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Pre-Hospital Intubation Factors and Pneumonia in Trauma Patients

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Abstract

Background: We reported similar rates of ventilator-associated pneumonia (VAP) previously in trauma patients intubated either in a pre-hospital (PH) venue or the emergency department. A subset of PH intubations with continuous quality assessment was re-examined to identify the intubation factors associated with VAP.
Methods: The subgroup was derived from an existing data set of consecutive adult trauma patients intubated prior to Level I trauma center admission July 2007–July 2008. Intubation details recorded included bag-valve mask ventilation (BVM) and the presence of material in the airway. The diagnosis of VAP was made preferentially by quantitative bronchoalveolar lavage (BAL) cultures ($\geq 10^4$ colony-forming units indicating infection). Baseline data, injury characteristics, and circumstances of intubation of patients with and without VAP were compared by univariable analysis.
Results: Detailed data were available for 197 patients; 32 (16.2%) developed VAP, on average 6.0 ± 0.7 days after admission. Baseline characteristics were similar in the groups, but diabetes mellitus was more common in the VAP group (4 [12.5%] vs. 5 [3.0%]; $p = 0.02$). There was a higher rate of blunt injury in the VAP patients (28 [87.5%] vs. 106 [64.2%]; $p = 0.01$) and higher injury severity scores (33.1 ± 2.8 vs. 23.0 ± 1.0; $p = 0.0002$) and chest Abbreviated Injury Scores (2.6 ± 0.3 vs. 1.5 ± 0.1; $p = 0.002$). Lower Glasgow Coma Scale scores (7.9 ± 0.9 vs. 9.9 ± 0.4; $p = 0.04$) and greater use of BVM (18 [56.3%] vs. 56 [34.0%]; $p = 0.02$) were observed in patients who developed VAP. Among aspirations, 10 (31.3%) of patients with emesis developed VAP compared with only 4 (12.5%) with blood in the airway ($p = 0.003$).
Conclusion: Aspiration, along with depressed consciousness and greater injury severity, may predispose trauma patients to VAP. Prospective studies should focus on the quality and timing of aspiration relative to intubation to determine if novel interventions can prevent aspiration or decrease the risk of VAP after aspiration.

Ventilator-associated pneumonia (VAP) is the most common healthcare-associated infection in severely injured patients, accounting for substantial morbidity and excess cost [1,2]. Trauma patients appear to be particularly at risk, as higher rates of VAP have been associated with traumatic brain injury, thoracic trauma, and acute lung injury [3–5]. Although the attributable mortality rate of VAP is controversial [6], this high-profile infectious complication increasingly is viewed by policy makers as a "never event," with mandatory public reporting driving quality improvement initiatives [7].

The safety and benefit of pre-hospital (PH) rapid-sequence intubation (RSI) in trauma patients has been demonstrated [8], but even successful PH RSI has been associated with a higher incidence of VAP [9]. This raises the question whether there are modifiable factors to prevent the event or whether the state of the patient on arrival of PH care providers determines the outcome. Whereas aspiration during intubation has been studied extensively in the operating room, emergency department (ED), and intensive care unit (ICU), the PH environment is a challenging venue for data collection, and there are few data regarding the role of aspiration in trauma patients intubated prior to arrival at the hospital [10].

Through rigorous training and internal quality assessment, the Seattle Medic One program has pioneered advanced PH care, with a high rate of successful PH airway

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intubation [11–13]. This setting provides the ideal opportunity for a population-based study of the incidence of aspiration in trauma patients, its timing relative to intubation, and the subsequent development of VAP.

In a previous analysis of 572 trauma patients intubated in the PH or ED environment, we demonstrated that there was no difference in the rate of VAP according to the location of intubation [14]. A diagnosis of VAP was associated with higher injury severity, blunt injury, and mechanical ventilation lasting more than 24 h, but among these, only injury severity was an independent predictor of VAP. The purpose of this subgroup analysis was to explore PH intubation circumstances and patient-related factors that may contribute to the development of VAP in critically injured patients. We hypothesized that documented aspiration would be associated with VAP.

Patients and Methods

We conducted a secondary analysis of a data set of all consecutive adult (≥18 years) patients intubated endotracheally prior to admission to a Level I trauma center between July 2007 and July 2008. As described previously, burned, asphyxiated, or drowned patients; patients who died; and those who were discharged within 48 h, as well as transfers from other facilities, those from field surgical airways, and patients lacking PH data were excluded. Baseline characteristics, injury mechanism and severity, length of stay, and in-hospital deaths were recorded from the trauma registry [14].

Ventilator-associated pneumonia was characterized using a quality database tracking bronchoscopic bronchoalveolar lavage (BAL) performed in our facility. The diagnosis of VAP was made on the basis of quantitative cultures of material obtained by BAL ($\geq 10^4$ colony-forming units [CFU]) or brushing ($\geq 10^3$ CFU) whenever possible. Antibiotic therapy was directed by existing protocols recommending empiric treatment according to the time of diagnosis, with levofloxacin or ampicillin/sulbactam recommended for early VAP (<5 days of hospitalization) or imipenem-cilastatin and vancomycin for late-onset VAP out of concern about the historically high rate of *Acinetobacter* spp. and methicillin-resistant *Staphylococcus aureus* (MRSA) pneumonias. Clinicians were directed to narrow antibiotic coverage on the basis of the final culture results, which generally were available at 72 h. Clinical VAP was diagnosed without quantitative cultures at the discretion of the treating physician according to the U.S. Centers for Disease Control and Prevention (CDC) guidelines and treated with empiric antibiotics [15]. During the time period studied, all ventilated patients were subject to clinical protocols intended to prevent VAP (ventilator bundle), including head of bed elevation to 30° or greater, daily sedation vacation, gastrointestinal prophylaxis or enteral feeding, and daily oral care with tooth brushing and chlorhexidine mouth cleansing.

For the purpose of this study, patients intubated in the PH setting by Seattle and King County Medic One providers were identified and cross-referenced to two airway management quality databases maintained by these organizations to obtain additional information in the peri-intubation period, including vital signs, medications administered, extent of the experience of the intubating provider, use of bag-valve mask-assisted breathing (BVM), and presence of material (secretions, blood, or gastric contents) in the airway. Additionally, all PH documentation available in the electronic medical record was reviewed for evidence of airway secretions, blood, or emesis during intubation.

Univariable analysis was performed to compare baseline data, injury characteristics, and circumstance of intubation in the patients who did and did not develop VAP during hospitalization. Categorical variables were compared with the chi-square test or Fisher exact test for counts <5. The means of continuous variables with normal distributions were compared using the Student *t*-test; otherwise, the Wilcoxon rank sum non-parametric test was used. A p value ≤0.05 was considered statistically significant. Analyses were performed using STATA v. 10.1 (Stata, College Station, TX).

Results

The original data set of 3,383 adult trauma patients was reviewed and cross-referenced with the two PH quality improvement databases. An additional seven patients originally excluded were found in the course of data review to have been intubated by King County medics, resulting in a total of 197 PH-intubated patients, who constituted the study population (Fig. 1). Of these, 32 patients (16.2%) developed VAP, and the diagnosis was made by quantitative culture in 21 of these (65.6%).

Patients who developed VAP generally were older and more often had diabetes mellitus than those who did not develop pneumonia (Table 1). There was a higher rate of blunt injury among those who developed pneumonia than in those who did not (28 [87.5%] vs. 106 [64.2%]; p=0.01). The VAP group had a higher percentage of patients who sustained injury as pedestrians, in motor vehicle crashes, and other blunt trauma; there were no stab wounds in the VAP group (Fig. 2). Injury severity, as measured by the Injury Severity Score (ISS), Maximum Abbreviated Injury Score (AIS), and Chest AIS,

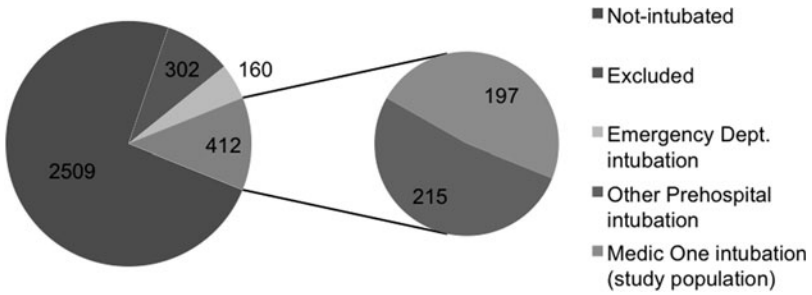

FIG. 1. Description of study population.

Table 1. Baseline Characteristics of Study Cohorts

	VAP (n=*32*)	*No VAP* (n=*165*)	p *value*
Age (years)±SD	41.5±3.6	35.2±1.2	0.05
Male (%)	26 (81.3)	135 (81.8)	0.9
Race (%)			
White	19 (59.4)	84 (51.0)	
Black	5 (15.6)	41 (24.9)	
Asian	6 (18.8)	17 (10.3)	
Native American	1 (3.1)	1 (0.6)	
Other	1 (3.1)	17 (10.3)	
Unknown	0	5 (3.0)	0.2
Co-morbid disease (%)			
Cardiac	0	4 (2.4)	0.5
Hypertension	3 (9.4)	7 (4.2)	0.3
Pulmonary	1 (3.1)	6 (3.6)	0.7
Cirrhosis	0	1 (0.6)	0.8
Endocrine (diabetes mellitus)	4 (12.5)	5 (3.0)	0.02
Seizures	0	0	
Drug abuse	4 (12.5)	23 (13.9)	0.8
Alcohol abuse	2 (6.25)	15 (9.1)	0.6
Tobacco abuse	2 (6.25)	14 (8.5)	0.5
Previous trauma	0	10 (6.1)	0.2

SD=standard deviation; VAP=ventilator-associated pneumonia.

was significantly higher in patients who went on to develop VAP (Table 2). The mean lowest recorded PH GCS did not differ between the groups, but the mean lowest recorded GCS in the ED was lower in the VAP group. Further examination of these data revealed that 82% of this group of intubated patients had a recorded GCS of 15 in the ED, suggesting a systematic coding error previously described [14]. The mean lowest recorded ED systolic blood pressure (SBP) was significantly lower in patients with VAP than in those who did not develop VAP (99.0±4.1 mm Hg vs. 115.0±1.8 mm Hg; p=0.0005) despite similar mean lowest SBPs in the two groups in the PH setting (112.6±10.6 mm Hg vs. 119.9±2.4 mm Hg; p=0.9). There also was a trend toward lower mean blood alcohol concentrations and fewer positive drug screens in the patients who developed VAP.

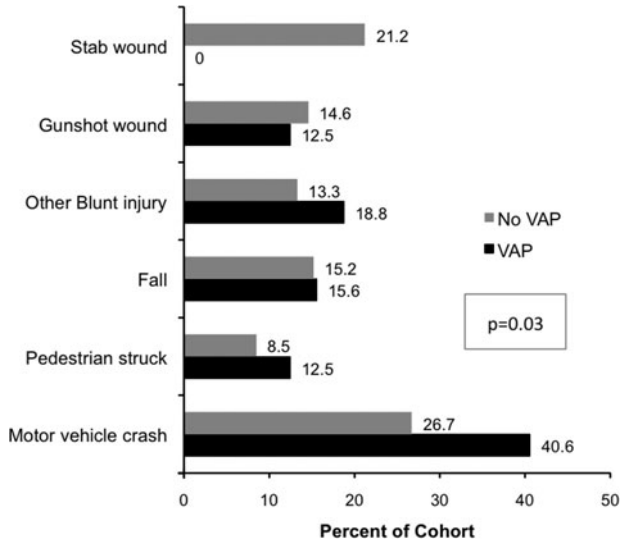

FIG. 2. Comparison of rate of ventilator-associated pneumonia (VAP) by mechanism of injury using chi-square analysis. Most of the VAPs (87.5%) were diagnosed after blunt injury.

Table 2. Severity of Illness

	VAP (n=*32*)	*No VAP* (n=*165*)	p *value*
ISS	33.1± 2.8	23.0±1.0	0.0002
Maximum AIS	4.4± 0.2	3.7±0.8	0.001
Chest AIS	2.6± 0.3	1.5±0.1	0.002
Lowest SBP PH	112.6±10.6	119.9±2.4	0.9
Lowest SBP ED	99.0± 4.1	115.0±1.8	0.0005
GCS PH	3.9± 0.4	3.8±0.2	0.8
GCS ED	13.3± 3.1	14.8±1.2	<0.0001
Blood alcohol concentration (mg/dL)	76.7±17.7	119 ±9.7	0.15
Drug screen positive (%)	8 (28.6)	57 (41.9)	0.19

AIS=Abbreviated Injury Score; ED=emergency department; GCS=Glasgow Coma Score; ISS=Injury Severity Score; PH=prehospital; SBP=systolic blood pressure; VAP=ventilator-associated pneumonia.

The available data from the immediate peri-intubation period is summarized by group in Table 3. The mean pre-intubation GCS (distinct from the mean lowest PH GCS) was lower in the patients later had VAP (7.9±0.9 vs. 9.9±0.4;

Table 3. Intubation circumstances[a]

	VAP (n=*32*)	*No VAP* (n=*165*)	p *value*
Systolic blood pressure (mm Hg)	113.3±10.1	121.8±2.6	0.6
Heart rate (beats/min)	90.6±6.5	101.2±1.9	0.10
Ventilatory rate (breaths/min)	16.8±1.9	18.5±0.6	0.3
Percent oxygen saturation	92.9±2.0	96.3±0.7	0.08
Glasgow Coma Score	7.9±0.9	9.9±0.4	0.04
CPR[b] in progress (%)	3 (1.8)	2 (6.2)	0.19
Bag-valve mask ventilation (%)	18 (56.3)	56 (34.0)	0.02
Neuromuscular blocker (%)	30 (93.8)	161 (97.6)	0.32
Sedative (%)	22 (68.8)	124 (75.2)	0.22
Medic experience (%)			
Senior	30 (93.8)	141 (85.5)	
Student	1 (3.1)	18 (10.9)	
Unknown	1 (3.1)	6 (3.6)	0.38
Intubation attempts prior to success (%)			
1	7 (21.8)	57 (34.6)	
>1	6 (18.8)	15 (9.1)	
Unknown	19 (59.4)	93 (56.4)	0.16

[a]Clinical observations, measurements, and treatments immediately prior to intubation attempt.
[b]Cardiopulmonary resuscitation.

p = 0.04). Although this group also had a lower mean oxygen saturation, the difference did not reach statistical significance. Patients who developed VAP were more commonly supported prior to intubation using assisted ventilation with BVM. Pre-intubation sedation was not used universally, despite a high rate of neuromuscular blocker use; use of these medications did not differ in the two groups. The extent of medic experience was not associated with development of VAP. There was a trend toward more attempts at intubation in the VAP group; however, the records of almost 60% of the patients did not have data on the number of attempts, so no correlation could be calculated.

Figure 3 summarizes the evidence of airway aspiration. In patients subsequently found to have VAP, the rate of airway vomit was more than three times that in patients who did not develop VAP (10 [31.3%] vs. 13 [7.9%]), and a documented clear airway was much less common (4 [12.5%] vs. 48 [29.1%]; p = 0.003). The presence of blood in the airway (4 [12.5%] vs. 20 [12.1%]) did not seem to contribute to the difference observed. Again, there was a large amount of missing data; for nearly half of the intubations, there was no mention of the presence or absence of airway blood, vomit, or secretions (14 [43.8%] vs. 81 [49.1%]).

In the 10 patients with vomit in the airway who went on to develop VAP, the diagnosis was reached clinically in 6 (60%) without quantitative cultures. Four of these cases (67%) were early VAP, diagnosed within the first four days of hospitalization. In contrast, all four cases of VAP diagnosed by BAL were late onset (p = 0.01). The organisms from the quantitative lower respiratory tract cultures from these late-onset VAP cases were methicillin-sensitive *S. aureus* (2), β-hemolytic *Streptococcus* (2), *Haemophilus influenzae*, *Enterobacter* spp., α-hemolytic *Streptococcus*, and coagulase-negative *Staphylococcus*. Table 4 summarizes the quantitative BAL cultures diagnostic for VAP.

Although VAP was not associated with a higher mortality rate, patients with VAP had longer hospital stays and a higher incidence of subsequent reintubation (Table 5). Only one patient with VAP was intubated for < 24 h, whereas almost half of the patients without VAP were intubated for < 24 h.

Table 4. Microbiology of Ventilator-Associated Pneumonia Diagnosed by Bronchoalveolar Lavage

	Early (n = *7*)	*Late* (n = *14*)	*All (%)*
Alpha-hemolytic *Streptococcus*	5	2	7 (33.3)
Methicillin-resistant *S. aureus*	1	3	4 (19.0)
Haemophilus influenzae	0	4	4 (19.0)
Beta-hemolytic *Streptococcus*	1	2	3 (14.3)
Methicillin-sensitive *S. aureus*	1	2	3 (14.3)
Non-hemolytic *Streptococcus*	2	1	3 (14.3)
Neisseria spp.	0	3	3 (14.3)
Klebsiella pneumoniae	0	2	2 (9.5)
Enterobacter spp.	0	2	2 (9.5)
Coagulase-negative *S. aureus*	0	2	2 (9.5)
Moraxella catarrhalis	1	0	1 (4.8)
Pseudomonas aeruginosa	1	0	1 (4.8)
Candida albicans	1	0	1 (4.8)
Proteus spp.	1	0	1 (4.8)
Rothia mucilaginosa	1	0	1 (4.8)
Actinobacillus ureae	0	1	1 (4.8)
Acinetobacter spp.	0	1	1 (4.8)
Stenotrophomonas spp.	0	1	1 (4.8)
Diphtheroids	0	1	1 (4.8)

Table 5. Outcomes of Interest According to Presence or Absence of Pneumonia

	VAP (n = *32*)	*No VAP* (n = *165*)	p *value*
Hospital LOS	32.8 ± 4.3	11.6 ± 0.99	<0.0001
Hospital death (%)	2 (6.3)	11 (6.7)	0.9
Intubated < 24 h (%)	1 (3.1)	78 (47.3)	<0.0001
Subsequent reintubation (%)	9 (28.1)	7 (4.2)	0.0001

LOS = length of stay; VAP = ventilator-associated pneumonia.

Discussion

Because of the high rate of coincident chest trauma and lung injury and the challenge of documentation in the PH environment, the clinical diagnosis of aspiration pneumonia is difficult in trauma patients; and the condition may be indistinguishable from VAP or even acute lung injury. The CDC surveillance definition of VAP does not distinguish between what might be considered a trauma-associated complication and a healthcare-associated infection. The organisms associated with "community-acquired aspiration pneumonia" are the same as those described in "early-onset" VAP, including *S. aureus, H. influenzae,* and *S. pneumoniae* [16,17]. A recent retrospective investigation of early-onset pneumonia in trauma patients with severe chest injury reported a similar group of common microorganisms [18]. Notably, these were the organisms we found in the small subset of BAL-proved VAP after emesis, all cases of which were diagnosed on or after day five of hospitalization, which technically is late-onset VAP. This observation suggests that pneumonia following aspiration occurring in the PH environment prior to any healthcare intervention may easily be misdiagnosed as healthcare-associated pneumonia. This is particularly troublesome when one considers the pressure to use VAP rates to compare the quality of ICU care across hospitals.

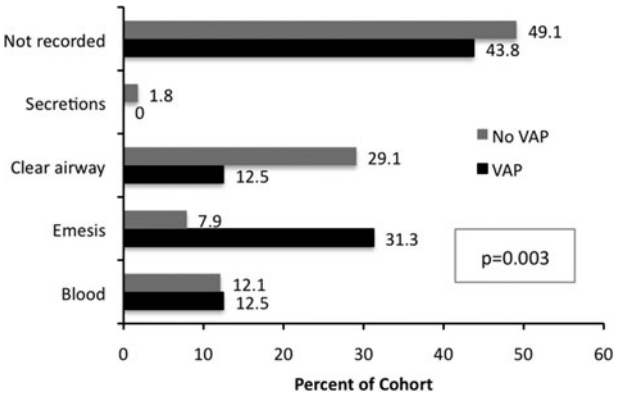

FIG. 3. Comparison of rate of ventilator-associated pneumonia (VAP) by character of aspiration using chi-square analysis. Note that VAP was significantly more common in patients with evidence of emesis-related aspiration, but there is a substantial amount of missing data.

In this retrospective subgroup analysis of trauma patients intubated prior to hospital arrival, we discovered an association with the presence of vomit in the airway at intubation and subsequent development of VAP, confirming the results of the only prospective trial of PH RSI in trauma patients [10]. However, we make the distinction that only airway vomitus, not blood, was associated with a higher rate of VAP. This finding is consistent with the results of other studies demonstrating the relation between aspiration of gastric contents and subsequent pneumonia [19]. It has been a long standing concern that BVM ventilation can cause stomach distention even when performed correctly, increasing the risk of regurgitation and aspiration [20,21]. To our knowledge, ours is the first report of an association between pneumonia and BVM-assisted ventilation prior to RSI. We also found that patients who went on to develop VAP were more severely injured and had lower GCS scores at the time of intubation than those who never developed pneumonia. This is consistent with previous studies that reported higher ISS scores and greater chest injury associated with the development of pulmonary complications, including VAP [22].

The study has a number of important limitations. First, although the data suggest a relation between emesis prior to PH intubation and community-acquired VAP in trauma patients, because of the retrospective nature of the study design, cause and effect cannot be established. Second, our conclusions are limited by the inconsistent coding of the ED GCS and by missing data, a common challenge in PH research. Although some PH medical records allow the automated recording of vital signs, key observations such as aspiration and number of attempts at intubation may be omitted because of the appropriate prioritization of patient care over documentation. Third, use of quality improvement databases specifically established for the monitoring of PH airway management likely increased our capture of significant pre-intubation aspiration events, but because the mandatory data fields were not standardized across the two systems, it is possible that some events were not recorded. Additionally, there are no published standardized criteria for PH airway control. Many subjects lacked a provider-assigned indication for intubation, and retrospective categorization was deemed too subjective for formal analysis. Our ongoing efforts to improve our quality assessment of PH intubations include a systematic initiative to establish these standardized criteria, as well as mandatory assessment of aspiration.

It is possible that the use of BVM and the presence of vomitus in the airway are merely markers for the severity of injury at the time of first-response evaluation, suggesting that for a subset of critically injured patients, it may not be possible to prevent VAP. However, not all patients who developed VAP had evidence of aspiration. Use of chlorhexidine gluconate mouthwash as part of the ventilator bundle delays the onset of VAP in already-intubated patients [23,24]. One group of investigators suggested that pre-emptive cleansing of the mouth at the time of intubation may reduce VAP rates through decontamination [25]. In the future, novel infection control methods during PH RSI such as mouth cleansing, elevation of the head of bed, or use of antimicrobial endotracheal tubes could be considered as ways to prevent lower respiratory tract infection in this high-risk group. For patients with witnessed gross aspiration, it may be beneficial to examine the impact of early toilet bronchoscopy or tracheostomy on outcomes.

Conclusions

In this retrospective analysis of trauma patients intubated in the PH setting, diagnosis of VAP was associated with a higher rate of vomit, but not of blood or secretions, in the airway at the time of intubation, suggesting that gastric aspiration predisposes patients to VAP. In view of the microbiologic profile of even the late-onset pneumonias that occurred after emesis, we propose use of the more explicit term "community-acquired VAP" when there is pre-intubation evidence of aspiration. It is unclear whether use of assisted ventilation contributed to the development of VAP or was just another marker for the greater injury severity and more depressed level of consciousness encountered at the beginning of PH care delivery. Further prospective characterization of aspiration and timing relative to intubation is needed to determine if novel PH interventions can prevent aspiration or decrease the risk of VAP after aspiration has occurred. Our analysis supports the need for standardized documentation of PH intubation criteria and peri-intubation events to allow risk stratification both for research and for quality improvement.

Author Disclosure Statement

No conflicting financial interests exist.

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