Impact of an infection control program on rates of ventilator-associated pneumonia in intensive care units in 2 Argentinean hospitals

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Background: Hospitalized, critically ill patients have a significant risk of developing nosocomial infection. Most episodes of nosocomial pneumonia occur in patients undergoing mechanical ventilation (MV).

Objective: To ascertain the effect of an infection control program on rates of ventilator-associated pneumonia (VAP) in intensive care units (ICUs) in Argentina.

Methods: All adult patients who received MV for at least 24 hours in 4, level III adult ICUs in 2 Argentinean hospitals were included in the study. A before-after study in which rates of VAP were determined during a period of active surveillance without an infection control program (phase 1) were compared with rates of VAP after implementation of an infection control program that included educational and surveillance feedback components (phase 2).

Results: One thousand six hundred thirty-eight MV-days were accumulated in phase 1, and 1520 MV-days were accumulated during phase 2. Rates of VAP were significantly lower in phase 2 than in phase 1 (51.28 vs 35.50 episodes of VAP per 1000 MV-days, respectively, RR = 0.69, 95% CI: 0.49-0.98, $P \leq$ .003).

Conclusion: Implementation of a multicomponent infection control program in Argentinean ICUs was associated with significant reductions in rates of VAP. (Am J Infect Control 2006;34:58-63.)

Hospitalized, critically ill patients have a significant risk of developing nosocomial infection. In Argentina, the rate of nosocomial infections in intensive care units (ICUs) is high.[1] Most episodes of nosocomial pneumonia occur in patients undergoing mechanical ventilation (MV).[2] Ventilator-associated pneumonia (VAP) significantly increases health care costs[3] and prolongs hospitalization[3-8] but, more importantly, is associated with significantly attributable mortality.[3,5,7]

Many hospitals in Latin America, in particular Argentina, lack formal infection control programs, primarily as a result of limited governmental oversight. Not surprisingly, most cases of VAP occur in health care facilities that lack caregivers who are familiar with published infection control guidelines.[9]

We have previously reported significant reductions in rates of intravascular device-related bloodstream infection (IVDR BSI)[10,11] and catheter-associated urinary tract infection (CAUTI)[12] following the introduction of infection surveillance and control programs in a number of Argentinean hospitals. Studies from developed countries have found significant reductions in institutional rates of VAP in association with the introduction of multidimensional infection control programs.[13-18] We are unaware of published studies from Argentina or other Latin American countries that have examined the effectiveness of a multidimensional infection control program on reducing institutional rates of VAP. As a result, we embarked on a prospective, multicenter before-after study to evaluate the impact of an infection control program—consisting of surveillance, education, and feedback components—on rates of nosocomial pneumonia in mechanically ventilated patients in 4 intensive care units (ICUs) in 2 Argentinean medical centers.

METHODS

Setting

The study was conducted in 2 medical centers in Buenos Aires, Argentina (Bernal Medical Center and Colegiales Medical Center). Each center has an infection control team composed of a medical doctor with a formal education and background in internal medicine, infectious diseases, and hospital epidemiology and an infection control nurse.[19]

Bernal Medical Center is a private 150-bed hospital situated in the province of Buenos Aires with 1 medical/surgical ICU (17 beds) and 1 coronary ICU (15 beds). Colegiales Medical Center is a private 180-bed hospital situated in the city of Buenos Aires with 1 medical/surgical ICU (10 beds) and 1 coronary ICU (10 beds). All ICUs in the study centers operate at a third level of complexity, caring for patients who have undergone open-heart, neurosurgical, and orthopedic surgery as well as patients with severe medical illness. The institutional review board at each center approved the study protocol.

Data collection

All patients admitted to the study units who were mechanically ventilated for more than 24 hours were enrolled in this study. An infection control nurse at each study center prospectively abstracted patient demographic data from patient charts. The principal investigator (V.D.R.) trained the data collectors at each center before initiation of the trial. The patient's age, sex, duration of mechanical ventilation, antibiotic use, use of other invasive devices, and other sites of infection while mechanically ventilated were recorded for each study patient. Study center data collection sheets were checked for potential errors and missing items by the study coordinator to confirm each diagnosis of VAP.

The Acute Physiology and Chronic Health Evaluation (APACHE) or other severity-of-illness index scores are used infrequently in developing countries[20]; however, we calculated average severity-of-illness scores (ASIS) as described by Emori et al[21] for study participants to assess whether differences in case-mix were present between study phases. Briefly, patients undergoing MV in study units were assigned a severity-of-illness score from 1 to 5 based on their expected resource utilization. For example, a stable postoperative patient expected to be discharged from the ICU within 48 hours would be assigned a score of 1, whereas a physiologically unstable patient in coma or shock who required intensive medical and nursing care with frequent need for reassessment would be assigned a score of 5. Severity-of-illness scores were then combined and averaged over each study period and compared statistically for differences.

Surveillance

A nosocomial infection surveillance system was implemented in each center. All charts of patients who were diagnosed with pneumonia by their physician or had a positive lower respiratory tract culture were reviewed to determine whether an episode of VAP had occurred during the 24 months of the study period. Decisions to obtain cultures were made independently by the patient's attending physicians. Standard laboratory methods were used to identify microorganisms.

Incidence rates of VAP per 1000 MV-days were calculated prospectively by an infection control nurse using a standard Centers for Disease Control and Prevention (CDC)/National Nosocomial Infection Surveillance (NNIS) system definition[21,22]:

A mechanically ventilated patient has a chest radiographic examination that shows a new or progressive infiltrate, consolidation, cavitation, or pleural effusion and at least 1 of the following: (1) new onset of purulent sputum or change in character of sputum; (2) organism cultured from blood; (3) isolation of an etiologic agent from a specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy.[22]

Intervention

Active surveillance for VAP without feedback to health care workers (HCWs) was initiated in January 2001 and continued for 12 months through December 2001 (phase 1). One-hour educational sessions based on the 1997 CDC Nosocomial Pneumonia Prevention Guidelines[9] were initiated during the last 2 months of phase 1 and continued throughout phase 2. These sessions were offered to all physician, nursing, and ancillary staff, although attendance was not mandatory. Each 1-hour session was self-contained and emphasized the following: (1) epidemiology and pathogenesis of nosocomial pneumonia; (2) hand hygiene before and after patient contact; (3) proper handling of the respiratory secretions and suction catheters; and (4) percussion and postural drainage to stimulate coughing.

Phase 2 of the study continued for an additional 12 months, from January 2002 through December 2002. Monthly educational sessions and active surveillance for VAP continued through this phase; however, in addition, feedback of VAP rates was provided to ICU HCWs on a monthly basis. Feedback was provided to staff at infection control meetings in the form of bar charts. A formal report of VAP rates was forwarded to administrators in each study ICU, respectively. No attempts to measure compliance with aspects of VAP prevention emphasized in the educational sessions were made.

Outcomes and statistical methods

The primary outcome was the rate of VAP in phase 2 compared with the rate in phase 1. EpiInfo version 6.04b (Centers for Disease Control and Prevention, Atlanta, GA) was used for data analysis. Monthly incidence rates of VAP were calculated by dividing the number of documented episodes of VAP by the total

Table 1. Baseline characteristics of patients

Variable	Preintervention (n = 435)	Intervention (n = 366)	P value
Sex (male)	236 (54.3%)	188 (51.4%)	.41
Age (yr), mean ± SD	72.38 ± 12.21	73.79 ± 10.93	.08
ASIS, mean ± SD	3.69 ± 0.74	3.74 ± 0.70	.36
Medical admission	312 (71.7%)	282 (77.0%)	.10
Diabetes	66 (15.2%)	55 (15.0%)	.96
Hypertension	182 (41.8%)	153 (41.8%)	.95
Heart failure	65 (14.9%)	72 (19.07%)	.09
Myocardial infarction	35 (8.0%)	34 (9.3%)	.61
Valve replacement	7 (1.6%)	2 (0.5%)	.19*
Smoker	40 (9.2%)	31 (8.5%)	.81
Cancer	16 (3.7%)	17 (4.6%)	.61
Obesity	29 (6.7%)	25 (6.8%)	.96
Ethanol use	3 (0.7%)	5 (1.4%)	.40*
Hip replacement	6 (1.4%)	4 (1.1%)	.76*
Stroke	79 (18.2%)	76 (20.8%)	.39
Urinary catheter use	419 (96.3%)	354 (96.7%)	.90

*Fisher exact test.

Table 2. ICU stay, antibiotic use, device utilization, and device-related infections during study periods

Variable	Preintervention	Intervention
ICU stay, patient-days	5.32 (SD: 6.04)	5.65 (SD: 7.01)
Antibiotic use	729 DDD per 1000 patient day	602 DDD per 1000 patient day
Duration of mechanical ventilation, patient-days	3.68 (SD: 5.04)	3.89 (SD: 6.41)
Utilization of mechanical ventilation	0.12	0.11
Utilization of vascular catheters	0.15	0.26
CVC-related BSI per 1000 CVC-days	6.91 (24/3469)	5.96 (11/1845)
Utilization of urinary catheters	0.53	0.53
CAUTI per 1000 catheter-days	13.10 (93/7097)	16.22 (110/6779)

CVC, central venous catheter; *BSI*, bloodstream infection; *CAUTI*, catheter-associated urinary tract infection, *DDD*, defined daily dose.

number of MV-days observed in the preceding calendar month. This product was then multiplied by 1000 to give the episodes of VAP per 1000 MV-days.[23] Baseline differences between treatment groups were analyzed using[2] analyses for dichotomous variables and Student *t* test for continuous variables. When appropriate, Fisher exact probability test was used. Relative risk (RR) ratios, 95% confidence intervals (CI), and *P* values were determined for all primary and secondary outcomes. All statistical tests were 2-tailed.

RESULTS

Eight hundred one adult patients–435 in phase 1 and 366 in phase 2–in the study ICUs required MV for greater than 24 hours, and all of these patients were enrolled in the study. Patients from phase 1 were very similar to patients from phase 2 with regard to sex, ASIS, age, diabetes mellitus, cancer, HIV, and other underlying diseases (Table 1). Similarly, no differences in ICU length of stay between phase 2 and phase 1 of the study was identified (Table 2; 5.65 versus 5.32 days, respectively, *P* = .47).

Utilization of intravascular devices was significantly less in phase 2 versus phase 1 of the study (0.15 vs 0.26, respectively, *P* < .0001; [number of device-days per number of patient-days]), although the incidence rate of IVDR BSI was not significantly different between the 2 phases of the study (6.0 vs 6.9 BSIs per 1000 IVD-days, respectively, *P* = .81) (Table 2). In contrast, no differences in the utilization of urinary catheters (0.53 vs 0.53 catheter-days per 1000 bed-days, respectively, *P* = .61) and rates of CAUTI (16.2 vs 13.1 UTIs per 1000 catheter-days, respectively, *P* = .15) were found between phase 2 and phase 1 of the study (Table 2).

A total of 3158 MV-days were accumulated during the course of the study: 1638 MV-days during phase 1 and 1520 MV-days during phase 2. Utilization of MV (0.12 vs 0.11, respectively, *P* = .64) and mean duration of MV (3.89 vs 3.68 days, respectively, *P* = .60) did not differ significantly between phase 2 and phase 1 of the study. Despite a similar duration of MV, the rate of VAP during phase 2 was significantly lower than during phase 1 (35.52 vs 51.28 episodes of VAP per 1000 MV-days, respectively, RR = 0.69, 95% CI: 0.49-0.98, *P* ≤ .003) (Table 3).

Secondary outcomes, such as crude mortality and mortality attributable to VAP were not assessed in this study; however, antibiotic utilization–measured by defined daily doses (DDD) per 1000 patient-days–during phase 2 was found to be significantly lower than during phase 1 (602.5 vs 729.4 DDD per 1000 patient-days, respectively, RR = 0.89, 95% CI: 0.87-0.91, *P* < .0001) (Table 2). Whether this reduction in antibiotic utilization was a direct result of implementation of an infection control program was not assessed by the current study design.

DISCUSSION

Critically ill patients often require MV for support of breathing. Unfortunately, patients undergoing MV are at considerable risk of developing infection, in particular, nosocomial pneumonia.[2] When pneumonia associated with MV does occur, studies have repeatedly demonstrated an increased length of hospitalization, excess health care costs, and increased attributable mortality.[3-7] For example, Dietrich et al found that VAP resulted in an excess length of hospitalization of 14 days and increased direct medical costs by an

Table 3. Rates of ventilator-associated pneumonia in phase 1 versus phase 2

	VAPs per 1000 MV-days*	RR	95% CI	P value
Phase 1	51.28 (84/1638)			
Phase 2	35.50 (54/1520)	0.69[†]	0.49-0.98	<.003

*Phase 1: baseline; phase 2: reporting nosocomial infection rates to HCW.
[†]Phase 2 versus phase 1.

average of nearly $14,890.[24] Similarly, Rosenthal et al found that VAP prolonged hospitalization by almost 9 days and increased the cost of health care by $2255 per VAP episode.[3,8] More importantly, several studies have found that VAP is associated with increased attributable mortality ranging from 33% to 72%,[3,5,7,8,25,26] although this has not been a universal finding.[4,6,27,28] In spite of this controversy, most studies found that VAP is associated with excess length of stay (range, 6.55-25 days)[3,24,29,30] and increased health care utilization (range, $8800-$14,606).[24,29,30]

VAP is largely preventable, and studies have documented the effectiveness of a number of preventative interventions such as handwashing,[31] semirecumbant positioning,[32] early removal of nasogastric and endotracheal tubes,[33] maintenance of endotracheal cuff pressure,[34] and continuous subglottic suctioning.[35,36] The decision to implement one or more of these interventions must be guided by a knowledge of institutional rates of VAP if the infection control professional is to approach VAP reduction interventions in a cost-effective manner.[37] Unfortunately, many health care institutions in Latin America, including Argentina, lack basic infection control programs, and most caregivers are unaware of their institutional rates of VAP.

A number of studies have demonstrated the benefit of multicomponent infection control programs that stressed educational interventions.[13-18] However, the benefits derived from educational efforts may be short-lived without regular reinforcement. Likewise, surveillance of infection rates in and of themselves should not be expected to lead to a reduction in rates of selected nosocomial infections unless the collection of these data is used for improvement of patient care practices.[38] As a result, buttressing educational efforts with regular feedback in the form of monthly incidence rates of nosocomial infections may provide maximal benefit.[11,12]

We have shown that implementation of a multicomponent infection control program, which includes surveillance, education, and feedback of rates of VAP to HCWs, resulted in a significant reduction in rates of VAP over a 24-month study period. This is the first study in Argentina and Latin America to document a reduction in rates of VAP associated with implementation of an infection control program. Our findings are similar to other studies examining the impact of infection surveillance feedback on rates of nosocomial infection.[39-41] For example, Mead et al found that rates of surgical site infection (SSI) were reduced by 42% when SSI rates were provided to surgical team members on a monthly basis.[42] Likewise, Reilly found that implementation of a SSI rate feedback program resulted in significant reductions in SSI rates when SSI rates were provided to surgical team members on a monthly basis.[43]

The multidimensional nature of our study design makes ascribing reductions in rates of VAP to a specific component of the infection control program difficult; however, we believe that all 3 components–surveillance, education, and feedback–are important because previous studies by our group have demonstrated incremental reductions in rates of IVDR BSI when surveillance, education, and feedback were sequentially introduced into an ICU.[11] The educational component of the infection control program initiated in this study stressed simple infection control practices related to hand hygiene, appropriate respiratory circuit care, and pulmonary toilet because more costly preventative interventions such as using sucralfate instead of H_2-blocking agents,[44] selective digestive tract decontamination,[45] and continuous subglottic suctioning[46] are not routinely available in hospitals of developing countries. We did not attempt to measure specific changes in HCW behaviors that changed as a result of the infection control program. However, we hypothesize that improvements in respiratory circuit care and pulmonary toilet had the greatest impact on the reduction in VAP because an aggressive campaign to improve hand hygiene had already been in place prior to initiating the current study. It is possible that unintended changes in other practices such as increased attention to oral hygiene[47] or a more aggressive approach to ventilator weaning occurred as a result of increased HCW awareness to the problem of VAP, although the latter seems less likely, given the similar durations of average MV between the 2 study periods.

A number of limitations inherent to our study design deserve mention. One of the biggest limitations of this study is that we did not randomize the ICUs or the patients in the ICUs. As a result, it is possible that the reduction in rates of VAP observed over the course of our study was the result of regression toward the mean or a maturation effect from unmeasured confounders. Along this line, the possibility of case-mix differences between the study phases is a possibility, even though the ASIS in study units was not significantly different between study periods. Our inability to employ more sophisticated severity-of-illness scoring systems like the Acute Physiology and Chronic Health Evaluation (APACHE) scoring system, the Simplified Acute

Physiology Score (SAPS), or the Mortality Probability Models (MPM) scoring system[20] may have limited our ability to detect subtle difference in group-level severity-of-illness, which would have biased our study results.

In addition, our study is susceptible to a number of other biases. Clinical definitions of VAP, such as the one used in this study, have been shown to have poor sensitivity and specificity,[48] and the possibility of misclassification bias in our study cannot be ruled out. However, the same observer and definition for VAP were used in both study periods. As a result, any misclassification bias because of use of a poor definition would be nondifferential in nature and would tend to bias study results toward the null and not toward the alternative. In contrast, the possibility of observer bias cannot be ruled out entirely, although the observer used in both study periods was well versed in infection surveillance methodologies and was directly supervised by an infectious disease specialist, which should have minimized the impact of this type of differential misclassification bias. Finally, although programmatic surveillance of VAP rates was not actively advertised during phase 1, it is reasonable to assume that HCWs became aware of surveillance activities during this period, and rates of VAP during phase 1 may have been reduced as a result of the Hawthorne effect, thereby biasing study results toward the null. Taking these limitations on the whole, we believe that our study results provide strong evidence of benefit from a multidimensional infection control program.

In conclusion, our data show that VAP is a common problem in Argentinean hospitals. However, implementation of a multicomponent infection control program that stresses simple hygienic practices can significantly reduce rates of VAP. Our study should be an encouragement to other hospitals in developing countries because our results suggest that the incidence of VAP can be significantly reduced with relatively little capital investment.

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