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Major article

Effectiveness of infection prevention measures featuring advanced source control and environmental cleaning to limit transmission of extremely-drug resistant *Acinetobacter baumannii* in a Thai intensive care unit: An analysis before and after extensive flooding

Anucha Apisarnthanarak MD [a,*], Uayporn Pinitchai RN [a], Boonyasit Warachan PhD [b], David K. Warren MD [c], Thana Khawcharoenporn MD, MSc [a], Mary K. Hayden MD [d]

[a] *Division of Infectious Diseases, Faculty of Medicine, Thammasat University, Pathumthani, Thailand*
[b] *Department of Applied Statistics, Faculty of Science, King Mongkut's Institute of Technology, Ladkrabang, Thailand*
[c] *Division of Infectious Diseases, Washington University School of Medicine, St Louis, MO*
[d] *Division of Infectious Diseases, Rush University Medical Center, Chicago, IL*

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Background: Advanced source control (once-daily bathing and 4-times daily oral care with chlorhexidine aqueous solution) and thorough environmental cleaning were implemented in response to an increased incidence of colonization and infection with extremely drug-resistant (XDR) *Acinetobacter baumannii* in a Thai medical intensive care unit (MICU).

Methods: During the 12-month baseline period (P1), contact isolation, active surveillance for XDR *A baumannii*, cohorting of XDR *A baumannii* patients, twice-daily environmental cleaning with detergent-disinfectant, and antibiotic stewardship were implemented. In the 5.5-month intervention period (P2), additional measures were introduced. Sodium hypochlorite was substituted for detergent-disinfectant, and advanced source control was implemented. All interventions except cleaning with sodium hypochlorite were continued during the 12.5-month follow-up period (P3). Extensive flooding necessitating closure of the hospital for 2 months occurred between P2 and P3.

Results: A total of 1,365 patients were studied. Compared with P1 (11.1 cases/1,000 patient-days), the rate of XDR *A baumannii* clinical isolates declined in P2 (1.74 cases/1,000 patient-days; $P < .001$) and further in P3 (0.69 cases/1,000 patient-days; $P < .001$). Compared with P1 (12.15 cases/1,000 patient-days), the rate of XDR *A baumannii* surveillance isolates also declined in P2 (2.11 cases/1,000 patient-days; $P < .001$) and P3 (0.98 cases/1,000 patient-days; $P < .001$). Incidence of nosocomial infections remained stable. Six patients developed chlorhexidine-induced rash (1.4/1,000 patient-days); 31 patients developed mucositis (17.1/1,000 patient-days).

Conclusions: These results support advanced source control and thorough environmental cleaning to limit colonization and infection with XDR *A baumannii* in MICUs in resource-limited settings.

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The global emergence of multidrug-resistant (MDR) pathogens calls for immediate action.[1] Advanced source control is a strategy for decreasing the burden of patient skin and/or oral cavity carriage of MDR pathogens.[2,3] An example of this approach is the use of chlorhexidine bathing with or without oral care. Chlorhexidine bathing has been shown to reduce individual patient risk of infection and to decrease health care worker hand contamination during patient care, thereby reducing the risk of cross-transmission of MDR pathogens by contaminated hands.[2,4,5] Thorough environmental cleaning also has been shown to reduce the incidence of cross-transmission of various MDR pathogens.[6-8] However, little data are available concerning the effectiveness of advanced source control together with thorough environmental cleaning for control of MDR pathogens in the Asia Pacific region. There is also limited published information on the impact of extensive black water

* Address correspondence to Anucha Apisarnthanarak, MD, Division of Infectious Diseases, Faculty of Medicine, Thammasat University, Pathumthani 12120, Thailand.
E-mail address: anapisarn@yahoo.com (A. Apisarnthanarak).

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flooding (ie, flood water contaminated with soil and feces) on the control of MDR pathogens in hospitals.[9]

In response to an increase in colonization and infection by extremely-drug resistant (XDR) *Acinetobacter baumannii*, we analyzed the impact of advanced source control and thorough environmental cleaning on incidence rates of XDR *A baumannii* in a Thai medical intensive care unit (MICU) in which an existing bundle intervention had proven ineffective. Because extensive flooding occurred at 5.5 months after initiation of the intervention, forcing the hospital to close for 2 months, we monitored the incidence of XDR *A baumannii* for another 12.5 months after the flood.

METHODS

Setting

Thammasat University Hospital is a 650-bed university hospital located in central Thailand. The 8-bed MICU, where the present study was conducted, is a multibed open ward in which a multidisciplinary staff of 35 health care workers provides care for approximately 550 patients annually. All patients are intubated. During the study period, the patient-to-nurse ratio of 2:1 was stable, and there were no changes in medical or nursing leadership of the MICU. The same infectious diseases physician evaluated all patients throughout the study period. Nurses and respiratory therapists were dedicated to the care of MICU patients and did not rotate to any other hospital units.

The study population comprised all patients admitted to the MICU between May 1, 2011, and December 31, 2012. Throughout the entire study period, basic infection prevention measures, including hand hygiene and contact precautions, were standard practice to prevent nosocomial transmission of MDR pathogens. An antibiotic stewardship program for 5 major classes of antibiotics (third-generation cephalosporins, β-lactam/β-lactamase inhibitor compounds, glycopeptides, fluoroquinolones, and carbapenems) had been in place at the hospital since July 2004 and did not change during the study.[10] No other protocols aimed at influencing the rates of XDR *A baumannii* were introduced during the study period. The hospital's Institutional Review Board approved the study.

Definitions and data collection

MDR *A baumannii* was defined as an *A baumannii* isolate that was resistant to any 3 of 5 classes of systemic antibiotics (cephalosporins, aztreonam, carbapenems, aminoglycosides, fluoroquinolones), whereas XDR *A baumannii* was defined as an *A baumannii* isolate that was resistant to all currently available systemic antibiotics (ie, cephalosporins, aztreonam, carbapenems, aminoglycosides, fluoroquinolones, and sulbactam), except polymyxin B or tigecycline.[11] Bacterial identification and antimicrobial susceptibility testing were performed in accordance with Clinical and Laboratory Standards Institute guidelines.[12]

Nosocomial infections were defined using Centers for Disease Control and Prevention criteria.[13] MICU acquisition of an XDR *A baumannii* surveillance isolate was defined as detection of this microorganism by active surveillance culture >48 hours after MICU admission, following a negative active surveillance culture result at the time of MICU admission. Adverse reactions to chlorhexidine were determined by a dermatologist. Grading of skin reactions and mucositis is described elsewhere.[14] The numbers of patient admissions and patient-days were extracted from the hospital's medical records database.

The same infection prevention specialist tracked XDR *A baumannii* colonization and infection rates, as determined by clinical and surveillance culture results, during the 3 study periods. Rates were expressed as number of patients with positive clinical or surveillance cultures per 1,000 patient-days. Data collected included patient demographic characteristics, underlying diseases, and severity of illness (as measured by Acute Physiology and Chronic Health Evaluation II [APACHE-II] score); incidences of central line–associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infection (CAUTI); rates of methicillin-resistant *Staphylococcus aureus*, extended-spectrum β-lactamase–producing *Escherichia coli* and *Klebsiella pneumoniae*, MDR *Pseudomonas aeruginosa* colonization and infection, archived from hospital infection control databases; potential adverse reactions to chlorhexidine bathing and oral care (eg, skin rash, allergic or anaphylactic reaction, mucositis); and health care worker compliance with infection prevention measures (eg, contact isolation, environmental cleaning).

Study design

The study consisted of a 12-month baseline period (May 1, 2010, to April 30, 2011; period 1 [P1]), followed by a 5.5-month intervention period (May 1 2011, to October 14, 2011; period 2 [P2]) and then a 12.5-month follow-up period (December 12, 2011, to December 31, 2012; period 3 [P3]). The intervention team included a hospital administrator, an infectious diseases physician, 2 infection prevention specialists, a hospital epidemiologist, a clinical microbiologist, attending MICU physicians, and the MICU chief nurse.

Between P2 and P3, on October 15, 2011, the hospital experienced a major black water flood that necessitated hospital closure and study cessation from October 16, 2011, to December 11, 2011.[9] After the flood receded and before the hospital reopened, the MICU environment was cleaned multiple times with 1:100 sodium hypochlorite (bleach).[9] P3 was undertaken to evaluate the long-term effect of the intervention to control XDR *A baumannii* after the hospital MICU reopened on December 12, 2011.

During P1, infection prevention measures in the MICU included (1) implementation of enhanced contact isolation precautions (ie, strict adherence to hand hygiene before and after patient care and donning of clean gowns and gloves before patient care); (2) active surveillance cultures for XDR *A baumannii*; (3) establishment of an XDR *A baumannii* patient cohort in 1 section of the unit; (4) twice-daily environmental cleaning with a phenolic or quaternary ammonium disinfectant-detergent, as appropriate; and (5) antimicrobial stewardship. In P2, all P1 interventions were continued, but bleach was used to clean environmental surfaces (eg, bed rails, sinks, overbed tables, infusion pumps, surrounding countertops) twice daily,[15,16] and advanced source control was introduced. Advanced source control consisted of bathing patients once daily with 2% chlorhexidine in aqueous solution and performing oral care 4 times daily with 2% chlorhexidine. All P2 interventions were continued during P3, except an appropriate detergent-disinfectant replaced bleach.

Hand hygiene was promoted during all study periods using educational sessions (performed every 4 months), posters to encourage hand hygiene with alcohol gel, and monthly feedback on hand hygiene compliance. Incidence rates of XDR *A baumannii* in clinical and surveillance cultures were communicated monthly to MICU staff members.

Active surveillance

Active surveillance for XDR *A baumannii* comprised tracheal aspirate and rectal swab cultures collected on all MICU patients on day 0, day 7, and then weekly until discharge from the MICU. Surveillance specimens were inoculated onto MacConkey agar with a

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