JOURNAL OF CLINICAL MICROBIOLOGY, July 1983, p. 160–164
0095-1137/83/070160-05$02.00/0

Vol. 18, No. 1

A Three-Year Study of Nosocomial Infections Associated with *Pseudomonas aeruginosa*

ROBERT J. SHERERTZ† AND FELIX A. SARUBBI*

Division of Infectious Diseases, Department of Medicine, University of North Carolina School of Medicine, and Department of Hospital Epidemiology, North Carolina Memorial Hospital, Chapel Hill, North Carolina 27514

Received 1 November 1982/Accepted 28 March 1983

During a 3-year study period in a university teaching hospital, 417 nosocomial infections associated with *Pseudomonas aeruginosa* were documented in 321 patients. The overall rate of *P. aeruginosa* nosocomial infection was 5.3 cases per 1,000 patients. Residence on the surgery or medicine service, advanced patient age, and exposure to the burn, surgery, or medicine intensive care units correlated with higher rates of infection. The most common sites for *P. aeruginosa* infection were the lower respiratory tract, urinary tract, blood stream, and surgical wounds. Nosocomial *P. aeruginosa* lower respiratory tract and blood stream infections were significantly associated with exposure to certain intensive care units, whereas *P. aeruginosa* urinary tract infections more commonly occurred on the neurology and neurosurgery services. Results of live antigen serotyping showed that serotype 6 was most common, followed by serotypes 1 and 11. Serotype 6 correlated with resistance to carbenicillin, gentamicin, and tobramycin, and serotype 11 correlated with resistance to carbenicillin. Two-thirds of the isolates tested were sensitive to carbenicillin, gentamicin, and tobramycin, but 13.2% were resistant to all three of these drugs. *P. aeruginosa* isolates resistant to all three drugs were associated with urinary tract infections.

In recent decades, *Pseudomonas aeruginosa* has emerged as an important nosocomial pathogen. According to data accumulated by the Comprehensive Hospital Infections Project, *P. aeruginosa* strains accounted for approximately 11% of all pathogens recovered from nosocomial infections (3). Hospital-acquired infections caused by this organism are often associated with high morbidity and mortality rates. Examples are pseudomonal bacteremia (35 to 50% mortality) and pseudomonal pneumonia (70 to 90% mortality) (10, 11, 13).

Although several published studies (1, 3–5) have presented overviews or specific aspects of the epidemiology of hospital-acquired infections caused by *P. aeruginosa*, a detailed epidemiological description for a particular hospital setting is lacking. Therefore, we undertook a study of *P. aeruginosa*-associated nosocomial infections at our institution. During a 3-year period, 321 patients developed a total of 417 hospital-acquired infections from which *P. aeruginosa* was recovered. Serotyping and antibiotic sensitivity tests were performed on 86% of the isolates. An analysis of these and other epidemiological data are the subject of this report.

† Present address: Division of Infectious Diseases, Department of Medicine, University of Florida School of Medicine, Gainesville, FL 32610.

MATERIALS AND METHODS

The study was conducted from December 1976 to December 1979 at the North Carolina Memorial Hospital, a 640-bed teaching hospital for the University of North Carolina School of Medicine. Nosocomial infection surveillance was done by two full-time infection control practitioners who used criteria established by the Centers for Disease Control for defining nosocomial infections (7). In all cases, the infections were not believed to be either present or incubating at the time of admission, and in no instance was the patient considered to be simply colonized with the organism. Signs of active infection were present in every case. Patients with asymptomatic bacteriuria were not recorded as having a urinary tract infection.

The hospital infection control files were examined for each patient with a nosocomial infection from which *P. aeruginosa* was recovered during the study period. The following data were recorded: patient age, sex, and race, hospital service (medicine, surgery, etc.), admission date, ward location, intensive care unit (ICU) stay before infection, the date that *P. aeruginosa* was isolated, the infection site, and the antibiogram and serotype of the organism. Each isolate of *P. aeruginosa* was recovered from a specific infection site. For example, among nosocomial pneumonias, the organism was cultured from purulent sputum obtained from a patient with a persistently

abnormal chest radiograph (parenchymal infiltrate) and fever. In many cases, evidence for infection was found on the gram-stained sputum samples. When the organism was recovered from a particular site on several occasions, it was counted only once. The frequency of recovery of other bacteria from nosocomial infections which occurred during the study period was also noted.

Antimicrobial sensitivity testing was performed in the clinical microbiology laboratory of the hospital by the Kirby-Bauer disk method (2).

Serotyping (O antigen) was carried out in the hospital epidemiology laboratory by the live-antigen method of Brokopp et al. (6) with two exceptions: (i) antisera pools were not used, and (ii) organisms initially found to be nontypable were incubated overnight in tryptic soy broth. The culture was then boiled for 15 min and centrifuged, and the pellet was suspended in 10 ml of sterile saline. This preparation was then used in the live-antigen testing procedure.

Rates of infection were calculated from the number of cases per 1,000 admissions. Statistical analysis was done by the chi-square test, with Yates correction as needed, or by Fisher's exact test.

RESULTS

During the 3-year study period, *P. aeruginosa* was recovered from 417 documented nosocomial infections in 321 patients. Overall, it was found in 12.5% of all hospital-acquired infections in that period, behind *Escherichia coli* (13.2%) and ahead of *Staphylococcus aureus* (10.5%) infections. Based upon comparisons of antibiogram and serotype patterns, there was very little evidence for cross-infection with *P. aeruginosa* during the study period, and no significant outbreak of infections caused by this organism was documented during the 3-year period.

The overall rate of nosocomial *P. aeruginosa* infections was 5.3 cases per 1,000 patient admissions. The low rate was 1.4 cases per 1,000 admissions in the 11 to 20 age group, and the high was 13.7 cases per 1,000 admissions in the 71 to 80 age group (Fig. 1). The majority of infections (60%) occurred in patients between 50 and 80 years of age. Case breakdown by race revealed 63% of the patients were white and 37% were nonwhite. This closely paralleled the hospital's overall admissions statistics for race (62% white and 38% nonwhite). Males accounted for 57% of all cases and represented 43% of the total patient population admitted during the study period. The surgery service accounted for 55% of the cases and the medicine, pediatric, and obstetrics and gynecology services accounted for 36, 5, and 4% of the cases, respectively. Rates of infection by service were as follows (per 1,000 admissions): surgery, 10 cases; medicine, 5 cases, and 1 case each for both pediatrics and obstetrics and gynecology.

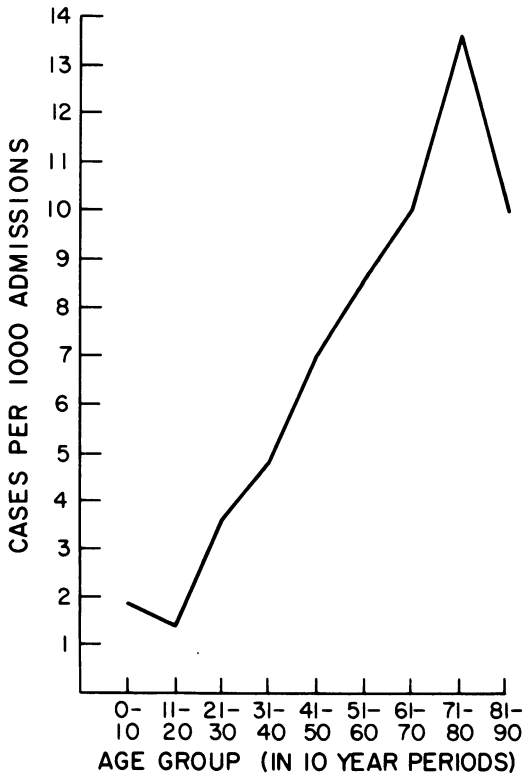

FIG. 1. Age-related rate of occurrence for nosocomial infections associated with *P. aeruginosa*.

The rate of nosocomial *P. aeruginosa* infections was strongly related to patient exposure to an ICU. The rate was 41 cases per 1,000 admissions for patients who stayed in an ICU, compared with 2 cases per 1,000 admissions for patients who were never exposed to an ICU (Table 1). The high rate was 130 cases per 1,000 admissions in the burn ICU, and the low was 3 cases per 1,000 admissions in the coronary ICU. A total of 506 patients developed nosocomial infections while hospitalized in an ICU during the study period, and 180 (35.6%) developed

TABLE 1. Rates of nosocomial *P. aeruginosa* infection in various ICUs

Unit	No. of patients infected	Rate of infection (cases per 1,000 admissions)
Burn	24	130
Surgery	52	39
Medicine	67	35
Neurosurgery	12	15
Cardiothoracic	12	9
Pediatric	8	6
Coronary	5	3

TABLE 2. Infection sites associated with *P. aeruginosa* isolates

Infection site	No. of isolates	Frequency (% of total)
Lower respiratory tract	130	31.1
Urinary tract	122	29.3
Bloodstream	62	14.8
Surgical wound	59	14.1
Burn wound	14	3.3
Nonsurgical skin	7	1.7
Ear and sinus	7	1.7
Eye	5	1.2
Vascular catheter	3	0.7
Central nervous system	3	0.7
Abdomen	2	0.5
Other	3	0.7

infections from which *P. aeruginosa* was recovered. Nosocomial infections associated with *P. aeruginosa* were uncommon in the premature infant nursery (neonatal ICU); the rate of infection was 1.4 cases per 1,000 admissions during the study period.

The lower respiratory tract, urinary tract, bloodstream, and surgical wound sites were the source of 90% of the nosocomial *P. aeruginosa* isolates (Table 2). The majority (75%) of the lower respiratory tract infections were pneumonias. Of the bacteremias, 88% were believed to be secondary to *P. aeruginosa* infections at other sites, and 80% of the wound infections were judged to be skin infections at operative sites. During the study period, the overall rate of nosocomial surgical wound infections was 20.8 per 1,000 operative procedures, and the rate of wound infections associated with *P. aeruginosa* was 2.3 per 1,000 operative procedures. The four most common sites of *P. aeruginosa* infection and the rate of occurrence per 1,000 admissions were: lower respiratory tract, 2.1 cases; urinary tract, 1.9 cases; bloodstream, 1.0 cases; and surgical wounds, 0.9 cases. The occurence rates for these sites were 22.9, 12.9, 8.7, and 6.6%, respectively, for patients exposed to an ICU. Further analysis of these data revealed that the occurrence of nosocomial *P. aeruginosa* lower respiratory tract infections was significantly related to exposure to the medicine ($P < 0.001$) and surgery ($P < 0.01$) ICUs and that nosocomial *P. aeruginosa* bloodstream infections were associated with exposure to the medicine ICU ($P < 0.02$). Nosocomial *P. aeruginosa* urinary tract infections were associated with residence on the neurology or neurosurgery services ($P < 0.01$).

P. aeruginosa was the second most common nosocomial pathogen found in the respiratory tract, urinary tract, and bloodstream and the fourth most common in surgical wounds. It ranked behind *S. aureus* as a cause of nosocomial infection in the respiratory tract and behind *E. coli* as a cause of nosocomial infection in the urinary tract and bloodstream.

Serotype 6 was the most commonly documented (20.7% of all isolates), and serotypes 1, 6, 10, and 11 accounted for 65% of the isolates tested (Table 3). There was a limited number of nontypable isolates (7.0%), and isolates with multiple serotype patterns (agglutinated in more than one antiserum) were infrequent (4.8%). The majority of the isolates tested (64.2%) were sensitive to carbenicillin (C^s), gentamicin (G^s), and tobramycin (T^s), but 13.2% were resistant to all three of these antibiotics (CGT^r). This latter drug resistance pattern was statistically related to recovery of the organism from the urinary tract ($P < 0.005$). However, no relationship between drug resistance and patient exposure to an ICU was found. There was a statistically significant relationship between antibiotic sensitivity pattern $C^r G^s T^s$ and serotype 11 ($P < 0.01$) and between sensitivity pattern CGT^r and serotype 6 ($P < 0.001$). Three serotype 11 strains with the $C^r G^s T^s$ sensitivity pattern were recovered from the bloodstream, three from the urinary tract, two from the respiratory tract, and one each from spinal fluid, eye, and pleural fluid samples. Twelve serotype 6 organisms with the CGT^r sensitivity pattern were recovered from the urinary tract, four from the respiratory tract, three from surgical wounds, two from the bloodstream, and one each from spinal fluid, eye, and skin samples.

Serotype data were available for 333 of the 374 *P. aeruginosa* isolates obtained from the four major sites, and no significant association between serotype and infection site was found (Table 4). Likewise, no correlation between serotype and hospital service or location in the hospital was noted.

DISCUSSION

P. aeruginosa is a well-recognized nosocomial pathogen that can cause severe infections in hospitalized patients. Interestingly, little has been written on the epidemiology of this organism in specific hospital settings. Therefore, we studied the epidemiology of 417 nosocomial *P. aeruginosa* infections documented in 321 patients over a 3-year period. We found that *P. aeruginosa* was associated with 12.5% of all nosocomial infections during the study period. This percentage is similar to the ~10% figure reported by Bennett (3), whose data reflected the experience of community hospitals in the Comprehensive Hospital Infections Project. The overall rate of *P. aeruginosa* infection (5.3 cases per 1,000 admissions) documented in our study

TABLE 3. Serotype and sensitivity data for 356 nosocomial *P. aeruginosa* isolates

Sensitivity pattern	No. of isolates (%) that were serotype:[a]													Total no. (%) of isolates showing sensitivity pattern
	1 (16.8)	3 (7.0)	4 (3.9)	5 (5.0)	6 (20.7)	8 (2.2)	9 (2.0)	10 (10.6)	11 (16.8)	16 (2.2)	NT (7.0)	MT (4.8)	Other (1.1)	
CGT^s	47	19	7	16	37	5	5	23	34	6	15	13	3	230 (64.2)
$C^b\ G^s\ T^s$	2	1	0	0	6	0	0	5	1	1	2	1	1	20 (5.6)
$C^r\ G^s\ T^s$	5	3	0	1	4	0	1	1	11	1	0	0	0	27 (7.5)
$C^s\ G^r\ T^r$	0	1	0	0	0	0	0	3	4	0	1	0	0	9 (2.5)
$C^r\ G^r\ T^r$	0	0	7	0	24	0	0	5	3	0	6	2	0	47 (13.2)
Other	6	1	0	1	3	3	1	1	7	0	1	1	0	25 (7.0)

[a] NT, Nontypable; MT, multiple serotype.
[b] Indeterminate sensitivity.

and the particular occurrence of these infections in older patients (Fig. 1) also agreed with the findings of Bennett (3). When compared with data from the National Nosocomial Infections Study hospitals (8), our overall rate for *P. aeruginosa* infection was higher (5.3 versus 3.4 cases per 1,000 admissions). The most notable differences were found in the rates for bloodstream and lower respiratory tract infections; the rates we found exceeded those reported by the National Nosocomial Infections Study hospitals by 10- and 3.5-fold, respectively.

The vast majority of nosocomial *P. aeruginosa* infections (91%) were found on the surgical and medical services (55 and 36%, respectively). On a hospitalwide basis, the lower respiratory tract and urinary tract represented the most common sites of nosocomial *P. aeruginosa* infection (Table 2), followed by the bloodstream and surgical wounds.

TABLE 4. Serotype distribution of 333 isolates of *P. aeruginosa* obtained from the four major sites

Serotype	No. of isolates from infection site:			
	Respiratory tract	Urinary tract	Blood-stream	Surgical wound
1	14	22	13	7
2	1	0	0	0
3	10	6	3	6
4	5	6	2	0
5	8	8	1	1
6	22	19	14	10
7	0	1	0	0
8	1	1	1	1
9	2	1	2	2
10	11	11	10	4
11	21	13	12	9
14	0	0	0	1
15	0	0	0	1
16	4	3	1	0
NT[a]	11	7	3	3
MT[b]	8	6	0	4

[a] NT, Nontypable.
[b] MT, Multiple serotype.

Compared with the data in Bennett's report (3), the rate of lower respiratory tract *P. aeruginosa* infection documented in our study was two times higher, and the rate of bloodstream infection was five times higher. These differences may be partly explained by different patient populations. Our facility serves largely as a tertiary-care referral center, whereas the Comprehensive Hospital Infections Project encompassed a community hospital population. We probably have a larger proportion of patients who require intensive support measures (respiratory assistance, invasive monitoring, etc.) than the community hospital does, and our patients may be more prone to developing certain nosocomial *P. aeruginosa* infections. Similarly, differences between our results and those of the National Nosocomial Infections Study hospitals are probably due to different patient populations. Approximately 70% of the National Nosocomial Infections Study hospitals are categorized as community or community-teaching hospitals.

We found a rate of *P. aeruginosa* infection of 41 cases per 1,000 admissions for patients exposed to an ICU, in marked contrast to the rate of 2 cases per 1,000 admissions for patients not so exposed. The type of ICU exposure was also important, as 80% of the cases occurred in the burn, surgery, and medicine ICUs (Table 1). There was a significant correlation between the occurrence of nosocomial lower respiratory tract *P. aeruginosa* infection and exposure to the medicine or surgery ICU. *P. aeruginosa* bloodstream infections also were significantly related to exposure to the medicine ICU. Compared with the other ICUs at our hospital, the burn, surgery, and medicine ICUs generally provide care to sicker patients with multiple underlying illnesses and host defense deficiencies and to those who require a variety of invasive monitoring and support devices. An interesting contrast was seen in the coronary ICU, where the rate of nosocomial *P. aeruginosa*

sa infection was essentially the same as that for persons without any ICU exposure.

Serotype data generated by our study showed that serotypes 1, 6, and 11 were the most commonly identified and that serotype 6 was recovered most often (Table 3). This finding is consistent with that reported by Brokopp et al. (6), who serotyped *P. aeruginosa* isolates supplied by six different hospitals. We also describe a statistically significant association between certain serotypes and particular antibiotic sensitivity patterns. Serotype 6 was associated with resistance to carbenicillin, gentamicin, and tobramycin, and serotype 11 was associated with resistance to carbenicillin. An association between particular serotypes and sensitivity patterns is not unique and has been reported by others (12). In contrast, there was no significant association between serotype and site of infection, service, or location in the hospital. Interestingly, the association between nosocomial *P. aeruginosa* urinary tract infections and patient residence on the neurology or neurosurgery service did not also involve an association between a particular sensitivity pattern or serotype. Our inability to document correlations in these areas might be due to the few instances of suspected cross-infection during the study period. It is conceivable that we might have shown a clustering of a particular serotype, as recently suggested by Farmer et al. (9), if more significant outbreaks of *P. aeruginosa* infection had occurred during the period.

Antibiotic sensitivity testing showed that nearly two-thirds of the isolates were susceptible to carbenicillin, gentamicin, and tobramycin, but 13.2% were resistant to all three antibiotics. There was no association between the recovery of resistant isolates and patient exposure to an ICU, but the association between recovery of isolates resistant to all three drugs and urinary tract infection was significant.

In summary, we found that *P. aeruginosa* was the second most common pathogen isolated from nosocomial infections at our hospital. It was particularly likely to be recovered from elderly patients exposed to the burn, surgery, or medicine ICU, for which the rate of lower respiratory tract *P. aeruginosa* infections was high. The recovery of isolates resistant to carbenicillin, gentamicin, and tobramycin was relatively limited and was particularly associated with urinary tract infections. Serotyping proved to be an important tool in our assessment of suspected *P. aeruginosa* outbreaks.

ACKNOWLEDGMENTS

This work was supported in part by Public Health Service training grant A107151-05 from the National Institute of Allergy and Infectious Diseases.

We thank the Hospital Epidemiology staff at North Carolina Memorial Hospital for their assistance and Greg Samsa for help with the statistical analyses.

LITERATURE CITED

1. **Baltimore, R. S., A. S. Dobek, F. R. Stark, and M. S. Artenstein.** 1974. Clinical and epidemiological correlates of Pseudomonas typing. J. Infect. Dis. **130**:S53–S60.
2. **Bauer, A. W., W. M. Kirby, J. C. Sherris, and M. Turck.** 1966. Antibiotic susceptibility testing by a standardized single disk method. Am. J. Clin. Pathol. **196**:493–496.
3. **Bennett, J. V.** 1974. Nosocomial infections due to Pseudomonas. J. Infect. Dis. **130**:S4–S7.
4. **Bobo, R. A., E. J. Newton, L. F. Jones, L. H. Farmer, and J. J. Farmer.** 1973. Nursery outbreak of *Pseudomonas aeruginosa*: epidemiological conclusions from five different typing methods. Appl. Microbiol. **25**:414–420.
5. **Bodey, G. P.** 1970. Epidemiological studies of pseudomonas species in patients with leukemia. Am. J. Med. Sci. **260**:82–89.
6. **Brokopp, C. D., R. Gomez-Lus, and J. J. Farmer III.** 1977. Serological typing of *Pseudomonas aeruginosa*: use of commercial antisera and live antigens. J. Clin. Microbiol. **5**:640–649.
7. **Center for Disease Control.** 1974. Outline for surveillance and control of nosocomial infections. Center for Disease Control, Atlanta, Ga.
8. **Centers for Disease Control.** 1981. National nosocomial infections study report: annual summary 1978. Centers for Disease Control, Atlanta, Ga.
9. **Farmer, J. J., III, R. A. Weinstein, C. H. Zierdt, and C. D. Brokopp.** 1982. Hospital outbreaks caused by *Pseudomonas aeruginosa*: importance of serogroup O11. J. Clin. Microbiol. **16**:266–270.
10. **Flick, M. R., and L. E. Cluff.** 1976. Pseudomonas bacteremia: review of 108 cases. Am. J. Med. **60**:501–508.
11. **Kreger, B. E., D. E. Craven, P. C. Carling, and W. R. McCabe.** 1980. Gram-negative bacteremia. III. Reassessment of etiology, epidemiology and ecology in 612 patients. Am. J. Med. **68**:332–355.
12. **Legakis, N. J., M. Aliferopoulou, J. Papavassiliou, and M. Papapetropoulou.** 1982. Serotypes of *Pseudomonas aeruginosa* in clinical specimens in relation to antibiotic susceptibility. J. Clin. Microbiol. **16**:458–463.
13. **Pennington, J. E., H. Y. Reynolds, and P. P. Carbone.** 1973. Pseudomonas pneumonia: a retrospective study of 36 cases. Am. J. Med. **55**:155–160.