Objective: To examine the impact of adherence to a ventilator-associated pneumonia (VAP) bundle on the incidence of VAP in our surgical intensive care units (SICUs).

Design: Prospectively collected data were retrospectively examined from our Infection Control Committee surveillance database of SICU patients over a 38-month period. Cost of VAP was estimated at $30,000 per patient stay.

Setting: Two SICUs at a tertiary care academic level I trauma center.

Patients: Ventilated patients admitted to a SICU.

Intervention: The Institute for Healthcare Improvement VAP bundle was instituted at the beginning of the study and included head-of-bed elevation, extubation assessment, sedation break, peptic ulcer prophylaxis, and deep vein thrombosis prophylaxis. A daily checklist was considered compliant if all 5 items were performed for each patient.

Main Outcome Measures: Patients were assessed for VAP. Staff were assessed for compliance with the VAP bundle.

Results: Prior to initiation of the bundle, VAP was seen at a rate of 10.2 cases/1000 ventilator days. Compliance with the VAP bundle increased over the study period from 53% and 63% to 91% and 81% in each respective SICU. The rate of VAP decreased to 3.4 cases/1000 ventilator days. A cost savings of $1.08 million was estimated.

Conclusions: Initiation of the VAP bundle is associated with a significantly reduced incidence of VAP in patients in the SICU and with cost savings. Initiation of a VAP bundle protocol is an effective method for VAP reduction when compliance is maintained.


Prevention of ventilator-associated pneumonia (VAP) has become a priority for all intensive care units (ICUs) in the United States.1,2 The critical importance of this issue reflects the high incidence (5.2 VAP cases/1000 ventilator days in surgical ICUs [SICUs] and 10.2 VAP cases/1000 ventilator days in trauma ICUs,3 making VAP among the most common infection in ICUs4) and the high cost of treatment ($11,000-$57,000).5-7 Although increased attributable mortality in this group is controversial,5,6,8-12 it is clear that those with VAP spend additional days on the ventilator,6 additional days in the ICU,5,8,11 and additional days in the hospital.5-8 Adding to the pressure to eliminate VAP, the Centers for Medicare and Medicaid Services have announced that they may cease to reimburse hospitals for costs incurred as a result of VAP,13 thus shifting this profound financial burden directly to hospitals.

Evidence-based clinical practice guidelines aimed at reducing VAP have been available for many years14,15 and include dozens of clear prevention strategies. Sadly, widely published guidelines often do not result in changed behaviors in the clinical setting,16 and VAP prevention guidelines have proven no exception.17 Awareness of the gap between guideline dissemination and clinical practice has led to efforts by individual hospitals and health care systems to institute programs aimed at complying with VAP prevention guidelines to reduce the burden of this nosocomial infection. The bundle approach has been very successful at effecting evidence-based recommendations.18-26 When our institution’s SICUs revealed mediocre VAP rates in 2006, a bundle practice was adopted to reduce this complication. By complying with 4 VAP bundle elements described by the Institute for Healthcare Improvement (IHI),17 we believed that we could lessen our VAP burden.
The VAP bundle program began October 1, 2006. Compliance was assessed twice daily by the respiratory care service, who entered data into an electronic database. Compliance data were summarized on a weekly basis. These data were reviewed monthly by a multidisciplinary team including intensive care nursing managers who supplied feedback to the SICU nursing staff.

### OUTCOME MEASURES

The primary outcome measure was the relationship between VAP bundle compliance and VAP incidence. Cases of VAP were identified by the infection control team during routine daily surveillance rounds through the ICUs using Centers for Disease Control and Prevention criteria. All suspected VAP cases were reviewed thoroughly, including individual radiographs by the infection control team of nurses and physicians before a VAP diagnosis was confirmed. The members of the infection control team did not change during the study period.

Rates of VAP were defined as the number of VAP cases per 1000 ventilator days. Ventilator days were counted daily by the infection control team. A ventilator day was defined as a calendar day for which the patient was charged for mechanical ventilation.

A secondary outcome of interest was the cost savings resulting from the VAP bundle program. At our institution, the cost to treat a VAP case was estimated to be $30 000 based on average costs documented in the literature.

### STATISTICAL ANALYSIS

Differences in VAP rates were compared using the $\chi^2$ test. Summary statistics are provided as annual VAP rate (VAP cases per 1000 ventilator days) with $P$ value. Annual percentage of compliance was compared via 95% confidence intervals.

### COMPLIANCE MEASURES

Total bundle compliance increased every year in both SICUs throughout the study (Figure 1), from 53% to 91% in the TICU and from 63% to 81% in the SICU. The TICU showed the greatest increase in total compliance. Both ICUs showed greater improvement in overall compliance between the first and second years of the study than between the second and third years of the study.

Individual bundle items also showed improvement during the study period (Table). The HOB elevation and deep vein thrombosis prophylaxis bundle elements were initially the most deficient, but they improved greatly by the end of the study. Compliance with peptic ulcer prophylaxis, sedation break, and assessment for extubation were initially excellent and remained at or higher than 92% throughout the study.

### VAP MEASURES

The overall VAP rates in our 2 ICUs were similar prior to the bundle program (Figure 2) and were comparable to the 50th percentile reported by the 2004 National Nosocomial Infections Surveillance System for SICUs and TICUs.

The incidence of VAP decreased in each ICU during the study period. The TICU had a greater and more statistically significant reduction in VAP compared with the...
SICU, which only approached statistical significance. The VAP incidence at the SICU increased slightly during the first year of the VAP bundle program but showed the greatest decrease during the second year. The TICU saw the greatest decrease in VAP during the third study year.

Combined VAP rates decreased during the study period and were statistically significant in 2008 and 2009 (Figure 2). This suggests a 67% risk reduction by the end of the study period.

COST ANALYSIS

The combined VAP incidence in our ICUs was 10.2 VAP cases/1000 ventilator days at the beginning of the study period. At that rate, 36 additional VAP cases would have been acquired by our patients during the study without the bundle. At an estimated expense of $30,000 (±$20,000)/VAP case, $1,080,000 ($360,000-$1,800,000) was saved as a result of VAP prevention.

COMMENT

Our data show a correlation between VAP bundle compliance and reduction in VAP incidence. This effect was seen across 2 separate SICUs at our institution, it was sustained for 3 years, and it saw our VAP incidence decrease between the 10th and 25th national percentiles for SICUs and TICUs by the end of the study period. Prior to initiation of the VAP bundle, the VAP incidence was slightly higher at the TICU than at the SICU. We attribute this to the trauma population treated at the TICU and their higher risk of VAP. Overall compliance was proportional to the decrease in the VAP rate. The TICU experienced a higher level of compliance and a lower VAP rate at the end of 3 years than the SICU. This was likely because the VAP bundle project was initiated by TICU staff, although this does not explain why the first year saw better compliance at the SICU.

Of the individual bundle elements, compliance with HOB elevation had the greatest impact on VAP reduction. Compliance with HOB elevation was initially very low in both ICUs but had the greatest improvement during the study period. Deep vein thrombolysis prophylaxis compliance, also initially poor, improved but does not contribute to VAP reduction. Other bundle elements had excellent compliance throughout the study period. Head-of-bed elevation was the single element associated with reducing VAP risk that improved during the study period.

Evidence-based guidelines for the prevention of nosocomial pneumonia have been published and revised by the Centers for Disease Control and Prevention since the 1980s. Since the publication of these guidelines, a decrease in the VAP rate has been appreciated by the National Nosocomial Infections Surveillance System. The SICU VAP rate was 25 VAP cases/1000 ventilator days in 1987 and decreased to 15 by 1991, to 9.3 by 2004, and to 5.2 in 2006. Managan et al described compliance data obtained in 1995 via mailed self-report surveys regarding recommendations for management of ventilator equipment. This group found that compliance with timing of breathing circuit change (category 1A recommendation) had increased from 65% to 98% and that compliance with routine changing of the hygroscopic condenser-humidifiers or heat-moisture exchangers (category 1B recommendation) increased from 62% to 93% since guideline publication. Most other recommended practices were not as well heeded or showed little change in behavior.

In 1999, Cabana et al reviewed 76 studies that examined guideline compliance and concluded that al-

<table>
<thead>
<tr>
<th>Bundle Item</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SICU</td>
<td>TICU</td>
<td>SICU</td>
</tr>
<tr>
<td>DVT prophylaxis</td>
<td>83 (77-88)</td>
<td>78 (73-84)</td>
<td>96 (94-98)</td>
</tr>
<tr>
<td>HOB elevation</td>
<td>77 (73-82)</td>
<td>65 (57-72)</td>
<td>84 (80-89)</td>
</tr>
<tr>
<td>Peptic ulcer prophylaxis</td>
<td>98 (96-99)</td>
<td>99 (98-100)</td>
<td>99 (98-100)</td>
</tr>
<tr>
<td>Sedation break</td>
<td>98 (97-99)</td>
<td>97 (96-99)</td>
<td>97 (96-98)</td>
</tr>
<tr>
<td>Assessment for extubation</td>
<td>96 (94-98)</td>
<td>92 (87-97)</td>
<td>97 (95-98)</td>
</tr>
<tr>
<td>Total bundle compliance</td>
<td>63 (57-69)</td>
<td>53 (46-60)</td>
<td>78 (73-83)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; DVT, deep vein thrombosis; HOB, head-of-bed; SICU, surgical intensive care unit; TICU, trauma intensive care unit.
though the guidelines are widely distributed, they have only a small impact on changing physician practice. Rello et al17 confirmed this disappointing reality for VAP guidelines as well. In this international study, critical care physicians deemed “opinion leaders” in the field of VAP were surveyed about evidence-based guidelines described by Kollef.14 Rello and colleagues discovered a 25.2% noncompliance rate for recommended guidelines; noncompliance rates of 41.3% and 35.7% were seen for grade A and B recommendations, respectively. While Rello and colleagues found “disagreement with interpretation of reported trials”17 and “lack of resources”17 to be the main factors for noncompliance, Cabana and colleagues reported “lack of awareness, lack of familiarity, lack of self-efficacy, lack of outcome expectancy, and inertia of previous practice”16 as important barriers to implementing guidelines.

Acknowledgment of widespread guideline noncompliance led to speculation by Sinuff et al32 into methods for improving knowledge translation relevant to VAP prevention in ICUs. This group suggested that a multifaceted approach would yield the greatest success. An active educational strategy combined with reminders, audit, and feedback led by a guidance implementation team was recommended for further study. Craven8 similarly advised that a cure for poor compliance with VAP guidelines should involve a multidisciplinary team that sets prevention benchmarks, establishes goals and timelines, and provides education, training, audits, and feedback.

An enormous amount of effort has been spent overcoming barriers to guideline implementation. The earliest programs aimed at reducing VAP by complying with established recommendations were described in the mid-1990s.

Kelleghan et al33 described a 1989 quality improvement project at Kaiser Permanente in California that was modeled after the principles of continuous quality improvement described by W. Edwards Deming, PhD. This is among the earliest attempts at reducing VAP incidence by enforcing existing infection control and prevention guidelines. With a multipronged approach, a multidisciplinary infection prevention team established a checklist of respiratory guidelines for staff, addressed barriers to compliance, instituted a hand-washing surveillance program, held educational seminars, began prospective VAP surveillance, and gave compliance feedback. This institution had a 57% reduction in VAP in 1 year, estimating 15 VAP cases prevented, 3 lives saved, and $105,000 in cost savings.

Joiner et al34 described similar efforts in Ohio in 1992. Also borrowing from continuous quality improvement theory, which stipulates that outcome improvement stems from change in process, a multidisciplinary quality improvement team compared the institution’s process of ventilator care management with evidence-based best-care practices and created a protocol to eliminate the gap between current and best care. The VAP and process evaluation data were collected and reviewed monthly, and areas for improvement were addressed. This institution also saw a dramatic decrease in VAP incidence, from 26 to 16 VAP cases/1000 ventilator days, saving approximately $126,000 over 3 years.

The VAP bundle concept grew from the IHI’s 100,000 Lives Campaign to reduce VAP incidence.1 The bundle is a “small set of evidence-based interventions for patients on mechanical ventilation.”18 Created in 2002, the IHI-defined bundle included 4 elements: HOB elevation, daily sedation vacation, peptic ulcer prophylaxis, and deep vein thrombosis prophylaxis. Clinical evidence supports that each item reduces patient mortality and morbidity19 and that patients on mechanical ventilation should receive these things, despite the fact that only HOB elevation and sedation vacation reduce VAP risk.

In 2005, Resar et al19 described the IHI Impact Network’s experience implementing the IHI VAP bundle at 61 hospitals. The ICUs achieving greater than 95% compliance saw a 59% reduction in VAP rates. Resar and colleagues emphasized that while bundle use may improve clinical outcomes, its use would also improve process reliability. They speculated further that the multidisciplinary teams, daily goal-setting, and increased attention to detail stimulated by the bundle importantly contributed to improved clinical outcomes.

Cocanour et al21 described VAP bundle use in their Houston, Texas, TICU. On discovery of high VAP incidence, a bundle program that included elements of the IHI VAP bundle in addition to several other precautions was initiated. The initial improvements in VAP incidence were modest and unsustainable. When a computerized audit tool was implemented to calculate weekly bundle compliance data, the VAP rate decreased below the National Nosocomial Infections Surveillance System’s 25th percentile and was sustained for the remaining months of the study. This result reveals the importance of process quality evaluation and feedback in improving clinical outcome when using a bundle.

A similar experience was described by Hawe et al20 in Scotland. They implemented a similar VAP bundle by displaying copies of the protocol at every ICU bedside. Compliance, assessed only periodically, was dismal during this passive implementation phase and no VAP reduction was seen. An active implementation phase that included educational workshops, compliance reporting, addressing barriers to delivery, and discussion of bundle adherence on daily multidisciplinary rounds was initiated. Compliance improved from 0% to 54% and VAP rates decreased dramatically from 19.17 to 7.5 VAP cases/1000 ventilator days. Here, the education, feedback, and daily goal-setting were key to clinical success.

Zaydfudim et al25 made compliance feedback the keystone of their VAP bundle program in Nashville, Tennessee. When implementation of a bundle program with intermittent compliance monitoring failed to reduce VAP incidence, a real-time VAP bundle compliance dashboard was installed on every SICU computer monitor. Daily compliance reports were reviewed by multidisciplinary rounding teams and by physician and nursing leaders. Real-time compliance feedback resulted in an increase in total bundle compliance from approximately 20% to about 90% over 1 year. Compliance with individual bundle items increased in every parameter during the study period, and overall VAP rates improved.

We attribute the success of our VAP bundle program to several of the factors described earlier. First, we used
a concise, well-established bundle described by the IHI\textsuperscript{17,25} where each component has a well-documented impact on morbidity.\textsuperscript{16} Numerous other ICUs in the United States have had success in decreasing VAP incidence using the IHI bundle.\textsuperscript{17} Second, our comprehensive approach to bundle implementation and its incorporation to daily rounds and goal-setting contributed to our success.\textsuperscript{18} Daily multidisciplinary rounds with a checklist by a team including nurses, pharmacists, and physicians ensured that bundle-appropriate orders were entered and completed. Our system of regular audit and feedback may have made the greatest impact on bundle compliance. The VAP compliance and incidence data were reviewed weekly, monthly, and quarterly. Weekly data were summarized in an electronic newsletter that included days since last VAP. Quarterly VAP data were posted in several locations throughout the hospitals and the ICUs. Nursing supervisors who attended monthly meetings discussed compliance data, comparing current and prior performance, and provided feedback to the ICU nursing staff. Presumably once the trend in reduced VAP incidence became apparent with improved bundle compliance, the staff became even more motivated to improve performance. These same feedback and reminder mechanisms continue presently.

Strengths of our study include the large number of patients (approximately 4000) treated in our SICUs over 2½ years. The similar results achieved at both SICUs underscore the validity of our results. Another important strength is the measurement of our primary outcome (VAP incidence) by an experienced, unchanging infection control team.

Among the weaknesses of this study, we did not compare our SICU populations between units or years. It is possible that healthier patients with fewer risk factors for VAP were admitted in 2009 than in 2006. We did not account for contraindications to VAP bundle items when scoring compliance. This may have led to underestimation of actual guideline compliance. Finally, the greatest weakness of our study is that it does not account for other ongoing programs at our institution aimed at reducing nosocomial infections, including a hand-washing campaign, blood glucose control protocols, a chlorhexidine gluconate mouthwash protocol, and availability of an endotracheal tube that supports continuous aspiration of subglottic secretions. While we have documented improved compliance with hand washing, which may have had an impact on our VAP rates, compliance data are not available for the other interventions. Use of chlorhexidine mouthwash and of the endotracheal tube that supports continuous aspiration of subglottic secretions began in 2005 at our institution, 1 year prior to initiation of the bundle program.

In summary, our study demonstrates the success of a VAP bundle in reducing the incidence of VAP and in cutting costs in 2 SICUs when excellent compliance is maintained. Compliance was achieved by incorporating the bundle into daily multidisciplinary rounds and through regular audit and feedback. This is a simple, inexpensive, effective method of reducing VAP in the SICU.

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REFERENCES


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