Early pneumonia diagnosis decreases ventilator-associated pneumonia rates in trauma population

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BACKGROUND: Ventilator-associated pneumonia (VAP) is a source of morbidity and mortality for trauma patients. Aspiration events are also common because of traumatic brain injury, altered mental status, or facial trauma. In patients requiring mechanical ventilation, early pneumonias (EPs) may be erroneously classified as ventilator associated.

METHODS: A prospective early bronchoscopy protocol was implemented from January 2020 to January 2022. Trauma patients intubated before arrival or within 48 hours of admission underwent bronchoalveolar lavage (BAL) within 24 hours of intubation. Patients with more than 100,000 colony-forming units on BAL were considered to have EP.

RESULTS: A total of 117 patients underwent early BAL. Ninety-three (79.5%) had some growth on BAL with 36 (30.8%) meeting criteria for EP. For the total study population, 29 patients (24.8%) were diagnosed with VAP later in their hospital course, 12 of which had previously been diagnosed with EP. Of EP patients (n = 36), 21 (58.3%) were treated with antibiotics based on clinical signs of infection. Of EP patients who had a later pneumonia diagnosed by BAL (n = 12), seven (58.3%) grew the same organism from their initial BAL. When these patients were excluded from VAP calculation, the rate was reduced by 27.6%. Patients with EP had a higher rate of smoking history (41.7% vs. 19.8%, $p < 0.001$) compared with patients without EP. There was no difference in median hospital length of stay, intensive care unit length of stay, ventilator days, or mortality between the two cohorts.

CONCLUSION: Early pneumonia is common in trauma patients intubated within the first 48 hours of admission and screening with early BAL identifies patients with aspiration or pretraumatic indicators of pneumonia. Accounting for these patients with early BAL significantly reduces reported VAP rates. (*J Trauma Acute Care Surg.* 2023;94: 30–35. Copyright © 2022 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level IV.

KEY WORDS: Trauma; pneumonia; ventilator-associated pneumonia; surgical critical care; bronchoscopy.

Ventilator-associated pneumonia (VAP) is a common source of morbidity and mortality in critically ill trauma patients requiring mechanical ventilation.[1–4] Cited risk factors include traumatic brain injury, acute kidney injury, blood transfusion within 24 hours, increased Injury Severity Score (ISS), spinal injury, prolonged mechanical ventilation, increased intensive care unit (ICU) stay, chronic obstructive pulmonary disease, and chest wall injury.[1,5] Other work in the realm of VAP has focused on early antibiotic utilization in patients at risk for VAP, which has been shown to decrease cost, decrease early VAP rates, and alter the organisms grown on culture.[6–8]

Overt or silent aspiration events are common in trauma patients because of factors such as traumatic brain injury, altered mental status, or facial trauma.[9–11] These patients may also be at risk for aspiration during rapid sequence intubation, which can also contribute to the risk of aspiration pneumonia.

Fiberoptic bronchoscopy (FOB) with bronchoalveolar lavage (BAL) is a standard to detect pneumonia in the ICU.[12,13] A recent meta-analysis indicated that FOB with BAL was the most sensitive and specific of the clinical tools available for the diagnosis of VAP with a sensitivity of 71.9% and a specificity of 79%.[14] A threshold of greater than or equal to 10^5 colony-forming units (CFU) on quantitative culture is diagnostic of infection and the threshold used in some surgical and trauma ICUs.[15–17] Loftus et al.[18] and Minshall et al.[19] have reported the use of screening BAL in intubated trauma patients for the detection of early pneumonia (EP).

In a population at high risk for aspiration, EP may be erroneously classified as ventilator associated, leading to artificially inflated VAP rates. The purpose of this study was to review a care pathway for FOB and BAL in trauma patients requiring early mechanical ventilation and use the quantitative culture results to identify and treat EP. We hypothesize that detection of patients with EP will lead to shorter ventilator days and tracheostomy rates, as well as decrease the reported rate of VAP.

PATIENTS AND METHODS

After obtaining a waiver of consent from the institutional review board, a care pathway for early FOB and BAL was implemented at a single American College of Surgeons-verified level 1 trauma center from January 2020 to January 2022. Trauma patients who were intubated before arrival or within 48 hours of admission were eligible for inclusion. Fiberoptic bronchoscopy was performed using a standard protocol reported elsewhere within 24 hours of intubation, and a BAL was obtained from areas suspicious for aspiration or infiltrate on chest x-ray or computed tomographic imaging of the chest.[20] If no area suspicious for aspiration or infiltrate was apparent on imaging studies, then the BAL was obtained from the lower lobe of the right lung. Pregnant patients, prisoners, or those with incomplete medical records were excluded. In addition, patients who underwent BAL outside of the prescribed timeline or without collection of quantitative pulmonary culture were excluded. Patients with planned short-term intubation (less than 48 hours) were also excluded from the protocol.

Ventilator-associated pneumonia was defined as a pneumonia that developed later than 2 calendar days after intubation, with the day of intubation being day 1.[21] Patients with greater than or equal to 10^5 CFU of an identified organism on an early BAL were considered to have EP. Early growth (EG) was defined as less than 10^5 CFU growth or greater than or equal to 10^5 growth of mixed respiratory flora on early BAL.

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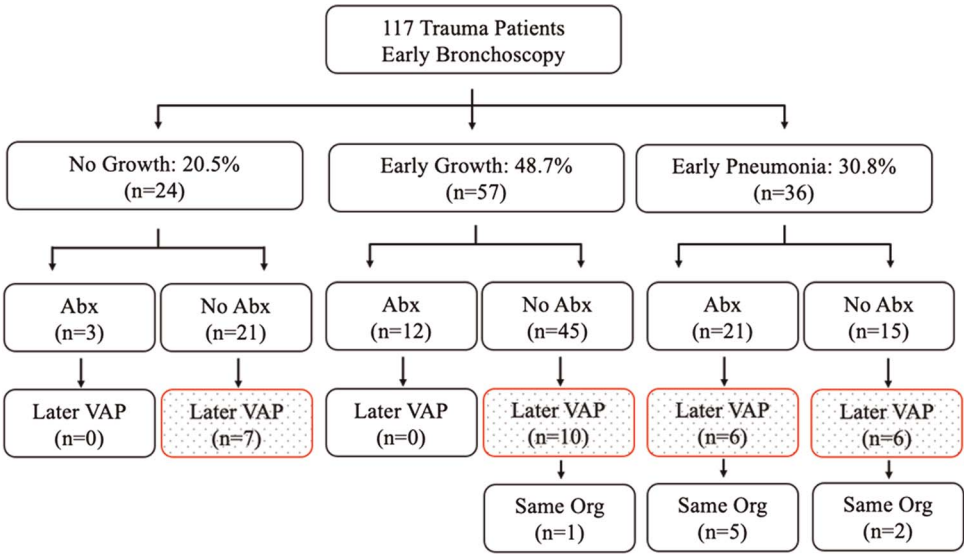

Figure 1. Study flowchart. No growth: no growth on early BAL. Early growth: $<10^5$ or mixed respiratory flora on early BAL. Early pneumonia: $\geq 10^5$ of identified organism on BAL. Shaded indicates VAP.

Antibiotic treatment of EP was at the discretion of the treating surgical critical care physician on duty, based on associated clinical signs of infection such as fever, leukocytosis, worsening ventilator requirements, and new infiltrate on chest radiograph. Antibiotics typically were not started until at least two of these conditions existed. Patients with EP detected on admission BAL were not considered to have VAP, based on the aforementioned definition.

Demographic data, mechanism of injury, subsequent bronchoscopy results, infectious complications, and outcome data were collected. Patients with EP were compared with those without EP. The primary outcome of interest was the development of VAP. Secondary outcomes included ventilator days, tracheostomy rate, mortality, hospital length of stay (LOS), and ICU LOS. Early pneumonia patients treated with antibiotics were compared with EP patients not treated with antibiotics. The Strengthening the Reporting of Observational Studies in Epidemiology guideline was used to ensure proper reporting of methods, results, and discussion (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/C723).

Statistical analyses were performed using SPSS Statistics 28.0 software (IBM, Armonk, NY). Patient groups were compared using Wilcoxon rank sum tests, χ^2 tests, or Fisher's exact tests for continuous and categorical variables, respectively. Median values (interquartile range) are presented. A binary logistic regression analysis was performed to investigate risk factors associated with EP. A p value of <0.05 was considered statistically significant.

RESULTS

During the study period, 117 patients met the inclusion criteria and underwent early FOB with BAL. Any level of BAL growth was observed in 93 patients (74.4%) sampled, with EP ($\geq 10^5$ CFU growth on BAL) diagnosed in 36 patients (30.8%) and EG diagnosed in 57 ($<10^5$ CFU growth) (Fig. 1).

The patient population was mostly male (74.4%) with a median age of 48 (29–61.5) years (Table 1). A majority of patients presented with a blunt mechanism of injury (94.0%) with a median ISS of 22 (14–29).

There was no difference in the age, sex, body mass index, injury mechanism, or ISS between the EP and no EP groups (Table 1). The EP group had a higher rate of smoking history (41.7% vs. 19.8%, $p = 0.024$) compared with the no-EP group.

TABLE 1. Patient Demographic and Injury Data Stratified by EP Diagnosis

Variable	All Patients (N = 117)	No EP (n = 81)	EP (n = 36)	*p*
Age, y	48.0 (29.0–61.5)	47 (30.5–62)	51 (27.25–60.5)	0.915
Sex (male)	87 (74.4%)	22 (27.2%)	8 (22.2%)	0.737
BMI	25.2 (22.8–29.5)	25.8 (22.8–29.65)	25.15 (22.15–28.23)	0.587
Blunt injury	110 (94.0%)	74 (91.4%)	36 (100%)	0.098
TBI	74 (63.2%)	50 (61.7%)	24 (66.7%)	0.761
Rib fractures	57 (48.7%)	38 (46.9%)	19 (52.8%)	0.700
ISS	22 (14–29)	22 (14–29)	26 (17–30)	0.185
Smoking history	31 (26.5%)	16 (19.8%)	15 (41.7%)	**0.024**

Bold text indicates $p < 0.05$.
BMI, body mass index; TBI, traumatic brain injury.

TABLE 2. Patient Procedure and Infectious Data Stratified by Early Pneumonia Diagnosis

Variable	All Patients (N = 117)	No EP (n = 81)	EP (n = 36)	*p*
HD of BAL	1 (0–1)	1 (0–1)	1 (0–1)	0.942
Treated	36 (30.8%)	15 (18.5%)	21 (58.3%)	**<0.001**
Antibiotic days	5 (3–7)	4 (3–5)	6 (3.75–7)	0.051
Later VAP	29 (24.8%)	17 (21.0%)	12 (33.3%)	0.232

Bold text indicates $p < 0.05$.
HD, hospital day.

Early BAL was performed on a median of hospital day 1 (0–1) (Table 2). The EP group had a higher rate of antibiotic treatment (58.3% vs. 18.5%, $p < 0.001$) based on clinical signs, although the median duration of antibiotic treatment was not statistically different (6 [3.75–7] days vs. 4 [3–5] days, $p = 0.051$) between the groups. Of all 117 patients included in the study, 29 (24.8%) were diagnosed with a VAP later in their hospital course as defined by greater than or equal to 10^5 CFU on a secondary BAL. This rate of VAP was not significantly different between the EP and no-EP groups (33.3% vs. 21.0%, $p = 0.232$).

Table 3 presents the outcome data for all patients and the no-EP and EP groups. There was no difference in tracheostomy rate, ICU LOS, hospital LOS, ventilator days, or mortality between the two cohorts.

A total of 53 patients (45.3%) were diagnosed with pneumonia via BAL during their hospital course as defined by $\geq 10^5$ CFU growth. Thirty-six (30.8%) of these patients were diagnosed with EP via the early BAL protocol, and 29 patients (24.8%) were found to have pneumonia on a secondary BAL after an infectious workup greater than 48 hours after intubation. Of these 29 patients, 12 had previously been diagnosed with EP, 7 of which grew the same organism from their first BAL. Five of these seven had previously been treated with antibiotics for EP, and two were not because they lacked clinical sign of pneumonia. An additional patient from the EG group had a later VAP growing the same organism, for a total of eight patients. When these eight patients who had the same organism grow from a secondary BAL are excluded from the 29 VAPs, a 27.6% reduction in VAP is appreciated. When considering the 36 patients with EP, 21 of these patients had clinical signs of pneumonia requiring treatment with antibiotics (Figs. 1 and 2). Of the 15 patients who had EP and did not receive antibiotics, 6 subsequently developed VAP, 2 with the same organism detected in the early BAL. Twenty-four patients had no growth early BAL, and seven (29.2%) later developed VAP.

A logistic regression analysis was performed to identify risk factors associated with EP. Only smoking history was identified as a significant risk factor (odds ratio, 2.90; 95% confidence interval, 1.23–6.85; $p = 0.015$). Rib fractures and traumatic brain injury were not associated with an increased odds of EP.

A subgroup analysis was also performed to compare outcomes in patients with EP who were treated with antibiotics to patients with EP who were not treated with antibiotics. No difference in ISS, hospital LOS, ICU LOS, ventilator days, tracheostomy rates, or rate of subsequent VAP was found between the two groups.

DISCUSSION

Early pneumonia identified on quantitative BAL culture with $\geq 10^5$ CFU was diagnosed in 30.8% (n = 36) of acutely injured trauma patients intubated before arrival or within 48 hours of admission. These cultures were obtained within 24 hours of intubation and thus excluded from a diagnosis of "ventilator-associated" pneumonia. No difference was observed between the EP and no-EP groups in hospital LOS, ICU LOS, ventilator days, mortality, or tracheostomy rates. A history of smoking was identified as significant risk factor for EP, increasing the odds by a factor of three. Initiation of this protocol allowed for a 27.6% reduction in reported VAP. If the 16 patients treated for EP alone are taken into the VAP calculation, a 53.3% reduction in VAP is realized.

In 1972, Cameron and Zuidema[10] highlighted the clinical impact of aspiration noting that trauma patients were at a high risk of aspiration and that it resulted in significant pulmonary complications. Benjamin et al.[9] identified aspiration in 25.4% of trauma patients, although aspiration was not associated with pneumonia development, while Fawcett et al.[22] found that trauma patients with aspiration had longer ventilator days and higher mortality.

Clinical evidence of aspiration during FOB was not routinely recorded in the current analysis, but aspiration is likely a large contributor to the EP identified. Aspiration can be overt in the case of inhalation of vomitus or occult in the case aspiration of oral secretions during periods of altered mental status. The aspiration of gastric contents is a well-known setup for chemical pneumonitis but does not exclude the possibility of aspiration pneumonia. Occult aspiration of oral secretions is less likely to cause chemical pneumonitis, but the higher bacteria content of oral secretions may predispose patients to the obvious risk of aspiration pneumonia. Both types of aspiration are believed to contribute to the development of EP in the trauma population. The other possibility accounting for the high incidence of EP would be that some patients, particularly smokers since they were identified as a high-risk group, have colonization of their lower airways with significant numbers of bacteria at the time of trauma, which predisposes them to the development of EP.

Interestingly, EP was not associated with worse outcomes in this current study. This finding may be explained by the fact that 21 of the 36 patients (58.3%) with EP also displayed clinical signs of pneumonia and were treated with antibiotics. Although a subgroup analysis was performed to compare treated and not treated EP patients, the groups were small (less than 20 patients per group), limiting any conclusions that could be drawn from this analysis. Administration of antibiotics in these patients

TABLE 3. Patient Outcome Data Stratified by Early Pneumonia Diagnosis

Variable	All Patients (N = 117)	No EP (n = 81)	EP (n = 36)	*p*
Tracheostomy	32 (27.4%)	23 (28.4%)	9 (25.0%)	0.876
Hospital LOS	12 (7–22.5)	13 (7–23.5)	12 (7–18)	0.517
ICU LOS	10 (7–18)	10 (7–18)	10.5 (6.25–18)	0.756
Ventilator days	5 (3–10)	5 (3–9)	6.5 (3–11)	0.852
Mortality	19 (16.2%)	12 (14.8%)	7 (19.4%)	0.723

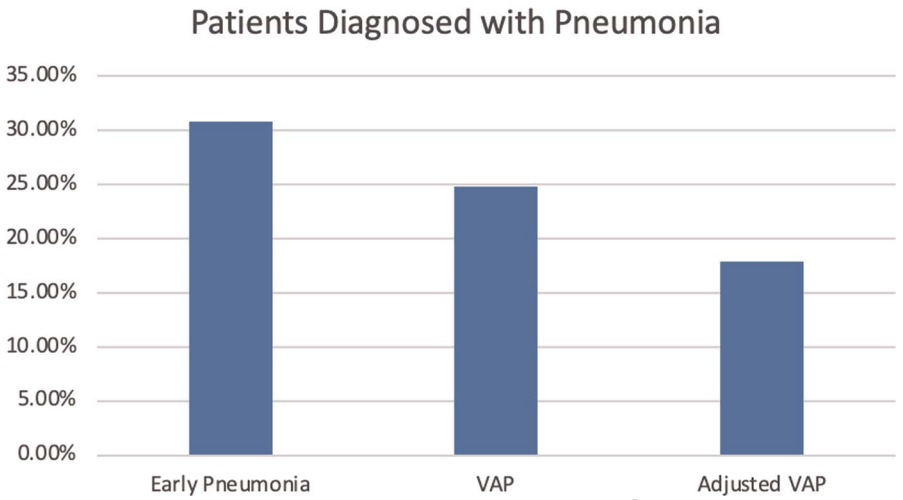

Figure 2. Percentage of patients diagnosed with pneumonia. Early pneumonia: $\geq 10^5$ growth on admission BAL. Ventilator-associated pneumonia: $\geq 10^5$ growth on secondary BAL greater than 48 hours after intubation. Adjusted VAP: VAP rate excluding patients with EP with a later VAP of the same organism.

certainly could have reduced the clinical impact of EP and improved patient outcomes, and future studies with better controls are needed to assess this potential impact.

Strategies for the diagnosis and treatment of VAP have been widely studied.[7,12,13,15,16,23,24] Loftus et al.[18] implemented an early BAL protocol in specific trauma patients with head and chest trauma and evidence of aspiration or pulmonary contusion, finding decreased antibiotic days, ventilator days, ICU LOS, and hospital LOS in the early group. A BAL screening protocol was also described by Minshall et al.,[19] which reported that a positive screen was associated with the development of VAP by the same organism. These protocols used a threshold of 10^4 CFU for VAP diagnosis, and the early BAL was performed 36 to 48 hours after admission or intubation. Our protocol BAL was performed within 24 hours of intubation and used a threshold of 10^5 CFU to diagnose EP, which aimed to identify infection present before or directly after intubation, rather than infection associated with mechanical ventilation.

As indicated, only 21 patients of the 36 (58.3%) diagnosed with EP received antibiotic treatment for this infection based on associated clinical signs. Mirtalaei et al.[6] found that prophylactic pipercillin-tazobactam decreased early-onset VAP in intubated patient. Another study by Nannapaneni et al.[25] found that patients intubated in the prehospital setting were less likely to develop VAP if they underwent BAL within 24 hours. Thakkar et al.[8] found that early antibiotic prophylaxis altered the antibiotic flora of subsequent VAP in intubated trauma patients. In the total EP group, 19.4% were diagnosed with a VAP later in their hospitalization with the same organism found on the early BAL. Our early BAL protocol did not significantly improve either of the primary outcomes. Larger, multicenter studies are needed to further investigate the benefits of early detection and treatment of EP in the trauma population.

Benchmarking of VAP is an important quality metric reported by trauma centers for accreditation. A positive BAL culture obtained within 24 hours of intubation is unlikely to be related to mechanical ventilation itself, but rather aspiration or community-acquired infection. The early BAL care pathway presented here allows for a more accurate reporting of VAP rates, which resulted in a reduction of VAP of 27.6% and a potential reduction of VAP by 53.3% by excluding patients treated for EP but likely would have been diagnosed with VAP if not managed by the care pathway. Further quality improvement efforts can target the patient population with true VAP as opposed to patients with infection present on admission. Separating the VAP and EP patient populations continues to clarify the definition of VAP, allowing for more consistent and trauma-related quality metric tracking.

This study was performed at a single center where FOB and BAL are the standard for the diagnosis of VAP. Other institutions may rely on a variety of other techniques available in the clinical armamentarium of the intensivist for detecting VAP thereby limiting this study's generalizability. Antibiotic management of EP was determined by the clinical judgment of the rounding team introducing some element of variability there. Neither the time antibiotics were initiated for EP or the time the patient developed the clinical stigmata of pneumonia was recorded making the precise definition of VAP in the 16 EP patients difficult to determine. In addition, there was a limited control group, as the subgroup analysis is likely underpowered to detect any differences in the effect of antibiotic treatment on EP. Future studies would ideally compare EP patients treated with antibiotics to untreated EP patients to further investigate the treatment benefits in these patients. While we believe that FOB with BAL is the most reliable clinical test available in the ICU for the diagnosis of pneumonia in ventilated patients, its sensitivity and specificity are imperfect making the diagnosis of VAP difficult to pinpoint.[14]

Early FOB and BAL allow the identification of EP in patients at high risk for aspiration and VAP and allow for prompt treatment of early respiratory tract infection. In addition, such a clinical pathway can reduce the reported diagnosis of VAP for a trauma ICU. Identifying patients with a significant nidus of bacterial growth at admission and initiating appropriate treatment may improve patient outcomes and reduce morbidity. Larger multicenter studies are needed to determine the true benefits of EP detection and treatment.

AUTHORSHIP

R.A.M., H.J.R., and W.B.L. designed the study. K.N.H., W.E.B., W.C., H.J.R., and W.B.L. performed the data collection. K.N.H. performed the statistical analysis. K.N.H. and R.A.M. interpreted the data. All authors contributed to the manuscript writing and critical revision.

DISCLOSURE

The authors declare no conflicts of interest.

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