ORIGINAL ARTICLE

Assessing the Burden of *Acinetobacter baumannii* in Maryland: A Statewide Cross-Sectional Period Prevalence Survey

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OBJECTIVE. To determine the prevalence of *Acinetobacter baumannii*, an important healthcare-associated pathogen, among mechanically ventilated patients in Maryland.

DESIGN. The Maryland MDRO Prevention Collaborative performed a statewide cross-sectional active surveillance survey of mechanically ventilated patients residing in acute care and long-term care (LTC) facilities. Surveillance cultures (sputum and perianal) were obtained from all mechanically ventilated inpatients at participating facilities during a 2-week period.

SETTING. All healthcare facilities in Maryland that provide care for mechanically ventilated patients were invited to participate.

PATIENTS. Mechanically ventilated patients, known to be at high risk for colonization and infection with *A. baumannii*, were included.

RESULTS. Seventy percent (40/57) of all eligible healthcare facilities participated in the survey, representing both acute care ($n = 30$) and LTC ($n = 10$) facilities in all geographic regions of Maryland. Surveillance cultures were obtained from 92% (358/390) of eligible patients. *A. baumannii* was identified in 34% of all mechanically ventilated patients in Maryland; multidrug-resistant *A. baumannii* was found in 27% of all patients. *A. baumannii* was detected in at least 1 patient in 49% of participating facilities; 100% of LTC facilities had at least 1 patient with *A. baumannii*, compared with 31% of acute care facilities. *A. baumannii* was identified from all facilities in which 10 or more patients were sampled.

CONCLUSIONS. *A. baumannii* is common among mechanically ventilated patients in both acute care and LTC facilities throughout Maryland, with a high proportion of isolates demonstrating multidrug resistance.

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Acinetobacter baumannii has emerged as an important healthcare-associated pathogen in both acute care and long-term care (LTC) settings,[1-3] particularly among critically ill patients and those receiving mechanical ventilation.[4,5] Outbreaks have been reported nationally and globally,[6] and this pathogen is well known in Maryland.[2,7-9] Despite its notoriety, the true burden of *A. baumannii* is unknown. In this report, we describe a statewide cross-sectional prevalence survey where surveillance sputum and perianal cultures were obtained from mechanically ventilated patients residing in all healthcare settings (acute care and LTC) to determine the prevalence of *A. baumannii* in Maryland. To our knowledge, this is the first report of this magnitude to assess the prevalence of *A. baumannii*, particularly across healthcare settings. Furthermore, collecting surveillance cultures (instead of clinical cultures alone) addresses both colonization and infection, which provides a better estimate of the actual burden and can therefore improve statewide prevention and control efforts.

METHODS

Data Collection

In 2009, the Maryland Department of Health and Mental Hygiene formed a multidisciplinary advisory group of healthcare partners, the Maryland MDRO Prevention Collaborative, to address statewide surveillance and prevention of multidrug-resistant organisms (MDROs). An initial focus was to determine the statewide prevalence of *A. baumannii* among mechanically ventilated patients in acute care and LTC facilities. All 45 acute care and 12 LTC facilities in Maryland

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providing care to mechanically ventilated patients were invited to participate in this survey; participation was voluntary. The prevalence survey was performed during a 12-day period in July–August 2010. Each facility was assigned to complete sample collection on a single day during the survey period. On the assigned day, sputum and perianal samples were obtained from eligible patients (ie, patients residing in the facility and receiving mechanical ventilation on the survey day). No patient-identifying information was collected. The survey was performed as a public health initiative (authorized by the Annotated Code of Maryland, Health-General §§2-104, 18-102, 18-201, 18-202, and 18-205, and the Code of Maryland Regulations 10.06.01.03 and 10.06.01.06).

Specimens were collected by facility-based staff (eg, infection preventionists, nursing staff, and/or respiratory therapists) in coordination with a Maryland MDRO Prevention Collaborative team member. Materials and culture collection protocols were provided prior to the survey date. As per protocol, perianal cultures were obtained using Staplex II cotton swabs with Aimes transport medium (Staplex), swabbing the perianal area in a circular motion from the anus out, and sputum cultures were collected during routine respiratory care using a closed tracheal suction procedure. A collaborative team member was on site on the collection day and was responsible for specimen transportation to the University of Maryland School of Medicine laboratory. Specimens were transported in a cooler and maintained at a temperature as close to 4°C as possible.

Laboratory Methods

Identification of A. baumannii *organisms.* All surveillance cultures (perianal and sputum) were plated onto CHROMAgar *Acinetobacter* agar (Gibson Laboratories) and MacConkey agar (Remel) and incubated at 35°–37°C for 24–48 hours.[10] Red colonies on CHROMAgar *Acinetobacter* agar (or lactose nonfermenting organisms on MacConkey agar if no red colonies were present on CHROMAgar *Acinetobacter* agar) were identified as *A. baumannii* with the Vitek II system (bioMérieux). Susceptibility testing was performed by disk diffusion and, in the case of polymyxin B, by broth microdilution methods, in accordance with Clinical and Laboratory Standards Institute guidelines.[11] Susceptibility to tigecycline was interpreted using published Food and Drug Administration guidelines (http://labeling.pfizer.com/showlabeling.aspx?id = 491). Multidrug resistance was defined as an isolate that was resistant to 1 or more agents in 3 or more antimicrobial categories (see Table 2 for complete definitions, modified from Magiorakos et al[12]).

Molecular typing. Molecular typing using pulsed-field gel electrophoresis (PFGE) was performed on all isolates to determine genetic relatedness. PFGE was performed following the protocol described at http://www.cdc.gov/pulsenet/protocols.htm with modifications.[10] Briefly, DNA was digested with *Apa*I according to the manufacturer's recommendations (New England Biolabs) and separated in 1% agarose on a contour-clamped homogeneous-field machine (CHEF-DR II; Bio-Rad). Electrophoresis was performed at 120V for 18.5 hours; pulse times ranged from 7 to 20 seconds. After electrophoresis, gels were stained with ethidium bromide and photographed under ultraviolet illumination. Band patterns were compared by means of the Dice coefficient using the unweighted pair-group method to determine band similarity and the criteria established by Tenover et al[13] to define pulsed-field type clusters. Isolates that had band patterns with at least 85% similarity were considered genetically related.

RESULTS

In total, 40 (70%) of the 57 eligible healthcare facilities participated in the prevalence survey. The median (interquartile range) bed size for all 45 eligible acute care facilities was 267 (140–320); for participating facilities it was 284 (218.25–320), and for nonparticipating facilities it was 194 (83.5–333.5). The median (interquartile range) bed size for all 12 LTC facilities was 142 (116–185); for participating facilities it was 129 (112–173), and for nonparticipating facilities the median was 193.5 (bed sizes of the 2 nonparticipating facilities were 147 and 240).

Among the 40 facilities that agreed to participate, 5 (4 acute care and 1 LTC) did not have mechanically ventilated patients during the survey period, and thus no specimens were collected (key findings are summarized in Table 1). *A. baumannii* was identified from at least 1 patient in 49% (17/35) of the remaining facilities surveyed—31% (8/26) of the acute care hospitals sampled and 100% (9/9) of the LTC facilities sampled. Of the facilities with at least 10 eligible patients on the survey day, 93% (13/14) had *A. baumannii* identified; all facilities in which surveillance cultures were actually collected from at least 10 patients had *A. baumannii* identified from at least 1 patient (the facility with at least 10 eligible patients in which *A. baumannii* was not found had 38% [5/13] compliance with collection of specimens, whereas the average compliance for the remaining 13 facilities was 92%).

Participating facilities were representative of all geographic areas of Maryland; 50% (6/12) of facilities in the National Capital region participated, as did 80% (4/5) in the Western Maryland region, 81% (25/31) in the Central Maryland region, 100% (3/3) in the Southern Maryland region, and 33% (2/6) in the Eastern Shore region. *A. baumannii* was identified in 38% of patients sampled (23/60 among 60 eligible patients) in the National Capital region, in 24% (6/25 among 31 eligible) in the Western Maryland region, and in 35% (93/267 among 293 eligible) in the Central Maryland region. *A. baumannii* was not found in any of the 5 patients (6 eligible) sampled in either the Eastern Shore or the Southern Maryland region.

In participating facilities, 390 patients (234 in acute care and 156 in LTC facilities) were receiving mechanical ventilation on the survey date and thus were eligible for sample

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TABLE 1. Key Findings: Comparison of Acute Care and Long-Term Care (LTC) Facilities

Characteristic	All facility types	Acute care	LTC	Fisher exact *P*
Facility participation				
No. of eligible facilities	57	45	12	
Participating facilities	40 (70)	30 (67)	10 (83)	
Acinetobacter baumannii results, by facility				
Facilities with *A. baumannii*, proportion (%)[a]	17/35 (49)	8/26 (31)	9/9 (100)	<.01
A. baumannii results, by patient	*n* = 358	*n* = 222	*n* = 136	
Patients with *A. baumannii*	121 (34)	36 (16)	85 (63)	<.01
Patients with imipenem-resistant *A. baumannii*	76 (21)	17 (8)	59 (43)	<.01
Patients with multidrug-resistant[b] *A. baumannii*	94 (27)	9 (21)	74 (54)	<.01
Patients with extensively drug-resistant[c] *A. baumannii*	79 (22)	7 (16)	63 (46)	<.01

NOTE. Data are no. (%), unless otherwise indicated.

[a] Among the 40 healthcare facilities that agreed to participate in the survey, 5 (4 acute care and 1 LTC) did not have eligible participants during the survey period, and thus no data were collected. Data shown are by number of participating facilities in which patient samples were obtained.

[b] Resistant to ≥1 agent in ≥3 antimicrobial categories.

[c] Resistant to ≥1 agent in ≤2 antimicrobial categories, where antimicrobial categories are defined as (1) antipseudomonal carbapenems (imipenem, doripenem, meropenem), (2) penicillins plus β-lactam inhibitors (ampicillin-sulbactam), (3) antipseudomonal penicillins plus β-lactam inhibitors (piperacillin-tazobactam), (4) extended-spectrum cephalosporins (cefepime, ceftazidime), (5) antipseudomonal fluroquinolones (ciprofloxacin), (6) folate pathway inhibitors (trimethoprim-sulfamethoxazole), (7) aminoglycosides (amikacin, gentamicin), and (8) polymyxins (polymyxin B).

collection. Samples (either sputum or perianal) were collected from 92% (358/390) of eligible patients, including 95% (222/234) of acute care and 86% (136/156) of LTC patients. Sputum samples were obtained from 89% (347/390) of patients, perianal samples were obtained from 85% (333/390), and both were obtained from 83% (322/390). *A. baumannii* was identified from either anatomical site in 34% (121/358) of patients; 27% (95/358) grew multidrug-resistant *A. baumannii* (Table 2). Sixteen percent (36/222) of patients sampled in acute care hospitals had *A. baumannii* identified from at least 1 clinical site (perianal or sputum), compared with 63% (85/136) of patients in LTC facilities (Fisher exact $P < .01$). *A. baumannii* was identified in 28% (98/347) of sputum samples and in 21% (70/333) of perianal samples. Of the 322 patients who had both sputum and perianal samples obtained, 47 (15%) had *A. baumannii* identified from both sites.

Molecular typing was performed on all 178 isolates identified from 121 unique patients. Among the 178 isolates, 93 PFGE groups (ie, a group of isolates exhibiting band patterns with at least 85% similarity and thus considered to be genetically related) were identified. Twenty-eight groups had multiple isolates; 6 included isolates identified from the same patient, 4 included 2 or more patients at a single healthcare facility, and 18 included 2 or more patients at 2 or more facilities (the largest group included patients from 7 facilities). Of the patients who had *A. baumannii* identified from both sputum and perianal samples, 62% (29/47) had isolates that were genetically unrelated.

In the acute care setting, PFGE was performed on all 50 isolates identified from 36 unique patients, and 34 groups were identified; 7 of these involved multiple isolates (2 within the same patient, 1 involving multiple patients at a single facility, and 4 involving 2 or more patients at 2 or more facilities). In the LTC setting, 68 PFGE groups were identified from 85 unique patients; 21 groups involved multiple isolates (5 within the same patient, 4 involving 2 or more patients a single facility, and 12 involving 2 or more patients at 2 or more facilities).

DISCUSSION

We present the first assessment of the burden of *A. baumannii* in the healthcare setting using a statewide cross-sectional active surveillance survey. The data are strengthened by the high rates of participation among different types of facilities (acute care and LTC) in all regions of the state. The results show that mechanically ventilated patients in Maryland frequently harbor *A. baumannii*; in fact, 34% of such patients across all healthcare settings were found to be colonized or infected with this bacterium. The prevalence of multidrug-resistant strains is also significant, with 27% of all patients harboring multidrug-resistant *A. baumannii*. Furthermore, identification of *A. baumannii* was highest in the LTC setting, with 100% of participating LTC facilities having patients with *A. baumannii*. These results represent a significant burden to the healthcare system and have important clinical implications when choosing empirical antimicrobial therapies for this patient population. Furthermore, these findings represent a substantial reservoir of *A. baumannii* with the potential for transmission to other patients both within a healthcare facility and

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TABLE 2. Antimicrobial Data

	All patients (n = 358)	Acute care patients (n = 222)	LTC patients (n = 136)
Imipenem	76 (21)	17 (8)	59 (43)
Doripenem	81 (23)	18 (8)	63 (46)
Meropenem	85 (24)	19 (9)	66 (49)
Ampicillin-sulbactam	52 (15)	9 (4)	43 (32)
Piperacillin-tazobactam	89 (25)	21 (9)	69 (50)
Cefepime	84 (23)	19 (9)	65 (48)
Ceftazidime	84 (23)	19 (9)	65 (48)
Ciprofloxacin	102 (28)	21 (9)	81 (60)
Trimethoprim-sulfamethoxazole	95 (27)	20 (9)	75 (55)
Gentamicin	77 (22)	15 (7)	62 (46)
Amikacin	55 (15)	11 (5)	44 (32)
Tigecyline	37 (10)	16 (7)	21 (15)
Polymyxin B	22 (6)	7 (3)	15 (7)
Multidrug resistant[a]	95 (27)	21 (9)	74 (54)
Extensively drug resistant[b]	79 (22)	16 (7)	63 (46)
Pandrug resistant[c]	4 (1)	0	4 (3)

NOTE. Data are no. (%) of all patients sampled with *Acinetobacter baumannii* isolates demonstrating antimicrobial resistance. LTC, long-term care.

[a] Resistant to ≥1 agent in ≥3 antimicrobial categories.

[b] Resistant to ≥1 agent in ≤2 antimicrobial categories.

[c] Resistant to all antimicrobial categories, where antimicrobial categories are defined as (1) antipseudomonal carbapenems (imipenem, doripenem, meropenem), (2) penicillins plus β-lactam inhibitors (ampicillin-sulbactam), (3) antipseudomonal penicillins plus β-lactam inhibitors (piperacillin-tazobactam), (4) extended-spectrum cephalosporins (cefepime, ceftazidime), (5) antipseudomonal fluroquinolones (ciprofloxacin), (6) folate pathway inhibitors (trimethoprim-sulfamethoxazole), (7) aminoglycosides (amikacin, gentamicin), and (8) polymyxins (polymyxin B).

across different facilities when patients are transferred between care settings.

The use of an active surveillance methodology to assess prevalence of both colonization and infection is a strength of this survey and complements data from the Centers for Disease Control and Prevention National Healthcare Safety Network, which includes only clinical cultures.[14] Performing surveillance using only clinical cultures likely underestimates the true prevalence, potentially missing the emergence of epidemiologically important bacteria. In the future, more studies should include surveillance cultures to identify subclinical colonization. These studies should be performed early, when novel resistant pathogens first appear, to identify resistance trends before they become endemic.

In this survey, identification of *A. baumannii* among patients was significantly more common in the LTC setting than in acute care hospitals (63% in LTC vs 16% in acute care; $P < .001$). In addition, *A. baumannii* was identified from at least 1 patient in 100% of LTC facilities. Antimicrobial resistance was also more common in the LTC setting (87% of isolates from LTC were classified as multidrug resistant, compared with 58% of acute care isolates; Fisher exact $P < .01$, data not shown). The preponderance of *A. baumannii* found among mechanically ventilated patients in the LTC setting may represent a certain high-risk population (eg, the chronically ill and chronically ventilated at increased risk of frequent transfer between acute care and LTC settings) or may reflect differences in infection control practices between the 2 settings. That *A. baumannii* was found in nearly all healthcare facilities (both acute care and LTC) if there were at least 10 eligible patients on the survey date may suggest the former. Other studies have found a high prevalence of *A. baumannii* in LTC facilities.[1,2] In 2010, Sengstock et al[1] reported on the epidemiology of *A. baumannii* within a large healthcare system in Detroit and demonstrated that patients with resistant isolates were more likely to be discharged to LTC facilities than home. Taken together, these data suggest that the LTC setting is a significant reservoir for *A. baumannii* and support the need for increased surveillance in this population. More prescriptive guidelines aimed at reducing transmission of this pathogen, both within the LTC setting and between LTC and acute care facilities, are also needed.

Results of the molecular typing showed that 52% of all isolates had a unique PFGE group, suggesting that this organism is highly endemic in Maryland. While the molecular diversity demonstrated by the PFGE results may be a limitation of the sensitivity of PFGE (eg, genetically related organisms acquire multiple resistance mechanisms over time

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and appear unrelated), the results may also suggest that antimicrobial selection is a significant factor in the acquisition of *A. baumannii*. These results also showed that several small clusters of PFGE groups were shared among patients both within healthcare facilities and among different facilities, suggesting that patient-to-patient transmission is occurring both at the facility level and between facilities.

The results outlined in this report, including both the high prevalence of *A. baumannii* and the molecular findings (eg, evidence for both a highly endemic process and patient-to-patient transmission), suggest the need to increase efforts aimed at reducing the transmission of *A. baumannii*. These efforts may include an emphasis on antimicrobial stewardship and other best practices (eg, hand hygiene), or they may include enhanced efforts such as universal gloving/gowning, geographic cohorting of patients, restricting traffic into patient rooms, enhanced environmental cleaning, and/or active surveillance.[7,15,16] A recent report by Palmore et al[17] describes the effective use of a multidisciplinary approach aimed at controlling outbreaks due to *Acinetobacter* that included many of the above measures as well as the use of dedicated nurses to enforce compliance. While some of these measures have been tested in the outbreak setting, more work needs to be done to determine their effectiveness (and cost-effectiveness) in reducing spread in the endemic setting.

This survey has several limitations. Since the survey was limited to patients receiving mechanical ventilation, the prevalence of *A. baumannii* cannot be generalized to other patients in healthcare settings. However, this population has a high risk for colonization or infection with *A. baumannii* and, due to typically long lengths of stay, likely represents a significant risk for transmission.[4,5] In addition, surveillance cultures were obtained only from the sputum and perianal area. By not including other sites known to harbor *A. baumannii* (eg, skin and wound), colonization with this organism may well have been underestimated.[18] Finally, by performing surveillance during summer months we may have overestimated the prevalence, since seasonal variation with higher rates of gram-negative bacterial infections (including with *A. baumannii*) has been reported in the summertime.[19] It is unclear, however, if seasonal variation is important for colonization in addition to infection. Furthermore, although this may overestimate the average annual prevalence, the bioburden of *A. baumannii* during the summer is clearly demonstrated in our survey and at the very least represents an important warning regarding organism transmission during this time period.

In summary, *A. baumannii* (including multidrug-resistant strains) is common among mechanically ventilated patients in Maryland in both acute care and LTC settings, representing a significant burden to the healthcare system and the potential for both patient-to-patient and interfacility spread. More surveys like this one are needed to assess the burden of this pathogen in other regions, in order to further characterize the epidemiology of *A. baumannii* and its potential impact on the healthcare system, allowing for potential allocation of resources to prevent transmission and reduce overall prevalence. Furthermore, surveys like this one in which colonization status is assessed are necessary to assess the burden of antimicrobial resistance before resistance becomes endemic and at a time when interventions are more likely to be successful.

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