

A prospective study of staphylococcal infection and its prevention among infants and mothers after childbirth in hospital and at home

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In a previous investigation it was shown that infants who became heavily colonized by *Staphylococcus aureus* soon after birth subsequently developed septic infections more often than other infants (Gillespie, Simpson & Tozer, 1958). Applications of 'Ster-zac' hexachlorophane powder to umbilicus, trunk and flexures greatly reduced both staphylococcal colonization and infection in infants and mothers (Simpson, Tozer & Gillespie, 1960; Corner, Crowther & Eades, 1960). Hexachlorophane powder has been in routine use since 1959 in the Bristol Maternity Hospital and the obstetric wards of Southmead Hospital. The incidence of staphylococcal disease has remained low and the treatment has caused no ill effects in patients or staff.

The purpose of this paper is to report a more extensive investigation of colonization and infection by *Staph. aureus* during the first 6 months after childbirth in hospital and at home. Infants, mothers and members of households were studied. The prophylactic value of hexachlorophane was confirmed and the effect of disinfecting infants' noses with 'Naseptin' cream was investigated. Results of a previous investigation, hitherto unpublished, are also reported.

MATERIALS AND METHODS

The principal survey included all infants born in the Bristol Maternity Hospital (B.M.H.) and in one ward of Southmead Hospital (S.H.) between 1 November 1960 and 30 April 1962, with the exception of premature, illegitimate and multiple births. Infants who left hospital before the 8th or after the 12th day of life were also omitted from the survey, but any who stayed longer in hospital because of staphylococcal disease were included. Infants who were born at home on even dates throughout the same period constituted the domiciliary group.

A total of 1707 infants and mothers entered the survey, and 165 left it before completing 6 months—93 because they moved from Bristol, 51 because of non-cooperation, 18 because information was inadequate and 3 infants who died. No death was caused by staphylococci. No mother died. The 1542 who remained in the survey for 6 months consisted of 712 who were born at home, 267 in Southmead Hospital, 351 in Floor 2 and 212 in Floor 3 of Bristol Maternity Hospital.

Records were kept of staphylococcal disease in infants, mothers and other members of households. Lesions were classified as pyoderma (pustules, boils, styes and paronychia), maternal mastitis, staphylococcal otitis, and staphylococcal conjunctivitis. Provision was made to record other lesions such as pemphigus neonatorum, deep abscess, osteomyelitis, and staphylococcal pneumonia, but none was observed. Purulent lesions of skin or breast were counted as staphylococcal even when cultures were not performed. Mastitis which resolved without suppuration during antibiotic treatment was counted as staphylococcal.

Conjunctivitis ('sticky eye') was regarded as staphylococcal only when culture yielded a profuse growth of *Staph. aureus*.

Lesions which started in the first two weeks of life were seen by doctors in hospital and by doctors or midwives at home and nearly all were swabbed. Health visitors called on the families in the sixth week and sixth month. They saw all mothers and babies, inquired about illnesses in the households and inspected and swabbed all lesions. In addition, mothers were asked to notify immediately any lesion, however trivial, using pre-addressed stamped postcards, and to see their family doctors. The doctors reported lesions which came to their notice and swabbed any that were discharging.

Saline-moistened nose swabs were taken from mothers on admission to the Bristol Maternity Hospital and from mothers and infants of all groups between the 8th and 12th post-partum days ('2nd week swabs'). The swabs were repeated 6 weeks and 6 months after delivery. Infants who were treated with nasal cream were swabbed 24 hr. after its last application. The bacteriological methods were described by Simpson *et al.* (1960). Most staphylococci were phage-typed (Anderson & Williams, 1956).

The nature of illnesses requiring admission to hospital was determined and the causes of all deaths ascertained by *post mortem*. Factors which might have influenced susceptibility to infection were recorded; these were sex, season of birth, maternal age, number and ages of others in household, parents' occupations, district, Registrar General's social class, quality of mothercraft, breast or artificial feeding and the types of baby powders and creams used at home. Data were entered on special forms by midwives, health visitors and bacteriologists and after coding were transferred to punched cards for analysis.

Prophylactic disinfectants

In accordance with routine practice, the umbilicus, trunk, groin and perineum of every infant in hospital were liberally dusted with 'Ster-zac' powder about 6 hr. after birth and again every time their napkins were changed (Simpson *et al.* 1960). The powder contains hexachlorophane 0.33%, in a pre-sterilized base. In addition, infants in Floor 2 of Bristol Maternity Hospital were treated once a day with 'Naseptin' nasal cream, which was smeared inside the anterior nares by means of sterile glass rods, followed by gentle massage of the nose. The cream contains neomycin 0.5% and chlorhexidine 0.1%. The effect of 'Naseptin' alone was not studied because it was not considered justified to stop the use of hexachlorophane.

Mothers were not advised to use any particular baby powder after leaving hospital, but some continued to use 'Ster-zac' for varying periods. 'Naseptin' was not used outside hospital.

In the domiciliary group, 'Ster-zac' was applied to the umbilicus during the first two weeks of life.

RESULTS

Analysis of factors that might have influenced susceptibility to infection revealed the following differences between the groups. In the domiciliary group, mothers were on average older than those in hospital and had larger households and higher proportions were in social classes 4 and 5. Mothers in Southmead Hospital were on average older, their parity was greater and their social class lower than in Bristol Maternity Hospital. There were more primagravidae and a smaller average size of household in Floor 3 than in Floor 2 of Bristol Maternity Hospital. The proportions of mothers who breast-fed their infants did not differ greatly (Table 1). None of these differences could be shown to influence staphylococcal colonization or infection.

Table 1. *Percentage of mothers who breast-fed their infants*

Duration of breast feeding	Place of birth			
	Hospital			At home
	B.M.H.		S.H.	
	Floor 2	Floor 3		
At least 2 weeks	84	88	77	80
At least 6 weeks	48	46	30	38
At least 6 months	18	14	10	10

Staphylococcal infection in infants

The incidence of staphylococcal disease was low in all groups (Table 2). No infection was severe nor required admission to hospital.

Previous surveys in both hospitals showed that the incidence of pyoderma during the first 2 weeks of life fell promptly to about one-fifth of its former value when hexachlorophane was introduced in 1959. Comparison with infants of the present series during their first 2 weeks showed that infection rates had remained low and confirmed the value of hexachlorophane (Table 3). Comparison of the B.M.H. groups in the present series (Table 2) showed that the use of 'Naseptin' in addition to hexachlorophane was accompanied by a further significant reduction of infection. A comparison of the total staphylococcal infections in the two floors gave a significant difference ($P = 0.0196$ by Fisher's Exact Probability Test). The infection rate in Floor 2, where both hexachlorophane and 'Naseptin' were used, was almost identical with the domiciliary rate.

Table 2. *Staphylococcal disease in infants during first 6 months of life (1960-62)*

Place of birth	Disinfectant treatment	No. of infants observed for 6 months (M = male, F = female)	Infants with staphylococcal lesion		
			Pyoderma	Conjunctivitis and otitis	Total infants infected
At home	Hexachlorophane to umbilicus	M 377	4	1	5
		F 335	5	4	7
		Total 712	9 (1.3%)	5 (0.7%)	12* (1.7%)
B.M.H. 2	Hexachlorophane to umbilicus, groin and perineum. 'Naseptin' to nose	M 117	2	0	2
		F 174	2	3	5
		Total 351	4 (1.1%)	3 (0.9%)	7 (2.0%)
B.M.H. 3	Hexachlorophane to umbilicus, groin and perineum	M 97	8	5	12
		F 115	0	0	0
		Total 212	8 (3.8%)	5 (2.4%)	12* (5.7%)
S.H.	Hexachlorophane to umbilicus, groin and perineum	M 138	3	1	4
		F 129	3	1	4
		Total 267	6 (2.2%)	2 (0.7%)	8 (3.0%)

* Some of these infants had pyoderma and conjunctivitis.

Sex distribution of infection

Elias-Jones, Gordon & Whittaker (1961) recorded a moderate but statistically significant excess of staphylococcal infection in male infants. Helms & Stenderup (1961) found no difference between boys and girls who were born in hospital, but slightly more boys than girls were infected after domiciliary delivery. Thompson *et al.* (1963) found a large excess of infection in males and suggested that it might be related to circumcision (Gezon *et al.* 1964). Plueckhahn & Banks (1964*a*) also found more infection in males, though few were circumcised. Williams (1964) found slightly more infections in boys, though the excess was not statistically significant.

In the present study, no sex difference was found except in B.M.H. Floor 3, where all pyoderma lesions were in boys (Table 2). The reason for the difference is not known. No infants were circumcised while in hospital.

Table 3. *Effect of hexachlorophane powder on the incidence of pyoderma in the first 2 weeks of life*

Disinfectant treatment	Previous investigations* (1957-60)		Present investigation (1960-62) Hexachlorophane
	None	Hexachlorophane	
Incidence of pyoderma			
Hospital			
B.M.H. Floor 2	19/365 (5.2%)	5/554 (0.9%)	0/351 ('Naseptin' was also used)
B.M.H. Floor 3	34/464 (7.3%)	—	5/212 (2.4%)
S.H.	277/3721 (7.4%)	54/3650 (1.5%)	1/267 (0.4%)

* See Simpson *et al.* (1960) and Corner *et al.* (1960).

Infection in mothers and households

The incidence of staphylococcal disease in mothers was low and similar in all groups (Table 4). This result differed markedly from that observed before hexachlorophane was introduced, when mastitis was much commoner after hospital than domiciliary delivery (Corner *et al.* 1960). All but one of the cases of mastitis were in mothers who breast-fed their infants for at least 1 week.

Infection usually came later in mothers than in infants, 84% of maternal lesions beginning after the second post-partum week, compared with 44% of infants.

The incidence of staphylococcal disease in other members of households did not differ significantly between the groups.

Phage patterns of the staphylococci

As previously observed (Gillespie *et al.* 1958), most hospital infections were by phage group I strains, usually penicillin-resistant. Few were resistant to other

Table 4. *Staphylococcal disease in mothers during the 6 months after delivery*

Where delivered	Disinfectant treatment of infants	No. of mothers observed for 6 months	Mothers with staphylococcal disease			Total
			Pyoderma	Mastitis	Otitis	
At home	Hexachlorophane to umbilicus	712	13 (1.8%)	7 (1.0%)	0	20 (2.8%)
B.M.H. 2	Hexachlorophane to umbilicus, groin and perineum. 'Naseptin' to nose	351	6 (1.7%)	2 (0.6%)	0	8 (2.3%)
B.M.H. 3	Hexachlorophane to umbilicus, groin and perineum	212	4 (1.9%)	3 (1.4%)	0	7 (3.3%)
S.H.	Hexachlorophane to umbilicus, groin and perineum	267	7 (2.6%)	1 (0.4%)	1 (0.4%)	8 (3.0%)
	Total hospital deliveries	830	17 (2.0%)	6 (0.7%)	1 (0.1%)	23 (2.8%)

Table 5. *Pyoderma in infants during the first 6 months of life in relation to nasal carriage of staphylococci in the second week*

Place of birth...	At home	B.M.H. 2	B.M.H. 3	S.H.	All	Incidence of pyoderma (number of infants infected/number in group)		
						During 1st 2 weeks	After 2nd week	Total
<i>Staph. aureus</i> absent	2/380	3/244	1/90	2/169	6/883	8/883 (0.9%)		
<i>Staph. aureus</i> present	7/312	1/57	6/98	4/91	7/558	18/558 (3.2%)		
<i>Staph. aureus</i> present (penicillin resistant)	2/113	1/37	5/58	4/52	8/260	12/260 (4.6%)		
<i>Staph. aureus</i> present (penicillin sensitive)	5/199	0/20	1/40	0/39	3/298	6/298 (2.0%)		
Not swabbed	0/20	0/50	1/24	0/7	1/101	1/101 (1.0%)		
Total	9/712	4/351	8/212	6/267	9/1542	19/1542 (1.8%)		

The totals for the two periods do not always agree with the total number of infants infected. One infant with penicillin sensitive *Staph. aureus* in its swab had an attack of pyoderma in the first two weeks and another attack later.

antibiotics. There was no predominant epidemic strain. Several mothers were infected by strains which had colonized their infants.

Most domiciliary infections were caused by group II strains which usually were penicillin sensitive.

Effect of infants' staphylococcal carriage on infection among infants and mothers

As previously demonstrated, infants who quickly became staphylococcal carriers developed pyoderma more often than others. In the present series 3.2% of infants who were nasal carriers in the 2nd week suffered from pyoderma, compared with 0.9% of non-carriers (Table 5). The difference was highly significant: by Fisher's Exact Probability Test, $P = 0.00145$. The incidence of sepsis was slightly but not significantly higher among carriers of penicillin-resistant than of sensitive strains, $P = 0.067$.

The incidence of mastitis was 1.8% in mothers of nasal carriers compared with 0.1% in mothers whose infants were not carriers (Table 6). This difference was highly significant; by Fisher's Exact Probability Test, $P = 0.00052$. In those who were swabbed, there was only one case of mastitis among mothers of infants who were not carriers when 2 weeks old.

Sepsis other than mastitis was only slightly and not significantly commoner in mothers of nasal carriers (Table 6).

Comparison of infection rates in the B.M.H. groups (Table 2) showed that the use of 'Naseptin' in addition to hexachlorophane gave increased protection against sepsis in infants. Comparison with earlier reports suggested that hexachlorophane played the greater part (Table 3). This was consistent with the fact that the umbilicus and flexures are generally colonized before the nose, at an age when the skin is very susceptible to infection (Gillespie *et al.* 1958). Jennison & Komrower (1961) showed that 'Naseptin' by itself reduced nasal colonization and slightly reduced skin infection.

There were slightly fewer infections in mothers of infants who were treated with 'Naseptin' than in other mothers (Table 4), but the difference was not significant. However, the relationship between maternal mastitis and infants' nasal carriage, described above, showed that the treatment of infants must have protected some mothers from breast abscess.

Influence of disinfectant treatment of infants on staphylococcal nasal carriage by infants and mothers

After the first week or two of life the infant's nose is perhaps the principal source from which staphylococci are transmitted from the maternity hospital to the community outside. It was hoped that nasal disinfectant treatment would reduce this source of dissemination and to some extent it did so (Table 7). At the age of 2 weeks infants in B.M.H. Floor 2, where 'Naseptin' was used, had a nasal carrier rate of 19% compared with 51% in Floor 3. This difference is highly significant ($\chi^2 = 64.637$; $P < 0.001$). By the 6th week, the rates were 43% and 53% respectively, and the difference was still significant ($\chi^2 = 5.294$; $P < 0.05$). There was no significant difference between the rates at 6 months, which by then

Table 6. *Staphylococcal disease in mothers in relation to nasal carriage of Staph. aureus by their infants in the second week of life*

Place of delivery	In hospital						All							
	At home		B.M.H. 2		B.M.H. 3		S.H.							
	P*	M*	P	M	P	M	P†	M	Pyoderma†	Mastitis	Total			
<i>Infant's nose swab</i>														
<i>Staph. aureus</i> absent	7	+ 1	4	+ 0	2	+ 0	2	+ 0	15	(1.7%)	1	(0.1%)	16	(1.8%)
	380		244		90		169						883	
<i>Staph. aureus</i> present	6	+ 6	1	+ 0	2	+ 3	4	+ 1	13	(2.3%)	10	(1.8%)	23	(4.1%)
	312		57		98		91						558	
<i>Staph. aureus</i> present (penicillin resistant)	1	+ 2	0	+ 0	1	+ 1	2	+ 0	4	(1.5%)	3	(1.2%)	7	(2.7%)
	113		37		58		52						260	
<i>Staph. aureus</i> present (penicillin sensitive)	5	+ 4	1	+ 0	1	+ 2	2	+ 1	9	(3.2%)	7	(2.4%)	16	(5.4%)
	199		20		40		39						298	
Not swabbed	0	+ 0	1	+ 2	0	+ 0	1	+ 0	2	(2.0%)	2	(2.0%)	4	(4.0%)
	20		50		24		7						101	
Total	13	+ 7	6	+ 2	4	+ 3	7	+ 1	30	(1.9%)	13	(0.8%)	43	(2.8%)
	712		351		212		267						1542	

* P = pyoderma. M = mastitis
 † Including 1 case of otitis in a mother whose infant carried penicillin resistant *Staph. aureus*.

Table 7. *Staphylococcal nasal carriage by infants and mothers 2 weeks, 6 weeks and 6 months after delivery (1960-62)*

Where delivered	Infants			Mothers		
	2 weeks	6 weeks	6 months	2 weeks	6 weeks	6 months
At home	327/727 (45%)	257/706 (36%)	133/701 (19%)	264/710 (37%)	279/703 (40%)	260/692 (38%)
Hospital						
B.M.H. 2	63/334 (19%)	154/359 (43%)	77/341 (23%)	113/331 (34%)	164/358 (46%)	137/341 (40%)
B.M.H. 3	113/220 (51%)	115/218 (53%)	50/205 (24%)	75/218 (34%)	100/221 (45%)	84/204 (41%)
S.H.	101/283 (36%)	123/273 (45%)	56/256 (22%)	87/279 (31%)	128/271 (47%)	105/253 (42%)

The disinfectant treatment of infants is shown in Table 2

Table 8. *Staphylococcal nasal carriage by infants and mothers in relation to disinfectant treatment of infants (investigations of 1959)*

Treatment	Infants. Proportions of swabs positive		Mothers. Proportions of swabs positive		
	2 weeks after birth	6 weeks after birth	On admission to hospital	2 weeks after delivery	6 weeks after delivery
Group 1. Non-disinfectant powder	42/47 (89%)	82/107 (77%)	31/91 (34%)	54/109 (49%)	99/132 (75%)
Group 2. Hexachlorophane powder	28/52 (54%)	36/67 (54%)	30/90 (33%)	33/82 (40%)	33/69 (48%)
Group 3. Hexachlorophane powder and 'Naseptin'	9/96 (9%)	55/168 (33%)	73/210 (35%)	51/152 (34%)	82/198 (41%)

Tests of significance for the differences between carrier rates	
Infants	Mothers
Between groups (1) and (2) At 2 weeks $\chi^2 = 15.034$ $P < 0.001$	At 2 weeks $\chi^2 = 1.631$ Not significant
At 6 weeks $\chi^2 = 9.903$ $P < 0.01$	At 6 weeks $\chi^2 = 14.842$ $P < 0.001$
Between groups (2) and (3) At 2 weeks $\chi^2 = 35.577$ $P < 0.001$	At 2 weeks $\chi^2 = 1.036$ Not significant
At 6 weeks $\chi^2 = 8.896$ $P < 0.01$	At 6 weeks $\chi^2 = 0.858$ Not significant
	Between groups (1) and (3) At 2 weeks $\chi^2 = 6.749$ $P < 0.01$
	At 6 weeks $\chi^2 = 36.075$ $P < 0.001$

had fallen to less than 30% in all groups, in accordance with the findings of Ludlam (1953). The nasal carriage rates in all four groups of mothers were almost identical at the three times of swabbing (Table 7).

The previous investigation

The actions of hexachlorophane and 'Naseptin' on staphylococcal nasal carriage were shown more clearly in an earlier investigation. Three groups of infants and their mothers were studied in the Bristol Maternity Hospital in 1959. In one group, the control, infants were treated for 2 weeks with a non-disinfectant dusting powder ('Ster-zac' base) at every napkin change; in another group they were treated with 'Ster-zac' hexachlorophane powder and in a third with 'Naseptin' nasal cream as well as 'Ster-zac'. The cream was applied twice a day, i.e. more

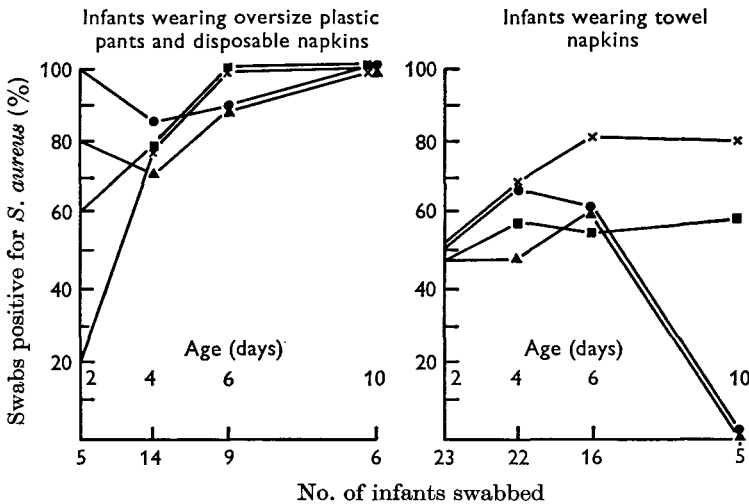


Fig. 1. Influence of clothing on staphylococcal colonization of newborn infants. x—x, Nose; ●—●, umbilicus; ■—■, perineum; ▲—▲, groin.

often than in the subsequent investigation. Four weeks after stopping treatment the hexachlorophane-treated infants still had a significantly lower nasal carriage rate than the control group. The group treated with hexachlorophane and 'Naseptin' had an even lower rate. The mothers of both groups of treated infants had significantly lower carriage rates than those of the control group (Table 8).

Skin moisture and staphylococcal carriage

Staphylococci on newborn infants' skin are usually most numerous in the umbilical area, groin, perineum and other flexures. Before hexachlorophane treatment was instituted, swabs from these areas often gave profuse growths of staphylococci, whereas those from the back of the neck and thorax gave only scanty growth or were negative. The moist skin of flexures appeared to encourage staphylococcal multiplication. Support for this belief was inadvertently obtained during a short period in 1959 when infants in a nursery where hexachlorophane

was not used were dressed in plastic waterproof pants worn outside their napkins. The pants were too large and covered most of the thorax as well as abdomen and thighs. During this period staphylococcal colonization increased (Fig. 1). Profuse growths were obtained from the front and back of the thorax, areas which normally yielded few staphylococci. Subsequently it was found that smaller pants could be worn without encouraging the growth of staphylococci, at any rate when the infants were treated with hexachlorophane powder.

DISCUSSION

The newborn infant's umbilicus, skin flexures and nose are remarkably susceptible to colonization by *Staph. aureus*. Susceptibility may be further increased by unsuitable garments which cause excessive moisture of the skin. The staphylococci, derived originally from adults, are often transmitted from baby to baby in hospital. The fact that disinfection of nurses' hands reduced cross-infection among infants showed that handling is an important mode of transmission (Gillespie *et al.* 1958).

The more rapid and profuse the colonization of an infant the more liable are he or his mother to clinical infection. Most sites of staphylococcal colonization of infants are superficial and accessible to topical disinfection. Repeated application of hexachlorophane to skin and umbilicus reduces colonization and consequently infection. The remarkable protection afforded by hexachlorophane described by Farquharson, Penny, Edwards & Barr (1952), has been amply confirmed (Simpson *et al.* 1960; Payne, Wood, Karakawa & Gluck, 1965). It contrasts strikingly with the prophylactic failure of systemic antibiotics described by Forfar *et al.* (1966).

Treatment of infants with hexachlorophane reduces the incidence of breast abscess in mothers (Corner *et al.* 1960; Plueckhahn & Banks, 1964*b*).

Most authors have described the use of hexachlorophane in baths. Dusting with a pre-sterilized powder containing hexachlorophane may be used instead by those who prefer to avoid frequent bathing of infants before the umbilical cord stump separates. Our experience and that of Hughes (1961) showed that the powder is convenient and effective. It must be applied, at every napkin change (i.e. 6-8 times a day), to the umbilical area, perineum and flexures.

Hexachlorophane treatment of skin and umbilicus reduced nasal carriage, probably because the nose is often colonized by staphylococci from the umbilicus (Gillespie *et al.* 1958). Nasal carriage and sepsis were further reduced when infants were treated with 'Naseptin' nasal cream in addition to hexachlorophane. The incidence of maternal breast abscesses, already very low in all groups, was not significantly less in mothers of infants who were treated with 'Naseptin'. But since breast abscesses were almost entirely confined to mothers whose infants were nasal carriers by the second week, the risk of this complication must have been reduced by 'Naseptin'.

Staphylococcal sepsis in many centres, including Bristol, in the past has been commoner after hospital than after domiciliary delivery. Such differences can be abolished by an efficient antiseptic regime.

The diminution of nasal carriage in infants which resulted from their treatment with disinfectants in hospital persisted after they went home. Colonization of mothers' noses was also diminished and the spread of hospital staphylococci into the general population presumably was reduced.

Of the two prophylactic agents studied in these trials, hexachlorophane was the more beneficial and was easier to use. 'Naseptin' was difficult to apply correctly and required frequent supervision of the nursery staff. It is therefore doubtful whether the routine use of 'Naseptin' is worth while. It might be valuable as an occasional supplement to hexachlorophane, for example, to control cross-infection by an unusually virulent or transmissible staphylococcus, except when the strain is resistant to neomycin.

SUMMARY

Staphylococcal colonization and infection were studied prospectively in infants, mothers and households after childbirth at home and in hospital. Infants were treated prophylactically with frequent applications of 'Ster-zac' hexachlorophane dusting powder. Some were treated in addition with 'Naseptin' nasal disinfectant cream.

The incidence of staphylococcal sepsis in infants was much less than before the adoption of hexachlorophane prophylaxis. The sepsis rate was further reduced when 'Naseptin' was used in addition to hexachlorophane. Of the two prophylactic agents, hexachlorophane was the more convenient and probably the more effective. 'Naseptin' was difficult to employ correctly and unsuitable for routine use.

The treatment of infants with disinfectants reduced nasal carriage markedly in infants and to a smaller extent in mothers. Both agents contributed to the reductions which persisted for some weeks after treatment ceased.

Breast abscesses were almost entirely confined to mothers of infants who became nasal carriers by the second week of life.

Staphylococcal colonization of infant's skin was greater when they wore impervious garments, probably because skin moisture increased.

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