Ecology of Staphylococci in a General Medical Service

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Investigation of the ecology of Staphylococcus aureus on the medical service of the Cincinnati General Hospital was carried out from 1964 to 1970. S. aureus was cultured from 1,442 patients. Overall, there was a progressive increase in the susceptibility of S. aureus to commonly used antibiotics, but not to penicillin. Hospital-acquired S. aureus remained highly resistant to all antibiotics except penicillinase-resistant penicillins. There was a progressive decline in the percentage of hospital-acquired infections from January 1964 to September 1969, followed by a rise during September 1969 to September 1970. No single bacteriophage group predominated among nosocomially acquired S. aureus. Major changes in the hospital environment did not appear to influence the prevalence of nasal carriage or hospital acquisition of S. aureus. This study identified the continuing problem of acquisition of S. aureus in the hospital, but no specific "epidemic strain."

A study of the ecology of Staphylococcus aureus on a medical service was carried out from 1964 to 1970. An opportunity to assess the importance of the hospital environment upon cross-infection and spread of S. aureus was available during this study. In September of 1969, the Cincinnati General Hospital moved from a 60-year-old pavilion type building to a new multistoried building. The investigation revealed no epidemic strain of S. aureus associated with hospital-acquired infection, a progressive increase in the susceptibility of isolates to all antibiotics except penicillin, and no reduction in the prevalence of hospital-acquired infections after the move to the new hospital.

MATERIALS AND METHODS

Study population. The Cincinnati General Hospital is the county hospital for a metropolitan area of approximately one million population. During the study, no changes in the admission policy occurred.

S. aureus was recovered from 1,442 patients on the medical wards in the period from January 1964 to September 1970. Cultures were obtained at the discretion of the ward physicians when clinically indicated. The surgical, pediatric, and other services were not included in the survey. S. aureus was cultured from 1,366 patients during a single hospitalization, and from 76 patients on each of two or more admissions. The patients identified as having positive cultures on multiple admissions were considered separately in the tabulation of data. Only one isolate per patient admission is included in the tabulation of the results.

Bacteriology. The method of Highsmith and Shotts (6) was used to confirm that the S. aureus were coagulase positive. Three colonies from each isolate were picked for phage typing. Bacteriophage typing was performed in a standard manner (3), utilizing a replicate-plate technique previously described (8). One of the three cultures of each S. aureus isolate was phage typed. If the culture was untypable (no major or minor reactions), the second and then the third culture were tested in the same fashion. If the first culture typed, the second and third were not tested. Routine test dilutions of bacteriophages were employed, and untypable strains were not retested with concentrated bacteriophage (1,000 × routine test dilutions) (3). Antibiotic susceptibility patterns were determined by the single disc method of Bauer et al. (2). During the first year of the study, the inoculum size was a 1:100 dilution of an overnight culture, and, during the last six years of the study, the overnight culture was diluted to match a barium sulfate standard. The antibiotics tested included methicillin, chloramphenicol, erythromycin, tetracycline, and penicillin. Ninety-one percent of the isolates (1,242) were tested.

Review of medical records. The day of hospitalization when the first positive culture was obtained and any contact with a medical facility within a month before admission to the hospital were noted. A
medial facility was defined as a clinic, nursing home, contact with medical personnel, or prior hospitalization. An organism was defined as hospital acquired if the culture was obtained four or more days after admission. *S. aureus* recovered during the first three days were considered to have been acquired in the hospital if the clinical situation justified the exception. Only 9.5% of *S. aureus* judged to have been hospital acquired were recovered in the first 72 hr of hospitalization. A decision as to whether or not the organism was hospital acquired could not be reached in 13% of the total study group.

**Nasal carriage survey.** Nasal carriage of *S. aureus* was surveyed immediately before and 12 months after the move to the new hospital. All ward personnel, as well as all medical patients, were cultured during a 24-hr period. A dry cotton-tipped swab was used to culture the anterior one-third of the nares. The swab was streaked on mannitol salt agar and incubated at 37 C for 36 hr. The number of colonies were counted to estimate semi-quantitatively the number of *S. aureus* carried in the nares.

**Alteration in physical environment.** The four medical wards in the old hospital occupied two floors of two pavilions. All were open wards containing 30 to 40 beds. No central unit, such as an intensive care or a coronary care facility, was available. In the new facility, a single floor encompasses the medical service, including a 12-bed intensive care unit and a 6-bed coronary care unit. The majority of the patients are housed in 5-bed rooms, but there are 2-bed rooms in each of the four wings which can be used for isolation. There were two washstands in the central aisle of the old wards; in the new hospital, each room contains a washbasin. Trash chutes are available in each wing in the new facility. Carts were used previously. Soiled linen is bagged in plastic rather than permeable cloth laundry bags, which were formerly utilized. The new hospital is air conditioned; outside air entering each patient’s room is filtered electrostatically and by dry pack. The exhaust maintains a negative pressure and no air is reused if the room doors remain shut. In practice, doors are open and no assessment of the extent of mixing of fresh and used air was carried out. The old Cincinnati General Hospital was not air conditioned. During the seven years of the study, there were no changes in hospital infection control procedures.

**RESULTS**

There were 19,440 patients admitted to the medical service from January 1, 1969, to September 19, 1970. Fifteen hundred forty of these admissions (1,442 patients) had positive cultures for *S. aureus*; 1,366 patients were admitted once, and 76, two or more times (total admissions 174). Thirty-one percent of the organisms were hospital acquired. Over 50% of the patients with positive cultures were 60 years of age or older. Although only 82 patients died as a direct result of staphylococcal infection, such infections contributed to 90 additional deaths. The mortality among the 1,442 patients was 32%, or approximately three times the death rate of the medical service as a whole.

The distribution of *S. aureus* among bacteriophage groups is presented in Table 1. The majority of *S. aureus* were untypable. There was a small yearly increase in the percentage of isolates in groups II and III, and the frequency of isolation of group I organisms varied from year to year. The decline in the percentage of nosocomially acquired organisms from 1964 to 1968 was associated initially with a decrease in the number of hospital-acquired group I organisms. In 1968, both group I and group III *S. aureus* were more frequently isolated, but the percentage of hospital-acquired *S. aureus* did not increase. Group III *S. aureus* were the most prevalent typable staphylococci noted in 1969 when there was an increase in nosocomial acquisition, and group I predominated in 1970 when the proportion of hospital-acquired *S. aureus* again rose.

The increase in the number of organisms susceptible to chloramphenicol, erythromycin, and tetracycline during the study was not accompanied by a change in the number of organisms susceptible to penicillin (Table 2). No methicillin-resistant *S. aureus* were noted. The percentage of susceptible isolates to specific antibiotics varied within each phage group. The percentage of group I *S. aureus* susceptible to tetracycline increased from 14.8% to 53.8% from 1964 to 1966, decreased in 1967 to 34.4%, and rose again to approximately 50% in the last two years of the study. In contrast, the percentage of tetracycline- and erythromycin-susceptible group III organisms decreased in the period 1964 to 1969. Penicillin resistance was also prevalent among strains of this bacteriophage group from 1965–1969. Hospital-acquired *S. aureus* were more often resistant to penicillin, chloramphenicol, tetracycline, and erythromycin than were community-acquired organisms (Fig. 1).

*S. aureus* was recovered from 76 patients who were admitted two or more times (174 admissions). Fifty-five patients, upon review of their charts, had been colonized before admission, and 21 acquired *S. aureus* during their first admission. *S. aureus* of the same phage type was recovered on a subsequent admission from only eight patients; from 35, a different type was cultured. Untypable *S. aureus* was recovered from 24 patients on each admission and phage typing was not carried out in 13 instances. The interval between hospitalizations of the eight patients who carried the same
TABLE 1. Bacteriophage grouping of isolates of S. aureus: single admissions

| Year | Percent phage group* | No. of isolates tested | Percent hospital acquired |
|------|----------------------|------------------------|--------------------------|
|      | I       | II      | III     | Others | Untypable |                          |                          |
| 1964 | 26.7 (28.3) | 1.9 (1.1) | 10.7 (8.7) | 23.8 (33.7) | 36.9 (28.3) | 206 (92) | 44.7 |
| 1965 | 13.6 (17.1) | 2.7 (2.4) | 13.6 (12.2) | 16.4 (12.2) | 53.6 (56.1) | 110 (41) | 37.3 |
| 1966 | 16.0 (14.6) | 2.4 (4.0) | 12.4 (4.0) | 14.8 (14.6) | 54.3 (62.7) | 242 (74) | 30.6 |
| 1967 | 12.9 (16.4) | 3.1 (1.4) | 16.1 (12.3) | 17.2 (19.2) | 56.6 (53.4) | 255 (73) | 28.6 |
| 1968 | 24.8 (36.2) | 3.4 (4.3) | 16.9 (23.4) | 11.4 (17.0) | 43.8 (19.1) | 201 (47) | 23.4 |
| 1969 | 13.1 (10.6) | 3.7 (2.1) | 16.3 (27.7) | 11.6 (10.6) | 55.3 (48.9) | 190 (47) | 24.7 |
| 1970 | 20.9 (25.5) | 5.6 (7.8) | 14.8 (7.8) | 6.8 (9.8) | 51.9 (50.9) | 162 (51) | 31.5 |

* Numbers in parentheses indicate percentage of hospital-acquired S. aureus.

TABLE 2. Antibiotic susceptibility of isolates of S. aureus: single admissions

| Year | Percent susceptible* | No. of isolates tested |
|------|----------------------|------------------------|
|      | TOT | I  | III | TOT | I  | III | TOT | I  | III |
| 1964 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |
| 1965 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |
| 1966 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |
| 1967 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |
| 1968 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |
| 1969 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |
| 1970 | 100 | 100 | 100 | 100 | 100 |       | 100 | 100 |       |

* Antibiotic abbreviations: MCN, methicillin; CMC, chloramphenicol; EMC, erythromycin; TET, tetracycline; PEN, penicillin. Other abbreviations: TOT, total; I, phage group I; III, phage group III.

Phage type averaged 277 days as contrasted with 371 days when differing bacteriophage types were recovered. Contact with other medical facilities before admission did not result in colonization by a specific phage type.

The prevalence of hospital-acquired infections, bacteriophage typing, and nasal carriage rates by personnel and patients was analyzed to assess the effect of the change of hospital facilities upon the ecology of S. aureus in the medical center. Table 3 demonstrates that, during the 12-month period following the move, there was a small increase in the number of hospital-acquired infections, but no major shift in the bacteriophage grouping of the isolates. Approximately 35% of patients and 25% of personnel were nasal carriers of S. aureus in both the old and new hospital, and similar numbers of personnel and patients were heavy carriers in both surveys (Table 4). In September 1969, 14 of the patients had been hospitalized for less than 72 hr at the time of the survey. Only 1 of these 14 patients was a nasal carrier of S. aureus. In contrast, 37 of the remaining 92 patients in the hospital for 4 days or longer were nasal carriers of S. aureus. In September 1970, 8
One page of the document contains tables and text discussing bacterial infections, specifically focusing on *S. aureus*. The text details the prevalence of this bacteria in hospital settings, noting that it is transmitted through cross-infection and is associated with various types of hospital-acquired infections. The text also mentions the use of antibiotics and the importance of antibiotic susceptibility testing. The discussion section highlights the integration of antibiograms for adequate and accurate management of infections, particularly concerning methicillin-resistant *S. aureus*.

The table lists the bacteriophage grouping of *S. aureus* isolates from single admissions in 1968-1970, showing the distribution among various groups. The survey of nasal carriage of *S. aureus* among personnel and patients is also presented, indicating the prevalence of carriers and the necessity for strict infection control measures.

The DISCUSSION section delves into the replacement of *S. aureus* as a major cause of nosocomial infections by gram-negative bacteria, emphasizing the importance of monitoring and adapting antimicrobial strategies. It touches upon the impact of environmental factors on bacterial transmission and the role of personnel in controlling hospital-acquired infections.

In conclusion, the document underscores the significance of *S. aureus* infections and the need for continuous surveillance and intervention strategies to mitigate its prevalence and impact on hospital health care environments.
PREVALENCE OF S. AUREUS PHAGE TYPE 84/85

| Year | Number of Patients |
|------|--------------------|
| 1967-68 | 10 |
| 1968-69 | 5 |
| 1969-70 | 1 |

FIG. 2. Yearly prevalence of S. aureus bacteriophage type 84/85—September 1967 to September 1970—in the intensive care unit (ICU) and medical wards.

when compared to the preceding 12 months.

In summary, this investigation noted a decrease in the percentage of S. aureus which were hospital acquired and an increase in antibiotic susceptibility of S. aureus over a 7-year period on a medical service. No epidemic strain of S. aureus was identified, although the problem of nosocomial infection with antibiotic-resistant organisms persisted. The biology of S. aureus which underlies such infections is poorly understood and represents an area in need of continuing investigation if control of hospital infection is to be achieved.

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LITERATURE CITED

1. Barrett, F. F., J. I. Casey, C. Wilcos, and M. Finland. Bacteriophage types and antibiotic susceptibility of staphylococcus aureus: Boston City Hospital 1967. Arch. Int. Med. 125:867-873.
2. Bauer, A. W., D. M. Perry, and W. M. M. Kirby. 1959. Single disc antibiotic sensitivity testing of staphylococci. Arch. Int. Med. 104:208-216.
3. Blair, J. E., and M. Carr. 1960. The techniques and interpretation of phage typing of staphylococci. J. Lab. Clin. Med. 55:650-662.
4. Bulger, R. J., and J. G. Sherris. 1968. Decreased incidence of antibiotic resistance among staphylococcus aureus. A study in a university hospital over a 9-year period. Ann. Int. Med. 69:1099-1108.
5. Cohen, L. S., R. F. Fekety, and L. E. Cluff. 1962. Studies of the epidemiology of staphylococcal infection. IV. The changing ecology of hospital staphylococci. N. Engl. J. Med. 266:367-372.
6. Highsmith, A. K., and E. B. Shotts. 1965. Rapid method of determining coagulase activity during staphylococcal bacteriophage typing. Appl. Microbiol. 13:34-36.
7. Jessen, O. K., K. Rosendal, P. Bulow, V. Faber, and K. R. Eriksen. 1969. Changing staphylococci and staphylococcal infections. A ten year study of bacteria and cases of bacteremia. N. Engl. J. Med. 281:627-635.
8. Simon, H. J., and S. Undsetter. 1963. Simple method of phage typing of staphylococci. J. Bacteriol. 85:1447-1448.
9. William, R. E. O. 1970. Changing perspective in hospital infection, p. 1-10. In Proceedings of the International Conference on Nosocomial Infection. Center for Disease Control, Atlanta.