

Pseudomonas aeruginosa Colonization in Patients with Spinal Cord Injuries

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The prevalence of *Pseudomonas aeruginosa* colonization of patients with spinal cord injury was studied annually from 1976 to 1980. The urethra, perineum, rectum, drainage bag, and urine of patients on the spinal cord injury service were cultured. A total of 224 men and 32 women were studied. Most patients were managed with an external urinary collection system or padding, with or without intermittent catheterization. *P. aeruginosa* was cultured from one or more body sites (urethra, perineum, or rectum) in 65% of men and 18% of women. Drainage bags on the beds were frequently colonized with *P. aeruginosa* (73%). Significant bacteriuria with *P. aeruginosa* was present in 19% of the men and 13% of the women. *P. aeruginosa* colonization of body sites in men was closely associated with the use of an external urinary collection system. Significantly greater urethral and perineal colonization was found in men using an external urinary collection system. *P. aeruginosa* serotype 11 was the predominant serotype for the first 3 years, and the number of patients colonized with serotype 11 increased with length of hospital stay. The prevalence of serotype 11 significantly decreased in the last 2 years. The antibiotic susceptibility of the strains of *P. aeruginosa* isolated from these patients did not change in the 5 years, except that there was increasing susceptibility to carbenicillin in later years. This increasing susceptibility to carbenicillin was a reflection of a decreased prevalence of serotype 11 in these patients, since serotype 11 was more resistant than other serotypes to carbenicillin.

Pseudomonas aeruginosa has been a frequent cause of urinary tract infections in patients with spinal cord injury (SCI). The incidence of *P. aeruginosa* bacteriuria has closely correlated with *P. aeruginosa* colonization of the urethra, perineum, and rectum in these patients. Initial studies in 1976 revealed a high incidence (85%) of *P. aeruginosa* colonization in the urethra, perineum, or rectum in male patients on the SCI service (4). Surveillance of urinary tract infections has been continued, and colonization of patients has been examined annually.

This paper reports the prevalence of body colonization and bacteriuria with *P. aeruginosa* over 5 years and examines the factors that may influence this colonization.

MATERIALS AND METHODS

Prevalence studies were carried out annually from 1976 to 1980. All inpatients on the SCI service were included in the study. The patients were cared for in two wards, which consisted of six-bed rooms.

Most patients were transferred from other hospitals with an indwelling urethral catheter which was re-

moved on admission, and intermittent catheterization (IC) was carried out until spontaneous voiding occurred. An external urinary collection system was used with male patients when spontaneous voiding occurred. This system consisted of an external condom catheter connected to either a leg bag or a drainage bag on the bed. Beginning in 1977, the external urinary collection system was changed daily. Before that time, drainage bags were changed weekly. Female patients were either diapered or kept on IC.

The urethra, perineum, rectum, and drainage bag of all patients were cultured during a 72-h period. Sterile cotton swabs (Cheseborough-Ponds) moistened in normal saline were used to culture body sites. Swabs were inserted approximately 1 cm into the urethra and rectum. Perineal cultures were obtained by swabbing the skin surface. Drainage bag cultures were obtained by collection of urine through the drainage tube into a sterile container. Urine for culture was obtained by catheter from patients on the IC program. After IC was discontinued, urine was obtained when the residual urine was measured.

Urinary tract infections (bacteriuria $\geq 10,000$ colony-forming units per ml in a catheter urine) were treated with antibiotics, usually aminoglycosides, for 5 days, plus an oral agent for 10 days. Many patients

TABLE 1. Clinical features of patients

Patient sex	Total no. of patients	Age in years (mean)	No. of quadriplegics	No. of patients with			
				IC	Antibiotics	Indwelling urethral catheter	EUCS ^a
Male	224	15-69 (29)	122	64	168	21	142
Female	32	16-62 (30)	14	15	21	7	

^a EUCS, External urinary collection system.

were maintained on macrodantin or trimethoprim-sulfamethoxazole as prophylactic agents for 4 to 6 weeks.

Swabs were placed in 4 ml of tryptic soy broth (Difco Laboratories) with 0.03% cetrime (cetrime broth), incubated for 24 h at 37°C, and plated onto cetrime agar (0.03% cetrime agar; Pseudose; BBL Microbiology Systems). The identification of *P. aeruginosa* was carried out by standard techniques.

Serotyping was carried out by using *P. aeruginosa* antisera (Difco) with a viable culture. The slide agglutination technique was carried out with viable bacteria from isolated colonies mixed directly with antisera. Antibiotic disk sensitivities were carried out on Mueller-Hinton agar by the Kirby-Bauer technique (1).

RESULTS

A total of 224 men and 32 women with SCI were studied over 5 years. The clinical features of the patients are shown in Table 1. Most male patients (63%) were using an external urinary collection system with or without IC at the time of the study. Twenty-eight patients (21 male and 7 female) had an indwelling urethral catheter at the time of culture.

The sites of colonization with *P. aeruginosa* are shown in Table 2. *P. aeruginosa* was cultured from one or more body sites (urethra, perineum, or rectum) in 146 of 224 men (65%) and 5 of 28 women (18%). In men, the perineum was the body site most frequently colonized. In patients with drainage bags (approximately half the male patients), *P. aeruginosa* was cultured from the contents of the bag in 73% of patients. This colonization of the bag was closely associated with colonization of one or more body sites.

TABLE 2. *P. aeruginosa* colonization of patients

Site	No. (%) of patients positive/no. tested	
	Male	Female
Urethra	100/215 (47)	2/22 (9)
Perineum	115/223 (52)	3/28 (11)
Rectum	91/224 (41)	5/28 (18)
Urethra, perineum, or rectum	146/224 (65)	5/28 (18)
Drainage bags	77/105 (73)	2/5 (40)
Urine	35/181 (19)	4/31 (13)

P. aeruginosa bacteriuria (greater than 10⁴ bacteria per ml) was found in 19% of the men and 13% of the women. Two of the four women with bacteriuria had indwelling urethral catheters. In men, bacteriuria was associated with colonization of one or more body sites in all but six instances. Cultures of body sites from women with *P. aeruginosa* bacteriuria were all negative.

Colonization with *P. aeruginosa* varied from year to year in men, with some decrease over the years (Table 3). The greatest incidence of *P. aeruginosa* bacteriuria was found in men using an external urinary collection system or indwelling catheter (Table 4). *P. aeruginosa* bacteriuria was uncommon in men managed solely by IC.

Men using an external urinary collection system had significantly greater colonization with *P. aeruginosa* in the urethra ($P < 0.001$ by chi square) and perineum ($P < 0.025$ by chi square) than men who did not use an external urinary collection system (Table 5).

Antibiotics had little effect on colonization with *P. aeruginosa* (Table 6). The effect of antibiotics generally considered active against *P. aeruginosa* (amikacin, tobramycin, gentamicin, and carbenicillin) was examined separately. Less urethral colonization with *P. aeruginosa* was found in men who received antipseudomonal therapy, but this reduction was not statistically significant.

Colonization patterns of men changed with length of hospital stay (Table 7). *P. aeruginosa* was found in a higher percentage of urethral cultures obtained from patients who had been hospitalized for more than 3 weeks. Perineal and rectal colonization remained constant.

The predominant *P. aeruginosa* serotype found was serotype 11, accounting for 46% of the cultures typed (Table 8). However, colonization with serotype 11 significantly decreased ($P < 0.005$) in the last 2 years. This was associated with a significant increase in serotypes 4 and 6 ($P < 0.005$). Several patients did have more than one serotype cultured from body sites, but only four patients were found with more than one type in the same site.

Colonization with *P. aeruginosa* serotype 11 increased with length of stay in the hospital (Table 9). Significantly greater colonization of

TABLE 3. *P. aeruginosa* colonization of patients in different body sites in different years

Site	Patient sex	No. (%) of cultures positive/no. tested				
		1976	1977	1978	1979	1980
Urethra	Male	22/38 (58)	17/33 (52)	23/43 (53)	21/51 (41)	17/50 (34)
	Female	0/0	0/4	0/8	1/3	1/7
Perineum	Male	27/39 (67)	17/40 (42)	30/43 (70)	20/51 (39)	21/50 (42)
	Female	0/5	0/5	0/8	1/3	2/7
Rectum	Male	21/39 (54)	15/41 (37)	24/43 (53)	18/51 (35)	13/50 (26)
	Female	0/5	0/5	2/8	1/3	2/7
Any body site	Male	34/39 (85)	25/41 (63)	33/43 (77)	26/51 (51)	28/50 (56)
Urine	Male	14/43 (37)	15/40 (38)	5/43 (12)	1/31 (3)	0/24 (0)

the perineum ($P = 0.015$ by Fisher exact) was found in men hospitalized longer than 8 weeks compared with men hospitalized less than 3 weeks. Urethral and rectal carriage with this serotype also increased with time.

The antibiotic susceptibility of the strains of *P. aeruginosa* isolated from patients is shown in Table 10. There was no significant change in the susceptibility of these strains to the antibiotics tested, except that there was an increasing susceptibility to carbenicillin with time. When the susceptibility of the main serotypes of *P. aeruginosa* was examined, serotype 11 was found to be more resistant than the other strains to carbenicillin (Table 11). Therefore, the increasing susceptibility of the strains as a group over the years depended on the reduced numbers of serotype 11 isolated. Tobramycin and gentamicin resistance was greater in serotype 4 than in serotypes 6 and 11.

DISCUSSION

These studies confirm our previous results, which showed a high incidence of *P. aeruginosa* colonization in patients with SCI (4, 5). This colonization was again shown to be significantly influenced by the use of an external urinary collection system, and men were much more

frequently colonized than women. The perineum proved to be the most frequent site of *P. aeruginosa* colonization, and *P. aeruginosa* frequently colonized drainage bags on the beds.

A predominance of *P. aeruginosa* serotype 11 was seen the first 3 years. This particular strain was also cultured more frequently from patients hospitalized longer than 3 weeks. Cultures, including environmental sampling to examine an endemic situation in this group of patients, identified no reservoirs for this strain of *P. aeruginosa* other than the patients themselves (4). Serotypes 4 and 6 emerged in the last 2 years of the study. The reason for the change in serotypes is not clear. Serotype 4 was more resistant to gentamicin and tobramycin, which are frequently used in these patients. However, colonization

TABLE 5. *P. aeruginosa* colonization associated with urinary management in men

Site and technique ^a	No. (%) of men positive/ no. tested
Urethra	
EUCS only	69/108 (64)
EUCS and IC	14/31 (45)
IC only	5/32 (16)
Indwelling catheter	4/15 (27)
No device	8/29 (28)
Perineum	
EUCS only	63/110 (57)
EUCS and IC	17/32 (52)
IC only	7/32 (22)
Indwelling catheter	15/20 (75)
No device	13/29 (45)
Rectum	
EUCS only	46/110 (42)
EUCS and IC	15/32 (47)
IC only	10/32 (31)
Indwelling catheter	7/21 (33)
No device	13/29 (45)

TABLE 4. *P. aeruginosa* bacteriuria^a associated with urinary management in men

Management technique ^b	No. (%) of men positive/ no. tested
EUCS only	16/78 (21)
EUCS with IC	6/30 (20)
IC only	1/32 (3)
Indwelling catheter	10/17 (59)
No device	2/24 (8)

^a $>10^4$ colony-forming units per ml in a catheter specimen.

^b EUCS, External urinary collection system.

^a EUCS, External urinary collection system.

TABLE 6. *P. aeruginosa* colonization associated with recent antibiotic use in men^a

Site	Antibiotic use	No. (%) of men positive/ no. tested
Urethra	Yes	72/162 (44)
	No	25/53 (53)
	Antipseudomonal antibiotic	9/33 (27)
Perineum	Yes	82/168 (49)
	No	33/55 (60)
	Antipseudomonal antibiotic	13/36 (36)
Rectum	Yes	67/169 (40)
	No	24/55 (44)
	Antipseudomonal antibiotic	13/35 (37)

^a Patients receiving antibiotics or urinary antiseptics at time of culture or within 2 weeks before culture.

TABLE 7. *P. aeruginosa* colonization in relation to duration of hospital stay

Site	No. (%) of patients positive/no. tested		
	≤3 weeks	4 to 8 weeks	>8 weeks
Urethra	17/52 (33)	31/66 (47)	52/96 (54)
Perineum	25/55 (45)	37/69 (54)	53/99 (54)
Rectum	24/55 (44)	29/70 (41)	38/99 (38)

with *P. aeruginosa* of any serotype did not seem to be influenced by antibiotic use.

The decreasing prevalence of serotype 11 in the last 2 years was associated with a decrease in the prevalence of significant bacteriuria with *P. aeruginosa* and raised the possibility that sero-

TABLE 9. *P. aeruginosa* serotype 11 colonization of patients in relation to duration of hospital stay

Site	No. (%) of serotype 11 isolates/ no. of <i>P. aeruginosa</i> isolates		
	≤3 weeks	4 to 8 weeks	>8 weeks
Urethra	2/11 (18)	12/24 (50)	20/36 (55)
Perineum	4/17 (24)	18/36 (50)	24/38 (63)
Rectum	5/18 (28)	9/28 (32)	16/30 (53)

type 11 may be more virulent. The incidence of serotype 11 in body sites (112 of 282 [40%]) was compared with the incidence of serotype 11 isolated from the urine of patients with significant bacteriuria (13 of 23 [61%]). This difference did not reach a significant level ($P = 0.07$), but many urine cultures were not available for serotyping.

The body colonization of these patients with *P. aeruginosa* was only partially influenced by the duration of hospital stay. Many patients admitted to Rancho Los Amigos Hospital, Downey, Calif., were already colonized with *P. aeruginosa* (5). Many of these patients had already spent time at acute hospitals in intensive care units and had acquired *P. aeruginosa* at those hospitals. There was no increase in the colonization of these patients in relation to length of hospital stay, except that urethral colonization increased after 4 weeks. This was associated with increased use of an external urinary collection system, since reflex voiding usually occurs after 4 weeks. In addition, however, there was a change in serotype with duration of hospital stay. Serotype 11 was endemic at

TABLE 8. *P. aeruginosa* serotypes^a

Site	Yr	No. of isolates of serotype:														Multiple type	NT	
		1	2	3	4	5	6	8	9	10	11	12	15					
Urethra	1976	1	1	1					1		6							2
	1977			1	1	1					9						3	1
	1978	1		1	1				1	3	12						2	1
	1979			1	4		3				7						3	3
	1980	1		1			3	1	1	2	1						4	
Perineum	1976	1	1		1	1				1	14						2	3
	1977				1	2					11	1					2	
	1978	1		2	1	1		1		2	16			1			1	4
	1979	1	1		4		3				5						4	2
	1980	2		3	3	1	5	1		1	1						2	1
Rectum	1976	1	1		1					1	8						2	5
	1977					2	1				9	1					2	1
	1978	2		3	1			1	1	2	9			1			2	1
	1979	1			3		3				4						2	4
	1980	2			1	2	2	1		1								1

^a No isolates of serotypes 7, 13, or 14 were found.

^b NT, Not typable.

TABLE 10. *P. aeruginosa* strains susceptible to antibiotics

Antibiotic	No. (%) of susceptible strains/no. tested				
	1976	1977	1978	1979	1980
Carbenicillin	2/5 (40)	23/33 (55)	19/33 (58)	20/31 (65)	24/31 (77)
Gentamicin	4/5 (80)	18/22 (82)	21/33 (64)	24/31 (77)	24/31 (77)
Tobramycin	4/5 (80)	19/22 (86)	31/33 (94)	28/31 (90)	26/31 (84)
Amikacin	4/5 (80)	19/22 (86)	32/33 (97)	28/31 (90)	31/31 (100)

Rancho Los Amigos Hospital and became the predominant serotype with increasing hospital stay.

We can only speculate as to why the use of an external urinary collection system influences colonization. Others have shown that gram-negative bacilli may persist more readily and show a marked increase in number in continuously moist, occluded areas on the skin (3). Such an area of skin on the penis is created by continuous use of an external urinary collection system. We have shown that colonization of the perineal skin is associated with an increase in pH on the skin (D. S. Gilmore, D. G. Schick, and J. Z. Montgomerie, Abstr. Annu. Meet. Am. Soc. Microbiol. 1982, B3, p.18). The amount of *P. aeruginosa* colonization and the serotypes were episodic, with some decrease in the incidence of *P. aeruginosa* urinary tract infections and colonization over the 5 years. In 1977, the drainage system on the bed was changed daily, which may have accounted for some reduction in *P. aeruginosa* urinary tract infections, although it did not significantly change the prevalence of body colonization. Over these years, there was also increasing infection surveillance, improved inservice training for nursing and medical personnel, and improved techniques, which may also have influenced the incidence of urinary tract infection.

During the 5 years, some attempts were made to influence the colonization of these patients with *P. aeruginosa*. A study was carried out to

determine whether colonization of patients with *P. aeruginosa* could be reduced by discontinuing the use of external urinary collection systems at night. Removal of external urinary collection systems at night significantly reduced the rates of urethral colonization with *P. aeruginosa*, but did not alter the rates of perineal or rectal colonization (unpublished observations). In that study, patient participation was difficult to maintain because of a number of wet beds. Urine spills from urinals were frequent because of body spasms. In a later study, we examined the effect of bathing on *P. aeruginosa* colonization. Meticulous bathing with regular bath soaps did not alter long-term colonization of the perineum (2). Further studies will be necessary to understand and alter the pattern of *P. aeruginosa* colonization and urinary tract infection in SCI patients.

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TABLE 11. Antibiotic susceptibility of dominant serotypes

Antibiotic	No. (%) of susceptible strains/no. tested		
	Serotype 11	Serotype 6	Serotype 4
Carbenicillin	19/39 (49)	10/13 (77)	5/12 (42)
Gentamicin	31/39 (79)	11/13 (85)	5/12 (42)
Tobramycin	37/39 (95)	13/13 (100)	6/12 (50)
Amikacin	36/39 (92)	12/13 (92)	11/12 (92)