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Risk Factors and Outcome of Ventilator Associated Tracheitis (VAT) in Pediatric Trauma Patients

Maroun J Mhanna, M.D., Ibrahim S Elsheikh, M.D., and Dennis M Super, MD, MPH

Department of Pediatrics, MetroHealth Medical Center, Case Western Reserve University, Cleveland, Ohio

Abstract

We sought to investigate the risk factors and outcome of Ventilator Associated Tracheitis (VAT) according to the Center for Disease Control (CDC) definition in pediatric trauma patients who were ventilated for ≥ 48 hours. In a retrospective cohort study, medical records of all pediatric trauma patients admitted to our Pediatric Intensive Care Unit (PICU) between April, 2002 and April, 2007 were reviewed. Medical records were reviewed for patients' demographics, Trauma Injury Severity Score (TISS), Glasgow Coma Scale (GCS), type of trauma, and other potential risk factors prior to the development of VAT (such as hyperglycemia, rate of re-intubation and tracheotomy, presence of chest tubes and central lines, urinary tract infection, seizures, need for cardiopulmonary resuscitation, use of total parental nutrition, transfusion, use of H₂ blockers, steroids, pressors/inotropes). Medical records were also reviewed for days of mechanical ventilation, PICU length of stay, and PICU mortality. During the study period, 217 trauma patients were admitted to the PICU, 113 patients met our inclusion criteria and 21.2% (24/113) developed VAT. On average patients with VAT (in comparison to patients without VAT), had a higher TISS score on admission [38.6 ± 16.9 vs. 24.2 ± 10.6 ; respectively ($p < 0.01$)], longer days of ventilation and PICU length of stay [11.5 ± 6.2 vs. 3.7 ± 2.3 days ($p < 0.001$) and 16.4 ± 8.3 vs. 5.4 ± 2.8 days ($p < 0.001$) respectively]. There was no difference in mortality between the two groups. In a logistic regression model adjusting for possible confounders, the TISS score (adjusted OR 7.53; CI: 2.01–28.14; $p = 0.03$ and use of pressors/inotropes (adjusted OR 4.64; CI: 1.28–16.86; $p = 0.01$) were the only independent risk factors associated with VAT. We conclude that the severity of illness and use of pressors/inotropes are associated with VAT in pediatric trauma patients. We also conclude that VAT is associated with an increase in days of mechanical ventilation and PICU length of stay in pediatric trauma patients.

Keywords

Ventilator associated tracheitis; pediatric; trauma patients

INTRODUCTION

Ventilator associated pneumonia (VAP) is one of the most common nosocomial infections in critical care. It occurs in patients who have been intubated for ≥ 48 hours, and accounts for an increase in their mortality, morbidity, prolonged hospital length of stay, and cost.^{1,2,3,4} Although in pediatric patients, the incidence of VAP is substantially lower than in adults but it is still associated with a significant morbidity.^{5,6,7,8,9,10} Ventilator associated tracheitis (VAT) is common in adults and it has been described as a risk factor for the

development of VAP.¹¹ Studies have shown that treatment of VAT is associated with a lower rate of VAP and a lower mortality in adult critically ill patients.^{12,13,14} VAT has also been described in premature infants and children but it has been less studied than in adults.^{15,16}

Since the definition of ventilator associated infection in by itself is a challenge and the most serious and controversial of the infections of critically ill patients,^{17,18} and the risk factors for VAT are not well studied; we sought to investigate the risk factors and outcome of VAT, according to the CDC definition, in pediatric trauma patients.

METHODS

In a retrospective cohort study, medical records of all pediatric trauma patients admitted to the pediatric intensive care unit (PICU) at Metro Health Medical Center (MHMC) between April, 2002 and April, 2007 were reviewed. Patients were identified from our PICU log book. Inclusion criteria consisted of all pediatric trauma patients (< 18 years old), who required mechanical ventilation for > 48 hours. Exclusion criteria consisted of patients who did not have traumatic injuries, older than 18 years, and who required mechanical ventilation for less than 48 hours.

Medical records were reviewed for patients' demographics and characteristics on admission [including age, gender, Trauma Injury Severity Score (TISS), Glasgow Coma Scale (GCS), and type of trauma (head, chest, abdomen and extremities)]. Data were collected for potential risk factors that were present prior to the development of VAT [including hyperglycemia, the need for re-intubation and tracheotomy, chest tubes, central lines, central line associated infections, urinary tract infections, seizures, the need for cardio-pulmonary resuscitation, total parental nutrition, transfusions, H₂ blockers, steroids, pressors and inotropes]. Medical records were also reviewed for patients' outcome (including days of mechanical ventilation, PICU length of stay, and PICU mortality). In our unit, there was no routine screening of tracheal cultures.

The CDC definition was used to identify patients with VAP and VAT.¹⁹ In our study The CDC definition of VAP was based on clinical and X-ray criteria. Clinical criteria for VAP consisted of fever more than 38.5°C with no other cause, or leukopenia (<4,000 WBC/mm³) or leukocytosis (> 12,000 WBC/mm³), plus 2 additional respiratory signs or symptoms. X-ray findings required for diagnosis of VAP were new infiltrate on one or more x-rays or progressive and persistent infiltrate (consolidation, cavitation or pneumocele in <1 year old), in patients without underlying diseases; otherwise 2 or more serial x-rays were required. The CDC definition of Tracheitis was based on absence of clinical and radiographic evidence of pneumonia and the following criteria: positive culture obtained by deep tracheal aspirate and 2 signs of symptoms with no recognizable cause [such as fever (>38.5°C), cough, new or increased sputum production, rhonchi, or wheezing].¹⁹ All medical records were reviewed for VAT and VAP by a pediatric critical care specialist who is one of the authors (M.J.M) and who is familiar and trained in the CDC definitions of VAT and VAP.

Since the documentation of clinical symptoms was not uniformly and always available in medical records, the documentation and decision to treat VAT with antibiotics by the treating physician (a trauma surgeon, pediatric critical care physician or pediatric infectious disease specialist) was considered as supplemental criteria for the diagnosis of VAT if patients fulfilled other criteria. However not all of the treating physicians who made the diagnosis of VAT were familiar or trained in the CDC definitions of VAT. All patients who were diagnosed with VAT were treated with antibiotics.

The study was approved by the Institution Review Board (IRB) at MHMC.

Statistical Analysis

Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test for normality of continuous variables (including age, TISS, GCS, days of ventilation and length of stay). To compare patients with versus patients without VAT, t-tests were used for bivariate analysis of parametric data, and Mann-Whitney U tests (Wilcoxon Rank-sum test) were used for non-parametric data.

Pearson's Chi-square and Fisher's exact tests were used to study the correlation between different categorical variables (including patients' gender, type of trauma, all potential risk factors and mortality in patients with versus patients without VAT).

A binomial logistic regression analysis was conducted to study the association between the studied risk factors and VAT. Variables that were significantly associated with VAT in the initial bivariate analysis were entered into the logistic regression model as independent variables and VAT was entered as the dependent variable. The Hosmer and Lemeshow test was used to test the goodness of fit of the logistic model.

The sensitivity, specificity, positive value predictive, negative value predictive of VAT as a predictor of VAP was calculated.

Data were expressed as mean $\pm$ standard deviation, or as median with inter-quartile range (for better representation of non parametric data). Odds ratios with 95% confidence intervals were also calculated and a p value < 0.05 two-tail was considered statistically significant.

RESULTS

During the study period, 217 trauma patients were admitted to the PICU of whom 113 patients met our inclusion criteria, and 21.2% (24/113) developed VAT. On average, patients developed VAT at a mean of 4.6 ± 3.2 days of their hospital stay. Overall there were no differences in patients' demographics and characteristics between patients with and without VAT; except that patients with VAT were older, and had a higher TISS score on admission (Table 1).

In an attempt to determine potential risk factors for the development of VAT in pediatric trauma patients, an initial bivariate analysis was conducted comparing patients with VAT versus patients without VAT. The initial bivariate analysis showed that a TISS score 40, chest tubes, central lines, central line sepsis, transfusions, and pressors/inotropes were significantly associated with the development of VAT (Table 2).

To adjust for possible confounders, variables that were found to be significantly associated with VAT in the initial bivariate analysis were entered into a logistic regression model as independent variables and VAT was entered as the dependent variable. A backward stepwise Likelihood Ratio binary logistic regression was conducted with VAT as the dependent variable and, age, TISS score, chest tube, central line, central line sepsis, transfusion, and pressors/inotropes as independent variables. The TISS score (adjusted OR 7.53; CI: 2.01–28.14; $p=0.03$) and use of pressors/inotropes (adjusted OR 4.64; CI: 1.28–16.86; $p=0.01$) remained the only independent risk factors that were associated with VAT. The goodness of fit of the logistic model was tested [Hosmer and Lemeshow test (X^2 of 0.08, $p=0.95$)].

On average patients with VAT (in comparison to patients without VAT) had more days of mechanical ventilation and a longer PICU length of stay; however there was no difference in mortality between the two groups (Table 3).

Haemophilus influenzae, *Methicillin sensitive Staphylococcus Aureus*, *Klebsiella Pneumonia* and *Candida* species were among the most common micro-organisms responsible for VAT in our patients (table 4).

In our study 13.3% (15/113) of our patients developed VAP. Among all patients who developed VAP, 33.3% (5/15) developed VAT prior to the development of VAP. The sensitivity and specificity of VAT as a predictor of VAP was 0.33 (95% CI: 0.13–0.61) and 0.75 (95% CI: 0.65–0.83) respectively. VAT had a positive value predictive of 0.17 and a negative value predictive of 0.88.

DISCUSSION

VAP has been well studied in children and adults admitted to the ICU with multiple underlying conditions. However, to our knowledge, tracheitis has not been studied in pediatric trauma patients. This retrospective study was conducted to determine the potential risk factors and outcome of VAT in pediatric trauma patients. Risk factors that have been previously identified as risk factors for VAP in adults and pediatric patients were included in this study. Unlike previous studies, the main focus of our study was the population of pediatric trauma patients.

To our knowledge, this is the first study to report the risk factors and outcome of pediatric trauma patients with VAT. This study has shown that tracheitis is common among mechanically ventilated trauma patients, and that severity of illness and need for pressors and inotropes are the only independent risk factors associated with VAT in pediatric trauma patients. This study has also shown that VAT is associated with a significant morbidity such as prolonged days of mechanical ventilation and PICU length of stay.

The percentage of VAT in our population was higher than previously reported. In a retrospective cohort study, Tamma et al reported that 9% (150/1616) of all PICU admissions had a clinician-suspected VAT.¹⁶ In a meta-analysis, Agrafiotis et al reported that VAT frequency is 11.5% in adult critically ill patients.¹¹ Our findings might have differed from others because our data was limited to pediatric trauma patients only, and since we did not routinely screen all intubated patients for ventilator associated infections; therefore it is difficult to interpret the percentage of VAT in our study. Only prospective studies with daily screening of tracheal secretions are able to determine the true incidence of VAT in critically ill intubated children. The purpose of our study was not to determine the incidence of VAT in children but rather the potential risk factors and outcome. The majority of our patients were male reflecting the nature of our studied population. Most of our patients were adolescents who were referred to our PICU that is part of a level I trauma center. On admission our patients with VAT had a significantly higher initial TISS score than their controls reflecting their higher severity of illness on admission; and they were also older. To adjust for these two confounding variables, a logistic regression model was built with TISS and age as two of the independent variables and VAT as the dependent variable.

In an attempt to determine potential risk factors for the development of VAT in pediatric trauma patients, and to adjust for potential confounders, a binary logistic regression model was conducted. The severity of illness (TISS score) and use of pressors and inotropes remained the only independent factors associated with VAT. Studies in adult critically ill patients have shown that the severity of injury is a risk factor for VAP.^{20,21,22}

Studies in adult and pediatric critically ill patients have shown that re-intubation is a risk factor associated with VAP.^{7,23} In our study we did not find any association between re-intubation and VAT, most probably secondary to the small number of patients who required re-intubation in our unit. In critically ill adult patients few studies have shown that

tracheotomies increase the risk for VAP in surgical and multi-disciplinary intensive care units,^{20,23,24} whereas other studies have shown that tracheotomies decrease the risk for VAP.²⁵ In our study, we did not find any correlation between tracheotomy and VAT in pediatric trauma patients. Hyperglycemia has been extensively studied in critically ill patients, and it has been associated with increased morbidities in some studies.^{26,27,28} In our study, we did not find any correlation between hyperglycemia (blood glucose level > 200 mg/dl during the first 48 hr of admission) and VAT in pediatric trauma patients. The use of steroids has been shown to increase the risk for VAP in critically ill children.⁷ However in our study we did not find any association between steroids use and VAT.

Several studies have shown that VAP increases the days of mechanical ventilation and length of stay in critically ill adults,^{20,29,30} and pediatric patients^{7,10, 31} and tracheitis increases the length of stay in adult critically ill patients.³² These findings are consistent with ours. We found that patients with VAT had an increase in their days of mechanical ventilation and length of stay.

On average our patients developed VAT four days following their admissions to the PICU, which is consistent with previous reports in adult patients who usually develop ventilation associated infections between 5 and 10 days of ventilation.^{20,21} *Haemophilus influenzae* and methicillin sensitive *Staphylococcus Aureus* were the most commonly isolated organisms in our patients similar to the most commonly isolated organisms in pediatric and adult intensive care units (*Pseudomonas Aeruginosa* and *Staphylococcus Aureus*).^{5,33}

Long-term mechanical ventilation increases the risk for lower respiratory tract colonization. It has been hypothesized that endo-tracheal tubes provide a direct route for colonized bacteria to enter the lower respiratory tract, causing either tracheitis or early VAP that can be difficult to see on chest x-rays.³⁴ Also, it can be difficult to see on plain films, if there is any worsening of a pre-existing infiltrate on portable radiographs,¹ and therefore the decision to start antibiotics becomes a challenge to the practicing physician, especially when there is uncertainty about the efficacy of early treatment of tracheitis to prevent more invasive infections. In a retrospective cohort study of children 18 years old and younger, Tamma et al found that a prolonged course vs. a short course of antibiotics to treat VAT does not appear to protect against VAP.¹⁶ However in a prospective, randomized controlled study, patients with tracheitis had fewer episodes of VAP, days of mechanical ventilation and ICU mortality when they were treated with antibiotics instead of placebo.¹² In another study, patients with tracheitis had a shorter weaning time from mechanical ventilation when they were treated with antibiotics.³⁵ Therefore early identification of patients at risk for developing VAP may help guiding the practicing physician to start antibiotics early, in high risk patients and prevent VAP associated morbidities and mortalities. In our study VAT had a low sensitivity and positive value predictive and a high specificity and negative value predictive in predicting VAP; and since all patients with VAT were treated with antibiotics, it is difficult to speculate if treatment of VAT in our study had any impact on the development of VAP.

It has been shown that the implementation of a VAP prevention bundle decreases the rate of VAP and VAP related cost in pediatric critically ill patients.^{10, 36} In our study, a VAP or a VAT prevention bundle strategies were not implemented during the study period in our unit, and therefore it is difficult to determine if such prevention strategies would have had an effect of the incidence of VAT or VAP in our population.

Our study is a single center, retrospective study that has several limitations. Future multicenter, prospective observational studies are needed to confirm our findings. We did not screen our patients systematically for endotracheal bacterial colonization; therefore the

incidence of VAT might have been under-reported and the risk factors for VAT might have not been fully described, and many VAT that were treated with antibiotics might have been simply endotracheal bacterial colonization. Future prospective studies with serial endotracheal cultures and randomization of antibiotic therapy to treat tracheitis are needed to validate the definition of tracheitis in trauma and in pediatric patients. Also the diagnosis of tracheitis was partially based on the diagnosis of individual physicians and therefore the diagnosis of tracheitis could have been over called by different physicians with different expertise and subspecialties.

In conclusion we have shown that tracheitis is common among mechanically ventilated trauma patients, and that the severity of illness and need for pressors and inotropes are independent risk factors associated with the development of VAT in pediatric trauma patients. We have also shown that VAT is associated with a significant morbidity in pediatric trauma patients; morbidities such as prolonged days of mechanical ventilation and PICU length of stay.

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Table 1

Demographics & Characteristics of patients with and without Ventilator Associated Tracheitis (VAT)

	VAT (n=24)	Without VAT (n=74)	P values
Age ¹ (in years)	13.3±4.4 14.5 (12.7–16.2)	10.9±5.4 13.0 (5.0–16.0)	0.03
Gender (% Male)	20/24 (83.3%)	55/74 (74.3%)	0.38
TISS ^{1,2}	38.6±16.9 43.0 (21.5–50.0)	24.2±10.6 24.0 (16.0–29.0)	<0.01
GCS ^{1,3}	5.4±3.9 3.0 (3.0–6.0)	6.2±4.5 3.0 (3.0–8.0)	0.35
Type of Trauma:			
Head (%)	24/24 (100%)	67/74 (90.5%)	0.13
Chest (%)	13/24 (54.2%)	29/74 (39.2%)	0.19
Abdominal (%)	11/24 (45.8%)	21/74 (28.4%)	0.11
Extremities (%)	11/24 (45.8%)	20/74 (27.0%)	0.08

¹Data is expressed in mean ± standard deviation, and in median with inter-quartile range²TISS: trauma injury severity score.³GCS: Glasgow coma scale.

Table 2

Risk Factors associated with Ventilator Associated Tracheitis (VAT)

	VAT (n=24)	Without VAT (n=74)	P values
TISS ¹ 40	14/24 (58.3%)	6/74 (8.1%)	<0.01
GCS ² 8	21/24 (87.5%)	56/74 (75.7%)	0.23
Glucose 200 mg/dl	9/24 (37.5%)	17/74 (22.9%)	0.16
Re-intubations	1/24 (4.1%)	1/74 (1.4%)	1.00
Tracheotomies	1/24 (4.1%)	2/74 (2.7%)	1.00
Chest Tubes	8/24 (33.3%)	8/74 (10.8%)	<0.01
Central Line	21/24 (87.5%)	44/74 (59.4%)	0.01
Central line sepsis	4/24 (16.6%)	2/74 (2.7%)	0.03
Foley related UTI	4/24 (16.6%)	5/74 (6.8%)	1.00
Seizures	2/24 (8.3%)	3/74 (4.0%)	1.00
CPR ³	0/24 (0%)	2/74 (2.7%)	1.00
TPN ⁴	3/24 (12.5%)	5/74 (6.7%)	1.00
Transfusion	13/24 (54.1%)	19/74 (25.7%)	<0.01
H ₂ Blockers	22/24 (91.6%)	65/74 (87.8%)	0.65
Steroids	6/24 (25%)	20/74 (27%)	0.84
Pressors/Inotropes	14/24 (58.3%)	8/74 (10.8%)	<0.01

¹TISS: trauma injury severity score.²GCS: Glasgow coma scale.³CPR: Cardio pulmonary resuscitation.⁴TPN: Total parental nutrition.

Table 3

Outcome of patients with and without Ventilator Associated Tracheitis (VAT)

	VAT (n=24)	Without VAT (n=74)	P values
Days of Ventilation ¹	11.5±6.2 10.0 (8.0–14.5)	3.7±2.3 3.0 (2.0–5.0)	<0.001
Length of stay (days) ¹	16.4±8.3 14.5 (11.0–23.0)	5.4±2.8 4.0 (3.0–7.0)	<0.001
Mortality ²	1/24 (4.1%)	4/74 (5.4%)	0.88

¹Data expressed as mean ± standard deviation and median (inter-quartile range)²Pediatric Intensive Care (PICU) mortality

Table 4Endotracheal microorganisms found in patients with Ventilator Associated Tracheitis (VAT)¹

Microorganisms	Percentage
<i>Acinetobacter species</i>	1/24 (4.1%)
<i>Candida species</i>	6/24 (25%)
<i>Escherichia. coli</i>	1/24 (4.1%)
<i>Hemophilus influenza</i>	9/24 (37.5%)
<i>Klebsiella. pneumoniae</i>	3/24 (12.5%)
<i>Moraxella species</i>	1/24 (4.1%)
MRSA ²	2/24 (8.3%)
MSSA ³	7/24 (29.1%)
<i>Pseudomonas. aeruginosa</i>	3/24 (12.5%)
<i>Streptococcus pneumoniae</i>	2/24 (8.3%)

¹ Some patients had multiple pathogens isolated from trachea.² MRSA: Methicillin Resistant Staphylococcus Aureus.³ MSSA: Methicillin Sensitive Staphylococcus Aureus.