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ORIGINAL ARTICLE

Evaluation of Pneumonia Risk Factors in Blunt Trauma Patients Followed in Intensive Care

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Abstract

Introduction: Injuries, leading to significant health and economic burdens globally, have become a prominent concern. Data from the World Health Organization (WHO) in 2012 ranks injuries as the ninth leading cause of death across all age groups, while the Centers for Disease Control and Prevention (CDC) highlights injuries as the primary cause of death among individuals under 45 years of age. Notably, traffic accidents, pedestrian incidents, and falls stand out as the leading causes of these injuries. In 2019, injuries resulted in staggering economic losses in the United States, with substantial portions allocated to hospital expenses, work loss, and the broader societal impact. This study addresses the increased susceptibility to pneumonia in trauma patients and the factors contributing to it, shedding light on its clinical implications.

Methods: The study enrolled patients admitted to the Intensive Care Unit (ICU) following blunt trauma. Various statistical analyses were employed, including t-tests, Mann-Whitney U tests, chi-square tests, Fisher's exact tests, and Cox proportional hazards regression analysis, to identify potential risk factors for ventilator-associated pneumonia (VAP). The study examined variables associated with pneumonia in univariable and multivariate analyses, considering patient outcomes over time. Statistical significance was set at a p-value<0.05.

Results: Over a five-year period, 32.3% of the patients (n: 42) developed pneumonia among the 130 included in the study. While pneumonia was more common in males and younger patients, no significant relationship was found with age or gender. The SAPS2 score was significantly higher in patients who developed pneumonia, but there was no significant relationship with the ISS score. Patients with pneumonia experienced significantly longer hospital stays, ICU stays, and mechanical ventilation durations. Notably, intubated patients, sedation, and nasogastric tube placement were significantly associated with pneumonia development.

Discussion and Conclusion: This study investigates risk factors for pneumonia development in trauma patients in the ICU and confirms the increased susceptibility of these patients to pneumonia. Although the study confirms factors like intubation, sedation, and nasogastric tube placement as risk factors, it provides nuanced insights into their impact on pneumonia development. Furthermore, the study highlights the importance of assessing pneumonia risk over time, emphasizing the critical role of early interventions to mitigate pneumonia rates. In conclusion, this study underscores the significance of identifying and understanding risk factors for pneumonia development in ICU patients after blunt trauma. Recognizing these factors and implementing preventive measures may ultimately reduce mortality and morbidity in this patient population.

Keywords: Blunt trauma; Pneumonia; Risk factors.

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Injuries are a significant health issue worldwide due to work loss and economic burdens. According to the World Health Organization (WHO) data from 2012, injuries are the ninth leading cause of death among all age groups[1]. Data from the Centers for Disease Control and Prevention (CDC) indicate that among the population under 45 years of age, injuries are the most common cause of death[2]. When we look at the ways injuries occur, traffic accidents are the leading cause, followed by pedestrian accidents in second place, and falls in third[3].

It is reported that in 2019, injuries led to an economic loss of $4.2 trillion in the United States, with $327 billion attributed to hospital expenses, $69 billion to work loss, and $3.8 trillion to the value of statistical life and quality of life[4]. Patients in the working-age group of 25-64 years constitute more than half of this cost, accounting for over $2.4 trillion[4].

Despite younger age and fewer comorbid conditions in patients followed in intensive care units (ICUs) due to trauma, pneumonia frequently develops in these patients[5,6]. Severe trauma leads to hyperinflammation as a result of the overstimulation of host defense mechanisms. In addition to hyperinflammation, trauma patients experience T-cell dysfunction and delayed activation of the acquired immune system, which can result in immune system dysfunction. This contributes to the development of infections, sepsis, and multi-organ failure (MOF)[7-9].

Any factor that results in decreased consciousness (epileptic seizures, alcohol intake, etc.), endotracheal tube, nasogastric tube, mechanical ventilation, exposure to toxic agents, uremia, exposure to highly virulent microorganisms, and immunodeficiency (corticosteroid use, HIV infection, etc.) have been defined as risk factors for pneumonia development in ICU patients[10]. It is known that trauma patients who develop pneumonia have a worse clinical course. Complete recovery is less frequent in trauma patients with pneumonia, and these patients often require care facilities or long-term rehabilitation[11]. Moreover, it is known that the length of hospital and ICU stays is prolonged, and mortality is higher in patients who develop pneumonia in the setting of trauma[12].

Although the development of pneumonia in trauma patients is a significant concern, we believe that identifying risk factors and increasing awareness regarding these risk factors will reduce mortality and morbidity in this patient group. Therefore, in this study, we aimed to investigate the risk factors leading to the development of pneumonia in patients followed in the ICU due to blunt trauma.

Materials and Methods

We enrolled patients who required admission to the Intensive Care Unit (ICU) following blunt trauma. For continuous variables, we presented the results as either the mean (±standard deviation, SD) or as the median along with the interquartile range (IQR) when the data distribution was skewed. Statistical comparisons of continuous variables were conducted using the Student t-test or the Mann-Whitney U test, depending on the appropriateness of the test. Categorical variables were analyzed using the chi-square test or Fisher's exact test when the assumptions of the Pearson chi-square test were not met. We performed a forward stepwise Cox proportional hazards regression analysis to identify potential risk factors associated with the development of ventilator-associated pneumonia. Variables that demonstrated an association with pneumonia in the univariable analysis and had a p-value less than 0.20 were included in the multivariate regression analysis. To explore the possibility that the effects of risk factors varied over the duration of ICU stay, we employed a non-proportional Cox model. The non-proportional Cox model allowed us to assess how each risk factor influenced the hazard rate of pneumonia over time. This analysis was adjusted for other factors within the model and considered censoring due to patient death or discharge from the ICU. The hazard function derived from the Cox model was utilized to estimate the daily event rate of pneumonia throughout the ICU stay. Statistical significance was set at a p-value<0.05. The study conformed to the ethical rules of the 2013 Helsinki Declaration and was approved by our institutional review board (date: 26/11/2014, no: 20/1).

Results

In the five-year period, 32.3% (n=42) of the 130 patients included in the study developed pneumonia. Of the patients, 20% were female (n=26) and 80% were male (n=104). Although pneumonia was more common in males, this difference was not statistically significant. Due to trauma being more common in the young patient group, the average age of our patients was 39.3±19.3, but no relationship was found between age and the development of pneumonia. The low comorbidity rate in our young patient group did not show a significant relationship with the development of pneumonia. The average SAPS2 (Simplified Acute Physiology Score 2) score was 42.1±19.1, and the ISS (Injury Severity Score) score was 33.6±16.2. The SAPS2 score was significantly higher in patients who developed pneumonia, while no significant relationship

was found between the ISS score and the development of pneumonia. The average length of hospital stay for patients was 23.2±22.3 days, ICU stay was 17.6±20.7 days, and mechanical ventilation duration was 7.5±11.5 days. In patients who developed pneumonia, the length of hospital stay, ICU stay, and mechanical ventilation duration were significantly longer (p<0.001).

Out of the patients, 65.4% had a history of intubation, while 34.6% were followed without intubation. Pneumonia development was significantly higher in intubated patients. Approximately half of the patients received sedation (n:69, 53.08%), and pneumonia development was significantly higher in this patient group. Intubations were most often performed in the emergency department, followed by the intensive care unit, operating room, and on-site. When the relationship between the location of intubation and pneumonia development was evaluated, no significant relationship was found. Nasogastric tubes were applied to 56.2% of all patients, and 71.4% of these patients developed pneumonia, which was statistically significant. Enteral nutrition was applied to 45.4% of patients, and parenteral nutrition to 54.6%, but there was no relationship between the type of nutrition and the development of pneumonia.

When injuries were grouped according to the AIS, head trauma was the most common type of trauma, followed by abdominal and thoracic trauma. However, there was no significant relationship between trauma areas grouped according to ISS and the development of pneumonia. In 43.1% of the patients, the Glasgow Coma Scale score at the time of admission was below 9. The Glasgow Coma Scale score was lower in patients who developed pneumonia, but no relationship was found between the development

Table 1. Comparision of pneumonia and non-pneumonia group

	All Patients (n=130)	Non-Pneumonia (n=88)	Pneumonia (n=42)	p
Age	39.3±19.3	39.1±18.2	39.7±21.8	0.862
Mechanical Ventilation (days)	7.6±11.5	3.9±5.8	15.3±16.1	0.001
Blood Transfusion (Number)	1.7±2.1	1.7±2.2	1.6±1.9	0.923
Hospital Stay (days)	23.2±22.4	17.3±16.3	35.6±27.9	0.001
ICU Stay (days)	17.7±20.8	10.9±13.7	31.9±25.6	0.001
SAPS2	42.1±19.1	39.4±19.5	47.7±17.2	0.020
ISS	33.5±16.2	32.9±17.3	34.6±13.6	0.575
Gender				0.111
Male	104 (80.0%)	67 (76.1%)	37 (88.1%)	
Female	26 (20.0%)	21 (23.9%)	5 (11.9%)	
Comorbid Disease	23 (17.7%)	15 (17.0%)	8 (19.0%)	0.780
Intubation	85 (65.4%)	48 (54.5%)	37 (88.1%)	<0.001
Intubation Site				0.691
Emergency Service	33 (38.8%)	16 (33.3%)	17 (45.9%)	
Operation Room	16 (18.8%)	10 (20.8%)	6 (16.2%)	
On Site	7 (8.2%)	4 (8.3%)	3 (8.1%)	
ICU	29 (34.1%)	18 (37.5%)	11 (29.7%)	
Nasogastric Catheter	73 (56.2%)	43 (48.9%)	30 (71.4%)	0.015
Feeding Type				0.057
Enteral Feeding	59 (45.4%)	45 (51.1%)	14 (33.3%)	
Parenteral Feeding	71 (54.6%)	43 (48.9%)	28 (66.7%)	
Sedation	69 (53.1%)	37 (42.0%)	32 (76.2%)	<0.001
GCS<9	56 (43.1%)	35 (39.8%)	21 (50.0%)	0.271
Blood Transfusion	72 (55.4%)	47 (53.4%)	25 (59.5%)	0.512
Ampiric Antibiotics	100 (76.9%)	67 (76.1%)	33 (78.6%)	0.758
Operation	40 (30.8%)	25 (28.4%)	15 (35.7%)	0.399
Vasopressor	33 (25.4%)	24 (27.3%)	9 (21.4%)	0.474
Trauma Type				0.993
Abdominal Trauma	31 (23.8%)	21 (23.9%)	10 (23.8%)	
Head Trauma	75 (57.7%)	51 (58.0%)	24 (57.1%)	
Thorax Trauma	24 (18.5%)	16 (18.2%)	8 (19.0%)	

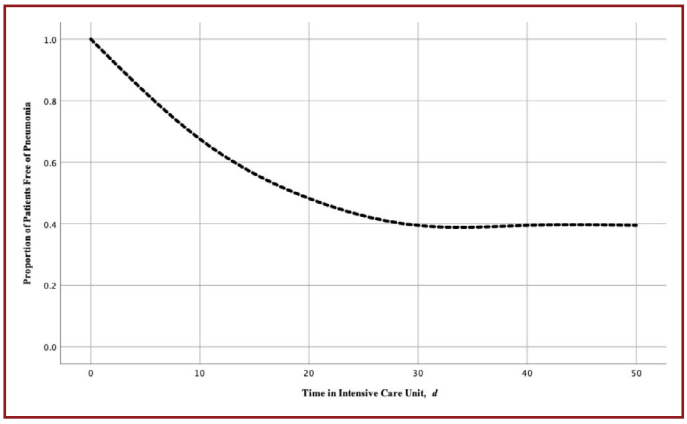

Figure 1. Proportion of Patients Free of Pneumonia.

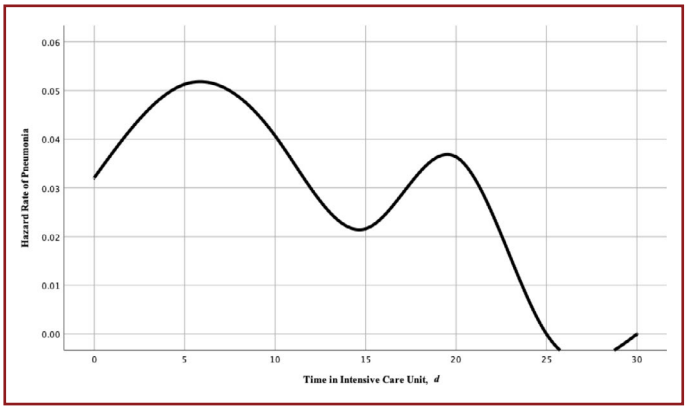

Figure 2. Hazard Rate of Pneumonia.

of pneumonia and the Glasgow Coma Scale score. Empirical antibiotic treatment was given to 76.9% of the patients for various indications, and empirical antibiotic treatment was not related to pneumonia. There was no relationship between surgery, vasopressor use, blood transfusion within 24 hours, and the development of pneumonia (Table 1). In multivariate analysis, it was observed that the duration of mechanical ventilation was an independent risk factor for the development of pneumonia (OR: 1.16, 95% CI 1.01-1.23; p<0.001). The hazard of developing pneumonia increased during the ICU stay, peaked at day 7, gradually decreased until day 15, reached a second peak at day 20, then gradually decreased and stabilized at 0 on day 30 (Figs. 1, 2).

Discussion

In this study, we investigated the risk factors associated with the development of pneumonia in patients admitted to the intensive care unit (ICU) due to blunt trauma. The diagnosis of pneumonia in ICU patients is typically based on clinical and radiological findings. However, pneumonia can occur in many patients even in the absence of clinical and radiological signs. Therefore, one of the major challenges in studies investigating pneumonia risk factors is establishing the diagnosis of pneumonia. Even the diagnostic methods considered as references for pneumonia diagnosis lack the desired level of sensitivity and specificity. To overcome these limitations, we used the criteria for pneumonia diagnosis set by the CDC in our study.

The most common age range for trauma is between 45 and 53 years old, which is why trauma is one of the leading causes of death in the young population. In parallel with this information, the average age of the patient group included in our study was determined to be 39.3±19.3. Because of the higher proportion of the young population in our country compared to developed countries, our patient group was younger[3]. Trauma is more common in males compared to females, and as a result, most of our patients were male, similar to other studies. Despite the younger age of patients admitted to the ICU due to trauma, pneumonia was more frequently observed, consistent with other studies[6].

Pneumonia was observed in 32.3% of the patients in our study, and this rate was close to the rates reported in other studies (10-36%)[6,10,13,14]. Different results have been reported in many studies evaluating risk factors for pneumonia development after trauma. For example, some researchers have suggested a relationship between advanced age and pneumonia, while in other studies, similar to our study, no relationship was reported between age and the development of pneumonia[5,15,16]. There are also varying results regarding the relationship between gender and the development of pneumonia. While some studies report that pneumonia is more common in male patients, most studies, like ours, do not find a significant relationship between gender and pneumonia development[5,14,16,17].

Certain conditions and factors such as HIV, COPD, diabetes, the use of immunosuppressive agents, renal replacement therapy, and cancer can predispose patients to pneumonia in the ICU. Due to the young age of our study group and the low number of patients with comorbidities, we did not find a significant relationship between comorbidity and the development of pneumonia.

After trauma, empirical antibiotic treatment is often initiated in patients admitted to the ICU, particularly those with open bone fractures, to prevent infections[18]. However, in our study, early-onset pneumonia was less common in patients who received empirical antibiotics due to open bone fractures[19]. On the other hand, delayed-onset pneumonia, caused by resistant gram-negative bacteria

and associated with complications related to antibiotics, was more common in patients receiving prophylactic antibiotic treatment[20]. Nevertheless, inappropriate antibiotic use increases morbidity and mortality in patients followed up with a diagnosis of ventilator-associated pneumonia (VAP)[21]. Given this high rate, we believe that patients who will be started on antibiotic treatment need to be better selected to avoid the difficulty of VAP treatment caused by resistant pathogens and its associated increase in morbidity and mortality.

Although pneumonia is reported to be more common in patients followed up in the ICU due to motor vehicle trauma, this is attributed to the higher frequency of chest trauma in motor vehicle accidents[16]. Studies have also reported a higher incidence of pneumonia in patients followed up due to chest and head trauma[6,14,15,22,23]. However, we did not find a significant relationship between the location of trauma and the development of pneumonia in our study.

Enteral nutrition is preferred more in ICU units to improve compliance with mechanical ventilation, but it also increases the risk of ventilator-associated pneumonia (VAP) [24]. Aspiration of gastric contents can lead to pneumonia in patients fed with a nasogastric tube[25]. In our study, only three patients had episodes of aspiration. However, a study tracking feeding products with fluorometry in patients with nasogastric tubes found at least one aspiration episode in 3/4 of the patients. In light of this information, our study showed that very few of the aspiration episodes that occurred in patients followed up in the ICU could be clinically detected. In addition, inflammation of the nasal mucosa in patients with nasogastric tubes can lead to more frequent maxillary sinusitis and pneumonia[26-28]. Bacteria colonized in the stomach of patients fed with nasogastric tubes can reach the lungs by ascending, potentially causing nosocomial pneumonia[29]. In line with this information, we found that pneumonia was significantly more common in patients with nasogastric tubes in our study, although there was no relationship between the type of nutrition and the development of pneumonia.

Another factor considered to contribute to pneumonia development is pre-hospital intubation. However, there are conflicting results regarding this factor. On the contrary, it has been reported that the most important factor for pneumonia development is aspiration before intubation, rather than out-of-hospital intubation[6,16,30,31].

It is known that intubation bypasses the mucociliary clearance and leads to the development of pneumonia. Some studies have reported a higher incidence of pneumonia in patients who are intubated at the scene before arriving at the hospital[6,30]. However, there are also publications suggesting that the site of intubation is not associated with pneumonia but that aspiration occurring before intubation is a risk factor for pneumonia development[16,31]. In our study, in line with the literature, pneumonia was significantly more common in patients who were intubated and followed[28]. However, there was no relationship found between patients being intubated in the field or in the hospital and the development of pneumonia.

Sedative agents given to patients in the ICU to improve compliance with mechanical ventilation can suppress host defense mechanisms such as cough and also contribute to pneumonia development due to their immunosuppressive effects[32]. In line with the literature, our study found a relationship between sedation and the development of pneumonia[19]. In our study, we found that patients who developed pneumonia had a lower Glasgow Coma Scale score compared to other patients, although this difference was not statistically significant. The Glasgow Coma Scale, used to assess the level of consciousness of patients, has been reported to be associated with the development of pneumonia in studies in the literature[5,6,33]. However, our study obtained a different result due to the relatively higher Glasgow Coma Scale scores of patients in the study group and the fact that even in patients with pneumonia, the median Glasgow Coma Scale score was above 8, which is the intubation threshold.

In our study, we did not find a significant relationship between other risk factors for pneumonia development, such as surgery within the first 24 hours and massive blood transfusion[6,34]. Scoring systems used to determine the severity of trauma, such as ISS and SAPS2, have been examined in many studies to determine whether they are a risk factor for pneumonia development, with different results[6,18,19,28,31]. In our study, while the SAPS2 score was significantly higher in patients who developed pneumonia, there was no significant difference in the ISS score. We believe that the SAPS2 score is a better predictor of pneumonia risk in trauma patients.

It is well-known that as the duration of mechanical ventilation increases, the risk of pneumonia development also increases[35]. Many studies have shown that ventilator-associated pneumonia prolongs ICU and hospital stays and the duration of mechanical ventilation[6,10,23,36]. Similarly, our study found that patients who developed pneumonia had significantly longer ICU stays, hospital stays, and mechanical ventilation durations.

We estimated the risk of hospital-acquired pneumonia to be 5% for each day. The risk peaked twice, on the 5th and 20th days. The decreasing risk suggests that high-risk patients develop pneumonia early, while other patients have a lower risk of pneumonia. Studies have shown that the first week is the highest-risk period for pneumonia development[37,38].

We evaluated the risk factors contributing to the development of pneumonia using the Cox proportional analysis, which takes into account patients who either passed away during follow-up or were discharged[38]. As a result of this analysis, we found that mechanical ventilation, regardless of its duration, was an independent risk factor for pneumonia development ($p<0.001$, HR: 3.9, 95% CI 1.53-9.95).

The main limitation of our study is that it was conducted retrospectively and the medical records before hospitalization were inadequate. For example, the presence of any foreign body in the mouth after trauma, micro aspirations, or asymptomatic aspirations could not be detected. Therefore, national databases need to be established to access information about patients for whom sufficient medical history cannot be obtained more quickly and easily.

Conclusion

In our study, we demonstrated that nasogastric tube placement, sedative drug use, intubation, and SAPS2 score were associated with the development of pneumonia, while mechanical ventilation was identified as an independent risk factor for pneumonia development. We also found that the risk of pneumonia development was highest on the 5th day in patients followed up in the ICU after trauma. We believe that to prevent the development of pneumonia in the ICU, patients should be separated from mechanical ventilation as soon as possible, and the use of sedative agents and nasogastric tube placement should be reduced to lower pneumonia rates.

Ethics Committee Approval: The study conformed to the ethical rules of the 2013 Helsinki Declaration and was approved by our institutional review board (date: 26/11/2014, no: 20/1).

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Authorship Contributions: Concept: Y.B.; Design: Y.B., I.K., T.D.; Supervision: Y.B., I.K., Ç.Z.; Fundings: Y.B.; Materials: Y.B., T.D., N.Ş.; Data Collection or Processing: Y.B., T.D., N.Ş.; Analysis or Interpretation: Y.B., R.B.; Literature Search: Y.B.; Writing: Y.B.; Critical Review: Y.B., R.B., I.K., Ç.Z., Ş.K., N.Ş.

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References

1. WHO. The top 10 causes of death. Available at: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death Accessed Mar 14, 2024.
2. Centers for Disease Control and Prevention. Leading causes of death and injury. Available at: https://www.cdc.gov/injury/wisqars/leadingcauses.html Accessed Mar 14, 2024.
3. National Confidential Enquiry into Patient Outcome and Death. Trauma: Who cares? 2007. Available at: https://www.ncepod.org.uk/2007t.html Accessed Mar 14, 2024.
4. Peterson C, Miller GF, Barnett SBL, Florence C. Economic cost of injury - United States, 2019. MMWR Morb Mortal Wkly Rep 2021;70:1655–59. [CrossRef]
5. Antonelli M, Moro ML, Capelli O, De Blasi RA, D'Errico RR, Conti G, et al. Risk factors for early onset pneumonia in trauma patients. Chest 1994;105:224–8. [CrossRef]
6. Hyllienmark P, Brattström O, Larsson E, Martling CR, Petersson J, Oldner A. High incidence of post-injury pneumonia in intensive care-treated trauma patients. Acta Anaesthesiol Scand 2013;57:848–54. [CrossRef]
7. Hietbrink F, Koenderman L, Rijkers G, Leenen L. Trauma: The role of the innate immune system. World J Emerg Surg 2006;1:15. [CrossRef]
8. Baue AE, Durham R, Faist E. Systemic inflammatory response syndrome (SIRS), multiple organ dysfunction syndrome (MODS), multiple organ failure (MOF): Are we winning the battle? Shock 1998;10:79–89. [CrossRef]
9. Hauser CJ, Joshi P, Jones Q, Zhou X, Livingston DH, Lavery RF. Suppression of natural killer cell activity in patients with fracture/soft tissue injury. Arch Surg 1997;132:1326–30. [CrossRef]
10. Vincent JL, Rello J, Marshall J, Silva E, Anzueto A, Martin CD, et al. International study of the prevalence and outcomes of infection in intensive care units. JAMA 2009;302:2323–9. [CrossRef]
11. Schellenberg M, Inaba K. Pneumonia in trauma patients. Curr Trauma Rep 2017;3:308–14. [CrossRef]
12. Vincent JL, Sakr Y, Sprung CL, Ranieri VM, Reinhart K, Gerlach H, et al. Sepsis in European intensive care units: Results of the SOAP study. Crit Care Med 2006;34:344–53. [CrossRef]
13. Nseir S, Di Pompeo C, Pronnier P, Beague S, Onimus T, Saulnier F, et al. Nosocomial tracheobronchitis in mechanically ventilated patients: Incidence, aetiology and outcome. Eur Respir J 2002;20:1483–9. [CrossRef]
14. Croce MA, Brasel KJ, Coimbra R, Adams CA Jr, Miller PR, Pasquale MD, et al. National trauma institute prospective evaluation of the ventilator bundle in trauma patients: Does it really work? J Trauma Acute Care Surg 2013;74:354–2. [CrossRef]
15. Battle CE, Hutchings H, Evans PA. Risk factors that predict mortality in patients with blunt chest wall trauma: A systematic review and meta-analysis. Injury 2012;43:8–17. [CrossRef]
16. Mangram AJ, Sohn J, Zhou N, Hollingworth AK, Ali-Osman

FR, Sucher JF, et al. Trauma-associated pneumonia: Time to redefine ventilator-associated pneumonia in trauma patients. Am J Surg 2015;210:1056–62. [CrossRef]
17. Shorr AF, Duh MS, Kelly KM, Kollef MH. Red blood cell transfusion and ventilator-associated pneumonia: A potential link? Crit Care Med 2004;32:666–74. [CrossRef]
18. Tejada Artigas A, Bello Dronda S, Chacón Vallés E, Muñoz Marco J, Villuendas Usón MC, Figueras P, et al. Risk factors for nosocomial pneumonia in critically ill trauma patients. Crit Care Med 2001;29:304–9. [CrossRef]
19. Lepelletier D, Roquilly A, Demeure dit latte D, Mahe PJ, Loutrel O, Champin P, et al. Retrospective analysis of the risk factors and pathogens associated with early-onset ventilator-associated pneumonia in surgical-ICU head-trauma patients. J Neurosurg Anesthesiol 2010;22:32–7. [CrossRef]
20. Hoth JJ, Franklin GA, Stassen NA, Girard SM, Rodriguez RJ, Rodriguez JL. Prophylactic antibiotics adversely affect nosocomial pneumonia in trauma patients. J Trauma 2003;55:249–54. [CrossRef]
21. Mueller EW, Hanes SD, Croce MA, Wood GC, Boucher BA, Fabian TC. Effect from multiple episodes of inadequate empiric antibiotic therapy for ventilator-associated pneumonia on morbidity and mortality among critically ill trauma patients. J Trauma 2005;58:94–101. [CrossRef]
22. Evans HL, Warner K, Bulger EM, Sharar SR, Maier RV, Cuschieri J. Pre-hospital intubation factors and pneumonia in trauma patients. Surg Infect Larchmt 2011;12:339–44. [CrossRef]
23. Eckert MJ, Davis KA, Reed RL 2nd, Santaniello JM, Poulakidas S, Esposito TJ, et al. Urgent airways after trauma: Who gets pneumonia? J Trauma 2004;57:750–5. [CrossRef]
24. Artinian V, Krayem H, DiGiovine B. Effects of early enteral feeding on the outcome of critically ill mechanically ventilated medical patients. Chest 2006;129:960–7. [CrossRef]
25. Metheny NA, Clouse RE, Chang YH, Stewart BJ, Oliver DA, Kollef MH. Tracheobronchial aspiration of gastric contents in critically ill tube-fed patients: Frequency, outcomes, and risk factors. Crit Care Med 2006;34:1007–15. [CrossRef]
26. Holzapfel L, Chastang C, Demingeon G, Bohe J, Piralla B, Coupry A. A randomized study assessing the systematic search for maxillary sinusitis in nasotracheally mechanically ventilated patients. Influence of nosocomial maxillary sinusitis on the occurrence of ventilator-associated pneumonia. Am J Respir Crit Care Med 1999;159:695–701. [CrossRef]
27. Desmond P, Raman R, Idikula J. Effect of nasogastric tubes on the nose and maxillary sinus. Crit Care Med 1991;19:509–11.
28. Wolkewitz M, Vonberg RP, Grundmann H, Beyersmann J, Gastmeier P, Bärwolff S, et al. Risk factors for the development of nosocomial pneumonia and mortality on intensive care units: Application of competing risks models. Crit Care 2008;12:R44. [CrossRef]
29. Heyland D, Mandell LA. Gastric colonization by gram-negative bacilli and nosocomial pneumonia in the intensive care unit patient. Evidence for causation. Chest 1992;101:187–93. [CrossRef]
30. Michelet P, Couret D, Brégeon F, Perrin G, D'Journo XB, Pequignot V, et al. Early onset pneumonia in severe chest trauma: A risk factor analysis. J Trauma 2010;68:395–400. [CrossRef]
31. Bronchard R, Albaladejo P, Brezac G, Geffroy A, Seince PF, Morris W, et al. Early onset pneumonia: Risk factors and consequences in head trauma patients. Anesthesiology 2004;100:234–9. [CrossRef]
32. Kalil AC, Metersky ML, Klompas M, Muscedere J, Sweeney DA, Palmer LB, et al. Management of adults with hospital-acquired and ventilator-associated pneumonia: 2016 clinical practice guidelines by the infectious diseases society of america and the American thoracic society. Clin Infect Dis 2016;63:e61–e111. [CrossRef]
33. Mosconi P, Langer M, Cigada M, Mandelli M. Epidemiology and risk factors of pneumonia in critically ill patients. Intensive care unit group for infection control. Eur J Epidemiol 1991;7:320–7.
34. Pawar M, Mehta Y, Khurana P, Chaudhary A, Kulkarni V, Trehan N. Ventilator-associated pneumonia: Incidence, risk factors, outcome, and microbiology. J Cardiothorac Vasc Anesth 2003;17:22–8. [CrossRef]
35. Klompas M, Anderson D, Trick W, Babcock H, Kerlin MP, Li L et al. The preventability of ventilator-associated events. The CDC prevention epicenters wake Up and breathe collaborative. Am J Respir Crit Care Med 2015;191:292–301. [CrossRef]
36. Bochicchio GV, Napolitano L, Joshi M, Bochicchio K, Shih D, Meyer W, et al. Blood product transfusion and ventilator-associated pneumonia in trauma patients. Surg Infect Larchmt 2008;9:415–22. [CrossRef]
37. Kalanuria AA, Ziai W, Mirski M. Ventilator-associated pneumonia in the ICU. Crit Care 2014;18:208. [CrossRef]
38. Cook DJ, Walter SD, Cook RJ, Griffith LE, Guyatt GH, Leasa D, et al. Incidence of and risk factors for ventilator-associated pneumonia in critically ill patients. Ann Intern Med 1998;129:433–40. [CrossRef]