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## Is Aerosolization a Problem With Carbapenem-Resistant *Acinetobacter baumannii* in Thailand Hospital?

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We evaluated the presence of air contamination with carbapenem-resistant *Acinetobacter baumannii* (CRAB) in medical units where patients with CRAB pneumonia were hospitalized, and in Obstetrics and Gynecology units with open-air ventilation in-patient settings. There was no evidence of CRAB contamination in either of the units.

**Keywords.** *Acinetobacter baumannii*; aerosolization; carbapenem-resistant; Thailand; ventilator-associated pneumonia.

Carbapenem-resistant *Acinetobacter baumannii* (CRAB) has emerged as a major cause of healthcare-associated infections (HAIs) globally, especially in Southeast Asian countries [1, 2]. In Thailand, CRAB was the most common pathogen associated with HAIs, and it has become an infection prevention and control challenge [3–5]. According to the National Antimicrobial Resistance Surveillance Centre reports, CRAB has been on the rise since 2000, and the carbapenem-resistant rate of *Acinetobacter calcoaceticus-baumannii* complex was estimated to be >73% in 2015 [6]. This high rate of resistance has greatly limited the therapeutic options. Existing evidence focusing on the frequency of air contamination suggested the presence of *A baumannii* in different units in the United States [7–9]. Therefore, we performed an experiment to ascertain the presence of air contamination with CRAB in a hospital in Thailand.

### METHODS

#### Setting

Thammasart University Hospital is a 650-bed tertiary care hospital in central Thailand. The hospital has 17 in-patient care

departments with 8 intensive care units (ICUs). All units except ICUs were open-air ventilation units with open windows and doors. All patients with CRAB pneumonia who were on ventilators were admitted to units throughout the hospital, where a cohorting area per unit was created as an infection control strategy to contain spread of CRAB. There is no central heating ventilation and air conditioning in any open unit.

#### Air Sampling and Data Collection

From January 4 to January 30, 2015, twice-weekly air sampling was performed to evaluate the presence of air contamination with CRAB in 4 different units. Units selected for study were 2 open medical care units that housed close-circuit ventilated CRAB patients (experimental units) and 2 open Obstetrics and Gynecology units (control units) that did not house patients with CRAB. In this hospital, a carbapenem is a commonly used antibiotic for empirical therapy in Medicine units and ICUs, whereas noncarbapenem  $\beta$ -lactam antibiotics are commonly used for empirical therapy in Obstetrics and Gynecology units. *Acinetobacter baumannii* identification was performed using Vitek 2 System (BioMérieux). Isolation of *Acinetobacter* spp was excluded from the analysis.

For the experimental units, air sampling was performed at the cohort area where patients' sputum cultures were positive at the time of air sampling. Air samples were also performed in the control units, which housed no patient positive to CRAB. The endemic rate of CRAB infections and colonization in the experimental units were 7.9 patients/1000 patient-days during the study period. The proportion of CRAB was at 65% of all *Acinetobacter* isolates. Twice-weekly air sampling was performed using the settle plate method, a standard technique that had been previously validated at this hospital [10]. Passive air sampling was performed by exposing 90 mm settle plates containing sheep blood agar medium to the air for 6 hours in all units. At each site, 2 settle plates were placed in the vicinity at the bedside of each ventilated patient with CRAB pneumonia in experimental units and 2 settle plates were placed in the vicinity at the bedside of each patient in control units; all plates were placed at 1-meter above the floor. In each location, a total of 4 plates were placed over a 24-hour period; each plate was left opened for 6 hours and was streaked within 1 hour after the exposure period. The distance between patient bed and the vicinity where the plate was placed was 0.5 meter. All samples were incubated for 5 days at 32°C. The bacterial colony counts were expressed as forming units (CFUs)/mm<sup>3</sup> and were estimated using the Koch sedimentation method according to Polish Standard PN89/Z-04008/08 and the following equation: CFUs/mm<sup>3</sup> = (the number of colonies on Petri plate  $\times$  1000)/the

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surface area in Petri plate in  $\text{cm}^2 \times$  the time of Petri Plate exposure in minutes  $\times 0.2$ ) [11]. Temperature and humidity were measured once at the time of air sampling using Q-TRAK indoor air quality meter 7565 (TSI, Inc., Shoreview, MN).

### Data Collection

Data that were prospectively collected included patient characteristics, the rate of *A baumannii* infection in each of the units, the proportion of ventilated patients, patient-days, and CFUs of bacteria per cubic square meter for each patient. The average bacterial air bioburden value at each site was used for analysis. Analyses were performed using IBM SPSS Statistics, version 20 (SPSS Inc., Armonk, NY). A  $\chi^2$  or Fisher exact test was used to compare categorical data, as appropriate. Continuous variables were compared using Mann-Whitney *U* test. All *P* values were 2-tailed; *P* < .05 was considered statistically significant.

### RESULTS

Patient characteristics were significantly different between experimental vs control units (Table). In the experimental unit, ventilated patients consisted of 39% (69 of 180) of the patient population and 64% (1049 of 1640) of the patient-days, whereas

there was no ventilated patient in the control units. The median proportion of *A baumannii*-positive patients was 20% (range, 18%–25%) in experimental units vs 0% in the control units on the specific days that air sampling was performed. The median density of *A baumannii* was 7.1 cases/1000 vs 0 cases/1000 patient-days in experimental vs control units (*P* < .001), respectively. The air humidity and temperature of experimental and control units were similar (Table 1). There were 856 patient areas that were cultured: 434 in experimental units and 422 in control units. The median number of bacterial colonies on air sampling was 781 vs 514 CFU/mm<sup>3</sup> in experimental units vs control units (*P* < .001), respectively. Multiple microorganisms were isolated from the air sampling; however, the patterns were different from experimental vs control units: *Corynebacterium* spp (240 vs 860 CFU/mm<sup>3</sup>; *P* = .02), *Staphylococcus* coagulase negative (440 vs 660 CFU/mm<sup>3</sup>; *P* = .04), *Micrococcus* spp (440 vs 860 CFU/mm<sup>3</sup>; *P* = .01), *Proteus mirabilis* (651 vs 106 CFU/mm<sup>3</sup>; *P* = .001), nonfermentative Gram-negative rods—not *Pseudomonas* spp or *Acinetobacter* spp—(151 vs 54 CFU/mm<sup>3</sup>; *P* = .001). *Acinetobacter baumannii* did not grow in any of the plates. There was no difference in the patterns of all isolated organisms in an individual unit among experimental vs control units.

**Table 1. Patient-Level, Unit-Level Characteristics and Air Sampling Among Experimental and Control Units**

Variables	Experimental Units	Control Units	<i>P</i> Value
Unit-level characteristics			
Total patients	180	180	
Ventilated patients	69 (39%)	0 (0%)	<.001
Patient-days	1640	1640	
Ventilator-days	1049 (49%)	0 (0%)	<.001
Density of <i>Acinetobacter baumannii</i> (median) <sup>a</sup>	7.1	0	<.001
Patient area cultures (N)	434	422	
Patient-level characteristics			
Number of patient	434	422	
Age (years; median, range)	56 (46–74)	28 (19–45)	<.001
Underlying diseases			<.001
Diabetes	198 (45.6)	45 (10.6)	
Hypertension	160 (36.8)	34 (8)	
Chronic pulmonary disease	165 (38)	14 (3.3)	
Stroke	153 (35.2)	0 (0)	
Renal disease	102 (23.5)	2 (0.4)	
Density of CRAB infection/colonization	7.9/1000 PD	0/1000 PD	<.001
Air sampling microorganisms (CFU/mm <sup>3</sup> )			
Total bacterial count (median)	781	514	<.001
<i>Corynebacterium</i> spp	240	860	.02
<i>Staphylococcus</i> coagulase negative	440	660	.04
<i>Micrococcus</i> spp	440	860	.01
<i>Proteus mirabilis</i>	651	106	.001
Nonfermentative Gram-negative rods <sup>b</sup>	151	54	.001
<i>A baumannii</i>	0	0	NA
Temperature (°C, median, range)	27.6 (25.5–28.6)	26.6 (21–28.5)	.59
Relative humidity (% , median, range)	60.3 (57.3–72.4)	60.9 (57–74.1)	.64

Abbreviations: CFU, colony forming unit; CRAB, carbapenem-resistant *A baumannii*; NA, nonapplicable; no (%), unless indicated otherwise; PD, patient-days.

<sup>a</sup> Cases/1000 PD.

<sup>b</sup> Not *Pseudomonas* spp and *Acinetobacter* spp.

## DISCUSSION

There were several notable findings from this study. First, despite the fact that skin microorganisms and nonfermentative Gram-negative bacteria were identified in all units, we were not able to detect the presence of *A baumannii* and CRAB in the air despite substantial sampling time. This finding implies that the nature of an open unit allows frequent air exchanges and may contribute to undetectable burden of *A baumannii* and CRAB in the endemic setting [7]. Thus, airborne isolation is not indicated in patients on closed ventilator circuit with *A baumannii* pneumonia in an open unit with adequate ventilation. Second, we found that the pattern of bacterial air bioburden differed greatly between each type of unit, suggesting that patients in different hospital units can shed different types of airborne skin particles carrying microorganisms [12]. Thus, the unit patient activity and the type of patients in each unit might contribute to the type and amount of bacterial air bioburden detected. Third, our data contributed to the body of evidence for the lack of *A baumannii* aerosolization among close-circuit ventilated patients in a tropical country with high temperature and humidity.

The report of *A baumannii* aerosolization has been inconsistent [7–9]. Although some reports claim the presence of airborne *A baumannii* [7,8], others reported the lack of aerosolization [9]. Factors that may impact study findings include setting of each study, baseline endemicity of *A baumannii*, baseline prevalence of *A baumannii* rectal carrier, use of concurrent antibiotics that have activity toward *A baumannii*, use of close ventilator circuit, type of unit (closed vs open air unit), as well as the frequency of air exchange in the studied unit. The results of our study confirm the findings by Rock et al [9] who reported the lack of air contamination of *A baumannii* of air surrounding known colonized or infected patients. This finding was likely contributed to the patients' closed-circuit ventilator status as well as the frequent air exchanges in the studied units, despite using 24-hour air sampling time.

There are some limitations in this study. First, we used passive air sampling method (settle plates), which may have a lower sensitivity to detect bacterial air bioburden than volumetric air sampling. Second, we did not collect data on the patient's bed activities, such as changing of linens and manipulating of the ventilators, or other sites of colonization (eg, rectum). Third, because all patients who had confirmed diagnosis of *A*

*baumannii* ventilator-associated pneumonia received antibiotic therapy, this might have contributed to the lack of detection of *A baumannii* in the air. Fourth, this study was only performed during a single month at 1 hospital. Finally, it is possible that our study contained a population that had a lower association with air contamination rate, because we did not perform rectal swab cultures to detect CRAB rectal colonization.

## CONCLUSIONS

Our findings support existing evidence on the low to no contamination of *A baumannii* in air among closed-circuit ventilated patients in the open ventilated patient care units. Additional studies in different settings are needed to provide more insights into whether airborne precautions for *A baumannii* are needed.

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