National Trauma Institute prospective evaluation of the ventilator bundle in trauma patients: Does it really work?

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BACKGROUND: Since its introduction by the Institute for Healthcare Improvement, the ventilator bundle (VB) has been credited with a reduction in ventilator-associated pneumonia (VAP). The VB consists of stress ulcer prophylaxis, deep venous thrombosis prophylaxis, head-of-bed elevation, and daily sedation vacation with weaning assessment. While there is little compelling evidence that the VB is effective, it has been widely accepted. The Centers for Medical and Medicaid Services has suggested that VAP should be a "never event" and may reduce payment to providers. To provide evidence of its efficacy, the National Trauma Institute organized a prospective multi-institutional trial to evaluate the utility of the VB.

METHODS: This prospective observational multi-institutional study included six Level I trauma centers. Entry criteria required at least 2 days of mechanical ventilation of trauma patients in an intensive care unit (ICU). Patients were followed up daily in the ICU until the development of VAP, ICU discharge, or death. Compliance for each VB component was recorded daily, along with patient risk factors and injury specifics. Primary outcomes were VAP and death. VB compliance was analyzed as a time-dependent covariate using Cox regression as it relates to outcomes.

RESULTS: A total 630 patients were enrolled; 72% were male, predominately with blunt injury; and mean age, Injury Severity Score (ISS), and 24-hour Glasgow Coma Scale (GCS) score were 47, 24, and 8.7, respectively. VAP occurred in 36%; mortality was 15%. Logistic regression identified male sex and pulmonary contusion as independent predictors of VAP and age, ISS, and 24-hour Acute Physiology and Chronic Health Evaluation as independent predictors of death. Cox regression analysis demonstrated that the VB, as a time-dependent covariate, was not associated with VAP prevention.

CONCLUSION: In trauma patients, VAP is independently associated with male sex and chest injury severity and not the VB. While quality improvement activities should continue efforts toward VAP prevention, the Institute for Healthcare Improvement VB is not the answer. Financial penalties for VAP and VB noncompliance are not warranted. (*J Trauma Acute Care Surg*. 2013;74: 354–362. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Therapeutic study, level III.
KEY WORDS: Ventilator-associated pneumonia; ventilator bundle; trauma; pneumonia; bundle compliance.

Ventilator-associated pneumonia (VAP) remains the most common serious nosocomial infection in trauma patients. It has an attributable mortality rate that ranges from 15% to 47%.[1] Intubated trauma patients are more likely to develop VAP than intubated nontrauma patients.[2] In addition to these human costs, VAP is associated with substantial health care costs, estimated to cost the health care system approximately $40,000 for each episode.[3]

The Institute for Healthcare Improvement (IHI) initiated its 100,000 Lives Campaign in 2005.[4] The concept of a ventilator bundle was promoted. The IHI ventilator bundle consists of the following four components that are designed to improve the outcomes of mechanical ventilation:

1. Stress ulcer prophylaxis (SUP),
2. Deep vein thrombosis,
3. Elevation of the head of the bed, and
4. Daily sedation vacation (SV) with assessment of weaning

There has been widespread implementation of the bundle with claims of great success in reducing VAP rates.[5–8]

However, not all studies have been positive. Zilberberg et al.,[9] in a literature review, identified four studies that evaluated the IHI ventilator bundle. They found problems with study designs and results, in addition to study biases and lack of generalizability. Halpern et al.[10] noted a number of problems with the widespread adoption of the ventilator bundle, including inconsistencies in reported studies, methodologic problems, lack of agreement on diagnosis, and, most importantly, that despite claims to the contrary, the IHI bundle is not supported by a preponderance of evidence.

Because strong data to support the ventilator bundle is lacking, we sought to provide evidence either for or against the bundle by embarking on this prospective observational multi-institutional trial. The practical application of the ventilator bundle is dependent on the patient's condition, which varies during time spent in the intensive care unit (ICU). Indeed, we were unable to identify a study that accounted for the time-dependent nature of bundle application. Published data have evaluated the bundle according to the individual patient, ignoring the inherent differences between patients with multiple exposures to the bundle (longer ICU stays) and those with fewer exposures to the bundle (shorter ICU stays). The present study attempted to determine the time-dependent impact of the ventilator bundle on VAP and death in trauma patients and to identify other patient-related factors (including injury severity) that are related to VAP and death.

PATIENTS AND METHODS

This prospective observational multi-institutional study was performed during a 16-month period ending February 2012 by six Level I trauma centers affiliated with the following institutions: The Medical College of Wisconsin, University of California San Diego, Brown University, Wake Forest University, Lehigh Valley Health Network, and the University of Tennessee Health Science Center. The institutional review boards at each medical center approved the study. Since this was an observational study, consent was waived at each institution. In addition, the Department of Defense also approved the study.

All trauma patients admitted to an ICU and receiving mechanical ventilation for at least 48 hours were eligible for the study. Patients were followed up daily in the ICU until the development of VAP, ICU discharge, or death. The primary outcomes were development of VAP or death.

Patients were observed daily after study enrollment for compliance with the four components of the ventilator bundle: SUP, deep vein thrombosis prophylaxis (DVTP), elevation of the head of the bed (HOB), and SV with weaning assessment. This was an observational study, and each institution applied its own protocol for each bundle element. Specifically, proton pump inhibitors were used in the overwhelming majority of

patients for SUP. DVTP was accomplished using unfractionated heparin, low-molecular-weight heparin, sequential compression devices, or a combination thereof. HOB and SV was evaluated daily by research personnel at a single time according to the institution's routine. No attempt was made to standardize any of the components, and the compliance evaluations were conducted according to each institution's routine since the study was strictly observational. Study personnel recorded either 1 (compliant) or 0 (noncompliant) for each component of the bundle daily. No credit was given even if the bundle component was medically contraindicated. Reasons for bundle noncompliance were recorded. Oral chlorhexidine was not part of the bundle since it was added by the IHI after the study protocol was already approved. Use of oral chlorhexidine was allowed according to each institution's protocol.

Bundle compliance was assessed in two ways—by *individual patient* and by patient-days. For individual patient compliance calculations, the sum of each individual component score was divided by the number of days on the study, giving a value from 0 to 1. Bundle compliance per individual patient was then the sum of these four averages, giving a value from 0 to 4, which was then divided by 4. For example, if a patient was on the study 4 days and was flat in bed for 2 days, but all other components were done on each day, then this patient would receive scores of 1 for each of SUP, DVTP, and SV, and 0.5 for HOB. His bundle compliance score would be 87.5% (3.5 / 4). Overall or average component compliance on a per individual patient basis was obtained by summing each component score over all patients and then dividing by the total number of patients (N = 630). Overall or average bundle compliance was obtained by summing the bundle compliance scores and then dividing by the number of patients. Although this method is commonly used to calculate compliance,[5–8,11–14] this method may not accurately measure bundle or component compliance because patients with either short or long stays are weighted equally. Thus, equal weight is given to less severely injured patients with perfect or near-perfect compliance as is given to more severely injured patients with contraindications to some bundle components.

To avoid this bias toward short stays, compliance was also calculated by *patient-days*. This method counted each day's compliance as an unique event. Thus, patients who stayed longer in the ICU were weighted more heavily than those who did not. Component compliance on a patient-days basis was calculated by summing all of the values across all patient-days and then dividing by the total number of patient-days (N = 1,492). The bundle compliance was calculated by summing the number of patient-days with perfect compliance and dividing by the total number of patient days. (N = 1,492). There are also shortcomings associated with this method of assessing compliance because more weight is given to more severely injured patients who have contraindications to bundle elements and longer stays compared with those with shorter stays and higher compliance.

Patient data collected included routine demographics, significant history, smoking history, and injury specifics. Severity of shock was measured by transfusion requirements at 6, 24, and 48 hours. Brain injury was measured by Glasgow Coma Scale (GCS) score at admission, 24, and 48 hours. Anatomic injury was measured by Abbreviated Injury (AIS) score and Injury Severity Score (ISS). Pulmonary contusion required an nonanatomic infiltrate seen either on plain radiograph or on computed tomographic scan. VAP as diagnosed according to each institution's protocol.

For univariable analysis, discrete variables were compared using χ^2 test. For continuous variables, Student's t test was used. SAS (Cary, NC) was used for statistical analysis. Preliminary data analysis consisted of identifying variables with associations ($p \leq 0.15$) with VAP or death during the first 16 days after enrollment. Multivariable logistic regression was used to eliminate variables affected with excessive colinearity and to identify those remaining variables, which were independently associated with VAP or death. To eliminate biases associated with estimating bundle compliance on both a per-patient basis and a patient-days basis, we modeled bundle compliance as a time-dependent covariate to more accurately describe the process by which the bundle was applied in the ICU setting. The counting process form of Cox regression included the ventilator bundle as a time-dependent covariate, which allowed for a change in the application of the bundle to each patient during the period of his or her mechanical ventilation. This method combines both methods of evaluating compliance. Both within-patient compliance (patient-days) and between-patient compliance (individual patient) are considered. Time was censored at 16 days because the effect of the bundle was expected to be greatest early in a patient's ICU stay. Study sites were included in the models as strata. Variables identified by logistic regression were included as potential static covariates. Importantly, all methods of model selection identified the same final Cox regression models of VAP and death.

RESULTS

During the 16-month period, there were 630 patients enrolled in the study. Most were victims of blunt trauma (90%), and most were male (72%). Characteristics of the study population are shown in Table 1. Overall, this was a seriously injured group of patients, reflecting the entry criteria of ICU admission with at least 2 days of mechanical ventilation. The incidence of VAP was 36% (96% diagnosed with quantitative bronchoalveolar lavage), and the overall mortality was 15%. There were no statistical outcome differences between study sites.

Since the primary objective of the study was to determine if the efficacy of the ventilator bundle and its impact on VAP would be greatest early in the patient's ICU stay, those patients who developed VAP late in their ICU stay (after 16 days on the study) were censored. The frequency distribution of ICU days and VAP are shown in Figure 1. Late VAP occurred in only 16 patients (7.0% of those with VAP). Among the 210 patients who developed VAP within 16 days of enrollment, there were significantly more males, and they had more severe brain injuries (Table 2). Patients who developed VAP were compared with those who did not develop VAP. Although there was no difference in ISS, the body regions injured were different, with those developing VAP having more brain and chest injuries. Since there was a sex difference, males were compared with females. The only significant differences were age (male, 46 years vs. female, 50 years; $p < 0.02$), body mass

TABLE 1. Study Population

	All Patients	VAP	No VAP	*p*
n	630	226	404	
Age	47	47	47	0.94
Male, %	72	77	69	0.03
Blunt injury, %	90	94	86	0.02
BMI	29	29	29.3	0.30
Smoker, %	44	47	43	0.29
Rib fractures, %	45	53	40	0.0015
Pulmonary contusion, %	33	42	27	0.0004
Chest AIS	1.9	2.1	1.8	0.001
ISS	23.5	23.8	23.2	0.39
Spinal cord injury, %	7	8	6	0.42
GCS admission	9.0	8.8	9.2	0.31
GCS 24 h	8.7	8.4	8.8	0.14
GCS 48 h	8.8	8.5	8.9	0.11
Transfusion 6 h	2.9	2.8	2.9	0.98
Transfusion 24 h	3.9	3.9	3.9	0.93
Transfusion total	6.9	7.3	6.8	0.57
APACHE 24 h	17.6	17.9	17.4	0.40
APACHE 48 h	15.8	16.1	15.6	0.31
Death, %	15	14	15	0.97

index (BMI) (28.6 vs. 30.5, $p < 0.02$), and smoking history (48% vs. 34%, $p < 0.003$).

Compliance with the ventilator bundle was measured two ways—by individual patient and by patient-days (Table 3). The differences in compliance rates illustrate the impact of which method was used to calculate the rates. The overwhelming reasons recorded for noncompliance were patient-related factors, such as spine fractures, severe brain injuries, and pulmonary failure. There were no statistical differences in compliance between study sites.

The relationship between injury severity and bundle compliance on a per-patient basis was examined. There was no difference between ISS when bundle compliance was compared with noncompliance (22.6 vs. 23.9, $p < 0.11$). Bundle compliance was then compared over time with ISS (Fig. 2). Compliance was calculated on a per-patient basis for each of the first 10 study days, and patients with less severe injuries (ISS < 25) were compared with those with more severe injuries (ISS ≥ 25). There was a significant difference between these two groups ($p < 0.01$), demonstrating the compliance change over time. More severe injury was associated with bundle noncompliance over time.

Using multiple logistic regression analysis, male sex and pulmonary contusion were independently and positively associated with VAP (Table 4). The individual bundle components and overall bundle compliance as measured by individual patient were then entered into the model. SUP, DVTP, and SV were all significantly associated with prevention of VAP (each $p < 0.007$); HOB was not. Overall bundle compliance was likewise associated with VAP prevention ($p < 0.001$).

Bundle compliance is a dynamic, time-dependent process during which an individual patient's status may change from noncompliant to compliant and then back and forth over

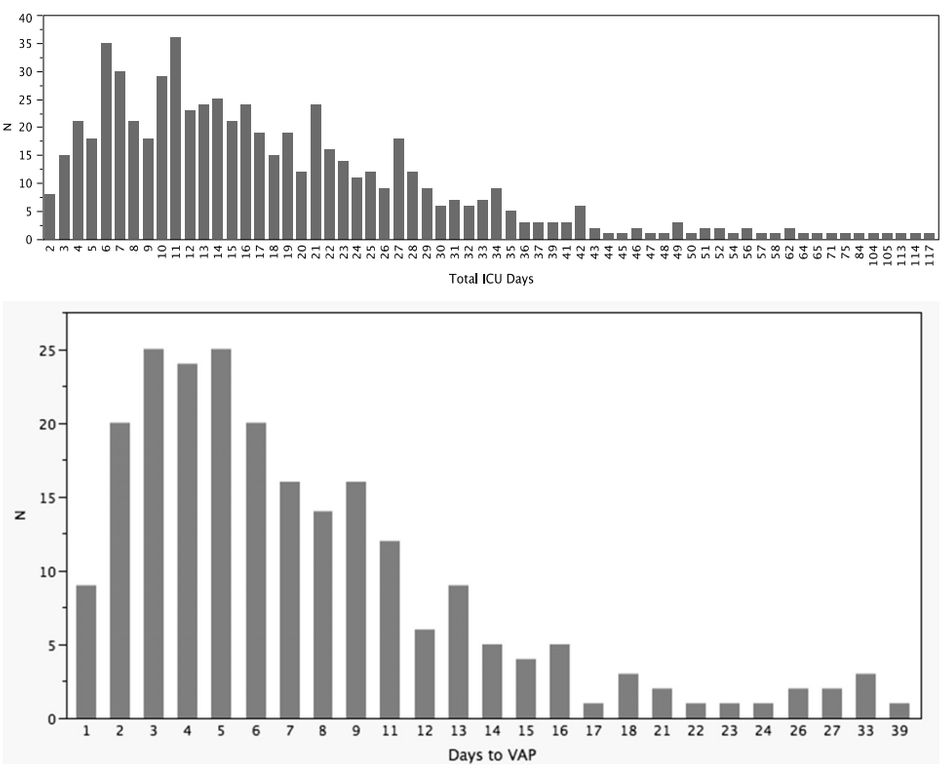

Figure 1. Frequency distribution of ICU days and VAP for all patients.

TABLE 2. Comparison of Patients Within 16 Days of Study Enrollment

	VAP	No VAP	*p*
n	210	403	
Age	46	47	0.64
Male, %	79	69	0.009
Blunt injury, %	93	88	0.05
BMI	28	29	0.13
Smoker, %	46	43	0.46
Rib fractures, %	51	40	0.008
Pulmonary contusion, %	40	28	0.002
Chest AIS	2.1	1.8	0.02
ISS	24.3	23.2	0.18
Spinal cord injury, %	7	6	0.66
GCS admission	8.6	9.2	0.20
GCS 24 h	8.2	8.8	0.05
GCS 48 h	8.4	8.9	0.04
Transfusion 6 h	2.9	2.9	0.98
Transfusion 24 h	3.9	3.9	0.90
Transfusion total	6.9	6.7	0.84
APACHE 24 h	18.0	17.4	0.38
APACHE 48 h	16.2	15.6	0.23
Death, %	14	15	0.79

time, depending on the patient's condition. Its effect on VAP was modeled by Cox regression. By eliminating the bias seen when compliance is solely measured by individual patient, the time-dependent analysis demonstrated that ventilator bundle compliance was associated neither with the development nor with the prevention of VAP (Table 4). Because the association was positive, patients who developed VAP were slightly more likely to be compliant at the time the VAP developed compared with those who did not develop VAP; however, this association was not statistically significant and the 95% confidence interval for the hazards ratio included 1.00. Only male sex was an independent risk factor for the development of VAP in severely injured patients.

Patients who lived were compared with patients who died in Table 5. Not surprisingly, those that died were significantly older, had more severe brain injuries, and had more severely altered physiology. Logistic regression identified age, ISS, and 24-hour Acute Physiology and Chronic Health Evaluation (APACHE) as independent predictors of mortality. Using Cox regression to evaluate the impact of bundle compliance on mortality showed that bundle compliance was inversely related

TABLE 3. Bundle Compliance by Individual Patient and Patient-Days

	Individual Patient, %	Patient-Days, %
SUP	92.5	83.5
DVTP	90.3	81.0
HOB elevation	91.5	83.3
SV with weaning assessment	70.5	56.2
Overall bundle compliance	86.2	48.9

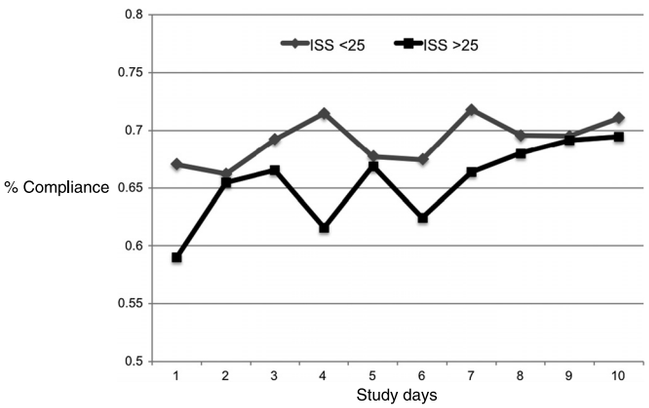

Figure 2. Comparison of bundle compliance by injury severity over time.

to patient death. After adjusting for severity of injury based on 24-hour APACHE, those patients who died were less likely to be compliant with the bundle at the time of their deaths compared with those who did not die. Thus, bundle compliance was lower among patients who ultimately died within the first 16 days of the study.

DISCUSSION

During the past decade, there has been increased attention on patient morbidity and mortality, especially in hospitalized patients. Infectious processes, such as urinary tract infections and intravenous catheter-related infections have been described as preventable. The Centers for Medical and Medicaid Services (CMS) has threatened eliminating payment for such patients[15] since these infections are considered reasonably preventable through proper care. Perhaps, the most

TABLE 4. Logistic Regression and Cox Regression Analyses for VAP and Death

Logistic Regression		
VAP	**Odds Ratio**	**95% Confidence Interval**
Pulmonary contusion	1.601	1.110–2.316
Male sex	1.681	1.131–2.529
Death		
Variable	**Odds Ratio**	**95% Confidence Interval**
Age	1.031	1.018–1.045
ISS	1.029	1.005–1.054
APACHE 24 h	1.088	1.053–1.125
Cox Regression		
VAP	**Hazards Ratio**	**95% Confidence Interval**
Bundle compliance	1.260	0.845–1.877
Pulmonary contusion	1.161	0.862–1.565
Male sex	1.750	1.233–2.483
Death		
Variable	**Hazards Ratio**	**95% Confidence Interval**
Bundle compliance	0.255	0.122–0.532
APACHE 24 h	1.100	1.053–1.148

TABLE 5. Comparison of Patients Who Lived and Died

	Lived	Died	*p*
n	538	92	
Age	45.3	57.0	0.0001
Male, %	71	76	0.31
Blunt injury, %	90	91	0.81
BMI	30	30	0.39
Smoker, %	45	39	0.33
Rib fractures, %	44	52	0.14
Pulmonary contusion, %	33	32	0.83
Chest AIS	1.9	2.0	0.43
ISS	23.1	25.7	0.06
GCS admission	9.2	8.0	0.04
GCS 24 h	8.9	7.4	0.003
GCS 48 h	9.1	7.1	0.0001
Transfusion 6 h	2.8	3.4	0.43
Transfusion 24 h	3.8	4.8	0.31
Transfusion total	6.8	7.6	0.57
APACHE 24 h	16.8	22.4	0.0001
APACHE 48 h	15.1	19.9	0.0001
VAP, %	36	35	0.98

common serious infection, VAP, is also being considered by CMS to be a "never event," which would substantially reduce or eliminate payment for patients treated for VAP.[15]

The IHI has tried to help reduce morbidity and mortality by offering "bundles" of care. These are described as "small sets of evidence-based practices—generally three to five—that, when performed collectively and reliably, have been proven to improve patient outcomes."[16] Perhaps, the best known of these is the ventilator bundle. Resar et al.[5] reported that shortly after implementation of the bundle, VAP rates decreased with increasing adherence to the use of the bundle. They reported a 59% reduction in VAP rates in ICUs with at least 95% bundle compliance. This remarkable improvement was met with enthusiasm as an important adjunct for VAP prevention, and the bundle underwent widespread implementation. Other investigators have also reported improvement in VAP rates after bundle implementation. Bird et al.[6] reported a decrease in VAP rates from 10.2 per 1,000 ventilator days to 3.4 per 1,000 ventilator days as bundle compliance increased. Cachecho and Dobkin[8] studied 299 trauma patients and also showed a significant reduction in VAP rates using the IHI bundle. Other researchers demonstrated VAP rate reductions by implementing various other quality improvement methods, such as developing teams and protocols designed to reduce VAP, which included parts of the IHI bundle.[7,11,12,14,17,18]

However, there are serious methodologic problems with many of these studies. In some, reporting bundle compliance required all four components, but credit was given if a component was medically contraindicated,[5,6,11] and others made no mention of how compliance was assigned when a bundle component was not medically indicated.[7,8,13] Assigning credit for something that was not performed makes data interpretation very difficult. The present study did not assign credit if a component was medically contraindicated. Furthermore, it seems that compliance for all these studies was calculated per *individual patient* as opposed to patient-days, thus ignoring the effect of time dependency of the ventilator bundle application in the trauma ICU setting.

In the current study, we evaluated the impact of the ventilator bundle on VAP in two ways—by individual patient and by patient-days. When the individual patient method was used, we found results similar to those of other investigators—that bundle compliance was associated with VAP prevention. However, when evaluating the bundle's impact as modeled as a time-dependent covariate, no such association was found. As mentioned previously, bundle use is time dependent and at times dynamic, depending on the patient's condition. For example, DVTP may be stopped in the perioperative period and then restarted, or SV may not be appropriate in the patient with intracranial hypertension or adult respiratory distress syndrome. Thus, a "yes/no" method of analysis will not provide an accurate representation of the relationship between the ventilator bundle and VAP. A time-dependent analysis, however, will provide an accurate depiction of this relationship. When this analysis was performed using Cox regression, there was no relationship between the ventilator bundle and development of VAP in this population of severely injured patients. Whether the bundle is helpful in other patient populations, when it is properly analyzed as a time-dependent covariate, is unknown.

Male sex was independently associated with the development of VAP using either logistic regression or Cox regression analysis. This is not a new finding, as others have shown similar relationships between male sex and VAP.[19–23] Reasons remain unclear.

While ventilation bundle compliance was not independently associated with VAP prevention, its compliance was associated with survival. This finding does not mean that bundle noncompliance is somehow predictive of death. Rather, it simply demonstrates that its utility in severely injured patients is not always practical. Injury severity and its attendant physiologic perturbations remain the most important causes of death. The relationship (or lack thereof) between bundle compliance and VAP is intriguing. Not surprisingly, static variables such as sex and chest injury are independently associated with VAP as measured by logistic regression. These static variables are more important for VAP development than is the time-dependent bundle compliance. While quality improvement initiatives are extremely important in the care of critically ill and injured patients, any potential penalty for institutions that actively participate in such initiatives is unwarranted since they cannot control the static variables of sex and injury severity. This does not mean that providers and hospitals should not strive for a zero VAP rate in trauma patients, although achieving such a rate is unlikely. VAP will always be a blight on severely injured patients. In an editorial comment, Klompas[24] recently stated "that it might be possible to achieve an apparent VAP rate of zero by maximally exploiting the subjectivity and inconsistencies of VAP definitions." It is important that CMS and third party payers realize that in trauma patients, VAP is closely associated with uncontrollable risk factors such as sex and injury severity and its prevention is not associated with the four components of the IHI ventilator bundle.

In summary, the results of this prospective multi-institutional trial demonstrate that the noncontrollable factors of sex and chest injury severity are associated with VAP development. Compliance with the ventilator bundle, when measured as a time-dependent variable, is not associated with VAP prevention. Only through continued quality improvement programs that are appropriately analyzed can we successfully reduce VAP rates.

AUTHORSHIP

M.A.C., K.J.B., R.V., C.A.A., P.R.M., M.D.P., C.S.M., and S.V. designed this study. C.S.M. and S.V. collected the data, which M.A.C., K.J.B., C.S.M., S.V., T.C.F., and E.A.T. analyzed. M.A.C. and E.A.T. performed data interpretation. M.A.C. wrote the article, which K.J.B., R.C., C.A.A., P.R.M., M.D.P., T.C.F., and E.A.T. critically revised.

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DISCLOSURE

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DISCUSSION

Dr. David A. Spain (Stanford, California): I'd like to point out two important things. First, this was a prospective study from six trauma centers and represents an incredible amount of work. And, secondly, this was funded by the National Trauma Institute which makes it very important.

Now leave it to Dr. Croce to ask if the Emperor has no clothes. So I have a few questions, Martin. How and when was compliance measured? You didn't really outline this.

For three of the four variables they're really dichotomous events but head of the bed elevation is a continuous event. Is it possible that the head of the bed was up 30 degrees for just a few minutes a day when the compliance police happened to walk by but the patients were flat in bed for the rest of the day? By my account, head of the bed elevation is probably one of the more important measures of this bundle.

In 2010 the IHI added oral daily hygiene with chlorhexidine as another measure. Did you include this in your study, depending on the timeframe? Again, I think this is probably another important aspect.

Most of your patients had early VAP, within two or three days. This probably represents aspiration at the time of emergency intubation and in fact for those patients there may

be no role at all for prophylaxis if they've already got ongoing, brewing aspiration pneumonia when they are admitted to the ICU.

If the major endpoint of the study was the development of VAP why not standardize the criteria across all centers? I realize the vast majority were diagnosed with bronchoscopy and bronchoalveolar lavage, which I support, but what were the indications to perform bronchoscopy? Did this vary between institutions?

And then, finally, I have a hard time reconciling the difference between your two models where in fact the bundle did prevent VAP in your logistic regression analysis but not in the Cox regression which makes me think this is a function of the definitions used in your two models.

Martin, you appeal to my inherent skeptical nature. And I must admit to being pretty annoyed a few years ago when our hospital bought wholesale into these bundles. But we have seen sustained and substantial decreases in both VAP and catheter-related bloodstream infections in our hospital with these bundles. So I must admit I went from being annoyed to being a convert. I'm not sure I buy the argument that the ventilator bundle doesn't work. But it is very important to realize that 100% compliance does not guarantee 100% prevention.

Dr. Frederick Moore (Gainesville, Florida): There is high percentage of pulmonary contusion in this patient population. How do you diagnose pneumonia in that group of patients? Many years ago at Denver General we had a trauma ICU and a neurosurgery ICU and we did a study to determine the impact pneumonia had on multiple organ failure (MOF) and death. In the traumatic brain injured (TBI) patients, pneumonia had no adverse outcome, but major torso trauma patients pneumonia often triggered MOF and did have attributable mortality. So did you break out the TBI patients?

Dr. R. Lawrence Reed (Indianapolis, Indiana): Very nice paper, Martin. And I think it underscores a lot of our concerns that these bundles may not be all they are assumed to be. One major problem, of course, is that two of the components in the bundle you studied don't have anything to do with pneumonia.

Nevertheless, it strikes me that you are actually studying Bundle Version 1.0. As you know, in May of 2010, the bundle was modified to include a fifth component, which was daily oral care with chlorhexidine in intubated patients. That feature could have a large impact on pneumonia rates because it mirrors the proven concepts involved in the selective digestive decontamination model that has been so popular in Europe.

Do you think the addition of chlorhexidine in the bundle would have changed your analysis?

Dr. Edward Kelly (Boston, Massachusetts): Did the presence or absence of a tracheotomy have any bearing on the incidence of compliance or on pneumonia?

Dr. Jennifer Watters (Portland, Oregon): Did you look at prehospital alcohol abuse or intoxication on arrival as a predictor?

Dr. H. Gill Cryer (Los Angeles, California): Since time on the ventilator, it seems to me, is a big predictor of whether you get VAP or not, did you look at that? In other words, what was the time on the ventilator on the people who did not get VAP compared to those who did?

Dr. Martin A. Croce (Memphis, Tennessee): First of all I'd like to thank everyone for their questions. Dr. Spain, the compliance was measured as per the individual institution's protocol.

And typically that meant going to the unit at a specific time. And if the head of the bed happened to be elevated then, a one was checked in that box; if it was not elevated, a zero was checked in that box.

Frankly, I'm not really sure of any other way to do that but it also sort of gets into the whole difference in how compliance is measured, which I'll talk a little bit more about in a second.

The oral hygiene question is an excellent one and Larry asked the same thing. When we initially wrote up this protocol and started this study oral hygiene was not part of the IHI ventilator bundle so we had two options.

One is to stop everything, add oral hygiene and then continue which, frankly, would have added a level of complexity that we just chose not to accept. So, therefore, the four components of the original Version 1.0 of the IHI ventilator bundle were studied.

The aspiration is a difficult thing to diagnose unless you see pieces of chicken that are actually coming out of the endotracheal tube.

One thing to remember is that patients, even though on that frequency distribution slide there were many early, this was all after the patients had already been on the ventilator for two days before they even got to that point so you have to add two days to everything.

We did look at aspiration and it really didn't seem to matter. But, again, that's a very difficult thing to diagnose.

Because this was an observational study we did not dictate the diagnostic method for ventilator associated pneumonia – And I realize that is a limitation. However, perhaps that will be in the next version of this prospective trial – although 96 percent of the cases of ventilator associated pneumonia were measured by quantitative cultures, by quantitative bronchoalveolar lavage.

Again, since this was an observational study, each institution has their own triggers for bronchoscopy with BAL, although I would wager to say that they were all very similar with the presence of fever, leukocytosis, new or changing infiltrate on the chest x-ray, and a purulent sputum.

That sort of leads into the whole difference between the compliance measures. Again, it is very easy to measure compliance as measured by the individual patient: you simply add everything up and divide it by the number of patients.

But the problem with doing that is that each patient is weighted equally when we all know that in the ICU each patient is not equal. And in the examples that we showed, those were three very different patients with differing severities and the compliance rates were very different.

Take, for example, the patient who has open lower extremity fractures and a closed head injury. That patient will be going back and forth to the operating room several times.

Their DVT prophylaxis may be stopped in order for them to go to the operating room at various times or neurosurgery is waiting for their head to get better or there is a litany of reasons as to why this occurs.

But measuring compliance by individual patient that really isn't taken into account, the dynamic method of compliance – on-off, on-off – that occurs in the normal care of the ICU patients.

Now, it is pretty clear, though, that ventilator associated pneumonia seems to be decreasing across the country. Is this because of the bundle? Is it because if we institute the bundle and other quality improvement programs that we're actually providing better care for the patient?

Is it because there is no standard way to define pneumonia and that we choose at times to use a diagnosis that will make us look better when we present, when these numbers gets posted on various websites?

I don't really know the answer to that. I have my suspicions, being the skeptic that I am. But I'm not sure what the answer is.

If the bundle, even though it may not prevent pneumonia, if it increases the focus and makes us take care of better patients, provide better doctor care, provide better nursing care, then it's worth doing. Otherwise, I'm not quite sure.

Fred, in looking at ventilator associated pneumonia and pulmonary contusion difference, there really was no difference, nor was there a difference in rate in patients with a brain injury.

Dr. Kelly, we didn't specifically look at tracheostomy, although we did collect that data.

Dr. Watters, we did not look at the incidence of substance use because each institution either captures that data or doesn't capture that data.

And, Dr. Cryer, the ventilator days–we didn't specifically look at that because there was no weaning protocol included in this particular trial. So in order to look at ventilator days that would wind up giving us un-interpretable data.

I'd like to thank the association for the privilege of the floor and especially the National Trauma Institute for funding this study. Thank you.