Infection Control & Hospital Epidemiology (2019), **40**, 365–367
doi:10.1017/ice.2018.335

Concise Communication

Droplet aerosol dissemination of carbapenem-resistant *Acinetobacter baumannii* surrounding ventilated patients

Madelyn Mousa BMSc[1], David Schwartz PhD[2], Yehuda Carmeli MD[1,2] and Amir Nutman MD[1,2]

[1]Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel and [2]National Center for Infection Control and Antibiotic Resistance, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel

Abstract

We measured droplet aerosol dissemination of carbapenem-resistant *Acinetobacter baumannii* (CRAB) by sampling air surrounding 10 ventilated patients with CRAB isolated in sputum. Over 70 hours, we sampled 252,000 L of air; CRAB was detected in 39,600 L (16%). CRAB growth was higher during patient care, notably suctioning and sheet changing.

(Received 26 July 2018; accepted 10 November 2018)

Acinetobacter baumannii is a rapidly emerging nosocomial pathogen associated with a high fatality rate.[1] It contaminates the hospital environment and its prolonged survival on dry surfaces and resistance to disinfectants lead to outbreaks that are hard to contain.[2] Carbapenem-resistant *Acinetobacter baumannii* (CRAB) has been isolated from bed surfaces, curtains, and medical equipment.[3,4] Although aerial spread of *A. baumannii* was described more than 30 years ago,[5] it was ignored at the time. Recently there is renewed interest in the topic.[6] Contamination of air may occur because of respiratory ejection from the mouth and nose or shedding of bacteria from skin and infected lesions,[7] as well as through actions such as bed making.[8]

We aimed to measure droplet aerosol dissemination of CRAB in the environment surrounding ventilated patients with CRAB respiratory infection or colonization and to determine whether specific treatment activities were associated with greater dissemination.

Methods

Setting and study sample

The study was conducted from September to December 2016 at Tel-Aviv Sourasky Medical Center, Israel, a tertiary care center with endemic CRAB: the incidence of microbiologically confirmed CRAB infections was 41.8 per 100,000 patient days in 2016 (Israeli Ministry of Health, unpublished data). We recruited adult ventilated patients with sputum cultures growing CRAB in the previous 7 days. Patients were hospitalized in intensive care units (ICUs) or medical step-down units with routine air handling of 10 air changes per hour. We collected the following data: age, gender, ward, current antibiotic treatment, and timing of last chlorhexidine bath. We recorded all patient care activities performed during air sampling. The ethical review board of the Tel-Aviv Sourasky Medical Center approved this study.

Microbiological methods

Air sampling

Air sampling was performed using the Buck Bio-Culture pump (Model B30120, AP Buck, Orlando, FL), a sieve impactor-type bioaerosol sampling pump designed to draw air onto a standard agar plate. The air sampler was placed 1.5 m from the patient's head at a height of 1 m. Air sampling was performed continuously for 7 hours for each patient. The sampler was calibrated to 60 L per minute, and agar plates were changed every 30 minutes (1800 L of air sampled per plate). Two types of agar media were used (3.5 hours each) to compare yields: a nonselective 5% blood agar plate and a selective CHROMagar MDR *Acinetobacter* plate (both from Hylabs, Rehovot, Israel).

Clinical and environmental sampling

Cultures were taken from tracheal aspirate. The buccal mucosa was sampled by swab. Sterile premoistened sponges were used to sample each patient's skin and the immediate environment as previously described: bed rail, bed sheet, a 10-cm^2 wall portion, outlets near the head of the bed, and monitor screens.[4]

Sample processing

Air-inoculated plates and samples were transferred to the laboratory soon after sampling. Swab and sponge samples were inoculated directly onto CHROMagar MDR *Acinetobacter* plates and after overnight enrichment in brain-heart infusion broth. Samples were incubated at 37°C overnight. The numbers of colonies grown per plate were counted. Colonies grown on blood agar plates were subcultured on CHROMagar MDR *Acinetobacter* plates. *Acinetobacter baumannii* identification was confirmed by MALDI-TOF using VITEK-MS (bioMérieux, Marcy-l'Étoile, France).[9]

Author for correspondence: Amir Nutman, Email: amirn@tlvmc.gov.il

PREVIOUS PRESENTATION: This research was first presented at the 28th European Congress of Clinical Microbiology and Infectious Diseases on April 22, 2018, in Madrid, Spain.

Cite this article: Mousa M, *et al.* (2019). Droplet aerosol dissemination of carbapenem-resistant *Acinetobacter baumannii* surrounding ventilated patients. *Infection Control & Hospital Epidemiology*, 40: 365–367, https://doi.org/10.1017/ice.2018.335

Statistical analysis

CRAB growth in air was expressed as number of colony forming units (CFU) per 1,000 L of air. We devised a scoring system to assess CRAB growth from patient and environmental samples semiquantitatively: 0 for no growth, 1 for growth in enrichment culture only, 2 for growth ≤10 CFU from direct plating, 3 for 10–100 CFU, and 4 for ≥100 CFU. We used Spearman's rank correlation to test the association between CRAB growth in air samples and in patient and environmental cultures, and between CRAB growth in air and time since last chlorhexidine wash. We used a *t* test to test the association between CRAB growth in air and antibiotic use. Statistical analyses were performed using SPSS version 25 software (IBM, Armonk, NY).

Results

Overall, 10 patients with CRAB in respiratory cultures were included in the study: 8 had clinical CRAB infection and 2 were colonized. All patients had CRAB growth in respiratory (sputum or buccal mucosa) and skin samples taken on the study day. The mean age was 51 years (range, 18–76 years) and 8 patients were male. Furthermore, 9 patients were mechanically ventilated throughout the entire sampling period and 1 patient was weened during sampling and was spontaneously breathing through a tracheostomy. In addition, 7 patients were on antibiotics with in vitro activity against CRAB.

Total sampling time was 70 hours (140 sampling periods), during which 252,000 L of air (25,200 L per patient) was sampled; 72,000 L of air (40 sampling periods) was sampled during patient care; and 180,000 L of air (100 sampling periods) was sampled while no treatment activity was occurring in the room. CRAB was detected in 39,600 L of sampled air (16%). Quantitative analysis revealed a mean of 0.36 CRAB CFU per 1,000 L of air (range, 0–1.15 CFU/1,000 L). The yield was similar for 5% blood agar and CHROMagar MDR *Acinetobacter* plates.

Air samples were taken from the surroundings of all 10 patients; samples from air surrounding 8 of these were positive for CRAB. For all 8 patients, there was a positive air culture during patient care; for 3 patients, an air culture was also positive during a period of no treatment activity. CRAB was isolated from air during 19 of 40 sampling periods (47.5%) during patient care and during 3 of 100 sampling periods (3%) without treatment activity. Mean CRAB growth was higher during periods of treatment activity than during periods of no activity: 1.17 CFU per 1,000 L of air (range, 0–5 CFU/1,000 L) versus 0.02 CFU per 1,000 L (range, 0–0.1 CFU/1,000 L). Endotracheal suctioning, changing of bed sheets, and diaper changing were the activities most likely to be associated with contamination of air (Table 1).

We found no association between CRAB growth in the air surrounding a patient and the degree of CRAB growth in the patient's respiratory tract or skin, time since last chlorhexidine wash, or antibiotic treatment. The immediate environments of these patients were heavily contaminated by CRAB: CRAB was isolated from 9 of 10 bed rails, 9 of 10 bedsheets, 9 of 10 monitor screens, 8 of 10 bed head outlets, and walls near 4 of 10 patients. There was no correlation between CRAB growth in air and the environmental contamination score.

Table 1. Carbapenem-Resistant *A. baumannii* (CRAB) Growth in Air Samples by Type of Treatment Activity during Sampling

Activity	Total Air Sampled, ×1,000 L[a]	Sampled Air With CRAB Growth, ×1,000 L (% of Total Air Sampled)	Time Spent on Activity, % of Total Sampling Time[a]
Open system endotracheal suctioning	21.6	16.2 (75)	8.6
Closed system endotracheal suctioning	9	7.2 (80)	3.6
Changing of bed sheets	21.6	16.2 (75)	8.6
Changing of diaper	5.4	3.6 (66.7)	2.1
Other treatment activity	25.2	10.8 (42.9)	10.0
No treatment activity	180	5.4 (3)	71.4

[a]Because some activities were performed together during the 30-minute sampling period, total air sampled and activities add up to >100%.

Discussion

We detected CRAB in the air adjacent to ventilated patients with CRAB respiratory colonization or infection. Air contamination was intermittent; CRAB was detected almost half of the time during periods of patient care but in only 3% of periods without treatment activity. Air contamination was almost 60 times greater during treatment activities, especially during endotracheal suctioning, changing of bedsheets, and diaper changing.

Measures to limit the spread of multidrug-resistant bacteria are aimed at preventing contact transmission. However, reports of aerosolized bacteria such as *S. aureus* suggest that droplet aerosol dissemination may also be an important route for environmental contamination and possibly patient-to-patient transmission.[8] A recent study found clonal relatedness between *Acinetobacter* strains isolated from air and subsequent clinical strains, suggesting the possibility of airborne transmission.[10] Although it is premature to recommend airborne isolation of patients with respiratory CRAB, recognizing the possibility of droplet aerosol dissemination, especially during patient care activities that generate CRAB aerosols, has implications for infection control.

Our study has several limitations. First, our sample size was small. Second, most patients had an active infection; their CRAB load may have been higher, potentially causing greater spread of CRAB into the environment. Third, we sampled air in only 1 location; thus, we could not evaluate the distance of CRAB spread.

In conclusion, CRAB contaminates air surrounding ventilated patients with CRAB respiratory infection or carriage, especially during patient care activities. Our results support previous studies suggesting the risk of droplet aerosol transmission.

Acknowledgments. The work performed by Madelyn Mousa was part of the requirements for a medical doctor (MD) degree, Sackler Faculty of Medicine, Tel Aviv University, Israel. We thank Dr Elizabeth Temkin for her helpful comments on this manuscript.

Financial support. This work was supported by the European Commission FP7 AIDA project "Preserving Old Antibiotics for the Future: Assessment of Clinical Efficacy by a Pharmacokinetic/Pharmacodynamic Approach to Optimize Effectiveness and Reduce Resistance for Off-Patent Antibiotics" (grant no. Health-F3-2011-278348).

Conflicts of interest. All authors report no conflict of interest related to this article.

References

1. Peleg AY, de Breij A, Adams MD, *et al.* The success of *Acinetobacter* species: genetic, metabolic, and virulence attributes. *PLoS One* 2012;7:e46984.
2. Peleg AY, Seifert H, Paterson DL. *Acinetobacter baumannii*: emergence of a successful pathogen. *Clin Microbiol Rev* 2008;21:538–582.

https://doi.org/10.1017/ice.2018.335 Published online by Cambridge University Press

3. Das I, Lambert P, Hill D, Noy M, Bion J, Elliott T. Carbapenem-resistant *Acinetobacter* and role of curtains in an outbreak in intensive care units. *J Hosp Infect* 2002;50:110–114.
4. Nutman A, Lerner A, Schwartz D, Carmeli Y. Evaluation of carriage and environmental contamination by carbapenem-resistant *Acinetobacter baumannii*. *Clin Microbiol Infect* 2016;22:949.e5–949.e7.
5. Allen KD, Green HT. Hospital outbreak of multiresistant Acinetobacter anitratus: an airborne mode of spread? *J Hosp Infect* 1987;9:110–119.
6. Shimose LA, Doi Y, Bonomo RA, *et al.* Contamination of ambient air with Acinetobacter baumannii on consecutive inpatient days. *J Clin Microbiol* 2015;53:2346–2348.
7. Obbard JP, Fang LS. Airborne concentrations of bacteria in a hospital environment in Singapore. *Water Air Soil Pollut* 2003;144:333–341.
8. Shiomori T, Miyamoto H, Makishima K, *et al.* Evaluation of bed making–related airborne and surface methicillin-resistant *Staphylococcus aureus* contamination. *J Hosp Infect* 2002;50:30–35.
9. Toh BE, Paterson DL, Kamolvit W, *et al.* Species identification within *Acinetobacter calcoaceticus-baumannii* complex using MALDI-TOF MS. *J Microbiol Methods* 2015;118:128–132.
10. Yakupogullari Y, Otlu B, Ersoy Y, *et al.* Is airborne transmission of *Acinetobacter baumannii* possible: a prospective molecular epidemiologic study in a Tertiary Care Hospital. *Am J Infect Control* 2016;44:1595–1599.

https://doi.org/10.1017/ice.2018.335 Published online by Cambridge University Press