

***Pseudomonas aeruginosa* and the general hospital: a six-year survey**

BY D. M. HARRIS AND P. B. GRAY

Departments of Bacteriology and Histology, Royal Hospital, Sheffield

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SUMMARY

The incidence of infections caused by *Pseudomonas aeruginosa* did not increase significantly among general surgical and medical patients between 1967 and 1972, and the majority of such infections were trivial. Serious infections were virtually confined to the intensive care unit and the renal transplant unit, and were usually associated with major trauma, surgical mishap or immunosuppression. The majority of these patients had received prior antibiotic therapy. Persistent isolation of *Ps. aeruginosa* from surgical wounds was often associated with severe intra-abdominal sepsis, and antibacterial therapy was commonly ineffective in these cases. Apparently susceptible patients did not necessarily acquire infection, though the organism was present in their environment. It is suggested that this may reflect a variation of virulence among environmental strains of *Ps. aeruginosa*, and that further study of this aspect may contribute to improved control of infection.

INTRODUCTION

In recent years, some hospitals have reported an increased incidence of Gram-negative bacilli in clinical material. Members of the Enterobacteriaceae have predominated (Dans, Barrett, Casey & Finland, 1970; Adler, Burke & Finland, 1971) but *Pseudomonas aeruginosa* has accounted for significant numbers of isolations in certain instances (Harris, Orwin, Colquhoun & Schroeder, 1969; Noone & Shafi, 1973). To some extent, the frequency with which this species is isolated reflects the type of hospital and the opportunities available within it for cross-infection. Many reports deal with epidemics of infection which have occurred in specialized units where basic hygienic precautions have been neglected.

Although isolation of *Ps. aeruginosa* from specimens is not necessarily synonymous with infection, serious disease such as septicaemia and necrotizing pneumonia occasionally occurs in patients with underlying immunological deficiencies. However, the incidence of severe *Ps. aeruginosa* infection among the general hospital in-patient population remains ill-defined. In an attempt to identify and assess the relative importance of factors predisposing to major infection, a survey has been made of all isolations of the species from in-patients of this hospital over the years 1967-72.

METHODS

The hospital has 329 beds. It undertakes acute general medicine and surgery, and also has wards for orthopaedics, urology, ophthalmic surgery and ear, nose and throat surgery. There is a five-bedded intensive care unit (I.C.U.), previously described in detail (Harris *et al.* 1969), and a four-bedded renal transplant unit (R.T.U.). Frequent (often daily) bacteriological monitoring is carried out on relevant clinical material from patients in these two units. Bacteriological investigation of patients in other wards is more variable, but on the whole the laboratory is well used, the total number of specimens investigated annually having risen from 19073 in 1967 to 23836 in 1972.

Most strains of *Ps. aeruginosa* were identified on the basis of their characteristic colonial appearance. Less typical strains were investigated further. Isolations were classified as 'transitory' (isolation on one occasion only) or 'persistent' (isolation on two or more occasions from the same patient). A few strains were pyocine-typed by the method of Gillies & Govan (1966). The term 'strain' is used to indicate an organism isolated from a particular patient, irrespective of the number of occasions on which it was isolated. Relevant additional information was obtained from the clinical records, and the necropsy report was consulted in the case of patients who died.

RESULTS

Of a total of 73725 patients admitted to the hospital, *Ps. aeruginosa* was isolated from the wounds, urine or respiratory tracts of 388; the distribution of these strains is shown in Table 1.

Although 73% of the isolations were transitory, persistent isolation was as common as, or even commoner than, transitory isolation in patients from the two highly specialized units. A quarter of the strains were first isolated on the I.C.U. or R.T.U. Of the remaining 280 strains, 224 were distributed over nine general medical and surgical wards and 56 were isolated from patients in the ophthalmic, orthopaedic and ear, nose and throat (E.N.T.) units. The interval elapsing between successive isolations varied widely for different types of ward. For example, in the medical wards the mean interval was 148 days, in the general surgical wards it was 71 days, and in the urology ward it was 25 days. Despite the greater susceptibility of its patients, the mean interval between isolations on the renal transplant unit was 95 days, which was probably attributable to the existence of individual cubicles and consequent lack of opportunity for cross-infection. The I.C.U., which has only one cubicle, was the only unit where 'clustering' of infection was noted (in the sense of three or more infections occurring within a fortnight). This happened on three occasions, the first episode involving six patients and the others each involving three. However the mean interval between isolation of successive strains on this unit was 21 days; on twelve occasions there were periods of 6 weeks when no patient in the unit was colonized by *Ps. aeruginosa*, and the longest interval recorded was 17 weeks.

Table 2 shows the annual incidence of *Ps. aeruginosa* infection in relation to

Table 1. Number of patients from whom *Pseudomonas aeruginosa* was isolated

Initial isolation:		Location of patient when first isolated			
		Surgical wards	Medical wards	I.C.U.	R.T.U.
Respiratory tract	<i>a</i>	15	21	27	1
	<i>b</i>	0	7	53	0
Surgical wounds, chronic discharges	<i>a</i>	86	20	11	0
	<i>b</i>	11	0	6	3
Urine	<i>a</i>	85	25	3	0
	<i>b</i>	8	2	2	2

a, Isolated on one occasion only.
b, Isolated on two or more occasions.

Table 2. Number of patients infected annually by *Ps. aeruginosa* and *Staph. aureus*

Year	Admissions	No. infected		<i>Ps. aeruginosa</i> : <i>Staph. aureus</i> ratio	
		<i>Ps. aeruginosa</i>	<i>Staph. aureus</i>	Whole hospital	I.C.U.
1967	11441	67 (0.58)*	201 (1.75)	0.33	0.83
1968	11516	76 (0.67)	242 (2.10)	0.31	0.91
1969	11813	65 (0.55)	290 (2.45)	0.22	0.48
1970	12649	56 (0.44)	314 (2.47)	0.18	0.50
1971	13068	74 (0.56)	308 (2.48)	0.24	0.94
1972	13238	50 (0.38)	388 (2.93)	0.13	0.93
Total	73725	388 (0.52)	1743 (2.36)	0.22	0.71

* Figures in parentheses indicate infections expressed as percentages of annual admissions.

annual admissions and to the number of strains of *Staph. aureus* isolated during the same period.

The proportion of patients infected by each species showed little variation over the years. However the ratio of *Ps. aeruginosa* to *Staph. aureus* infections was consistently greater in the I.C.U. than in the hospital as a whole. Thirty-four (33 %) of those patients infected by *Ps. aeruginosa* in the I.C.U. also had either previous or concurrent staphylococcal infection, as compared with 19 (6.7 %) of those acquiring *Ps. aeruginosa* in the general wards.

Thirty-seven patients acquired respiratory tract colonization by *Ps. aeruginosa* during assisted ventilation, 27 (73 %) of them having been previously infected by other bacteria (Table 3). No patient was colonized by *Ps. aeruginosa* in the first 3 days of ventilation, although 20 strains (54 %) were isolated during the first week. However, prolonged ventilation did not necessarily lead to acquisition of *Pseudomonas*; of 21 other patients who were ventilated for 7 days or longer, seven remained free of any bacterial infection, six acquired *Staph. aureus*, seven coliform bacilli and one *Haemophilus influenzae*. These patients were broadly comparable in age and severity of illness to those infected by *Ps. aeruginosa* and, since there was a high incidence of multiple antibiotic-resistance in the coliform bacilli and

Table 3. Colonization of tracheostomies in relation to duration of intermittent positive pressure ventilation (I.P.P.V.) in patients who eventually acquired *Ps. aeruginosa*

No. colonized by ...	Days after the institution of I.P.P.V.																
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	21	26	28
<i>H. influenzae</i>	.	1	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.
β -Haemolytic Streptococcus	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Coliform bacilli	3	1	1	.	1	1	3	.	.	.	2	.	1	1	.	.	.
<i>Proteus</i>	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Staph. aureus</i>	3	.	1	1	1	1	.	.	.	.	.	.	.	.	1	1	.
<i>Ps. aeruginosa</i>	.	.	.	5	5	4	6	2	1	1	3	2	3	3	.	1	1

staphylococci isolated from both groups, predisposing antibacterial therapy was essentially similar.

Septicaemia was suspected in 26 patients (all from either the R.T.U. or I.C.U.). Blood from these patients was cultured on 39 occasions, but *Ps. aeruginosa* was isolated in only one instance (from a severely burned patient). Only five of these patients were receiving antibiotics capable of inhibiting the growth of *Ps. aeruginosa* at the time of blood culture.

The 48 patients who died were between 6 and 86 years old; 24 were below 60 years of age, and only three were over seventy. In all cases, *Ps. aeruginosa* was only one of several bacterial species which had infected the patient during life. Nine of the patients had multiple injuries, three had received renal transplants, 15 had required intensive care after other forms of surgery (mostly abdominal) and 15 had been ventilated for respiratory failure of varying aetiology. The remainder suffered from intracranial haemorrhage or encephalitis (4), severe burns (1) and acute renal failure following septicaemia (1). Factors contributing to infection included corticosteroid therapy and immunosuppression (3), diabetes mellitus (1) and malignancy (2). Necropsy was performed on 27 patients. It revealed a high incidence of major intra-abdominal sepsis in the surgical cases, eight patients having generalized peritonitis and a further five subphrenic or retroperitoneal abscesses. Bronchopneumonia was present in 14 patients, but the necrotizing vasculitis which has been recorded as characteristic of *Pseudomonas* infection was not encountered. Post-mortem bacteriology usually yielded a mixed flora similar to that isolated in life.

DISCUSSION

The epidemiology and pathogenesis of *Ps. aeruginosa* infections present a complex problem. The species can survive in moist environments on a minimum of nutrient, grow in dilute antiseptics and resist the action of many antibiotics. It is widely disseminated through most hospitals yet infection remains uncommon and life-threatening infection rare. The present survey does not suggest a significant increase in infections over the last 6 years, and the pattern remains that of trivial infection or transient colonization in most cases, with occasional episodes of more severe infection in seriously ill patients. It is difficult to compare hospitals, since

institutions vary in methods of therapy and cross-infection control. However, the situation in Sheffield is essentially similar to that reported for Edinburgh during 1961 and 1962 (Gould, 1963). More recently, Noone & Shafi (1973) reported an annual infection rate of 1.4–1.8 % of admissions to the Central Middlesex Hospital between 1968 and 1970; a vigorous cross-infection control policy led to an incidence of 0.6 % in 1971. All three surveys suggest that, although control measures may effectively reduce the number of trivial infections and transient colonizations, there remains a small group of susceptible patients in whom it is extremely difficult to prevent infection by *Ps. aeruginosa*. Like Gould, we did not find the extremes of age excessively represented in our cases, and comparatively few had an identifiable immunological deficiency. The chief predisposing factor appeared to be tissue damage, either due to accidental trauma or to radical surgery. In this context, surgical mishap (e.g. breakdown of anastomoses) appeared to be significant.

The intervals elapsing between successive isolations suggested that direct spread of infection between patients was unimportant on the medical and surgical wards. More opportunities exist for cross-infection on an intensive care unit, and it is difficult to explain the failure of some patients to acquire infection with *Ps. aeruginosa* when there were already infected patients in the unit. This may represent the success of aseptic nursing techniques, but it may also reflect subtle differences in the susceptibility of the patients. Although several toxins have been extracted from *Ps. aeruginosa*, the contribution of each fraction to the pathogenicity of the organism is uncertain, and Liu (1964) has suggested that the amount of individual toxins produced is dependent on the nature of the biochemical abnormalities present in damaged tissues. Such biochemical differences may be influential in determining whether *Ps. aeruginosa* is able to establish itself in the tissues of various patients who otherwise appear equally susceptible.

Opinions differ on the importance of environmental colonization. Some workers consider that the strains of *Ps. aeruginosa* endemic in sinks and other moist situations constitute a major source of infection (Teres *et al.* 1973). Others have failed to find such an association (Lowbury *et al.* 1970). However, the possession of toxic factors by strains unassociated with infection has not been investigated on a large scale, and further work is required to clarify the situation. The limited amount of pyocine typing performed on our strains revealed poor correlation between strains isolated from patients and from their immediate environment.

A striking finding in this survey was the association of persistent isolation of *Ps. aeruginosa* from surgical wounds with a subsequent finding of serious intra-abdominal sepsis. This is of some practical importance, since antibacterial therapy directed towards *Pseudomonas* isolated from a wound is unlikely to benefit the patient who has a subphrenic abscess requiring drainage.

Many of the seriously ill patients had received antibiotic therapy for other infections before the isolation of *Pseudomonas*, and it could be maintained that a more restricted use of antibiotics would reduce the incidence of *Ps. aeruginosa* infection. Price & Sleigh (1970) and Klastersky, Beuner & Daneau (1971) have shown that patients with *Klebsiella* or *Staph. aureus* infection of the respiratory tract can be treated successfully with vigorous physiotherapy and scrupulous

bronchial toilet alone. However there will probably always be an irreducible minimum of patients for whom antibacterial therapy is indicated. These will inevitably be the most gravely ill cases, and most of them will be receiving sophisticated medical care at some stage. Experience in the intensive care unit of this hospital showed that 84.2 % of strains of *Staph. aureus* isolated from patients in the unit were already present at the time of admission, and that the problem of infection was therefore related to conditions in the wards from which the patients had been transferred (Harris, 1973). This did not apply in the case of *Ps. aeruginosa*, since virtually all the seriously ill patients who acquired the organism did so while in the unit. The inherent virulence of strains endemic in the environment is therefore crucial, and an intensive study of the pathogenicity of such strains is required.

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