Antibiotic resistance in clinical isolates of *Pseudomonas aeruginosa* in Jamaica

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ABSTRACT

Objective. *To assess antibiotic resistance in clinical isolates of* Pseudomonas aeruginosa *in Jamaica, and to obtain baseline information on the presence of this important pathogen.*

Methods. *A total of 51 isolates of* Pseudomonas aeruginosa, *obtained from 162 clinical specimens from major hospitals and laboratories in seven parishes in Jamaica, were analyzed between May and August 2002. Isolates were tested against 18 different antibiotics by a disk diffusion method.*

Results. *Organisms were cultured from wound swabs (56%), high vaginal swabs (10.5%) and ear swabs (42.5%). Overall, the highest percentage rates of resistance were found for cefaclor (100% of all isolates), nalidixic acid (82.4%), kanamycin (76.5%), and trimethoprim/sulfamethoxazole (56.9%). Resistance rates were 25.5% or lower for tobramycin, gentamicin and polymyxin B, cefotaxime, ciprofloxacin and norfloxacin, piperacillin, carbapenems and amikacin. Forty-one isolates showed intermediate sensitivity to most of the antipseudomonal antibiotics, and the remaining 10 isolates were resistant to eight or more antibiotics. The multiresistant isolates, most of which were hospital isolates, were all resistant to tetracycline, nalidixic acid and trimethoprim/sulfamethoxazole, and highly (80%–90%) resistant to kanamycin, ciprofloxacin and norfloxacin.*

Conclusions. *This study confirms that antibiotic resistance in this clinical pathogen is emerging in Jamaica, and suggests that due care must be taken in hospital settings to adequately diagnose pseudomonal infections and prescribe the antibiotic treatment most effective in preventing the increase in multidrug resistant organisms.*

Key words Antibiotic resistance; *Pseudomonas aeruginosa;* clinical isolates.

Pseudomonas aeruginosa is a leading cause of nosocomial infection and can cause fatal illnesses in a variety of patients, including those suffering from cystic fibrosis, burn wounds, tissue injury, and immunosuppressive therapy (1). In the USA, *P. aeruginosa* ranked second among all nosocomial pathogens related to pneumonia in intensive care units reported to the National Nosocomial Infection Surveillance System in the last decade (2). In a recent study carried out at the University Hospital of the West Indies Intensive Care Unit, Akpaka et al. (3) found *P. aeruginosa* to be the second most common isolate among patients in the unit, with over 30% of the isolates being resistant to standard antipseudomonal antibiotics.

In Jamaica, health services are delivered through four semiautonomous regional health authorities (RHA) that have direct management responsibil-

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ity within a geographically defined region. The Northeast RHA comprises the parishes of St. Ann, St. Mary and Portland; the Southeast RHA includes Kingston and St. Andrew, St. Catherine and St. Thomas; the Southern RHA comprises St. Elizabeth, Manchester and Clarendon; and the Western RHA manages the parishes of Westmoreland, Hanover, St. James and Trelawney. Antibiotic treatment recommended locally for pseudomonal infections (including sepsis) includes piperacillin or amikacin as primary therapy, followed by ceftazidime, gentamicin or ciprofloxacin. For uncomplicated urinary tract infections, oral norfloxacin is used, followed by piperacillin, gentamicin, amikacin and ciprofloxacin.

Pseudomonas aeruginosa shows intrinsic and acquired resistance to many structurally unrelated antibiotics, and previous exposure to antibiotics often leads to multidrug-resistant *P. aeruginosa* strains (4–7). Because of these facts, it is of crucial importance to isolate and identify the offending strain in order for appropriate antibiotic therapy to be initiated. The aim of this study was to determine the characteristics and patterns of antibiotic resistance among isolates of *P. aeruginosa* recovered from clinical specimens in Jamaica.

MATERIALS AND METHODS

A total of 162 hospital and community specimens of wound and abscess swabs, high vaginal swabs, ear swabs, blood, urine, sputum, knee aspirates, cerebrospinal fluid, and semen submitted for routine bacterial studies were collected and analyzed during the period from May to August, 2002. The clinical specimens were brought without delay to the laboratory and were processed according to standard techniques (8). Hospital specimens were from inpatients, and community specimens were from persons seen at private primary care centers, or were sent to the laboratory from other centers.

Unless otherwise noted, bacteria were grown at 37 °C in Luria-Bertani medium (Oxoid, Basingstoke, UK) or in Mueller-Hinton broth or agar (Becton Dickinson, Cockeysville, MD). *Pseudomonas aeruginosa* isolates were grown on blood agar plates and MacConkey agar plates to assess purity, and on Mueller-Hinton agar plates to assess pigment production. The criteria for identifying a strain as *P. aeruginosa* were oxidase positivity, catalase positivity, growth at 42 °C, and pigment production (9).

Susceptibility to 18 antimicrobial agents (including 12 common anti-pseudomonal antibiotics) was determined by the standard disk diffusion technique in accordance with the recommendations of National Committee for Clinical Laboratory Standards (10). Antibiotics used in this study are listed in Table 3. Cartridges of antimicrobial-containing disks were obtained from Oxoid (Hampshire, UK), Mast Diagnostics (Merseyside, UK), BBL (Becton Dickinson, Cockeysville, MD) or Janssen-Cilag, Puebla, Mexico), stored between 4 °C and 20 °C, and allowed to come to room temperature prior to use. Mueller-Hinton plates were incubated for 24 h after inoculation with organisms and placement of the disks, and zones of inhibition were measured.

The significance of differences in resistance was evaluated using EpiInfo software (version 3.2.2). Resistance was calculated as a percentage with 95% confidence intervals. The chi-squared test with Yates' correction or Fisher's exact two-tailed test was used to evaluate the association of selected variables with the frequency of resistant isolates. A P value less than 0.05 was considered statistically significant.

RESULTS

Fifty-one isolates of mucoid, green-pigmented *Pseudomonas aeruginosa* were recovered from 147 specimens: 50 samples (28, or 56%) from wound swabs, 57 samples (6, or 10.5%) from high vaginal swabs, and 40 samples (17, or 42.5%) from ear swabs. These organisms grew on blood, MacConkey and Mueller Hinton agar plates, and were identified by their morphology, smell and pigmentation, as well as their Gram reaction and specific confirmatory biochemical tests. No *P. aeruginosa* isolates were recovered from the other 15 specimens.

The distribution of positive samples between hospital and community specimens is given in Table 1, which shows that most of the positive specimens were from Kingston and St. Andrew (n = 15) and Manchester (n = 14), followed by Clarendon (n = 8), St. James (n = 7), St. Elizabeth (n = 5) and St. Catherine (n = 2). According to Table 2, the largest number of positive samples were from wound swabs from male patients hospitalized in different parishes.

Antibiotic susceptibility of the 51 *P. aeruginosa* isolates is given in Table

TABLE 1. Distribution, by parish and source, of specimens from hospitals and laboratories in Jamaica analyzed in 2002 that were positive for *Pseudomonas aeruginosa*

Parish	Source	Specimen swabs[a]	Total isolates
Kingston and St. Andrew	Hospital	ES (2), WS (9)	11
	Community	ES (1), HVS (2), WS (1)	4
Manchester	Hospital	ES (2), WS (6)	8
	Community	ES (4), WS (2)	6
Clarendon	Hospital	ES (1), HVS (1), WS (2)	4
	Community	ES (3), WS (1)	4
St. James	Hospital	WS (5)	5
	Community	ES (1), HVS (1)	2
St. Elizabeth	Hospital		0
	Community	ES (2), HVS (1), WS (2)	5
St. Catherine	Hospital	HVS (1)	1
	Community	ES (1)	1

[a] ES, ear swab; HVS, high vaginal swab; WS, wound swab.

TABLE 2. Distribution, by gender, of specimens from hospital and community samples in Jamaica analyzed in 2002 that were positive for *Pseudomonas aeruginosa*

Samples	Hospital samples		Community samples	
	Male	Female	Male	Female
Wound swabs	15	7	4	2
High vaginal swabs	0	2	0	4
Ear swabs	3	2	4	8

3. The aminoglycoside amikacin was the only antibiotic all isolates were susceptible to ($P < 0.05$), while all of the isolates were resistant to cefaclor, 49 (96.1%) were resistant to tetracycline and amoxicillin/clavulanic acid, 46 (90.2%) to ampicillin, 43 (84.3%) to chloramphenicol, 42 (82.4%) to nalidixic acid, 39 (76.5%) to kanamycin and 29 (56.9%) to trimethoprim/sulfamethoxazole. Fewer than one fourth of the isolates were resistant to the other antibiotics.

Although 41 isolates were moderately sensitive to most of the antipseudomonal antibiotics, 10 were resistant to eight or more of the antibiotics (Table 4). The multiresistant isolates were all resistant to tetracycline, amoxicillin/clavulanic acid, ampicillin, cefaclor, nalidixic acid and trimethoprim/sulfamethoxazole, and highly (80%–90%) resistant to kanamycin, ciprofloxacin and norfloxacin. In contrast, piperacillin and the carbapenems (imipenem and meropenem) were more effective, with only one incidence of resistance among the resistant isolates. Seven out of the 10 multiresistant isolates were from wound swabs (Table 4) from patients in Kingston and St. Andrew (n = 5), St. James and Manchester. The other three isolates were from high vaginal swabs from three separate parishes.

The percentage rates of resistance of *P. aeruginosa* isolates to antibiotics were compared between the sites of infection (Table 5). Organisms isolated from ear swabs were the least resistant, whereas those from wound swabs were among the most resistant isolates ($P < 0.05$). Compared to those from wound or ear swabs, isolates from high vaginal swabs were more resistant to nalidixic acid, tobramycin, ciprofloxacin, and piperacillin ($P < 0.05$). Isolates from wound swabs were more resistant to ceftazidime and gentamicin than those from high vaginal swabs or ear swabs ($P < 0.05$). None of the isolates from high vaginal swabs was resistant to ceftazidime, and none of the isolates from ear swabs was resistant to gentamicin or ciprofloxacin.

The resistance rates of imipenem-, gentamicin-, piperacillin-, and ciprofloxacin-resistant isolates are presented in Table 6. Compared to the group as a whole, ciprofloxacin-resistant isolates were more resistant to five classes of antipseudomonal antibiotics (aminoglycosides, extended-spectrum cephalosporin, carboxypenicillin, carbapenems), whereas gentamicin-resistant isolates (extended-spectrum cephalosporin) and piperacillin-resistant isolates (aminoglycosides) were more resistant to one class of antipseudomonal agent ($P < 0.05$). Imipenem-resistant isolates were more susceptible to ceftazidime, piperacillin, gentamicin and tobramycin than ciprofloxacin-resistant isolates ($P < 0.05$). Piperacillin was the most active antibiotic against both imipenem- and ciprofloxacin-resistant strains.

Piperacillin-resistant isolates were more resistant to tobramycin than the group as a whole, but were more susceptible to ceftazidime and ciprofloxacin than gentamicin-resistant isolates ($P < 0.05$); both were equally susceptible to imipenem.

TABLE 3. Antibiotic resistance of *Pseudomonas aeruginosa* isolates encountered in Jamaica, 2002

Antibiotic	Disk potency (μg)	Number of isolates resistant
Tetracyclines		
• Tetracycline	30	49
Aminoglycosides		
• Amikacin	30	0
• Gentamicin	10	11
• Kanamycin	30	39
• Tobramycin	10	13
β-lactams: Penicillins		
• Amoxicillin/clavulanic acid	20/30	49
• Ampicillin	10	46
• Piperacillin	10	9
β-lactams: Cephalosporins		
• Cefaclor	30	51
• Ceftazidime	30	10
Carbapenems		
• Imipenem	10	5
• Meropenem	10	5
Quinolones		
• Nalidixic acid	30	42
• Ciprofloxacin	5	10
• Norfloxacin	10	10
Antifolates		
• Trimethoprim/sulfamethoxazole	25	29
Other antibiotics		
• Chloramphenicol	30	43
• Polymyxin B	300	11

TABLE 4. Antibiotic resistance profiles for multidrug resistant *Pseudomonas aeruginosa* isolates obtained in Jamaica, 2002

Antibiotic	Isolate (Source)[a]									
	#5 (WS)	#7 (HVS)	#16 (WS)	#20 (WS)	#26 (WS)	#30 (WS)	#34 (HVS)	#42 (WS)	#44 (WS)	#48 (HVS)
Tetracycline	+	+	+	+	+	+	+	+	+	+
Gentamicin	+	–	–	–	+	+	–	+	+	+
Kanamycin	+	+	+	+	+	–	+	+	+	+
Tobramycin	+	+	+	–	–	–	–	–	–	–
Amoxicillin/ clavulanic acid	+	+	+	+	+	+	+	+	+	+
Ampicillin	+	+	+	+	+	+	+	+	+	+
Piperacillin	–	–	–	–	–	–	–	–	+	–
Cefaclor	+	+	+	+	+	+	+	+	+	+
Ceftazidime	+	–	–	+	–	–	–	+	+	–
Imipenem	–	+	–	+	–	–	–	–	–	–
Meropenem	–	+	–	+	–	–	–	–	–	–
Nalidixic acid	+	+	+	+	+	+	+	+	+	+
Ciprofloxacin	+	+	–	–	+	+	+	–	+	+
Norfloxacin	+	+	–	–	+	+	+	+	+	+
Trimethoprim/ sulfamethoxazole	+	–	+	+	+	+	+	+	+	+
Chloramphenicol	+	+	–	+	+	+	+	–	–	–
Polymyxin B	+	–	–	+	+	–	–	–	–	–

[a] WS, wound swab, HVS, high vaginal swab; +, resistance; –, sensitivity.

DISCUSSION

Because of the widespread use of antibiotics, especially in developing countries, the resistance profile of microorganisms is changing, as evidenced by the increasing occurrence of antibiotic resistance among bacterial populations (11–13). *Pseudomonas aeruginosa* is naturally resistant to β-lactams, including broad-spectrum cephalosporins, quinolones, chloramphenicol and tetracyclines, mainly because of the very low permeability of their cell wall. Moreover, *P. aeruginosa* is characterized by the production of inducible cephalosporinase, active efflux and poor affinity for the target (DNA gyrase), three mechanisms that synergize with poor cell wall permeability (14). This resistance renders these organisms refractory to treatment with many currently available drugs, including the antipseudomonal antibiotics. Consequently, it is imperative that local surveillance with antibiograms be implemented to guide the current use of antibiotics.

TABLE 5. Percentage rates of resistance to antibiotics of *Pseudomonas aeruginosa* isolates from hospital and community samples in Jamaica, 2002

Antibiotic	Site of infection					
	Wound swab (n = 28)		High vaginal swab (n = 6)		Ear swab (n = 17)	
Amikacin	0	(0%)	0	(0%)	0	(0%)
Ceftazidime	7	(25.0%)	0	(0%)	3	(17.6%)
Piperacillin	5	(17.9%)	2	(33.3%)	2	(11.8%)
Gentamicin	10	(35.7%)	1	(16.7%)	0	(0%)
Tobramycin	9	(32.1%)	4	(66.7%)	2	(11.8%)
Nalidixic acid	21	(75.0%)	6	(100%)	15	(88.2%)
Ciprofloxacin	7	(25.0%)	3	(50.0%)	0	(0%)
Imipenem	2	(7.1%)	1	(16.7%)	1	(5.9%)

This study provides important data on current antimicrobial resistance for a collection of recent clinical isolates of *P. aeruginosa* from hospital and community sources across several parishes in Jamaica. The different antibiotic resistance patterns observed in the isolates indicate that the organism uses several mechanisms of resistance simultaneously, and that all isolates do not necessarily use the same mechanisms for resistance to particular classes of antibiotics. Further, isolates that were resistant to one class of antibiotics were also resistant to at least one other class.

At hospitals in Mandeville, Kingston and St. Andrew (where most of the isolates originated), oral norfloxacin is the empirical therapy of first choice for urinary tract infections, followed by piperacillin, gentamicin, amikacin and ciprofloxacin. For other infections including wounds and sepsis, piperacillin and amikacin are administered first, followed by ceftazidime, gentamicin and ciprofloxacin. These schedules are consistent with the recommendations of the Sanford Guide (15). It can be concluded that empirical treatment adopted in rou-

TABLE 6. Percentage rates of resistance to other antibiotics in imipenem-, gentamicin-, ciprofloxacin-, and piperacillin-resistant *Pseudomonas aeruginosa* isolates from hospital and community samples in Jamaica, 2002

Antibiotic	All isolates (n = 51)	Imipenem-resistant (n = 5)	Gentamicin-resistant (n = 11)	Ciprofloxacin-resistant (n = 10)	Piperacillin-resistant (n = 9)
Amikacin	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Ceftazidime	10 (19.6%)	1 (20%)	4 (36.4%)	4 (40%)	1 (11.1%)
Piperacillin	8 (15.7%)	0 (0%)	1 (9.1%)	1 (10%)	9 (100%)
Gentamicin	11 (21.6%)	0 (0%)	11 (100%)	7 (70%)	1 (11.1%)
Tobramycin	13 (25.5%)	1 (20%)	4 (36.4%)	6 (60%)	7 (77.8%)
Nalidixic acid	42 (82.4%)	2 (40%)	7 (63.6%)	10 (100%)	9 (100%)
Ciprofloxacin	12 (23.5%)	1 (20%)	6 (54.5%)	10 (100%)	1 (11.1%)
Imipenem	5 (9.8%)	5 (100%)	0 (0%)	1 (10%)	0 (0%)

tine hospital practice induced selective pressure on multiresistant strains, and may thus account for the levels of antibiotic resistance observed in isolates from high vaginal swabs. However, the same cannot be said about isolates from wound (sepsis) swabs.

Our findings with regard to microbial resistance suggest that cefaclor, tetracycline, kanamycin, amoxicillin/clavulanic acid, ampicillin, nalidixic acid, co-trimoxazole and chloramphenicol should not be considered effective agents for the treatment of *P. aeruginosa* wound infections in the hospital setting because of the high resistance rates observed in this study. The 9.8% rate of resistance to imipenem reported here contrasts with the 21% resistance rate obtained in Latin America (16), or with the 11%–19% rates in Europe (17–19). Resistance to ciprofloxacin in our isolates was 19.6%, compared to 26.8% in Latin America (16) and 10%–32% in Europe (17–19). In contrast, resistance to piperacillin was lower (15.7%), but this rate was higher than in Latin America (16) or Europe (17–19).

Gentamicin, amikacin, imipenem and ciprofloxacin are considered potent agents in the treatment of infections caused by multiresistant *P. aeruginosa.* In this study amikacin, followed by imipenem, were the most potent antibiotics ($P < 0.05$). This fact reflects the importance of controlling the use of these antibiotics in the hospital setting to prevent the emergence of aminoglycoside-resistant strains, and of restricting the use of antimicrobials when aminoglycoside-resistant strains are detected (20). Further, ciprofloxacin and gentamicin were both weakly effective against these resistant isolates. We detected a low number of strains resistant to piperacillin and ceftazidime, a result that suggests that these drugs can be considered effective against *P. aeruginosa* sepsis. However, the use of piperacillin and other β-lactams must be monitored, as these antibiotics induce selective pressure on β-lactamase-producing strains, resulting in the development of resistance in the hospital environment (21).

Isolates from both community and hospital wound swab specimens were highly resistant to several antibiotics. This may be attributable to poor wound treatment, poor hospital sanitation, and the rapid emergence of resistant organisms in these patients. Although no multiresistant isolates were obtained from ear swabs, it must be borne in mind that pseudomonal infection in this site can easily lead to severe meningitis if not treated appropriately.

In this study we found that most of the multiresistant isolates originated in Kingston and St. Andrew. This finding was not unexpected in view of the large population in this part of Jamaica as a result of urbanization, and because the area is served by several hospitals including two teaching hospitals. The association between multiresistant isolates and teaching hospitals is also supported by other studies (22–24).

In conclusion, this study examined the resistance profile of *Pseudomonas aeruginosa* in Jamaica and found that the level of multidrug resistance to antibiotics in Jamaican hospitals and laboratories in 2002 was relatively low. Because of increasing multidrug resistance seen elsewhere, however, these results underscore the importance of resistance surveillance studies. Further, due care must be taken—especially in the hospital setting—to diagnose pseudomonal infections correctly and prescribe the most effective antibiotic treatment. A combination of two drugs is likely to be most effective in preventing further increases in the number of multidrug-resistant organisms.

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RESUMEN

Resistencia a antibióticos en cepas clínicas de *Pseudomonas aeruginosa* en Jamaica

Objetivo. Evaluar la resistencia a antibióticos de cepas clínicas de *Pseudomonas aeruginosa* en Jamaica y obtener información de base sobre la presencia de este agente patógeno importante.

Métodos. Entre mayo y agosto de 2002 se analizó un total de 51 cepas de *Pseudomonas aeruginosa* que se obtuvieron de 162 especímenes clínicos procedentes de hospitales y laboratorios grandes en siete parroquias de Jamaica. Las cepas aisladas se sometieron a pruebas de susceptibilidad a 18 antibióticos mediante el método de difusión en disco.

Resultados. Los microorganismos se cultivaron a partir de muestras tomadas de heridas (56%), de la parte profunda de la vagina (10,5%) y de los oídos (42,5%). En general, el mayor porcentaje de resistencia correspondió al cefaclor (100% de todas las cepas aisladas), al ácido nalidíxico (82,4%), a la kanamicina (76,5%) y a la combinación de trimetoprima y sulfametoxazol (56,9%). Se detectó resistencia en 25,5% de las cepas o menos en el caso de la tobramicina, gentamicina y polimixina B, la cefotaxima, ciprofloxacina y norfloxacina, la piperacilina, las carbapenemas y la amikacina. Cuarenta y un cepas mostraron una sensibilidad inmediata a la mayoría de los antibióticos habitualmente usados contra las seudomonas, y las 10 cepas restantes fueron resistentes a ocho antibióticos o más. Todas las cepas con multirresistencia, provenientes de hospitales en su mayor parte, fueron resistentes a la tetraciclina, al ácido nalidíxico y a la combinación de trimetoprima y sulfametoxazole, y altamente resistentes (80 a 90%) a la kanamicina, la ciprofloxacina y la norfloxacina.

Conclusiones. Este estudio confirma que la resistencia a antibióticos está comenzando a observarse en este agente patógeno en Jamaica y apunta a la necesidad de tomar medidas para diagnosticar las infecciones por seudomonas en los hospitales y recetar el tratamiento con antibióticos que sea más eficaz, procurando de ese modo evitar que se produzca un aumento del número de microorganismos resistentes a los antibióticos.