American Journal of Infection Control 42 (2014) 283-7

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Effectiveness and cost of implementing an active surveillance screening policy for *Acinetobacter baumannii*: A Monte Carlo simulation model

Joseph R. Coyle MPH [a], Keith S. Kaye MD, MPH [a], Thomas Taylor PhD [a], Ryan Tansek MD [a], Michelle Campbell MD [a], Kayoko Hayakawa MD, PhD [a], Dror Marchaim MD [a,b,c,*]

[a] *Division of Infectious Diseases, Wayne State University, Detroit, MI*
[b] *Division of Infectious Diseases, Assaf Harofeh Medical Center, Zerifin, Israel*
[c] *Sackler School of Medicine, Tel-Aviv University, Tel-Aviv, Israel*

Key Words:
Isolation
Contact isolation precautions
Transmission
Multidrug resistance
Nosocomial

Background: *Acinetobacter baumannii* infections are common and associated with high mortality and costs. Early identification of asymptomatic carriers can reduce patient-to-patient transmission, but the sensitivity of *A baumannii* surveillance tools is poor, and thus active surveillance is not routine practice. This study examined whether an active surveillance screening policy can reduce the transmission, mortality, and costs associated with *A baumannii*.

Methods: A simulation model was developed to determine the impact of active screening on patient outcomes. Model parameters included *A baumannii* prevalence, screening sensitivity and specificity, probability of transmission, progression from colonization to infection, mortality, and cost of screening, contact precautions, and infection. A scenario analysis was performed to evaluate the robustness of the results when varying the sensitivity of the screening test and the prevalence rate of *A baumannii*.

Results: Assuming a screening sensitivity of 55%, active screening reduced *A baumannii* transmissions, infections, and deaths by 48%. As the screening sensitivity approached 90%, the reduction in transmissions, infections, and deaths reached 78%. For all scenarios tested, active surveillance was cost saving (19%-53% reduction in mean hospital cost per patient) except at a carrier prevalence of $\leq$2% and screening test sensitivity of $\leq$55%.

Conclusions: In institutions where *A baumannii* is endemic or during epidemics, implementing a surveillance program is cost-saving and can greatly reduce transmissions and deaths. Methodologies to improve the sensitivity of surveillance testing will help optimize the clinical impact of active screening programs on preventing the spread of *A baumannii* in health care facilities.

Acinetobacter baumannii is a common gram-negative nonfermentative bacterium that causes outbreaks in various health care settings.[1-6] Antimicrobial resistance is a major concern with *A baumannii*, and frequently no effective therapeutic options are available to treat infection with extensively drug-resistant (XDR) *A baumannii* strains isolated in nosocomial settings.[2,4,7-9] Infections due to XDR *A baumannii* strains are associated with devastating outcomes in terms of mortality, morbidity, and costs.[10]

Risk factors for *A baumannii* infection include advanced age, deteriorated functional status, intensive care unit (ICU) stay, recent exposure to antibiotics, recent invasive procedures or surgeries, prolonged hospitalization, and various immunosuppressive states.[11-19] Individuals who are elderly, permanently institutionalized, and transit frequently between health care facilities of different levels of care are at particularly high risk for *A baumannii* carriage. The frequent transit among health care facilities among high-risk patients who are asymptomatically colonized with *A baumannii* facilitates the spread of *A baumannii* throughout these facilities.[1]

Early identification of asymptomatic carriers (before they develop infection) is an important and well-established infection

* Address correspondence to Dror Marchaim, MD, Division of Infectious Diseases, 5 Hudson, Harper University Hospital, 3990 John R. Street, Detroit, MI 48201.
E-mail address: drormc@hotmail.com (D. Marchaim).

K.S.K. is supported by the National Institute of Allergy and Infectious Diseases (DMID Protocol 10-0065).
Conflict of interest: None to report.

http://dx.doi.org/10.1016/j.ajic.2013.09.027

control measure to contain the spread of multidrug-resistant organisms (MDROs).[20] Implementing a specific (ie, pathogen-directed) active surveillance policy by screening subjects for carriage of a pathogen, followed by isolation and cohorting of carriers of the targeted pathogen, has been used to control the dissemination of MRDOs, especially during epidemics and outbreaks.[20,21] Methicillin-resistant *Staphylococcus aureus* (MRSA),[22,23] vancomycin-resistant *Enterococcus* (VRE),[24,25] and carbapenem-resistant *Enterobacteriaceae* (CRE)[26] are pathogens for which active screening of a high-risk population followed by isolation and cohorting (and sometimes pathogen eradication) has been used to significantly reduce the burden in certain prone populations, including MRSA in patients scheduled for open heart surgery,[27] VRE in patients undergoing hemodialysis,[28-30] and CRE in residents of long-term care facilities.[26] However, unlike for other MDROs, screening for *A baumannii* has 2 serious limitations: (1) the optimum anatomic site for culturing has not been established, and (2) the sensitivity of screening patients for *A baumannii* carriage using traditional microbiological techniques is low. In a study that prospectively screened known *A baumannii* carriers in multiple anatomic sites using routine conventional methodology, the sensitivity of identifying carriers was only 55%.[31] Because of this poor sensitivity, most institutions do not routinely screen for *A baumannii* carriage.

The aims of the present study were to use mathematical modeling to determine whether an active surveillance program using standard microbiological methods for identifying *A baumannii* might be beneficial in terms of individual outcomes (ie, transmission, infection, and death) and costs, despite the low sensitivity, and also to evaluate the potential benefits of newer methodologies with improved sensitivity.

METHODS

Study setting and design

TreeAge Pro 2009 (Williamstown, MA) was used to design the decision tree (Fig 1) and run simulations. The model was constructed to evaluate 4 outcomes of interest between 2 potential decision pathways, screening and isolation versus no screening: (1) *A baumannii* transmission events, (2) *A baumannii* infections, (3) *A baumannii*—related mortality, and (4) *A baumannii*—attributable costs. Each divergence in the decision tree represents an event with a given probability determined from metrics in the literature (Table 1). These probabilities were adjusted to evaluate the outcomes for multiple values of a given parameter (ie screening sensitivity of 55%[31] or 90%[32]).

For all estimates, we attempted to choose studies that had a sufficient sample size and were well controlled. In some cases where evidence was lacking, model parameters were based on expert opinion. Beta distributions were used to approximate variations in the model parameters that we did not vary manually.

Probability parameters

Each patient who "enters" the model (where the model can be seen as representing a hospital or a particular ward or unit within a hospital) can be a carrier of *A baumannii* or not a carrier. In reality, this probability can vary based on established known population characteristics[11] and the regional *A baumannii* prevalence.[7] To account for this variability, we assumed a base case value of 4% for the carriage prevalence, with a range of 2%-6% (Table 1).[5,33,34]

In the active surveillance screening arm, some patients will be identified as positive and placed under contact precautions, thereby greatly reducing the probability of transmission.[35] In the pathway with no active surveillance policy implemented, the *A baumannii* carrier will not be immediately detected, and without the prompt initiation of contact precautions, there is a potential for transmission of the pathogen.

The protectiveness of contact precautions alone is very difficult to quantify. Numerous studies have demonstrated reduced transmission of organisms through a multitude of concurrent infection control interventions, but the independent protectiveness of contact precautions for *A baumannii* has not been definitively measured.[36] We estimated the reduction in transmission probability owing to the protective effects of contact precautions using data from Morgan et al[37] supplemented with expert opinion. Ultimately, we estimated the probability of *A baumannii* transmission as 20% in the absence of contact precautions and 2.5% when contact precautions were implemented.

Among those patients who acquire *A baumannii*, some will progress to infection, whereas others will be colonized but will remain infection-free. Finally, some infected patients will be effectively treated and recover, whereas a proportion will die due to complications of their acquired infection. Progression from colonization to infection was assumed to occur in 54.5% of patients,[15,34] and the mortality rate from an *A baumannii* infection was assumed to be 48% (Table 1).[10,18,38-40]

Cost parameters

To assess the economic impact of implementing an active surveillance policy, we chose a conservative estimate for the cost of an *A baumannii* infection. The cost was estimated to be the attributable length of stay due to an *A baumannii* infection multiplied by the average daily cost of an ICU unit bed.[34,41] This did not take into account other possible expenses related to *A baumannii* infections (eg, additional imaging, procedures, and/or surgeries). *A baumannii* colonization or *A baumannii*—attributable death were not assumed to add any additional costs. Owing to large variances in the cost of treating an *A baumannii* infection, we also decided not to include treatment of infection (ie, antimicrobials) as a cost variable in the model. As a result, our cost approximation is likely an underestimate of the actual cumulative cost of an *A baumannii* infection. The costs of screening and of implementing contact precaution measures (ie, gowns, gloves, lab supplies, and employee time to collect and process samples) were also estimated based on published data.[42]

Analysis

Monte Carlo analyses were performed with 10,000 samples. *A baumannii* transmissions, infections, deaths, and costs were determined for a screening sensitivity of 55%[31] or 90%[32] and with a corresponding *A baumannii* carrier prevalence of 2%, 4%, or 6%.[5,33,34,43] The outcomes were compared between the screening and isolation arm and the no screening arm to determine which strategy was the more advantageous in terms of patient outcomes and costs of hospitalization. Finally, a break-even analysis was performed to identify the combinations of test sensitivity and carrier prevalence that result in the same expected costs for screening versus no screening.

Results

Table 2 summarizes the clinical and cost outcomes associated with the implementation of a comprehensive surveillance policy directed at *A baumannii*. The model showed substantial decreases in transmission, infection, and mortality rates associated with *A baumannii* when screening and isolation are implemented. Even in a scenario with a surveillance culture screening sensitivity of only