ACQUISITION OF *STAPH. AUREUS* BY NEWBORN BABIES IN A HOSPITAL MATERNITY DEPARTMENT

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In hospital nurseries it has been repeatedly found that *Staphylococcus aureus* can be isolated from the noses of practically all newborn babies during the first two weeks of life (Cunliffe, 1949; Barber, Wilson, Rippon, and Williams, 1953). The way in which staphylococci spread in nurseries is unknown, although it has been shown that babies are not often colonized by their mother's staphylococci (Rountree and Barbour, 1950; Ludlam, 1953; Barber *et al.*, 1953).

The present investigation was an attempt to throw some light on the routes by which staphylococci spread in the infants' nurseries in this hospital. We began with the knowledge that virtually all our full-term babies acquired staphylococci in their noses in the first few days of life, and we hoped that, by excluding in turn each component of the babies' environment which might be responsible for contamination with staphylococci, we might be able to trace at least some of the normal routes of spread.

It does not necessarily follow that staphylococci causing clinical infection spread by the same routes as those responsible for symptomless colonization of the nose, but it is reasonable to think that some of the routes may be the same. If this is so, discovery of normal routes of staphylococcal spread might assist in devising measures for the control of spreading staphylococcal sepsis.

Methods

The Nurseries.—One of the two nurseries involved was a large airy room (34 by 21 by 12 ft.; 10.4 by 6.4 by 3.7 m.) containing 11 cots, each cot being approximately 2 ft. (60 cm.) from its neighbour. The other nursery, although considerably smaller (10 by 21 by 12 ft.; 3 by 6.4 by 3.7 m.) held the same number of cots, spaced approximately 1 ft. (30 cm.) from each other.

Babies.—All babies coming to the nurseries were full-term and breast-fed, being taken to their mothers. Where breast-feeding did not become established, the baby was nevertheless put to the breast four-hourly. Babies and mothers normally went home on the 14th day.

Staff.—The permanent nursing staff consisted of between 7 and 9 midwives, with at any one time about 7 junior nurses. The babies might be visited by any of 12 members of the medical staff and approximately 10 students, but only 5 of these 22 people were normally likely to handle them.

Nursing Procedures.—Babies were bathed at birth. Thereafter the face and nappie area were washed in water, but the whole baby was not bathed until the 13th day. From the third morning they were oiled all over with liquid paraffin. No masks or gowns were worn by nurses as a routine, and a bactericidal hand cream was not used.

Bacteriology.—Noses were examined by rubbing dry cotton-wool swabs six times round the inside of each nostril. Cultures were made on 5% horse-blood-agar plates, and this medium was also used for other cultures, except

in the case of stools, which were inoculated on to 8% salt agar plates. Bedding and gowns were examined by the sweep-plate method (Williams, quoted by Blowers and Wallace, 1955). Staphylococci which coagulated plasma in a tube were regarded as *Staph. aureus*.

Carriage of *Staph. aureus*

Nasal swabs were taken daily, with the occasional exception of Sundays, from 53 newborn babies. By the 10th day all the babies had staphylococci in their noses, and the rate at which they acquired them is given in the Table (see "control"). Forty-four stools from 12 babies were

Nasal Carriage of *Staph. aureus* by Newborn Babies. Babies Becoming Carriers on Successive Days of Life

Day of Life	Control	Chlorhexidine	Gown	Individual Gown	Triple Dye	Individual Gown and Triple Dye
1.. .. .	1	—	1	—	4	—
2.. .. .	9	4	2	1	1	1
3.. .. .	8	2	2	3	2	6
4.. .. .	16	5	3	3	5	3
5.. .. .	6	4	11	3	3	5
6.. .. .	4	3	4	4	5	2
7.. .. .	5	8	2	3	9	1
8.. .. .	3	—	4	2	5	—
9.. .. .	—	1	1	1	—	1
10.. .. .	1	—	2	1	2	1
11.. .. .	—	—	1	1	1	1
12.. .. .	—	1	—	—	1	1
Babies still negative on 12th day ..	—	3	2	7	17	8
Total ..	53	31	35	29	55	30
Median day ..	4	6	5	7	7	5

examined: 23 of these specimens contained staphylococci, and with one exception all the babies were found at some time to be positive. The negative baby was discharged home after only six days.

Role of Bedding.—Blankets from 16 babies were examined daily, and in each case the blankets were found positive before the baby's nose. The number of staphylococcal colonies per sweep-plate varied from 1 to 73 from any one blanket. Each new baby started with fresh blankets, but conventional laundering is known not to rid blankets of staphylococci. Sixteen blankets returned from the laundry were examined: eight were found to carry staphylococci. In view of this it was decided to see the effects of nursing 10 babies in sterilized bedding. After birth these babies were placed in cots containing autoclaved bedding, and when any changes were required the bedding was replaced with sterile bedding. This procedure, which could be used only on a limited experimental scale because it damaged the blankets, was continued until the baby became a nasal carrier. All 10 babies became carriers between the 2nd and the 10th day. In eight cases examination of the bedding on the first day failed to yield staphylococci, although for all but 2 of the 10 babies the bedding became positive before the baby. In the two exceptions the baby and the bedding were found to be positive for the first time on the same day. These results suggested that, although babies might acquire staphylococci from their bedding, the bedding was not in the first instance responsible.

Role of Staff.—Staphylococci might spread directly from the staff to babies in several ways. Babies must be handled, and they are frequently in contact with the nurses' clothes. To try to block the passage of staphylococci from attendants to babies, a trial was begun which involved 95 babies. One feature common to all the babies was that two months before the trial began chlorhexidine ("hibitane") hand-cream (1% in a water-miscible base) was placed at wash-basins, and those who handled the babies were asked to use the cream every time they washed their hands. With chlorhexidine cream as the only departure from normal practice 31 babies were watched in three months. Twenty-nine

of them were carriers by the end of their stay in hospital, and for the first time in this examination two babies left the hospital not carrying staphylococci in their noses (see Table), and three were free from staphylococci after 12 days.

Staff Gowns.—In addition to the hand-cream babies, a further 35 babies were looked after by nurses and medical staff wearing gowns over their usual uniforms. These gowns were clean daily, but no attempt to confine one gown to one baby was made. Once on, the gown might be worn by a nurse during the toilet of several babies. This procedure had the same effect as chlorhexidine hand-cream alone, two of the babies being free from staphylococci at 12 days. A possible explanation for the lack of effect of the gowns was that the practice of attending to several babies wearing the same gown meant that a baby might get from the gown staphylococci deposited there by preceding babies. Support for this idea was obtained by examining gowns in the nursery during the late afternoon on five days. *Staph. aureus* was isolated from 11 of the 18 gowns examined. The obvious alternative was to provide each baby with its own attendant's gown. This scheme had the drawback that while a nurse was handling a baby she was unable to respond to any other calls without first taking off the gown, but it was carried out for 29 babies. The results (see Table, "individual-gown" babies) suggested that the gown was of some value in addition to the hand-cream, as 7 of the 29 babies were free from staphylococci at 12 days. It should be made clear that, while a general measure, such as the use of hand-cream, related to all babies, it was not possible to use gowns for all the occupants of a nursery at once. During the trials of gowns, therefore, the nurseries contained babies attended to with gowns and babies nursed normally.

Role of the Umbilical Cord.—Jellard (1957) confirmed other authors' reports of the frequency with which umbilical cords are colonized by *Staph. aureus*. She suggested that cords might be a source from which staphylococci could spread, and claimed that by treatment of the umbilical cord with triple dye the spread could be reduced. We have used this method for 55 babies. At birth triple dye* was painted on and around the umbilical cord, and thereafter every morning until separation took place. The cords were left uncovered. Of these 55 babies, 17 were still not nasal carriers of staphylococci on the 12th day.

Combination of Individual Gowns and Triple Dye.—As individual gowns and triple dye both appeared to be in some degree effective in preventing colonization of babies' noses, it was decided to try the effect of both methods combined. While this was being done, all the babies in the nursery were treated with triple dye, but, as before, only two at a time were nursed with individual gowns. Of 30 babies, 8 were free from staphylococci in their noses after 12 days.

Mothers and Babies

We did not at first look to see if there was any relation between staphylococci in babies' and mothers' noses in view of other workers' repeated findings to the contrary. It was, however, possible that some of the measures taken had altered the situation, and that babies might now be obtaining their mother's nasal staphylococci. We did not find this to be so. Fifty mothers with 51 babies provided 21 pairs where both mother and baby were nasal carriers. Of these, in 10 cases the staphylococci differed in their sensitivity to antibiotics; of the other 11 pairs, in 9 cases the phage types were different. Two pairs had the same phage types, but in each case the baby was carrying another staphylococcus with a different antibiotic sensitivity. Additional proof was that for 24 pairs the baby was a nasal carrier while the mother was not.

If babies are not commonly infected with their mother's nasal staphylococci, it is possible that they obtain staphylococci from the area with which they are in closest contact—the breast. To test this, 20 mothers and babies were

examined daily (gowns and chlorhexidine hand-cream were not in use). In nine cases the baby became a nasal carrier before staphylococci were isolated from the mother's breast, in seven staphylococci were isolated for the first time from mother and baby on the same day, and in four staphylococci were recovered from the mother before the baby.

This suggested that the baby might be responsible for depositing staphylococci on the breast, as suggested by Duncan and Walker (1942), and sensitivity testing showed that in most cases the baby's nasal staphylococcus and the mother's breast staphylococcus were alike. Phage-typing confirmed this, as of eight pairs examined six were of the same phage type.

Sepsis.—There was no obvious epidemic of sepsis amongst the babies during this investigation. *Staph. aureus* was isolated from such lesions as whitlows, septic spots, or sticky eyes in 35 of 541 babies. There were in addition 40 babies with septic lesions from whom either swabs were not taken (18 babies) or from whom staphylococci were not isolated (22 babies).

Throughout the investigation no evidence was obtained that the carriage rate differed in the two nurseries.

Discussion

As it appeared that all our babies were colonized by staphylococci during their stay in hospital, this investigation was begun in the optimistic hope that, by blocking one or more routes by which staphylococci might spread, colonization could be prevented and the route identified.

Babies must be handled, and Murray and Calman (1955) used chlorhexidine cream to eliminate staphylococci from the hands of attendants. In our case this measure had some effect, seeing that of 31 babies 3 were still free from staphylococci in their noses on the 12th day. This rate was not improved on when the nurses wore gowns, probably because the babies seen to first left their staphylococci on the gowns for those dealt with later. The solution to this difficulty was to use one gown for one baby, and in this way 7 of 29 babies reached the 12th day free from staphylococci.

If this suggested that a proportion of babies acquired staphylococci from their attendant's hands or clothes, the reduction in nasal carriage by painting the umbilical cord with triple dye was presumably due to a different mechanism, and indicated the importance of the umbilical cord as a breeding-ground for staphylococci.

The final experiment in which individual gowns and triple dye to umbilical cords were used together showed that the two methods in combination were no better than each method by itself in preventing colonization of the babies' noses by the 12th day (see Table).

It is tempting to suggest from this that babies differ in their susceptibility to staphylococci and that the proportion of babies protected from staphylococci by either triple dye or individual gown represents the same proportion of babies—that is, those with a slightly greater resistance to staphylococci. Combination of the two methods may again only have picked out the same proportion of babies.

Looked at in another way, it suggests that perhaps about three-quarters of our babies acquired their staphylococci in some other way than direct from their attendants. This route we have not yet been able to identify. From a total of 420 c.ft. (11.9 cu.m.) of air examined in the course of eight months we isolated 22 colonies of *Staph. aureus*, and further work may show that aerial spread plays a significant part in the dissemination of staphylococci in our nurseries.

In agreement with other authors, no evidence was obtained that mothers were the source of their offspring's staphylococci, and, in fact, there was a strong suggestion that mothers' breasts acquired staphylococci from the babies. If this is so it would explain why staphylococci isolated from breast abscesses of mothers delivered in hospital are usually resistant to penicillin, although the mother herself may not have become a nasal carrier of a hospital antibiotic-resistant organism.

*Triple dye=brilliant green 2.29 g., proflavine hemisulphate 1.14 g., crystal violet 2.29 g., water 1,000 ml.

Summary

An investigation amongst full-time newborn babies in two nurseries has been carried out in an attempt to discover the usual routes of spread of *Staph. aureus*.

Initially 53 babies were all found to be nasal carriers by the 10th day, and 11 out of 12 of these babies also carried staphylococci in their stools. Examination of bedding suggested that this was not the immediate source of staphylococci, and prevention of possible contamination from the staff by the use of chlorhexidine hand-cream or gowns made little difference.

The use of triple dye to the umbilicus and individual gowns for each baby, both as separate and as combined measures, produced a reduction in the nasal carriage rate on the 12th day of life by about 25–30%.

No evidence was obtained that babies gained staphylococci from their mothers, but there was evidence that staphylococci on the mothers' breasts came from their babies.

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MASKING AND GOWNING IN NURSERIES FOR THE NEWBORN INFANT

EFFECT ON STAPHYLOCOCCAL CARRIAGE AND INFECTION

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Reports from various parts of the world testify that staphylococcal infection of the newborn infant is a widespread problem in maternity units, a problem to which, unfortunately, no easy solution is apparent. There is general agreement that in the control of this infection prophylaxis rather than the treatment of established lesions is the prime objective. As a prophylactic measure masks and gowns are worn extensively if somewhat uncritically by attendant personnel. Between one maternity unit and another the practice of masking and gowning can vary considerably, from a strictly regulated conscientiously performed regime to a meaningless ritual or mere gesture.

This paper describes a controlled trial carried out in a maternity unit with the object of determining the effect of masking and gowning on staphylococcal carriage and infection of the newborn infant.

The Experiment

In a 50-bedded maternity unit over a period of three months two nurseries were set aside for a controlled experiment.

At birth babies were allotted at random to one of these two nurseries. In one nursery (the "masked" nursery) a strict masking and gowning regime was in operation, in the other (the "unmasked" nursery) no masks or gowns were worn. The attendant staff was common to both nurseries. In the masked nursery all personnel entering the nursery, whether doctors, nurses, or cleaners, donned a mask and gown. The masks consisted of four layers of gauze with a "cellophane" insert, and extended below the chin. The nursing staff changed their masks at least every hour. The masks were autoclaved in a drum and when required were removed from the drum with sterile forceps. The instructions were that while being worn the mask should not be touched at all by hand. On discarding, the masks were dropped into a lidded receptacle containing antiseptic. Gowns donned before entering the nursery were put on in an ante-room, where they were kept hanging when not in use. In addition to the gown worn on entering the nursery each cot carried a folded gown which was worn when the baby in that cot was being handled. All gowns were changed every 24 hours or when soiled. They were not autoclaved, but one stage of the laundering was to raise the temperature of the washing water to 200° F. (93° C.) for 10 minutes. In the unmasked nursery nurses wore their ordinary uniform, the apron of which was changed daily or when soiled.

For the first two days the babies were taken to their mothers for feeding. In the case of the babies from the masked nursery the mothers were masked and gowned with the baby's "individual" gown. Thereafter the mothers fed their infants in the nurseries, and again in the masked nursery they were appropriately masked and gowned. Mothers were permitted to handle their own babies only. If any baby developed an infection in either nursery he was immediately removed to an isolation nursery. The babies from the masked nursery were bathed in a bathroom kept for them only; those in the unmasked nursery were bathed in another bathroom. There was thus no direct contact between the babies from the two nurseries. Bathing was carried out daily from the fourth day onwards.

So far as possible other factors were kept constant in the two nurseries. The rule that hands should be washed between handling each baby applied in both. Daily cleaning, by wet mopping, was carried out in both. Temperature, floor space per cot, and ventilation were the same.

Between occupants cot clothing was dealt with as follows. The cot mattress was aired unless the baby had suffered from an infection. If so, the mattress was autoclaved. Blankets were washed at 90° F. (32° C.). Other cot clothing, mattress cover, canvas bassinet, sheet, wrap, gown, napkin, and cot cover underwent a stage in laundering in which they were washed at 200° F. (93° C.) for 10 minutes.

Understandably the amount of traffic in the masked nursery was somewhat less than in the unmasked nursery, as the masking and gowning regulations in that nursery deterred entry for other than essential purposes. One other relevant factor was that this experiment was carried out at a time when a high infection rate for minor staphylococcal infection prevailed among the babies. This indeed was one of the considerations which prompted it. All infections in babies, no matter how trivial, were recorded, and, if possible, a swab was taken from the lesion. Each baby had an eye swab taken routinely on the fourth day, a nasal swab taken on the eighth day, and an umbilical swab taken at the time of separation of the cord (which on average was the eighth day). Nasal swabs were taken from the staff four times during the period of the experiment.

The total number of babies admitted to the nurseries during the course of the experiment was 82 to the masked nursery and 85 to the unmasked nursery.

The mean duration of stay in the masked nursery was just over 8½ days, the median being 9 days and the range