Direct costs of multidrug-resistant *Acinetobacter baumannii* in the burn unit of a public teaching hospital

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We conducted a case-control study to determine the attributable direct costs of multidrug-resistant *Acinetobacter baumannii* (MDRAB) in the burn unit of a public teaching hospital. The mean total hospital cost of patients who acquired MDRAB was $98,575 higher than that of control patients who had identical burn severity of illness indices ($P < .01$). These data should help infection control practitioners and others determine the cost-effectiveness of specific interventions designed to control this emerging nosocomial pathogen. (Am J Infect Control 2004;32:342-4.)

Acinetobacter baumannii is an opportunistic gram-negative bacillus that has emerged as an important nosocomial pathogen over the last decade. Of greatest concern is multidrug-resistant *A baumannii* (MDRAB), which has become increasingly common in burn units and other intensive care areas of hospitals worldwide.[1] Moreover, the authors of several recent studies conclude that routine infection control measures may not be adequate to control this difficult-to-treat bacterium.[2-5]

MDRAB emerged in the burn unit of our institution in July 2000. An outbreak investigation did not point to a common source, but subsequent emphasis on hand disinfection and contact isolation precautions failed to eradicate MDRAB. Thus, we decided to conduct a formal cost analysis of the extended MDRAB outbreak to determine whether specialized, more expensive, infection control measures might be cost-effective in trying to deal with this ongoing problem.

METHODS

Setting and study population

We conducted a case-control study in the adult burn unit of a university-affiliated, public teaching hospital. We defined MDRAB as any isolate resistant to all penicillins, all cephalosporins, ciprofloxacin, gentamicin, and imipenem. The cases included all 34 burn patients who acquired MDRAB in the burn unit (>48 hours after admission) from July 2000 through August 2001. All of the patients with MDRAB had more than 20% total body surface area (TBSA) burns. Thus, we randomly selected 34 controls from the subset of patients who had more than 20% TBSA burns in calendar year 1999 (prior to the emergence of MDRAB at our institution) to ensure that the cases and controls would be similar with regard to severity of illness.

Data collection

We collected the following data on each of the patients: hospital charge, length of stay, age, race, sex, percentage of TBSA burned, and Zawacki score. The latter is a standard severity of illness index used in burn patients.[6] We calculated hospital cost for each patient from the hospital charge using a cost-to-charge ratio of 0.7672, which was specific to our burn unit. We adjusted all dollar amounts to 2001 dollars using annual medical inflation rates in the public sector of 7.5% for the period 1999 to 2000 and 9.4% for the period 2000 to 2001.[7] Dollar amounts were rounded down to the nearest dollar.

Statistical analysis

We performed the statistical analysis using SAS 8.02 (SAS Institute Inc., Cary, NC). We compared the means of continuous variables between the cases and controls using the *t* test and the differences in proportions of categorical variables using the χ^2 test. All reported *P* values are 2-sided. In addition, because the cost data in this study were dependent on the cost-to-charge ratio, we conducted a sensitivity analysis of this

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measure to determine the robustness of our results. One control was excluded from the final analysis because of missing charge data.

RESULTS

From July 2000 through August 2001, 34 (16%) of the 217 patients admitted to the burn unit acquired MDRAB. Twenty-seven (79%) of the 34 patients had MDRAB isolated from wounds, 20 (59%) from respiratory specimens, 15 (44%) from blood, 4 (12%) from urine, and 12 (35%) from other sites. MDRAB was isolated from multiple sites in 22 (65%) of the 34 patients.

The mean total hospital cost was $201,558 for the cases compared with $102,983 for the controls ($P <$ .01). The mean length of stay was 37 days for the cases and 26 days for the controls ($P =$ .06). The mean cost per day was $5607 for the cases compared with $4017 for the controls ($P <$ .01). The cases and controls were not different with regard to age, race, sex, extent of burn injury, or Zawacki score (Table 1). Sensitivity analysis of the cost-to-charge ratio revealed that, even if this measure were as low as 0.5000, the mean total hospital cost would still have been $64,243 higher for the cases compared with the controls (Table 2).

DISCUSSION

MDRAB has emerged as an important nosocomial pathogen since the first hospital outbreaks were described a decade ago.[8] It has been a particular problem in burn units, likely because severely burned patients have large open wounds and are often mechanically ventilated because of inhalation injuries.[9] Infection control of MDRAB has been problematic because it can survive on dry surfaces for extended periods of time[4] and may also be spread by the airborne route.[5] Thus, routine infection control measures such as hand disinfection and contact isolation, although essential, may not be adequate to contain the spread of MDRAB in hospitals. In addition to routine measures, many experts have successfully utilized specialized infection control measures to manage hospital epidemics and endemics of MDRAB.[2,3,8,9] These specialized measures included the following: cohorting of patients, equipment, and staff; rigorous cleaning and disinfection of the environment; control of antibiotic use, especially third-generation cephalosporins and carbapenems; surveillance cultures of patients, environmental surfaces, and staff; and continuous quality control and education. Unfortunately, in today's era of cost containment, many hospital administrators are reluctant to spend money on infection control measures unless they can be convinced that it will result in near-term cost savings.[10]

Table 1. Patient demographics, severity of illness indicators, and hospital costs for burn patients with multidrug-resistant *Acinetobacter baumannii* compared with controls

Variable	Cases	Controls	P
Patient demographics			
Mean age (SD), y	44.3 (18.9)	43.5 (16.7)	.85
Race, white	82.4%	84.8%	.78
Sex, male	79.4%	78.8%	.95
Severity of illness			
TSBA burned, mean (SD)	35.1% (20.7%)	37.7% (17.4%)	.59
Zawacki Score, mean (SD)	4.1 (1.3)	4.2 (1.5)	.81
Length of stay, days, mean (SD)	36.8 (24.1)	25.6 (23.3)	.06
Hospital costs			
Total, mean (SD)	$201,558 ($160,781)	$102,983 ($116,592)	<.01
Per day, mean (SD)	$5607 ($2630)	$4017 ($2059)	<.01

SD, Standard deviation; *TBSA*, total body surface area.

To the best of our knowledge, we are the first investigators to quantify the economic burden associated with MDRAB in critically ill patients. We found that the mean total hospital cost for patients who acquired MDRAB in the burn unit was $98,575 higher than that of the control group. In addition, we found that the mean cost per hospital day was also significantly higher for patients with MDRAB. Thus, the substantially higher total direct costs were a function of both increased length of stay but also increased cost of care on a daily basis. We did not have an accurate breakdown of the individual hospital costs for this study; however, we hypothesize that patients with MDRAB may have had increased costs because of longer and more expensive antibiotic courses, more frequent return trips to the operating room for failed skin grafts, and/or other hospital complications. Future research projects on this topic should focus on testing these and other hypotheses.

We did not use a concurrent control group in this study because all of the patients with severe (>20% TBSA) burns during the study period had acquired MDRAB, and we deemed it more important to have controls with similar severity of illness to the cases. In fact, the cases and the controls that we selected were identical with regard to severity of illness as measured by the Zawacki score. We controlled for inflation using published health care inflation rates for the public sector, which reflected the patient population at the study hospital. Had we simply used the consumer price index, which yielded a lower inflation rate during the study period, the difference in costs between the cases and controls would have been artificially increased. Thus, we believe that the significant cost differences

Table 2. Sensitivity analysis of cost-to-charge ratio on hospital cost estimates for patients with multidrug-resistant *Acinetobacter baumannii* compared with controls

	Total cost, mean ($)			Cost per day, mean ($)		
Cost-to-charge ratio	**Cases**	**Controls**	**Difference**	**Cases**	**Controls**	**Difference**
0.7672*	201,558	102,983	98,575	5607	4017	1590
0.7000	183,903	93,962	89,941	5116	3665	1451
0.6000	157,631	80,539	77,092	4385	3141	1244
0.5000	131,359	67,116	64,243	3654	2618	1036

*Cost-to-charge ratio specific to our burn unit.

observed between the cases and controls in our study can reasonably be attributed to the acquisition of MDRAB.

Finally, even though we used a cost-to-charge ratio that was specific to our burn unit, we did a sensitivity analysis of this measure to determine the robustness of our results. This revealed that, even if the cost-to-charge ratio were as low as 0.5000, which is unlikely, the excess direct costs attributable to MDRAB would still have been greater than $60,000 per patient.

In conclusion, MDRAB in our burn unit was associated with significantly increased hospital costs. The data presented in this paper should help infection control practitioners and hospital epidemiologists estimate the economic burden of MDRAB at their own institutions. Future research should focus on prospective cost-effectiveness studies of specific interventions to control MDRAB.

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