Southwestern Surgical Congress

Trauma-associated pneumonia: time to redefine ventilator-associated pneumonia in trauma patients

Alicia J. Mangram, M.D.a,*, Jacqueline Sohn, M.B.S.b, Nicolas Zhou, M.S.b, Alexzandra K. Hollingworth, M.D.a, Francis R. Ali-Osman, M.D.a, Joseph F. Sucher, M.D.a, Melissa Moyer.a, James K. Dzandu, Ph.D.a

aHonorHealth John C. Lincoln Medical Center, Department of Trauma Services, 250 E Dunlap Avenue, Phoenix, AZ, USA; bArizona College of Osteopathic Medicine, Department of Surgery and Anesthesia, Midwestern University, Glendale, AZ, USA

KEYWORDS:
Ventilator-associated pneumonia; Trauma-associated pneumonia; Rib fracture; Pulmonary contusion; Failed prehospital intubation

Abstract

BACKGROUND: The high prevalence of ventilator-associated pneumonia (VAP) in trauma patients has been reported in the literature, but the reasons for this observation remain unclear. We hypothesize that trauma factors play critical roles in VAP etiology.

METHODS: In this retrospective study, 1,044 ventilated trauma patients were identified from December 2010 to December 2013. Patient-level trauma factors were used to predict pneumonia as study endpoint.

RESULTS: Ninety-five of the 1,044 ventilated trauma patients developed pneumonia. Rib fractures, pulmonary contusions, and failed prehospital intubation were significant predictors of pneumonia in a multivariate model.

CONCLUSIONS: It is time to redefine VAP in trauma patients based on the effect of rib fractures, pulmonary contusions, and failed prehospital intubations. The Centers for Disease Control and Prevention definition of VAP needs to be modified to reflect the effect of trauma factors in the etiology of trauma-associated pneumonia.

© 2015 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Patients and Methods

In this retrospective study, 1,077 ventilated trauma patients were identified from December 2010 to December 2013 using our trauma registry. Excluded from the study were patients who were diagnosed with pneumonia on admission to the emergency department (ED) (n = 2), patients who died less than 24 hours after admission to the ED (n = 28), and patients who had insufficient data (n = 3). Therefore, after the exclusion of those 33 patients, 1,044 ventilated trauma patients were identified for this study. Study outcome was dichotomous: patients who developed pneumonia and those who did not. For each patient, data collection included demographics, mechanism of injury (MOI), ISS, ventilation days, days to develop pneumonia, hospital and ICU length of stay (LOS), and discharge status. Furthermore, data on trauma factors including rib fracture, aspiration, blood in or around mouth, blood in or around nose, failed prehospital intubation, facial fractures, TBI, spinal injury, sternal fracture, and pulmonary contusions were collected. Variables were analyzed and compared between 2 groups: patients who developed pneumonia and those who did not. The relationship between the development of pneumonia and the trauma factors were also analyzed using univariate and multivariate logistic regression analyses. The group of patients who developed pneumonia was further studied by dividing them into groups depending on the number of trauma factors. The variables were compared using appropriate tests including chi-square test, Fisher’s exact test, and Student t test. A P value less than .05 was considered significant. Statistical analysis was performed using IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY).

Results

Over the 3-year study period, we identified 1,044 trauma patients who were intubated on the ventilator. The average age of the patients was 44.3 ± 19.9 years old, and the majority of them were male (74.9%). Motor vehicle collision (MVC) was the main MOI (56.5%), and other MOIs included falls (18.2%), gunshot wounds (10.4%), blunt injury (4.2%), penetrating injury (3.5%), and other unclassified MOIs (7.2%). In 202 patients (19.3%), prehospital intubation was attempted regardless of its success, and of the 202 patients, 77.7% had a failed prehospital intubation attempt.

Among the 1,044 ventilated trauma patients, 95 patients (9.1%) developed pneumonia and 949 patients (90.9%) did not. There was no difference in age between the pneumonia patients and nonpneumonia patients (Table 1). However, the rate of pneumonia was higher in men than in women. When various MOIs were compared between the 2 groups, there was a significant association between MVC and the development of pneumonia. The patients who had MVC were 1.2 times more likely to develop pneumonia than the patients who had other MOIs. When the disposition of the patients was studied, patients who developed pneumonia were discharged to either acute care facility, intermediate care facility, rehabilitation centers, or skilled nursing home facility more often than home (P < .001). Interestingly, the mortality rate of those who developed pneumonia was lower than those who did not (P = .01). The relationship between these variables and the development of pneumonia was studied by separating patients into 2 groups for each variable: below median and above median (Table 1). The median values of ISS, hospital LOS, and ICU LOS were 18, 8, and 4, respectively. Patients who had ISS greater than 18 were 1.5 times more likely to develop pneumonia, and patients with hospital LOS greater than 8 and ICU LOS greater than 4 were 2.3 and 2.6 times evidence of systemic infection, and laboratory detection of causative agent. However, the criteria for diagnosis of VAP has been criticized, and are still in debate for its poor accuracy and reliability. Even in medical intensive care unit (ICU) settings, for which the CDC VAP criteria were developed, it has been argued that VAP is possibly overdiagnosed because of the poor accuracy of the diagnosis criteria. However, because of its association with increase in patient morbidity and healthcare costs, it has been proposed as one of the measurements for quality of care. In the most recent 2012 National Healthcare Safety Network report, VAP rate was 3.6 per 1,000 ventilation days in the trauma critical care unit of 75 participating hospitals. On the other hand, VAP rate in the medical critical care unit of 112 participating major teaching hospitals was only .97 per 1,000 ventilation days. This shows that the reported prevalence of VAP in trauma patients is about 4-folds higher than in ventilated nontrauma patients. According to the study by Cook et al, trauma patients are at higher risk for developing pneumonia in comparison with the medical ICU patients. In trauma patients, additional variables such as injury severity score (ISS), which measures the severity of the trauma, and the critical need for prehospital intubation in the field increase the risk of developing a pneumonia. In addition, the risk of developing pneumonia also increases with patients who obtain severe head and neck trauma. Multiple studies also show that trauma factors such as pulmonary contusion, rib fracture, sternal fracture, spinal cord injury (SCI), and traumatic brain injury (TBI) increase the risk of developing a pneumonia. Therefore, the role of trauma factors in the development of pneumonia in ventilated trauma patients, and the distinction between VAP and trauma-associated pneumonia (TAP) remain in question. It is also disputable whether it is appropriate to report VAP in ventilated trauma patients under the same criteria as ventilated nontrauma or medical patients. In this study, we hypothesize that trauma factors play a critical role in aggravating the development of pneumonia in ventilated trauma patients, and consequently TAP should be differentiated from VAP.
more likely to develop pneumonia \((P < .001)\). When the relationship between ISS and hospital and ICU LOS were studied, patients with ISS greater than 18 were associated with hospital and ICU LOS above the median \(\chi^2 = 24.4, P < .001; \chi^2 = 49.2, P < .001\).

Additionally, the association between individual trauma factors and rate of pneumonia were studied. Statistically significant trauma factors found were spinal injury, rib fractures, pulmonary contusion, aspiration, TBI, and sternal fracture (Table 2). Patients who sustained chest injuries such as rib fractures or pulmonary contusions were greater than 3 times more likely to develop pneumonia than the patients who did not sustain those particular injuries. Furthermore, patients who had aspiration or sternal fractures were almost 3 times more likely to develop pneumonia. SCI and TBI also showed nearly 2.5 times increase in risk of developing pneumonia.

When prehospital intubation status was compared between the 2 groups, there was no difference in proportion of patients who had prehospital intubation attempt regardless of its success (Fig. 1A). However, significantly larger proportions of patients who had failure in prehospital intubation attempt developed pneumonia (Table 2, Fig. 1B). The patients who had failed prehospital intubation were 3.2 times more likely to develop pneumonia than those who had successful intubation.

Further logistic multivariate regression analysis identified that rib fractures, pulmonary contusion, and failed prehospital intubation were the most significant trauma factors in the development of pneumonia in ventilated trauma patients (Table 3). Moreover, when the numbers of trauma factors were compared, patients who developed pneumonia had significantly higher number of trauma factors compared with the patients who did not develop pneumonia \((4.1 \text{ vs } 2.4, P < .001)\). Among the 95 patients who developed pneumonia, 36 patients \(37.9\%\) did not have

### Table 1  Comparison between the 1,044 patients who developed pneumonia and those who did not

<table>
<thead>
<tr>
<th>Variables vs development of pneumonia</th>
<th>Pneumonia</th>
<th>No pneumonia</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (%)*</td>
<td>84.2</td>
<td>74</td>
<td>.03</td>
</tr>
<tr>
<td>Male</td>
<td>15.8</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Age (mean ± SD)</td>
<td>47.4 ± 19.6</td>
<td>44.0 ± 19.9</td>
<td>.11</td>
</tr>
<tr>
<td>MOI (%)</td>
<td>12.6</td>
<td>18.8</td>
<td>.16</td>
</tr>
<tr>
<td>Blunt injury</td>
<td>4.2</td>
<td>4.2</td>
<td>1.00</td>
</tr>
<tr>
<td>Fall</td>
<td>8.4</td>
<td>10.5</td>
<td>.60</td>
</tr>
<tr>
<td>GSW</td>
<td>68.4</td>
<td>55.2</td>
<td>.02</td>
</tr>
<tr>
<td>MVC*</td>
<td>5.3</td>
<td>7.5</td>
<td>.67</td>
</tr>
<tr>
<td>Penetrating injury</td>
<td>1.1</td>
<td>3.8</td>
<td>.25</td>
</tr>
<tr>
<td>Discharge location (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home*</td>
<td>25.3</td>
<td>47.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Expired†</td>
<td>6.3</td>
<td>15.9</td>
<td>.01</td>
</tr>
<tr>
<td>ACH, ICF, Rehab, SNF*</td>
<td>66.3</td>
<td>32.1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospice</td>
<td>2.1</td>
<td>2.5</td>
<td>1.00</td>
</tr>
<tr>
<td>LMA</td>
<td>.0</td>
<td>1.7</td>
<td>.39</td>
</tr>
<tr>
<td>Total ventilation days (mean ± SD)*</td>
<td>13.8 ± 7.7</td>
<td>3.8 ± 4.8</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

\(ACH = \text{acute care hospital}; GSW = \text{gunshot wound}; ICF = \text{intermediate care facility}; ICU = \text{intensive care unit}; ISS = \text{injury severity score}; LMA = \text{left against medical advice}; LOS = \text{length of stay}; MOI = \text{mechanism of injury}; MVC = \text{motor vehicle collision}; Rehab = \text{Rehabilitation center}; SD = \text{standard deviation}; SNF = \text{skilled nursing facility}.\)

*\(P < .05\), statistically significant.

†Fisher’s exact test was performed.
any of the 3 significant trauma factors (rib fractures, pulmonary contusion, or failed prehospital intubation), and 59 patients (62.1%) had at least one of them. The latter group developed pneumonia significantly faster than the patients who did not have any of the 3 significant trauma factors (4.4 vs 6.3 days, P = .015).

### Comments

In recent years, improving the quality of health care has become one of the focuses in our healthcare industry. Since the implementation of the Affordable Care Act, the Centers for Medicare and Medicaid Services established Quality Reporting Programs to improve patient safety and quality of health care. For the fiscal year 2018, ventilator-associated event is newly added to the Long-Term Care Hospital Quality Reporting Program, which will be published as a measure of healthcare quality and affect the payment outcomes. Furthermore, it has been proposed to include VAP in the list of “never events,” which was also created by Centers for Medicare and Medicaid Services. If this were implemented, this could have a significant negative effect on trauma centers. It is our belief that the reporting of ventilated trauma patients alongside with the nontrauma patients who are mechanically ventilated is not a proper assessment to measure healthcare quality and outcome.

In this study, the majority of the patients had MVC as their MOI, and they were more likely to develop pneumonia than the patients who had other MOIs. This can be explained by the fact that frequently MVC causes thoracic injury, SCI/TBI, and extremity fractures. In other previous studies, the investigators numerically scored the severity of traumatic chest injuries, and they showed that severe chest injuries including pulmonary contusion and rib fractures were strong predictors for poor outcomes such as mortality and pneumonia. Our study is consistent with these studies that significantly larger proportion of patients who had rib fracture or pulmonary contusion developed pneumonia. Forty-one percent of the patients with pulmonary contusion developed pneumonia (Table 2), and this was higher than the average of 11.8% to 33% reported

### Table 2

<table>
<thead>
<tr>
<th>Trauma factor†</th>
<th>Pneumonia (%)</th>
<th>No pneumonia (%)</th>
<th>P value</th>
<th>RR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial fracture</td>
<td>34.7</td>
<td>26.8</td>
<td>.12</td>
<td>1.40</td>
<td>.94–2.09</td>
</tr>
<tr>
<td>Spinal cord injury†</td>
<td>43.2</td>
<td>21.4</td>
<td>&lt;.001</td>
<td>2.49</td>
<td>1.70–3.64</td>
</tr>
<tr>
<td>Rib fracture</td>
<td>52.6</td>
<td>23.2</td>
<td>&lt;.001</td>
<td>3.19</td>
<td>2.18–4.65</td>
</tr>
<tr>
<td>Pulmonary contusion†</td>
<td>41.1</td>
<td>13.8</td>
<td>&lt;.001</td>
<td>3.58</td>
<td>2.46–5.21</td>
</tr>
<tr>
<td>Aspiration†</td>
<td>27.4</td>
<td>9.7</td>
<td>&lt;.001</td>
<td>2.96</td>
<td>1.97–4.45</td>
</tr>
<tr>
<td>Blood in/around mouth</td>
<td>27.4</td>
<td>20.4</td>
<td>.12</td>
<td>1.47</td>
<td>.91–2.37</td>
</tr>
<tr>
<td>Blood in/around nose</td>
<td>25.3</td>
<td>22.0</td>
<td>.52</td>
<td>1.18</td>
<td>.76–1.83</td>
</tr>
<tr>
<td>TBI†</td>
<td>65.3</td>
<td>41.1</td>
<td>&lt;.001</td>
<td>2.46</td>
<td>1.64–3.69</td>
</tr>
<tr>
<td>Sternal fracture†</td>
<td>5.3</td>
<td>1.8</td>
<td>.04</td>
<td>2.58</td>
<td>1.17–5.72</td>
</tr>
<tr>
<td>Failed prehospital intubation†</td>
<td>47.8</td>
<td>19.0</td>
<td>.01</td>
<td>3.20</td>
<td>1.51–6.76</td>
</tr>
</tbody>
</table>

CI = confidence interval; RR = relative risk; TBI = traumatic brain injury.
*These trauma factors are not mutually exclusive.
†P < .05, statistically significant.

![Figure 1](image1.png)  
**Figure 1**  (A) Proportion of patients with prehospital intubation attempt compared between patients who developed pneumonia and those who did not. (B) Proportion of patients who had failure of prehospital intubation among the patients who had prehospital intubation attempt and developed pneumonia.
Furthermore, rib fractures and pulmonary contusions were one of the significant trauma factors contributing to the development of pneumonia as shown by our univariate and multivariate analyses. Another chest injury that is frequently observed in blunt traumas, especially in MVC, is a sternal fracture. Sternal fractures are also associated with high ISS scores and usually occur as polytrauma with rib fractures and pulmonary contusions. This could explain our result of sternal fracture being one of the strong indicators for the development of pneumonia in univariate analysis, but not being very significant in multivariate analysis. Because of the strong association of rib fractures, pulmonary contusions, and sternal fractures, and the rarity of sternal fractures occurring alone, other strong predictors such as rib fractures and pulmonary contusions can mask the effects of sternal fractures in multivariate analysis.

SCI and TBI are other severe consequences of blunt trauma such as MVC, which showed increased risk of development of pneumonia in this study. Many patients who sustain SCI or TBI can experience cardiopulmonary dysfunction and weakness of expiratory muscles, which cause ineffective cough and aspiration. Depressed levels of consciousness, aspiration, and impaired natural defense mechanisms such as cough reflex and mucociliary clearance are listed risk factors for VAP, and the patients who sustain SCI and TBI are more likely to have those risk factors. It has been suggested that, especially in the patients with TBI, VAP may not be preventable, because of these nonmodifiable risk factors.

Our data showed that the patients who developed pneumonia have significantly higher ISS. The ISS has been associated with increased risk for pneumonia in other studies as well. On the other hand, hospital and ICU LOS were associated with both pneumonia and ISS. Thus, it is difficult to conclude whether hospital and ICU LOS were because of the severity of the injury, or if their stay was extended because of the treatment of pneumonia. It is important to note that majority of the patients (77.7%) had failed prehospital intubation. The patients who sustain traumatic injuries, especially SCI or TBI, are often intubated at the time of injury because their inspiratory and expiratory function could be compromised. Unfortunately, patients who are intubated in the prehospital setting are more likely to develop VAP than those who were intubated in the ED. In a study by Fawcett et al., it shows that 27.8% of the patients aspirated blood and 95% of them did so before intubation. In their study, 89 patients had aspiration and 11.2% of them developed VAP. In our study, 27.4% of the patients who aspirated developed pneumonia, and the patients who aspirated were almost 3 times more likely to develop pneumonia than those who did not have aspiration.

In a most recent study by National Institutes of Health as part of the ongoing microbiome project, the investigators found that 87% of the species in the bronchoalveolar lavage was also detected in the oral cavity. Furthermore, another study showed that the normal immune functions of the lungs are beginning to deteriorate 24 hours after pulmonary contusion, and these observations further explain the increased risk for mortality and complications in ventilated trauma patients. These individual studies in addition to our study suggest that trauma is an accelerating factor in the development of pneumonia amplified by these numerous trauma factors that increase the chance of pneumonia development.

### Conclusions

Assessing and analyzing the incidence of VAP to improve our nation’s healthcare quality and to ensure patient safety is potentially a beneficial tool. However, it seems amiss to evaluate medical patients and trauma patients, who notably have different underlying mechanisms, under same criteria. In the context of trauma patients, it is important to characterize whether trauma patients acquired pneumonia purely through the ventilator, or if they had any predisposing factors that could have accelerated the development of pneumonia. Our study analyzed various trauma factors such as trauma injuries to the face, oropharyngeal cavity, rib fractures, pulmonary contusion, and failed intubation in relation to the development of pneumonia in ventilated patients.
trauma patients. We then identified 3 statistically significant risk factors: rib fractures, pulmonary contusion, and failed prehospital intubation. In accordance with the previous studies on VAP in trauma patients, we propose that the mechanism of infection involves transfer of microbial agents from damaged mucosal surfaces into the lungs, and this process is accelerated in trauma patients who develop pneumonia while on the ventilator. Therefore, we advocate a different term called TAP for trauma patients to differentiate TAP from VAP. Furthermore, the risk factors for TAP that we identified are evidently unpreventable if a patient presents with these factors: rib fracture, pulmonary contusion, and failed prehospital intubation. Thus, it will be asked to consider VAP as a never event without establishing the difference between VAP and TAP. Further studies may be needed to develop specific criteria for TAP. However, current CDC definition of VAP needs to be adjusted to account for the effect of trauma factors in the etiology of TAP. Our study strongly supports that it is time to redefine VAP in the trauma population with rib fractures, pulmonary contusions, and failed prehospital intubations.

References


Discussion

Dr. Mike Truitt (Dallas, TX): In this review of over a thousand ventilated trauma patients, the authors identified patient-specific injuries that contribute to the development of a term that they have coined, a trauma-associated pneumonia. This is important because it could help explain why trauma patients have a four times higher incidence of VAP compared to nontrauma patients.
I have the three following questions.

Did the new definitions of VAC, like ventilated-associated complication or infection ventilator associated complication or probable, the PVAC, the IVAC, and the VAC currently in use by the NHSN have any effect on your data?

Secondly, how do you propose that the CDC and NHSN deal with these patient, ie, should they be included in the rates or should they be excluded since these are now patient-related factors? Frequently, we are looking at things like head of bed or oral hygiene. Those are things that we haven’t done that could be potentially contributing to the incidence of pneumonia.

Now what you are talking about are patients that come in with injury-specific factors that we really have no control over. So should hospitals be held accountable for those in the same way that they are for VAP?

Finally, given the three patient-related factors you identified, are there strategies we can employ to minimize their impact and potentially decrease the incidence, morbidity of your term, trauma-associated pneumonia?

Dr. Jacqueline Sohn: The first question, would the new definition change our data? That’s a good question, and we are aware of those new definitions. We don’t think those new definitions will change our data per se. However, it would be useful to look at those new algorithms and also use our study to establish the stronger relationship between the trauma factors that we identified with the newly established definitions such as VAC, IVAC, and PVAC. That could be our future study.

The second question about the CDC and how they should deal with the trauma-associated pneumonia, we think the first step is it’s important for the government or the CDC to realize that there’s a difference between the trauma population and the medical population and those patients who are on ventilator. When that is established, TAP, trauma-associated pneumonia, should be excluded from the NHSN rates.

This will be dependent on the replication of our studies, because this is only one study that we did, using the multicenter and collaborative efforts of retrospective and prospective studies, that these studies will be stronger in the future.

To address the last question, three patient factors, what can we do to minimize the impact of the incidence and mortality of trauma-associated pneumonia? These three factors that we identified are prehospital factors that we as physicians cannot prevent. These are things that just happen outside of hospital.

However, we can employ management strategies to decrease the incidence of trauma-associated pneumonia. For example, rib fractures, replating has been a more common intervention in the patients who have rib fractures. Dr. Mangram and our trauma team also do this. We would like to see in future studies how replating can affect the rates of trauma-associated pneumonia.

For pulmonary contusion, we can do such things as administering low tidal volume as a protective measure. For the failed prehospital intubation, we could work with the local EMS system to improve their competency and provide further education.

Dr. Frederic Pieracci (Denver, CO): I like the idea of the trauma patient with pneumonia being a separate set of patients, but I wonder, instead of replacing VAP, if they would be more like a subcategory of a VAP patient, because the whole idea of VAP is having that artificial airway obliterates the natural host defenses against pneumonia. All of that is still happening in the trauma patient, but, above and beyond that, there may be some other factors, like the rib fractures and the contusions, that are increasing the risk of pneumonia. I wonder if you would consider making the model where TAP is a subset of VAP.

Along those same lines, I imagine this would be the minority of your patients, but I wonder if you have looked at nonintubated critically ill patient who get pneumonia, which, again, is a small subset. Is pneumonia more common in nonintubated critically ill trauma patients than nonintubated critically ill surgical patients who are in there for a diverticulitis or something?

Dr. Jacqueline Sohn: I’ll address the second part of your question first. We did not look at the nonintubated trauma patients and their development of pneumonia. That could be in a future study where we compare the ventilated patient vs nonventilated patients.

To address the first question, I don’t know if you saw it, but the last conclusion slide shows that we propose VAP or trauma-associated pneumonia to be under the umbrella of ventilator-associated pneumonia just to distinguish the medical ventilator patients from the trauma patient, so not necessarily trauma-associated pneumonia should be separate from the ventilator-associated pneumonia, but, as you said, it should be under the subcategory of the ventilator-associated pneumonia.