i> in nose	Penicillin-sensitive <i>Staph. aureus</i> in nose	Total <i>Staph. aureus</i> in nose	Incidence of <i>Staph. aureus</i> (%)	% resistant strains
C	Nurses	19	3	1	4	21.0	75.0
F	Nurses	28	12	2	14	50.0	85.7
C	Infants*						
	(a) Nursed in mothers' ward	10	3	1	4	40.0	75.0
	(b) Nursed in separate nursery	12	3	1	4	33.3	75.0
F	Infants*						
	(a) Nursery 'U'	11	4	0	4	40.7	100.0
	(b) Nursery 'D'	16	7	0	7		
C	Mothers	22	1	7	8	36.4	12.5

* Aged from 1 to 10 days.

Table 7 summarizes the results of nasal swabbing of the nurses, infants and mothers. It was thought possible that infants nursed alongside their mothers would be less likely than nursery infants to pick up resistant strains of *Staph.*

aureus, but there was no evidence of this. The high incidence of resistant strains in babies swabbed in the clinics and previously born in hospital F is understandable when it is seen that all the strains isolated from babies in this hospital were resistant, but the results do not explain why a much lower proportion of strains of *Staph. aureus* from babies born in hospital C were resistant. Forty-two out of 48 strains of *Staph. aureus* isolated from the dust in the nurseries in hospital F were penicillin-resistant and phage-typing showed that the predominant strains in the dust in one nursery were also those found in the noses of the infants of that ward.

DISCUSSION

The incidence of nasal carriage of *Staph. aureus* in these infants was similar to that found by Cunliffe (1949). Cunliffe examined only a few infants born at home, but his figures suggested a low incidence. The figures obtained in the present work, however, suggest that the rate is fairly high even in infants born at home and only a few weeks old, although it tends to be lower than in infants born in hospital. A lower incidence in home-born babies was to be expected but the extreme susceptibility of the new-born infant to *Staph. aureus* infection appeared to produce a substantial carrier rate (about 60%) even in this group.

During the first year the carrier rate in the infants fell to reach a figure much lower than in a normal adult community. The low level persisted into the second year. The incidence in infants born at home fell in the 5–12-month age group to a level (8·7%) significantly lower than in the hospital-born infants of the same ages.

In contrast, with the exception of the first 2 months after delivery, the mothers had a carrier rate similar to that found in adult groups (approximately 40–60%) and showed no distinct fall over the year. However, in the first 2 months the incidence in the hospital-delivered mothers was significantly higher than in the home-delivered mothers. This may have been due to infection of the mothers by their infants at a time when the incidence in the hospital-born infants was higher than in those born at home.

The association of nasal carriage found in all groups of mothers and infants in the first two age groups (up to 5 months old) was most distinct when birth had occurred at home, but in the 'special home group' there was no evidence of association, perhaps because this group suffered from eye infections. These findings suggest that in this group infection of the infant's nose was not commonly from the mother's nose. In infants still in hospital there is little or no connexion between carriage in infant and mother (Cunliffe, 1949; Rountree & Barbour, 1950) and association found after leaving hospital is probably due to the continued contact between mother and infant leading to a mutual sharing of a strain of *Staph. aureus* carried by either. Phage-typing showed that although mother and infant commonly carried the same type, a rather unexpectedly high proportion carried different types.

Since carriage in mother and infant in the later part of the year was not associated, the infants were probably by then often resistant to strains carried by the mothers. The low incidence in the infants also provided evidence of an increased resistance. The development of resistance is unlikely to be due to the presence of

staphylococcal antitoxin in the serum, for by the end of the first year the anti-staphylolysin titre has fallen to a low level (Bryce & Burnet, 1932). Nasal carriage tends to be associated with a high anti-staphylolysin titre (Packalén & Bergqvist, 1947; Bergqvist, 1950). Similarly the low anti-staphylolysin titre in infants at the end of 1 year may be a result of their low carrier rate. The possibility has also to be considered that resistance is due to specific antibacterial antibodies. Experimentally, inoculation of staphylococcal vaccines will produce agglutinins showing a type-specificity but giving pronounced cross-reactions (Lyons, 1937; Cowan, 1939*a*; Hobbs, 1948). However, antibacterial antibodies have been regarded as probably less effective than antitoxin (Kitching & Farrell, 1936; Downie, 1937), although Cowan (1939*b*) found that intravenous staphylococcal vaccines produced an increased resistance to infection although little or no antitoxin was detectable in the blood, but that vaccination with *Pasteurella pseudotuberculosis* produced a similar degree of protection. Lichty, Katsampes & Baum (1943) found no fall in the titre of staphylococcal agglutinins after birth, but in view of the probable type-specificity of these antibodies the results obtained probably depend partly on the particular strain of staphylococcus used in the tests. If any of the resistance of infants is due to largely type-specific antibodies, one might expect resistance to develop towards familial strains, leaving the infant susceptible to strains acquired outside the home.

The resistance produced by *P. pseudotuberculosis* described by Cowan suggests that the infants' increased resistance may be non-specific, perhaps developing from contact with the normal bacterial flora of the body surfaces, or from mild infections of various kinds. More probably a non-specific resistance may be due to local changes in the nose occurring as a result of the normal maturing of the tissues.

The very high incidence of penicillin-resistant staphylococci in infants born some months previously in hospital F suggested that penicillin-resistant strains were acquired in the hospital itself. This was confirmed when a very high proportion of strains isolated from nurses, infants and nursery dust were found to be penicillin-resistant. Similar results have been obtained by Rountree & Barbour (1950). Less easy to explain is the comparatively low incidence of resistant strains in infants born some months earlier in another maternity hospital (C). A high proportion (75%) of resistant strains was found in the infants in this hospital, both in those nursed in the mothers' ward and those segregated in nurseries. It was thought that keeping the infants separated from one another and in close contact with their mothers might have reduced the risk of their picking up hospital strains of staphylococci, but this was not so. The discrepancy between the high incidence of resistant strains in hospital C and the low incidence in the clinic babies born earlier in the hospital is not easily explained. The work in the hospital was done some months after the birth of the clinic babies and conditions in hospital C may by then have changed. Alternatively, and rather improbably, the infants from hospital C may have been able to clear themselves more quickly of the types of infecting strains then prevalent in that hospital. That a high proportion of resistant strains was still found after some months in infants born in hospital F is

evidence that staphylococci acquired shortly after birth may persist for some months without losing their penicillin resistance. It was thought that the high incidence of resistant strains in infants from hospital F might have been due to a widespread and persisting strain of staphylococcus in the hospital environment, but phage-typing revealed a number of different types in the babies at the clinics, and in the hospital itself there was no evidence of one strain predominating.

Mothers attending the clinics showed a higher incidence of penicillin-resistant staphylococci when they had been delivered in hospital. Our experience agrees with that of other workers (Allison & Hobbs, 1947; Cunliffe, 1949; Parker & Kennedy, 1949) that there is little or no evidence of transmission of nasal staphylococci from mother to infant in hospital. A mother may become infected with resistant strains independently in hospital but mothers swabbed in hospital C had a low incidence of resistant strains. Rountree & Barbour also found a low incidence in mothers in a maternity hospital. A mother does not have much time in hospital to acquire a fresh strain of staphylococcus. Probably in most cases the hospital-delivered mother acquired her penicillin-resistant staphylococcus after her return home by infection from her hospital-infected infant.

The incidence of resistant strains even in infants born at home is rather high and tends to be higher than in their mothers. Some of these infants may have been cross-infected in the clinics from hospital-born infants. The degree of exposure to resistant strains in the clinics was much less than in hospital or at home, and in the 'special home group' where few, if any, of the infants had attended a clinic, 4 out of 16 strains tested were resistant. If there is a higher proportion of resistant strains among the home-born infants than among the population generally, it is perhaps due to contact with midwives who have recently been associated with maternity hospitals.

Patients frequently acquire penicillin-resistant staphylococci during a stay in hospital or even by attending hospital out-patients departments. There is no evidence that the incidence of resistant strains has increased yet in the general population, but there is an obvious risk of gradual infiltration of the population by resistant strains derived originally from hospitals. The work described here shows how resistant strains may be brought into many homes and may persist for at least some months. To what extent these strains are passed on to other members of the family is not known.

SUMMARY

1. Among infants attending Child Welfare Clinics there was a steady decline in the incidence of nasal carriage of *Staph. aureus* over the first year of life.
2. Infants born in hospital showed a much higher incidence of *Staph. aureus* in the first 2 months of life than infants born at home. A similar difference was also very distinct in the later part of the first year of life.
3. Mothers delivered 2 weeks to 2 months previously had a higher incidence of nasal carriage of *Staph. aureus* when delivered in hospital than when delivered at home. After this interval the incidence was similar in all groups of mothers throughout the rest of the year.

4. In the first few months of life there was a tendency for carriage in infants to be associated with carriage in the mother, but towards the end of the year there was no such relationship. This association appeared most clearly in infants born at home and in infants 2-5 months old born in hospital F.

5. A very high proportion (25 out of 30) of the strains tested from infants born in hospital F less than 5 months previously were penicillin-resistant. Infants born at home had a much lower incidence of resistant strains.

6. A high proportion of strains of *Staph. aureus* isolated from mothers delivered in hospital F were resistant throughout the first year. Strains from mothers delivered in hospital C or at home showed a much lower proportion of resistant strains.

7. Phage-typing showed a great variety of types, but those found among the penicillin-resistant strains were rather less varied than among the sensitive strains. When *Staph. aureus* was found both in infant and mother, although the same phage type was commonly present in both, in 16 out of 35 couples different types were found.

8. Investigation in maternity hospitals C and F showed a high proportion of penicillin-resistant strains of *Staph. aureus* among the nurses and infants and in the dust of the nurseries, but not among the mothers. There was no important difference between the two hospitals as regards the incidence of resistant strains isolated from nurses and infants in spite of the differences found in babies from the two hospitals when swabbed at the clinics.

9. The significance of these results is discussed.

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