Infect Control Hosp Epidemiol. Author manuscript; available in PMC 2012 July 02.

Published in final edited form as:
Infect Control Hosp Epidemiol. 2010 October ; 31(10): 1087–1089. doi:10.1086/656378.

Economic Impact of *Acinetobacter baumannii* Infection in the Intensive Care Unit

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Although the prevalence of *Acinetobacter baumannii* infection appears to have been increasing over the past decade, its economic impact remains unclear.[1,2] *A. baumannii* infection tends to affect critically ill patients, causing serious infections in the intensive care unit (ICU), potentially increasing hospital lengths of stay (LOS) and mortality rates.[2,3] Better understanding the economic effects of *A. baumannii* infection may help policy makers, hospital administrators, infection control professionals, and other healthcare workers determine how much to invest in interventions that can detect and control its spread.

Using TreeAge Pro 2009 (TreeAge Software), we developed a stochastic decision analytic computer simulation model that determined additional costs associated with *A. baumannii* in the ICU from the hospital perspective. An extended LOS associated with *A. baumannii* infection resulted in a loss of a hospital bed that could have been used by other patients and in corresponding lost revenues. Our model compared an ICU patient colonized with *A. baumannii* with a patient who was not colonized. Each colonized patient then had a probability of remaining simply colonized or developing an active *A. baumannii* infection, resulting in increased LOS and increased mortality. On the basis of findings from our search of the literature, we determined that colonization without infection did not affect a patient's LOS.

The model drew its clinical probabilities from the results of an extensive review of the literature. Our literature search identified all articles published from 1990 to the present in the Medline database using various combinations of the following key words: "acinetobacter," "infections," "prevalence," "multi-drug resistant," "nosocomial infections," "ICU," "colonization," "mortality," "length of stay," "economics," and "costs." We searched references from all relevant articles to identify additional studies. We reviewed and selected studies on the basis of the following inclusion and exclusion criteria: studies (largely case-control and cohort studies) were included if they included control subjects who were adequately matched on the basis of severity of illness and comorbidities (using measures such as Acute Physiology and Chronic Health Evaluation [APACHE] score, the McCabe score, and the Charlson comorbidity index), clearly identified and characterized the study population, and reported clinical outcomes (eg, mortality and LOS). A total of 5

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Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

studies reported the additional LOS after the infection event. Studies without human subjects or matching control subjects were excluded.

For our baseline scenario, patients with active *A. baumannii* infection had an additional LOS drawn from a γ distribution (mean LOS ± standard deviation, 25.23 ± 10.59 days).[1,3–6] This distribution represents the mean and standard deviation of all reported mean attributable LOSs from the studies identified by our literature review. The γ distribution models continuous variables that are always positive and have a skewed distribution, with a long upper tail representing patients with long LOSs. Those without active *A. baumannii* infection (ie, persons who were colonized but not infected) had an LOS of 0.66 times that of persons with active infection. (Sensitivity analyses varied the attributable LOS).[1–3,7] The cost per bed-day was $4,397.50 (triangular distribution; range, $1,000–$8,000) on the basis of mean daily costs for patients in the ICU who underwent ventilation and those who did not.[8] All costs were in 2010 US dollars, with a 3% discount rate used to convert costs from other years. We assumed that 20%–70% of *Acinetobacter*-colonized patients developed infection.

Each simulation run sent 1,000 simulated ICU patients 1,000 times (a total of 1,000,000 trials) through the model. Table 1 shows how per-patient *A. baumannii*–attributable costs increased as the proportion of patients with *A. baumannii* who have active infection increased. For a 20% infection probability, the mean cost to a hospital of each *A. baumannii* case (± standard deviation) was $8,246 ± $4,472. Increasing the proportion of infections to 70% increased the cost to the hospital to $29,019 ± $15,977. Table 1 also lists results from sensitivity analyses ranging attributable LOS from infection and how cost to the hospital changed with the number of *A. baumannii* cases per month.

These numbers could confer a considerable economic burden to hospitals. For example, over a 6-month period in 2008 in a University of Pittsburgh Medical Center hospital, 25 of 626 ICU-admitted patients were colonized with the organism (prevalence, 4%), translating to a cost to the hospital of $412,291–$1,621,199 for the year. During the period 2006–2007, 463 hospitals reported healthcare-associated infections to the National Healthcare Safety Network.[9] Of 28,502 reported infections, *A. baumannii* caused 902 (2.7%), resulting in costs ranging from $7.4 million to $26.1 million.

To our knowledge, our study is the first to use economic modeling to quantify the economic burden of *A. baumannii* to hospitals. Understanding costs from the hospital perspective is important, because it may help hospitals determine how much should be invested in infection control to prevent the spread of this organism. We demonstrated that, even with a conservative estimate of the proportion of colonizations to develop into infection (at least 20%), the financial burden to hospitals can be substantial. The ratio of infection to colonization may vary widely depending on the patient population. Studies from the literature have reported infection rates of 32.4%,[5] 53%,[10] and 64%.[7] Therefore, it is possible that the actual financial impact of *A. baumannii* colonization is closer to the upper end of our estimate (ie, approximately 50% of colonizations representing infection). Even low *A. baumannii* prevalence can be a significant burden to a hospital, suggesting that hospitals may consider further investigation into controlling this infectious pathogen. Our model may, in fact, underestimate the cost of *A. baumannii* colonization and infection, because it only considered lost bed-days and did not include additional costs associated with infection, such as treatment, additional surgery, and ventilator use. Attributing such treatment costs is difficult, because the patients tend to be very ill and to have multiple comorbidities.

Key limitations of our study include the facts that models simplify real life, cannot fully represent every event or outcome or the heterogeneity of patient populations, and draw disparate data from studies of varying quality. The studies from our literature review were limited, because it is difficult to perform outcome studies of antibiotic resistance that truly control for severity of illness and to determine attributable increased LOS.

Individual hospitals may want to use the results of our model to determine the economic burden of *A. baumannii* in their specific hospitals, given their unique circumstances. Additional research into the probability of infection and potential control measures may be warranted.

Acknowledgments

Financial support. The National Institute General Medical Sciences Models of Infectious Agent Study (1U54GM088491–0109) and the Pennsylvania Department of Health.

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TABLE 1

Cost of Cases of *Acinetobacter* Colonization to the Hospital

Proportion of subjects with active infection	Cost per case,[a] US$, mean ± SD	Cost per year, US$, mean ± SD		
		1 Case/mo	2 Cases/mo	3 Cases/mo
Baseline distribution of attributable LOS[b]				
20%	8,246 ± 4,472	98,950 ± 15,491	197,900 ± 21,908	296,849 ± 26,831
30%	12,490 ± 6,926	149,884 ± 23,994	299,797 ± 33,933	449,651 ± 41,559
40%	16,072 ± 8,870	192,866 ± 30,727	385,732 ± 43,455	578,598 ± 53,221
50%	19,731 ± 10,403	236,768 ± 36,036	473,536 ± 50,962	710,304 ± 62,415
60%	24,805 ± 12,956	297,656 ± 44,882	595,312 ± 63,473	348,231 ± 77,739
70%	29,019 ± 15,977	348,231 ± 55,345	696,462 ± 78,269	1,044,692 ± 95,860
5 Days attributable LOS				
20%	4,738 ± 1,567	56,857 ± 18,800	113,714 ± 37,599	170,571 ± 56,399
30%	7,211 ± 2,264	86,536 ± 27,168	173,072 ± 54,337	259,608 ± 81,505
40%	9,431 ± 3,040	113,176 ± 26,481	226,352 ± 72,963	339,527 ± 109,444
50%	11,777 ± 3,817	141,323 ± 45,802	282,645 ± 91,604	423,968 ± 137,406
60%	14,412 ± 4,589	172,942 ± 56,269	345,883 ± 112,537	518,825 ± 168,806
70%	16,895 ± 5,199	202,743 ± 62,374	405,486 ± 124,748	608,228 ± 187,122
10 Days attributable LOS				
20%	9,523 ± 3,062	114,274 ± 36,739	228,547 ± 73,479	342,821 ± 110,218
30%	14,207 ± 4,617	170,484 ± 55,401	340,968 ± 110,802	511,452 ± 166,203
40%	19,114 ± 6,289	229,364 ± 75,470	458,728 ± 150,940	688,092 ± 226,410
50%	24,038 ± 7,802	288,460 ± 93,619	576,921 ± 187,239	865,381 ± 280,858
60%	28,407 ± 9,158	340,882 ± 109,900	681,765 ± 219,800	1,022,647 ± 329,701
70%	33,003 ± 10,292	396,040 ± 123,508	792,080 ± 247,016	1,188,120 ± 370,524
15 Days attributable LOS				
20%	13,988 ± 4,559	167,855 ± 54,710	335,710 ± 109,419	503,565 ± 164,129
30%	21,245 ± 6,928	254,941 ± 83,131	509,883 ± 166,262	764,824 ± 249,392
40%	28,237 ± 9,091	338,844 ± 109,094	677,688 ± 218,188	1,016,532 ± 327,281
50%	35,312 ± 11,212	423,743 ± 134,541	847,485 ± 269,082	1,271,228 ± 403,623
60%	43,099 ± 14,115	517,183 ± 169,381	1,034,365 ± 338,762	1,551,548 ± 508,142
70%	49,608 ± 16,429	595,299 ± 197,148	1,190,599 ± 394,295	1,785,898 ± 591,443

NOTE. LOS, length of stay; mo, month; SD, standard deviation.

[a]A case was defined as carriage of *A. baumannii* or active *A. baumannii* infection.

[b]Baseline, 25.23 ± 10.59 days.