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Laura A. Puzniak
Saint Louis University

Kathleen N. Gillespie
Saint Louis University

Terry Leet
Saint Louis University

Marin Kollef
Washington University School of Medicine in St. Louis

Linda M. Mundy
Washington University School of Medicine in St. Louis

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Author(s): Laura A. Puzniak , PhD, Kathleen N. Gillespie , PhD, Terry Leet , PhD, Marin Kollef , MD, Linda M. Mundy , MD

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A COST–BENEFIT ANALYSIS OF GOWN USE IN CONTROLLING VANCOMYCIN-RESISTANT *ENTEROCOCCUS* TRANSMISSION: IS IT WORTH THE PRICE?

Laura A. Puzniak, PhD; Kathleen N. Gillespie, PhD; Terry Leet, PhD; Marin Kollef, MD; Linda M. Mundy, MD

ABSTRACT

OBJECTIVE: To determine the net benefit and costs associated with gown use in preventing transmission of vancomycin-resistant *Enterococcus* (VRE).

DESIGN: A cost–benefit analysis measuring the net benefit of gowns was performed. Benefits, defined as averted costs from reduced VRE colonization and infection, were estimated using a matched cohort study. Data sources included a step-down cost allocation system, hospital informatics, and microbiology databases.

SETTING: The medical intensive care unit (MICU) at Barnes–Jewish Hospital, St. Louis, Missouri.

PATIENTS: Patients admitted to the MICU for more than 24 hours from July 1, 1997, to December 31, 1999.

INTERVENTIONS: Alternating periods when all healthcare workers and visitors were required to wear gowns and gloves versus gloves alone on entry to the rooms of patients colonized or infected with VRE.

RESULTS: On base-case analysis, 58 VRE cases were averted with gown use during 18 months. The annual net benefit of the gown policy was $419,346 and the cost per case averted of VRE was $1,897. The analysis was most sensitive to the level of VRE transmission.

CONCLUSIONS: Infection control policies (eg, gown use) initially increase the cost of health services delivery. However, such policies can be cost saving by averting nosocomial infections and the associated costs of treatment. The cost savings to the hospital plus the benefits to patients and their families of avoiding nosocomial infections make effective infection control policies a good investment (*Infect Control Hosp Epidemiol* 2004;25:418-424).

Enterococci are the third most common pathogen associated with nosocomial infections, accounting for 12% of intensive care unit infections.[1] The increasing prevalence of enterococcal infections is problematic due to limited treatment and eradication strategies. Furthermore, the public health threat from vancomycin-resistant enterococci (VRE) is more imminent given the recent detection of vancomycin-resistant *Staphylococcus aureus* (VRSA).[2-4] The presence of *van*A in a clinical isolate of VRSA from a host colonized with VRE suggests exchange of genetic material between these gram-positive pathogens.[2]

Hospital Infection Control Practices Advisory Committee guidelines for controlling VRE include screening high-risk populations, using vancomycin appropriately, educating medical staff, and implementing infection control procedures.[5] Recommended infection control practices include the use of gloves and gowns with patients colonized or infected with drug-resistant pathogens.[5] Despite encouraging results for the efficacy of gown use, there is ongoing debate over the cost versus benefit of requiring gown use to prevent VRE transmission.[6-15]

Few studies have assessed the costs and benefits associated with gown use.[11-13] One study reported an annual cost increase of $11,303 for gowns and gloves after a VRE epidemic began.[12] The authors concluded that preventing a case of VRE bacteremia was worth the additional cost for implementing isolation precautions. In contrast, a study in a bone marrow transplant unit reported that discontinuing the use of gowns and shoe covers created a $70,000 savings for the unit with no increase in infection rates.[11]

Our prior work showed that requiring healthcare workers and visitors to wear gowns when entering the rooms of patients in a medical intensive care unit (MICU) reduced the patients' risk of VRE acquisition during periods of high VRE colonization pressure.[13] The purpose of this study was to determine the costs and benefits of this enhanced infection control program aimed at reducing VRE transmission.

Drs. Puzniak, Leet, and Mundy are from the Department of Community Health and Dr. Gillespie is from the Department of Health Management and Policy, Saint Louis University School of Public Health, St. Louis, Missouri. Drs. Kollef and Mundy are from the Department of Medicine, Washington University School of Medicine, St. Louis, Missouri.

Address reprint requests to Linda M. Mundy, MD, Washington University School of Medicine, 660 S. Euclid Avenue, Campus Box 8051, St. Louis, MO 63110.

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METHODS

Study Population

All patients staying more than 24 hours in a 19-bed MICU at Barnes–Jewish Hospital from July 1, 1997, to December 31, 1999, were eligible. All healthcare workers and visitors were required to wear gowns and gloves on entry into the rooms of patients colonized or infected with VRE from July, 1, 1997, to June 30, 1998, and from July 1, 1999, to December 31, 1999. During the 12 months between these two periods, gowns were not required. The institutional review board committees of Saint Louis University and Washington University approved this study.

During the entire study period, all patients were actively screened for VRE by collection of stool for cultures or rectal swabs on admission, every 7 days, and at discharge from the MICU. Per hospital protocol, stool specimens sent for the detection of *Clostridium difficile* toxin were also screened for VRE. For each patient with VRE, a sign requiring contact precautions and an isolation cart containing a dedicated stethoscope, a glass thermometer, and gloves were placed at the entrance to the patient's room. Contact precautions were continued unless a patient had two subsequent consecutive stool surveillance specimens that tested negative. Gowns that were fluid resistant and laundered after each use were added to the isolation cart during the designated gown periods.

A matched cohort study design was used to determine the attributable cost of VRE. Patients without VRE from the same MICU population were matched to patients with VRE by diagnosis-related group (DRG) code, Acute Physiology and Chronic Health Evaluation (APACHE) II[16] severity of illness score (± 2 points), and age (± 5 years).[17] One patient without VRE was randomly selected for each patient colonized with VRE when there were multiple patients without VRE with the same matching criteria. Two patients without VRE were randomly selected, using the same matching criteria, for each patient with VRE bacteremia. Two matched controls were used to increase statistical power due to the small number of patients with VRE bacteremia. Four patients colonized with VRE and two patients with VRE bacteremia were excluded from the study population because there was not a match of a patient without VRE.

Clinical endpoints were obtained from the hospital's informatics system. These included MICU and hospital lengths of stay, presence of nosocomial bacteremia due to oxacillin-resistant *S. aureus* (ORSA) or *Pseudomonas aeruginosa*, and presence of colitis or diarrhea associated with *C. difficile* toxin. The three nosocomial pathogens were used to determine whether the frequency of co-infections was similar between patients with and patients without VRE.

Costs

Overall costs for the VRE surveillance and infection control program were estimated using the hospital's step-down cost allocation system, which recorded line-item cost data per resource consumed and total cost per hospital admission. MICU costs were estimated from these data by dividing the patient's total hospitalization cost by total days of hospitalization and then multiplying the quotient by the patient's total MICU-days. This data system also provided hospital reimbursement data, type of insurance, case mix index, and DRG. Medicare patients from the study population were used to determine the average non-reimbursed hospitalization cost by VRE status.

The cost for each isolation cart included all initial supplies. In addition to the costs for gowns, the costs resulting from staff time to comply with gown use were estimated. Observational time trials were used to estimate the time required for healthcare workers to retrieve, don, doff, and properly dispose of gowns. On three separate occasions, two unobtrusive observers measured the amount of time required by 128 healthcare workers to comply with the gown policy. Our observations showed that the average worker needed 60 seconds (range, 35 to 95 seconds) to don and doff gowns, which was similar to the amount of time needed for the same activities in another study.[18] To estimate the cost associated with excess workload per VRE patient contact, the average time was multiplied by the average registered nurse salary (excluding fringe benefits). Because a range of healthcare workers entered a patient's room, the average registered nurse's salary was used to approximate this cost.

Microbiology costs for each patient were obtained from line-item reports from the hospital's microbiology database. Microbiology costs were inclusive of all related testing costs (ie, materials, technician time, nursing time for culture procurement, and overhead). Individualized costs associated with contact precautions and surveillance are listed in Table 1. All costs were reported in U.S. dollars.

Decision Analysis

An event pathway of the study was constructed showing VRE colonization and infection rates during this 30-month study period (Figure).[13] Costs were allocated to each arm based on actual resources consumed per patient. Each patient with VRE, regardless of study period, was charged the costs for a cart, gloves, and hand hygiene. During the gown period, patients with VRE were charged additional costs for gowns and nursing time to comply with the gown policy.

Benefits were measured as the number of VRE cases and the MICU costs averted. The number of VRE cases averted was estimated by multiplying the difference in the VRE rates between the study periods by the number of patients in the gown period. The number of VRE cases averted per 1,000 MICU-days was calculated by taking the number of cases averted and dividing it by the total number of MICU patient-days in the gown period and multiplying by 1,000. Averted attributable cost for the gown period and net benefit of the gown policy[19] were computed as shown in equations 1 and 2, respectively.

TABLE 1
INDIVIDUALIZED COSTS ASSOCIATED WITH CONTACT PRECAUTIONS AND VANCOMYCIN-RESISTANT ENTEROCOCCI SURVEILLANCE IN THE MEDICAL INTENSIVE CARE UNIT

Variable	Cost	Cost per Day
Gown	$0.75 each	$75.00
Gloves	$0.07/pair	$7.00
Hand hygiene	$0.10/use	$10.00
Nursing time to don and doff gowns	$27.00/hour	$45.00
Isolation cart set up (cost of initial cart set up—bag of gowns, stethoscope, thermometer, and box of gloves)	$18.00	One-time cost
VRE-negative test	$12.13	Varies
VRE-positive test	$24.29	Varies

VRE = vancomycin-resistant enterococci.

(1) averted attributable $cost_{gown}$ = (attributable cost of VRE colonization × annualized number of VRE colonized cases averted) + (weighted mean attributable cost of both diagnostic criteria of VRE bacteremia × annualized number of VRE bacteremic cases averted)

(2) net benefit = averted attributable $cost_{gown}$ - (annualized isolation/surveillance $cost_{gown}$ - isolation/surveillance $cost_{no\text{-}gown}$)

The latter term in equation 2 measured the incremental costs of the gown policy. Costs and benefits in the gown period were annualized because the gown period was 6 months longer than the no-gown period.

Sensitivity Analysis

A sensitivity analysis was performed varying several parameters related to the assumptions regarding the number of gowns used, time required to don and doff gowns, VRE transmission rates for this analysis, and cost of materials. Our baseline estimate for the number of gowns used was 100 gowns per patient per day. We used the previously reported value of 60 contacts per day[18] for the lower limit and an equivalent difference, 140 contacts per day, for the upper limit. The average number of VRE cultures performed during the study was 2 per patient per MICU stay. To adjust for variation in surveillance mechanisms,[20-23] we used 2 cultures as the baseline measure and varied this measure between 1 and 4 cultures per MICU stay. Because there were differences in cost between positive and negative cultures, we used the same proportion of positive cultures as the original analyses when the parameter was changed to 4 cultures per patient. Because the costs of isolation materials and laboratory testing can differ between hospitals and can increase due to inflation, we altered the costs for these items by 20% in both directions. As shown in the figure, the risks of both acquiring VRE and developing bacteremia were lower in the gown period; therefore, we altered the probability of acquiring VRE in the gown period from 40% to 100% of the probability of acquiring VRE in the no-gown period to determine the net benefit at varying levels of VRE transmission.

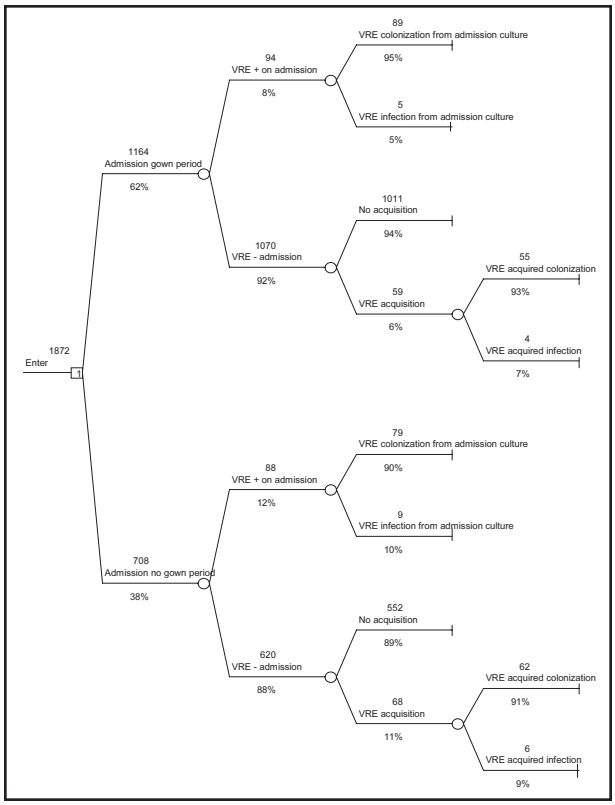

FIGURE. An event pathway showing vancomycin-resistant enterococci (VRE) colonization and infection rates from July 1, 1997, to December 31, 1999, for patients in the medical intensive care unit.

Statistical Analysis

Univariate statistics were obtained using SPSS software (version 10.0; SPSS, Inc., Chicago, IL). Differences in characteristics between patients with and patients without VRE were identified using *t* tests for continuous covariates and chi-square tests for categorical covariates. A Decision Tree Add-In for Microsoft Excel was used for the decision analysis (TreePlan, version 1.62; Microsoft Corp., Redmond, WA).

RESULTS

Matched Cohort

Based on the matching criteria, patients with and patients without VRE were closely matched. The mean APACHE II scores were similar between patients colonized with VRE and their matched controls and between patients with VRE bacteremia and their matched controls (22.0 vs 21.8 and 26.5 vs 26.3, respectively), as were the mean ages (62.3 vs 62.2 years and 65.4 vs 64.0 years, respectively). In addition, there were no significant differences in the frequency of co-infections between patients

TABLE 2
PRIMARY OUTCOMES STRATIFIED BY VANCOMYCIN-RESISTANT ENTEROCOCCI STATUS FOR PATIENTS IN THE MEDICAL INTENSIVE CARE UNIT

Outcome	VRE-Acquired Colonized Patients (N = 113)	VRE Bacteremia Patients* (N = 17)	VRE Bacteremia Patients† (N = 5)
VRE attributable length of MICU stay, d	4.0	18.9‡	25.3‡,§
VRE attributable length of hospital stay, d	8.3	38.2‡	18.9‡,§
VRE attributable MICU cost	$7,873	$43,152‡	$58,207‡,‖
VRE attributable hospital cost	$11,989	$66,194‡	$44,632‡,§

VRE = vancomycin-resistant enterococci; MICU = medical intensive care unit.
*Patients with one positive VRE blood culture (includes VRE colonization on admission and patients who acquired VRE).
†Patients with two positive VRE blood cultures or one positive blood culture and another site, other than stool, positive (includes VRE colonization on admission and patients who acquired VRE).
‡Versus VRE colonization ($P < .01$).
§Versus bacteremia with one positive VRE blood culture ($P < .01$).
‖Versus bacteremia with one positive VRE blood culture ($P < .05$).

colonized or infected with VRE and their matched controls (data not shown).

Primary Outcomes

The length of MICU stay, length of hospital stay, MICU costs, and hospital costs attributable to VRE were less for patients colonized with VRE than for patients with VRE bacteremia (Table 2). The length of MICU stay and MICU costs attributable to VRE were less for patients with VRE bacteremia who had one positive blood culture than for such patients who had two or more positive cultures, but the length of hospital stay and hospital costs attributable to VRE were less for patients with VRE bacteremia who had two or more positive blood cultures than for such patients who had one positive culture. However, five patients in the latter group died while hospitalized.

Decision Analysis

The costs, benefits, and net benefit for the enhanced infection control and VRE surveillance programs are listed in Table 3. The annualized costs were $179,816 and $105,821 for the gown and no-gown periods, respectively. Fifty-eight cases of VRE colonization, or 5.96 cases per 1,000 MICU-days, and 6 cases of VRE bacteremia, or 0.61 cases per 1,000 MICU-days, were averted during the gown period. The incremental cost per case of VRE colonization averted was $1,897. The annual net benefit of the gown policy was $419,346.

TABLE 3
COSTS, BENEFITS, AND NET BENEFIT OF GOWN USE FOR PATIENTS IN THE MEDICAL INTENSIVE CARE UNIT*

Intervention Costs	Gown Period (N = 1,164)	Annualized Gown Period†	No-Gown Period (N = 708)
Gown costs (gowns, nursing time to comply with gowns)	$116,040	$77,360	$0
Cart, gloves, and hand hygiene	$122,519	$81,679	$83,325
Surveillance (VRE rectal swabs and VRE stool samples)	$31,166	$20,777	$22,496
Total cost of policies	$269,725	$179,816	$105,821
Incremental cost of gown policy	-	$73,995	-
VRE colonization cases averted	58	39	-
VRE bacteremia cases averted	6	4	-
Averted VRE colonization attributable MICU costs	$456,634	$307,047	-
Averted VRE bacteremia‡ attributable MICU costs	$304,077	$186,294	-
Total averted VRE attributable MICU costs	$760,711	$493,341	-
Net benefit	-	$419,346	-

VRE = vancomycin-resistant enterococci; MICU = medical intensive care unit.
*Additional data regarding VRE classification were obtained in procurement of cost and microbiology data for this study. Although the VRE classification was altered from previously reported studies, the additional data did not alter the results of the previous study.[13]
†Costs were annualized because the gown and no-gown periods covered 18 and 12 months, respectively.
‡Mean attributable cost of both diagnostic criteria for bacteremia.

Sensitivity Analysis

Several parameters were changed to determine the impact of our four main assumptions on the net benefit of gowns. The variation of 60 to 140 patient contacts yielded net benefits of $388,664 and $450,017, respectively. The variation of 1 and 4 cultures per patient resulted in net benefits of $418,188 and $421,464, respectively. The variation in costs of labor and materials resulted in net benefits of $406,488 and $435,426, respectively.

The results were most sensitive to the probability of acquiring enteric VRE. Specifically, gowns are more likely to impact transmission when there are high rates of VRE colonization compared with when there are low rates. At 40% of the no-gown transmission rate, the incremental cost per case of VRE colonization averted was $3,217 and the net benefit was $546,182. If the gowns did not affect the rate of transmission (100%), there was a net cost of $148,358, because no cases of VRE were averted. The break-even point, or the point at which gowns become cost-saving, was approximately 88% of the no-

gown VRE transmission probability in this study. This corresponds to the prevention of 7 cases of VRE colonization.

DISCUSSION

The results of this cost–benefit analysis provide evidence that gown use adds costs to the delivery of health services in a MICU setting, but the benefits from averting enteric VRE transmission outweigh those costs. Our prior work demonstrated a protective effect of gowns for VRE acquisition when VRE colonization pressure was high.[13] In this analysis, the total attributable annual cost of the gown policy was $73,995. The averted cost due to preventing VRE colonization and bacteremia within the MICU was $493,341, yielding a net cost savings of $419,346. The attributable total hospital cost calculated for one case of VRE colonization was $11,989. Thus, the cost of the gown policy could be justified by averting 7 cases of VRE colonization. Because VRE colonization increases the risk for VRE bacteremia,[24-28] which has much higher costs, 7 cases is an over-estimate. The increased cost associated with gown use needs to be considered relative to the attributable length of stay, mortality, and costs associated with VRE acquisition.[29-40]

In an era of cost containment, hospitals benefit from focusing on effective ways to reduce non-reimbursable costs.[17,37-39] The hospital reimbursement structure, based on the principal DRG codes, may not cover costs attributable to iatrogenic problems, such as nosocomial infections, that contribute to prolonged stay.[38,39] In this study, the average cost not reimbursed from Medicare was significantly higher for patients with VRE than for patients without VRE (data not shown). From the perspective of the hospital's administration, this substantial difference accentuates the costs attributable to VRE. By enhancing resources for strategic infection control practices, hospital administrators can potentially reduce costs with infection control measures that reduce the rates of costly nosocomial infections.

A strength of this study was the close matching of patients who had VRE with patients who did not have VRE by DRG codes, APACHE II scores, and age. By matching on DRG codes, we expected to estimate the patient's length of stay and total hospital cost. The addition of matching on APACHE II score allowed further control of the complexity of illness within the DRG categories. As a result, differences in length of stay and cost closely estimated the attributable length of stay and cost associated with VRE.[17,37] The excess length of stay and costs attributed to nosocomial infections in our matched analysis were similar to those reported in the literature for nosocomial infections.[29,36] There is, however, difficulty in comparing rates across studies due to the variation in methodology.[17,37,38]

There are several limitations to this study. The limitation that biases the study toward finding gowns to be cost-saving relates to the fact that the infection control protocols for this study were already in place at this institution prior to the start of the study. Thus, costs for study implementation, staff education, and staff familiarity with the policy were not included in this study. If these costs are substantial, then the cost savings would be reduced. However, these costs would be incurred once, whereas the benefits would continue to accrue over time.

There are four limitations with uncertain or neutral implications: generalizability, the lack of molecular typing, the omission of blood culture costs, and the assumption of no differences in patient contacts or care due to the use of gowns. First, the findings from this study may not be generalizable to other settings. The unique characteristics of this MICU include the routine performance of active VRE surveillance, VRE endemnicity, and aggressive isolation of patients colonized and infected with VRE, ORSA, and *C. difficile* diarrheal disease. In this analysis, $53,662 was associated with surveillance activities. Surveillance can identify high rates of asymptomatic colonized patients and serve as a proxy to initiate enhanced infection control policies. Prevalence-based surveillance methods in hospitals range from passive surveillance, where a stool specimen is collected for another clinical reason and then is tested for VRE, to daily screening of patients for enteric VRE.[20-23] Depending on the existing VRE surveillance policy, the costs of implementing this intervention may vary. Another unique feature of the study setting is that all MICU patients had single rooms. Other studies have shown that the proximity to a VRE-positive patient increased the risk of acquisition.[24,29,41] The physical plant for this particular MICU may have contributed to lower rates of VRE compared with intensive care units with open ward settings containing multiple beds.

Second, we did not assess for confirmation of horizontal transmission through molecular typing. Although the conclusion regarding the effectiveness of gowns on VRE acquisition would have remained unchanged, we would have been potentially able to determine the number of secondary cases of VRE generated from a primary case of VRE and more accurately quantify the number of VRE cases averted.

Third, because blood cultures identify a range of pathogens and are not limited to VRE, the costs of blood cultures were excluded from the analysis. Nonetheless, the only way to detect VRE bacteremia is through a blood culture. Notably, most (87%) of the patients in this study had at least one blood culture. Because there were more cases of VRE bacteremia in the no-gown period than in the gown period, this may have underestimated the benefit of gowns.

Fourth, we assumed that the number of patient encounters and the quality of care provided did not differ by the use of gowns in this study. Two randomized, controlled trials suggest that the use of gowns did not interfere with the physician–patient relationship, the duration of visits, or the number of physical examinations performed.[41,42] However, a recent study found that patient care suffered when patients were isolated.[43] The

cost–benefit ratio was not very sensitive to the number of contacts. However, the sensitivity analysis did not account for differential numbers and lengths of patient contacts in the two periods. This assumption may have biased the results if there were more patient encounters during the no-gown period than during the gown period, although the direction of the bias is unclear. Decreased numbers of patient contacts would decrease the opportunity for horizontal transmission, but they might also be associated with more adverse outcomes.

There are three limitations that bias the study against finding gowns to be cost-saving. First, the addition of costs attributed to excess workload due to the time it takes nurses to don and doff gowns may have overestimated the costs of the gown policy. The staff payroll is unaffected by whether or not the MICU has a gown policy in place. Although the gown policy did not result in overtime pay, donning and doffing gowns may have prevented nurses from allocating time to other duties. From an economics point of view, it was necessary to calculate the opportunity costs of excess workload for the gowning policy at the detriment of potentially overestimating the cost of the policy.

Second, other benefits from surveillance and gown use, such as averting colonization or infection at other sites, decreasing the potential for horizontal transmission of other pathogens, and decreasing the potential transmission of resistant genes, were not quantified and thus the benefit of gowns may have been underestimated.[24,44,45]

Finally, the cost analysis for this study was from the perspective of the MICU and the hospital, not society. If a societal perspective had been used, the magnitude of the benefit would have been greater for averted cases of VRE by including the benefits to patients from decreased morbidity and mortality. The impact of these nosocomial infections on patients and family members, missed days of work, and time away from other activities were not determined.

Several studies now affirm the beneficial effects of gown use in preventing and controlling the spread of nosocomial pathogens.[7,8,12-15] This secondary analysis of the impact of gowns on VRE transmission confirms a modest increased cost for the enhanced infection control procedures associated with gown use that is offset by the benefit of averting cases of enteric VRE. When the attributable hospital cost of VRE ranged from $11,989 to $66,194 per patient and the increase in length of stay ranged from 8.3 to 38.2 days, the extra expenditure of $1,897 to prevent a case of VRE colonization yielded a net savings to the hospital. In comparison with the costs of other preventive health interventions (eg, immunization programs), this cost associated with the prevention and control of VRE is low given the anticipated benefits.[46-53] Furthermore, with the recent reports of clinical cases of VRSA, methods to control and prevent the spread of vancomycin resistance remain a core component of strategic hospital and public healthcare planning.[2-4]

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