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ECOLOGIC RELATION BETWEEN *STAPHYLOCOCCUS AUREUS* AND *PSEUDOMONAS* IN A NURSERY POPULATION*

Another Example of Bacterial Interference

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Abstract The effect of certain nursery procedures on the colonization of newborn infants with *Staphylococcus aureus* and gram-negative bacilli was examined. During a period of only hexachlorophene handwashing by personnel, 50 per cent of infants were colonized with *Staph. aureus* at either the nasal or umbilical site. The introduction of hexachlorophene bathing of infants resulted in a decrease in colonization with *Staph. aureus* to 4 to 6 per cent. The addition of an antibacterial foam to the handwashing procedure resulted in a

further small decrease in colonization with *Staph. aureus* at the nasal site. Concurrent with this decrease was a significant increase in colonization with gram-negative bacilli. A specific inverse relation existed between *Staph. aureus* and undefined *pseudomonas* species. This relation can be interpreted as another example of bacterial interference. It is suggested that the spontaneous acquisition of *Staph. aureus* may prevent the later acquisition of certain gram-negative organisms by newborn infants.

BARRIERS are placed between the sterile newly born infant and his nursery environment. Although these barriers are most effective in controlling staphylococcal colonization, they have not often been examined for their effect on total microbial flora of the infant. Staphylococcal control by hexachlorophene is well known.¹⁻⁴ The effect of hexachlorophene on other important groups of organisms has not been elucidated.

The present study was undertaken to investigate the interrelations between various groups of microorganisms in a nursery population.

MATERIAL AND METHODS

Nursery Units

The studies were carried out in the nurseries of the Cincinnati General Hospital. The facilities and the procedures used in these nurseries have been described previously.⁵ Infants weighing more than 2260 gm are transferred from the delivery room directly to the full-term nursery. Most of these in-

fants are discharged with their mothers on the fourth or fifth post-partum day. Those with potentially contagious diseases are transferred to a separate observation nursery. Infants weighing less than 2260 gm are admitted to a premature nursery in another building and remain there until they weigh 2260 gm.

Nursery Procedures

Hexachlorophene handwashing has been employed from the inception of the present study. On entering the nursery, personnel scrub hands and forearms with a brush, using hexachlorophene and water. With a stroke-count method⁶ nails, fingers, hands and arms up to the elbows are scrubbed with the solution. After a rinse with water, scrubbing is repeated with hexachlorophene. Hands are rinsed and then dried on clean paper towels. The procedure takes two or three minutes. Between handling babies, personnel wash their hands with hexachlorophene and water. All personnel don clean gowns on entering the nursery. Caps and masks are not used.

Before December, 1965, infants in the full-term nursery were bathed with tap water alone. Since then they have been bathed with hexachlorophene (pHisoHex) with the use of a modification of the

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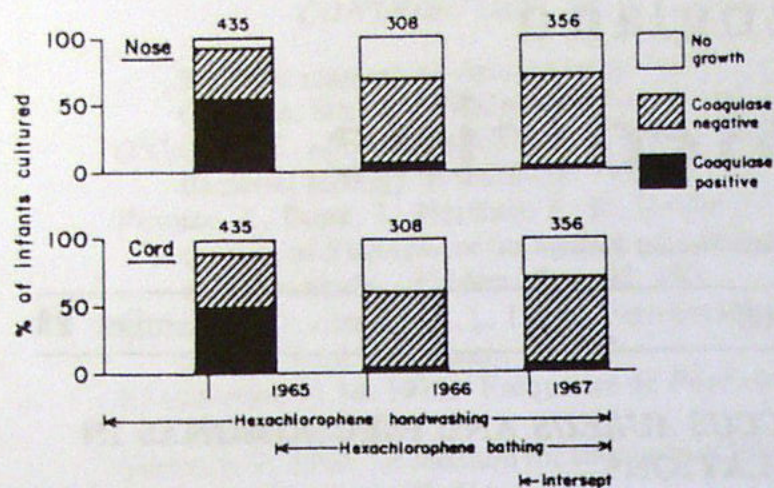


FIGURE 1. Rate of *Staphylococcal* Colonization among Infants in a Full-Term Nursery.

were examined. During the period of hexachlorophene handwashing alone, cultures in 54 per cent of infants showed colonization with coagulase-positive staphylococci at the nasal site and in 50 per cent at the umbilical site (Fig. 1). When hexachlorophene bathing was added, a striking decrease occurred in the frequency of colonization with coagulase-positive staphylococci. Coagulase-positive staphylococci at the nasal site decreased from 54 to 5.5 per cent (p less than 0.0005) and at the umbilical site from 50 to 4 per cent (p less than 0.0005). The addition of the antibacterial foam to the handwashing procedure resulted in an additional decrease in colonization with *Staph. aureus* from 5.5 to 2.5 per cent at the nasal site (chi square with Yates = 3.17, p equal to 0.07), and an increase from 4 to 6 per cent at the umbilical site (p less than 0.20).

During the period of hexachlorophene handwashing alone, 36 per cent of cultures showed colonization with gram-negative bacilli at the nasal site, and 45 per cent at the umbilical site (Fig. 2). After the introduction of hexachlorophene bathing, the figure for colonization with gram-negative bacilli rose to 48 per cent at the nasal site (p equal to 0.00125) and to 78 per cent at the umbilical site (p less than 0.0005). This increase occurred concurrently with a marked fall in colonization with *Staph. aureus* at

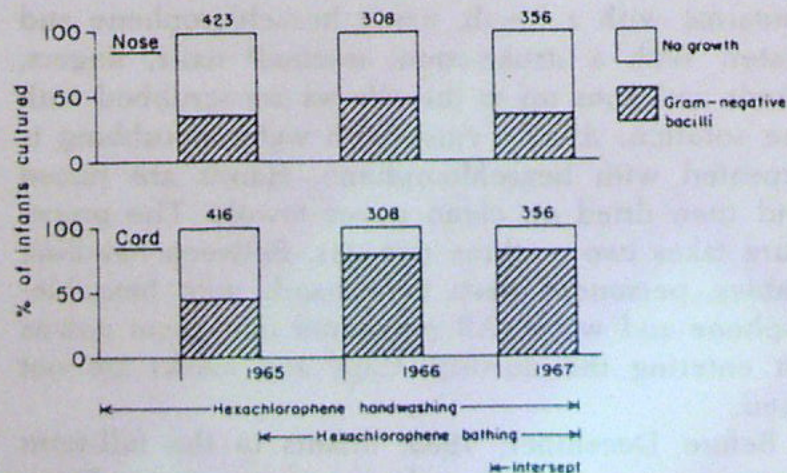


FIGURE 2. Rate of Colonization with Gram-Negative Rods.

both sites. After the addition of the antibacterial foam the proportion of colonizations with gram-negative bacilli at the nasal site fell to the prehexachlorophene bathing level. There was no change in the frequency of colonization with gram-negative bacilli at the umbilical site.

Specimens streaked onto mediums containing the hexachlorophene inhibitors mentioned above indicated that the changes in colonization with *Staph. aureus* and gram-negative bacilli did not result from contamination of the specimens with hexachlorophene.

Environmental Cultures

Specimens obtained from incubators, water baths and hexachlorophene dispensers failed to reveal any source of contamination with pathogenic gram-negative bacilli, particularly pseudomonas.

Pseudomonas Colonization

The results of the cultures of gram-negative bacilli from all sites from infants in the full-term nursery during the entire period between January 25, 1966, and July 5, 1967, were examined. Of 74 sites colonized with *Staph. aureus* none were colonized simultaneously with pseudomonas. Similarly, of 121 sites colonized with pseudomonas none were also colonized with *Staph. aureus*. Of the total of 1904 sites cultured there were no sites colonized with both pseudomonas and *Staph. aureus* (chi square, with Yates correction = 4.172, p equal to 0.041). There were no differences in rates of colonization with *Escherichia coli*, proteus or klebsiella-aerobacter at sites with or without *Staph. aureus* (Table 1). Pseudomonas colonization analyzed for time indicated no clustering of positive cultures over the entire period from January, 1966, to July, 1967.

Cultures obtained during the same period from infants in the premature nursery were similarly examined. Of 2623 total sites examined, pseudomonas and *Staph. aureus* were isolated concurrently from the nose of only one infant with purulent rhinitis. When all nasal and umbilical cultures from full-term and premature infants were examined together (Table 2) pseudomonas was isolated from only one of the total of 343 sites harboring *Staph.*

TABLE 1. Colonization with *Staphylococci* and Other Organisms in Total Sites Cultured (January 25, 1966, to July 5, 1967).

MICRO-ORGANISM	PERCENTAGE WITH <i>Staph. aureus</i>	PERCENTAGE WITHOUT <i>Staph. aureus</i>	P VALUE
Pseudomonas	—	6.6	<0.05
Proteus	6.4	4.3	<0.50
<i>Esch. coli</i>	20.0	31.0	<0.70
Klebsiella-aerobacter	28.0	29.0	<0.90

staphylococcal colonization and disease in newborn infants. An epidemic of *P. aeruginosa* has since been reported by Fierer et al.¹⁷ in one of these nurseries. More recently¹⁸ another epidemic due to *klebsiella* has been observed in the same nursery. These bacteriologic and epidemiologic observations, though not in themselves conclusive, support the suggested relation between staphylococci and certain strains of gram-negative bacilli, with the added suggestion that gram-negative colonization might occur as a consequence of staphylococcal eradication.

In contrast, Dugdale et al.¹⁹ studied the bacterial colonization of 50 healthy neonates. Undiluted hexachlorophene applied to the skin within 24 hours of birth and again on the third and fifth days of life did not decrease the rate of colonization with staphylococcus. Furthermore, in this small study, there was no evidence that colonization with staphylococci affected later colonization by coliform organisms. However, there were only 11 sites (anterior nares) colonized with *Staph. aureus*, and none of these were later colonized with gram-negative rods. *Pseudomonas* organisms were not identified in the study.

The mechanism of bacterial interference remains poorly understood. Experimental data²⁰ suggest that interference between strains of staphylococci results from competition for nicotinamide or production of an antibacterial substance that can be inhibited by nicotinamide. Certain bacteria elaborate bacteriocins^{21,22} that inhibit the growth of other related strains of bacteria. For example, *pseudomonas* produce pyocins^{17,22} inhibiting the growth of other strains of *pseudomonas*. Similarly, staphylococci elaborate staphylococcins^{22,23} that inhibit the growth of other staphylococci. However, such antibacterial substances have not been demonstrated between such unrelated strains as *pseudomonas* and *Staph. aureus*, and have not been proved to be a mechanism of clinical bacterial interference.

The importance of bacterial interference in protecting the newborn infant from colonization with pathogenic staphylococci is well established.⁸⁻¹⁰ The present study indicates that the spontaneous acquisition of *Staph. aureus* may prevent the subsequent acquisition of certain gram-negative bacilli by the newborn infant. In the absence of *Staph. aureus* spontaneous colonization of the infant with certain species of *pseudomonas* may be enhanced.

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