Exogenous acquisition of Pseudomonas aeruginosa in intensive care units: a prospective multi-centre study (DYNAPYO study)

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Summary

Pseudomonas aeruginosa remains one of the most common nosocomial pathogens in intensive care units (ICUs). Although exogenous acquisition has been widely documented in outbreaks, its importance is unclear in non-epidemic situations. We aimed to elucidate the role of exogenous origin of *P. aeruginosa* in ICU patients.

We performed a chronological analysis of the acquisition of *P. aeruginosa* using samples collected in 2009 in DYNAPYO cohort study during which patients and tap water were weekly screened. Molecular relatedness of *P. aeruginosa* isolates was investigated by pulsed-field gel electrophoresis. Exogenous acquisition was defined as identification of a *P. aeruginosa* pulsotype previously isolated from another patient or tap water in the ICU.

DYNAPYO cohort included 1,808 patients (10,402 samples) and 233 water taps (4,946 samples). Typing of 1,515 isolates from 373 patients and 375 isolates from 81 tap water samples identified 296 pulsotypes. Analysis showed an exogenous acquisition in 170 (45.6%) of 373 patients. The pulsotype identified was previously isolated from another patient and from a tap water sample for 86 and 29 patients respectively. The results differed according to the ICU.

The exogenous acquisition of *P. aeruginosa* could be prevented in a half proportion of patients. The overall findings of this survey supports the need for studies on routes of transmission and risk assessment approach to better define how to control exogenous acquisition in ICUs.

Introduction

Pseudomonas aeruginosa remains one of the most common hospital-acquired pathogens, and is endemic in many intensive care units (ICUs).[1,2] Infections caused by *P. aeruginosa*, especially ventilator-associated pneumonia or bloodstream infections, are often severe and associated with considerable mortality in ICU patients; morbidity and mortality rates are higher still in cases of multidrug resistance.[3–6] In ICUs, these infections are usually considered to be endogenous, arising from pre-existing colonization of patients. In addition, the roles of exogenous reservoirs and of patient-to-patient transmission have been convincingly documented during outbreaks. However, the importance of exogenously acquired *P. aeruginosa* in non-epidemic situations remains uncertain.[7,8] Several epidemiological studies have indicated that colonization pressure seems to be a more relevant risk factor than exposure to antibiotics for the acquisition of *P. aeruginosa*.[9–12]

A previous monocentric study showed a clear genetic temporal and spatial relationship between *P. aeruginosa* strains isolated from tap water samples and ICU inpatients.[13] Moreover, the first part of the multicentre DYNAPYO (Dynamics of *Pseudomonas aeruginosa* acquisition in ICU) study showed that exposure to contaminated taps water was a risk factor for *P. aeruginosa* colonisation in ICU patients.[14,15] It is essential to better understand the true contribution of the exogenous acquisition of *P. aeruginosa* in ICU to inform infection prevention and control strategies. We performed a chronological analysis within DYNAPYO participating ICUs to assess the respective contributions of *P. aeruginosa* exogenous acquisition by patient-to-patient transmission and from contaminated taps.

METHODS

93 **Study design and study population**

94 DYNAPYO was a prospective five-month observational survey performed in
95 2009 in ten ICUs (four medical, two surgical and four mixed medical and surgical
96 ICUs) from eight French health care facilities: University hospital of Besançon and
97 Lyon which included two ICUs; University hospital of Bordeaux, Garches, Montpellier
98 and Paris and general hospitals of Lens and Tourcoing which included one ICU.
99 These ICUs had 9 to 20 beds with an average length of stay of 8 to 16 days (Table I).
100 The ICUs did not implement changes during the course of the study, such as
101 infection control or antimicrobial stewardship initiatives. The ICUs had to follow
102 French recommendations in terms of water use for care and measures to prevent
103 patient-to-patient transmission. Outlet taps were equipped with antibacterial filters in
104 one ICU (ICU 1).

105 The DYNAPYO cohort included all adult patients admitted for more than 24 h
106 during the study inclusion period. Demographic and epidemiological data (admission
107 dates and discharge, room number) were collected prospectively. The type of taps
108 (electronic or conventional) was recorded, and patients and tap water were
109 monitored for contamination with *P. aeruginosa* weekly over the study period.
110 Specific trained healthcare workers were identified in each centre for water sampling
111 and for data collection on a secured online case report form. This study was
112 approved by the local ethics committee and the data underlying this study restricted
113 by the French data protection commission (Commission Nationale Informatique et
114 Liberté - France).

115 **Surveillance culture and microbiological analysis**

116 During the data collection period, patients were screened on admission (within
117 the first 48 h of ICU stay), and then once a week and on discharge or death.

Screening samples were oropharyngeal, rectal swabs and tracheobronchial aspirate (or sputum). Others clinical specimens were performed as clinically indicated (as appropriate).

Cold water samples were taken weekly from the 233 taps in the ten ICUs (patients' rooms and other sites) for testing for *P. aeruginosa* (without colony count). Taps were opened and the first 250 mL of flush of water were immediately collected in a sterile flask with sodium thiosulfate. The aerator was swabbed and the swab broken into the water sample. Tap water samples were processed by membrane filtration. A volume of 100 mL was filtered through a 0.45 µm pore size membrane filter (Millipore Microfil, Molsheim, France). Swabs and filters were cultured on cetrimide-agar plates (Bio-Rad, Marnes-la-Coquette, France) at 37°C and examined for growth of colonies after 24 and 48 hours. Any colony that grew on cetrimide-agar plate was identified using the API20 NE identification system (bioMérieux, Marcy l'Etoile, France). All *P. aeruginosa* isolates were sent to the coordinating centre (Bordeaux) on semi-solid agar.

Genotyping

Molecular relatedness of *P. aeruginosa* isolates was investigated by pulsed-field gel electrophoresis (PFGE). Clonality of strains was investigated by PFGE with DraI digestion as previously described.[16] The banding patterns were analysed by scanning photographic negatives. GelCompar software was used for analysis of PFGE patterns (Applied Maths, Kortrijk, Belgium). Pulsotypes were defined according to international recommendations.[17] All patients' first isolates from an anatomic site were analysed. Tap water isolates selected for comparison were:

isolates identified in water on the previous week and the week after of a newly identified patient.

Definitions

Exogenous acquisition was defined as colonisation or infection by a strain of *P. aeruginosa* with a pulsotype previously isolated from another patient (i.e. patient-to-patient transmission) or from tap water sample in the ICU. Patient-to-patient transmission was considered possible when a similar pulsotype was isolated in more than two patients hospitalised during overlapping period without similar pulsotype isolated from tap water. An exogenous origin from tap water was considered possible when a similar pulsotype was isolated in a patient and in at least one ICU tap water prior to *P. aeruginosa* identification in the patient.

RESULTS

Study population

Of the 1,808 patients included in DYNAPYO cohort, 206 were excluded because screening at admission was not carried out. A total of 10,402 screening samples were performed and 427 patients were positive for *P. aeruginosa;* of these 41 were found on entering the study. The average incidence of *P. aeruginosa* in the ten ICUs was 12.7 per 1 000 days hospitalisation (Table II).

Water samples

A total of 4,946 water samples were obtained. Among the 233 taps screened, 81(35%) were positive for *P. aeruginosa* at least once during the study, including 51 at the beginning of the study. The median duration of contamination was 5 weeks (range 1 to 13 weeks). The median duration of contamination differed between electronic and conventional taps (12.6 *vs.* 8 weeks respectively; p = 0.003).

Genotyping and chronological epidemiological analysis

Typing of 1,880 non-replicate isolates (1,515 from 373 patients and 375 from 81 water samples) identified 296 pulsotypes. A total of 270 different pulsotypes were found in patients: 201 (74%) were sporadic, 52 were shared by patients and 17 were shared by water and patient. Variations according to the ICU are shown in Table II.

The chronological epidemiological analysis showed an exogenous acquisition in 170 (45.6%) patients out of the 373 for which at least one isolate was available for typing with variation according to the ICU (from 16.3% in ICU 7 and 85.7 % in ICU 5; Table II). There was a patient-to-patient transmission for 86 of the 170 patients (50.6%) and an exogenous origin from tap water for 29 others patients (17.1%). Moreover, for 55 patients from the two ICUs with higher rate of positive tap water (ICU 5, ICU10) it

was not possible to conclude because pulsotypes were shared by many patients and tap water samples.

DISCUSSION

To our knowledge DYNAPYO is the largest cohort study intending to assess the relative contribution of exogenous acquisition of *P. aeruginosa* in ICUs.[14] We showed an exogenous origin of *P. aeruginosa* in nearly one in two patients. Patient-to-patient transmission was more frequent than acquisition from the tap water. At least half of colonisation or infection by *P. aeruginosa* could be preventable. Furthermore, our study showed discrepancies in the rates of exogenous origin of *P. aeruginosa* according to the ICU that could explain the differences in results in previous monocentric studies.

Patient-to-patient transmission occurs by carriage on the hands of healthcare workers or through contaminated medical equipment.[18–20] There is a considerable body of published literature for patient-to-patient transmission of multidrug resistant *P. aeruginosa* from outbreaks reports.[12,21,22] The strict maintenance of infection control measures is essential to limit the spread of this bacteria. Infection control strategies to decrease the incidence of infection due to *P. aeruginosa* in ICUs mostly includes bundle approaches involving general measures, disinfection and replacing reservoirs.[24,25]

Previous studies observed that clinical strains of *P. aeruginosa* were genetically related to the strains found in the patient's environment, such as in tap water, P-traps, sinks, handwashing stations, faucet aerators or washbasins drain; but a causal link was controversial.[25] In a systematic review, seven monocentric studies were assessed as providing plausible evidence of a link between tap water as a

reservoir for *P. aeruginosa* and colonization/infection in patient in an endemic setting. In these studies rates of exogenous acquisition of *P. aeruginosa* varied from 29% to 81% of patients as in our different ICUs.[13,19,26–30]

In our study, there was a wide heterogeneity in tap water contamination by *P. aeruginosa* among the ICUs. Like others authors, we showed that *P. aeruginosa* may persist in tap water over prolonged periods and that electronic taps are potential reservoirs of *P. aeruginosa* in ICUs.[31–33] Tap water could become positive for *P. aeruginosa* through contamination of the water supply or retrograde contamination (e.g. from splashing on to the faucet when water is drawn, especially if the water flow directly impacts on the drain outlet, or if fluids are inappropriately discarded in handwash basins.[34,35]

Discrepancies observed among ICUs may be explained by various factors: compliance to infection control measures, contamination load of the environment, biological features of the pathogen (intrinsic fitness factors).[36] Based on our finding we suggest monitoring tap water in ICUs with high rates of colonisation or infection with *P. aeruginosa*; although there are no recommendations for a systematic screening in search of *P. aeruginosa* in ICUs. Furthermore these ICUs should consider eliminating work processes involving sinks in proximity patients and favour compliance to alcoholic hand disinfection in order to limit the spread of *P. aeruginosa* among patients. Some guidelines recommend sampling outlets in ICUs on a six-month basis and taking remedial action for outlets that are positive for *P. aeruginosa*.[37]

The strengths of this study are the prospective multicentre design with a study population in accordance with most of the previous studies analysing *P. aeruginosa* colonisation/infection in ICUs; the use of methods enabling temporal relationship to

be identified between water taps and identification of colonisation/infection in patients; repeated sampling during the five months of the study and the huge number of isolates typed by PFGE. Some limitations should also be noted. First, we selected isolates for genotyping and then performed genotyping from one colony of each positive culture; however isolates were not available for some patients. It may not accurately represent the whole epidemiology. A robust methodology should be to type up to 4-10 different colonies from each culture. In a study of more than 1,600 isolates of *P. aeruginosa*, the authors found that over 60% of the tap water samples were contaminated by *P. aeruginosa* and overall 83% of the patient strains were classified as exogenous. They typed of at least four colonies that were representative of the different morphological types of *P. aeruginosa* present on each culture plate.[29] Second, the limitation of water samples may have underestimated the number of exogenous sources as we did not performed extensive microbiological samples of the environment other than water taps and patients. The range of reservoirs in healthcare environments from which *P. aeruginosa* has been isolated is wide, including respiratory therapy equipment, ice makers, endoscopes, and cleaning equipment. [38,39]

Conclusion

This multicentre study conducted in ICUs suggests that exogenous origin of *P. aeruginosa* could be prevented in a substantial proportion of patients. Given the possible consequences of *P. aeruginosa* infection in ICU, it is clear that strategies to prevent *P. aeruginosa* acquisition should become a key priority. We support the need for studies on routes of transmission and risk assessment approach to better define how to control exogenous acquisition in ICUs.

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Table I. Description of the intensive care units

	Type	**Rooms** (n)	**Length of stay in days** (mean)
ICU 1*	Mixed	20	14
ICU 2	Mixed	16	12
ICU 3	Medical	12	10
ICU 4	Surgical	14	14
ICU 5	Medical	18	8
ICU 6	Medical	12	10
ICU 7	Mixed	18	11
ICU 8	Medical	15	11
ICU 9	Surgical	15	11
ICU 10	Mixed	15	16

* ICU with filtered taps.

Table II. Data of surveillance, typing of isolates and chronological analysis

	ICU 1*	ICU 2	ICU 3	ICU 4	ICU 5	ICU 6	ICU 7	ICU 8	ICU 9	ICU 10	Total
Surveillance											
Patients included	203	135	152	138	295	190	200	123	204	168	**1808**
Patients colonised or infected	51	29	59	45	48	37	51	18	43	46	**427**
Patients colonised or infected at the beginning of the study	6	4	5	7	2	1	1	0	5	10	**41**
Incidence of patients colonised or infected *(patient per 1000 days of hospitalisation)*	14.8	14.6	13.3	9.6	15.9	11.5	9.4	9.5	11.2	15.5	**12.7**
Taps water screened	45	15	28	31	25	15	29	10	15	20	**233**
Taps water positives	3	2	10	5	22	11	9	1	0	18	**81**
Taps water positives at the beginning of the study	5	3	9	5	19	0	2	0	0	8	**51**
Typing											
Patients isolates	69	90	223	155	166	72	227	82	100	331	**1515**
Water taps isolates	11	13	69	34	112	18	20	0	0	98	**375**
Patients with at least one isolate typed	34	26	54	44	42	27	49	18	38	41	**373**
Pulsotypes **within patients**	31	21	37	34	16	27	45	10	28	21	**270**
Sporadic pulsotypes	22	17	32	22	11	22	37	4	21	13	**201**
Shared by patients	8	2	4	9	0	4	8	6	7	4	**52**
Shared by water and patient	1	2	1	3	5	1	0	0	0	4	**17**
Pulsotypes **in water taps**	3	4	7	5	6	4	3	0	0	11	**43**
Sporadic pulsotypes	2	2	6	2	1	3	3	0	0	7	**26**
Chronological analysis											
Exogenous origin	17	10	23	23	36	6	8	8	10	29	**170**
Patient-to-patient transmission	14	6	4	20	1	5	8	8	10	10	**86**
Exogenous origin from water tap	3	3	19	3	/	1	0	0	0	/	**29**
Origin not concluded	/	1	/	/	35	/	/	/	/	19	**55**

* ICU with filtered taps.