CLINICAL AND DEMOGRAPHIC CHARACTERISTICS OF ADULT VENTILATOR-ASSOCIATED PNEUMONIA PATIENTS AT A TERTIARY CARE HOSPITAL SYSTEM

by

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ABSTRACT

Background: When a mechanical ventilator is used, the endotracheal tube can act as a track for pathogens to follow into the patient's lungs where pneumonia can develop. This project evaluates reported Ventilator-Associated Pneumonia (VAP) events at an academic tertiary care hospital (TCH) system.

Objectives: The objectives of this study are to: 1.) Identify epidemiological data related to VAP, 2.) Identify the prevalence of possible (ps) and probable (pr) VAP, and 3.) Compare similar hospital groups for factors influencing cases and outcomes.

Methods: This project utilized data from the National Healthcare Safety Network (NHSN) and the TCH medical record system between January 1, 2013 and August 31, 2014. Only adult VAP patients were included in the study. Demographic and clinical data were analyzed using SAS 9.3 software.

Results: White men between 50-70 years of age were the majority of persons to develop VAP while at the TCH system. Most patients were diagnosed with psVAP, but had no major differences from prVAP patients. This review shows that daily PEEP values are not being monitored by hospitals. All hospitals had both a high mortality and a high readmission rate.

Suburban facilities accounted for 76% of psVAP cases, 41% of mortalities, and 60% of all readmissions.

Conclusions: Infection Prevention teams, especially in suburban hospitals, must identify the cause of high VAP complications and adverse outcomes within the dominant population. It is important that practice and procedure match to ensure patient safety.

Public Health Significance: Every community trusts healthcare facilities to provide safe and effective treatment. However, Healthcare-Acquired Infections (HAI) deter individuals from optimal health, and may lead to increased antibiotic use and resistance. Mechanical ventilation, while essential, breaches protective barriers and increases the risk for potential HAI. Infection Preventionists aid patients on their journey to better health by working to eliminate HAIs. This study is the first step to aid Infection Prevention teams throughout the healthcare system in encouraging continued surveillance, evaluation of practice and procedure, and decreasing hospital-acquired infections overall to reinforce community safety.

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1.0 INTRODUCTION

Health risks associated with mechanical ventilator use include collapsed lung, lung damage, sedative side effects, and infection [1]. An estimated 300,000 patients receive mechanical ventilation treatment in the United States each year [2]. Recent studies have shown that 5-10% of these ventilated patients develop a Ventilator-Associated Event (VAE) [3]. Another study estimated that, on average, VAP patients experience 9.6 additional days of mechanical ventilation, 6.1 additional days in the intensive care unit (ICU), and 11.5 additional days in the hospital [4]. This is a vicious cycle where individuals who require ventilation are at risk for pneumonia and, if infected, are at risk for excess vent days and corresponding costs of treatment. However, the life-saving benefits of ventilators outweigh the risk of infection or other side effects.

The probability of developing pneumonia, specifically, increases by one percent each day a patient spends on a ventilator system [1]. Longer ventilation creates hazards such as readmission and a higher mortality risk [2, 5]. As the number of days the patient is admitted in the hospital increases, directly correlated healthcare costs for both the facility and the patient also rise [2, 3]. A recent review estimated that, on a per-case basis, Ventilator-Associated Pneumonia (VAP) infections resulted in $40,144 extra fees and 13.1 excess days spent in a health-care facility [6]. Another study suggests the development of VAP is associated with a mean hospital charge to patients of $150,841 [4].

Multiple measures are in place to avoid VAE within hospital ICUs. Healthcare facilities have implemented basic strategies to specifically prevent VAP including: keeping patient beds elevated to between 30 and 45 degrees at all times while on a ventilator, up-keeping patient oral care, hand hygiene, and mechanical equipment, and daily assessing the readiness of the patient to extubate [7]. Although healthcare guidelines continue to be created and endotracheal tube designs have improved, VAP continues to affect patients [8].

A major Tertiary Care Hospital (TCH) system comprised of nine hospitals (A-I) requested an evaluation of their safety strategies. Participating hospitals had a total of 100,311 vent days. Individual healthcare facilities within the system vary between adult intensive care units, specialty care areas, and trauma centers. Populations served are different due to different specialties. For example, burn patients are usually admitted to hospital C, transplant patients taken to hospital E, and so forth. This is the first evaluation of possible (ps) and probable (pr) VAP events within the TCH system. This quality improvement study was used to determine common clinical and demographic characteristics of VAP patients at the TCH system that may be related to the infection, identify the prevalence of psVAP and prVAP at the system, and complete inter-hospital comparisons of VAP rates.

A prediction was made that patients of increased age and a social history of alcohol, tobacco, or illicit drug use will have a greater chance of developing VAP. This prediction was based on the evidence that behavioral changes and older age affect the immune system. It is likely that psVAP events will be higher than prVAP events. This is because the prVAP definition contains more required variables. It was also hypothesized that urban and suburban hospital locations would not have many differences between patient characteristics, incidence of

VAP events, or patient outcomes. This was based on the fact that all the hospitals included follow the same healthcare guidelines for mechanical ventilation safety.

2.0 BACKGROUND

2.1 SURVEILLENCE

Hospital Acquired Infection (HAI) surveillance is a powerful public health and infection prevention tool. One of the major benefits of surveillance is that it gives scientists a base line level of infection, and warns of any increase in incidence. The National Healthcare Safety Network (NHSN) is an Internet-based surveillance system managed by the Center for Disease Control and Prevention (CDC) with a Patient Safety branch to monitor device-associated events [8]. VAP is the most frequent device-associated infection in critical-care wards [9]. The NHSN is a tool developed for surveillance and plays no part in clinical diagnosis or treatment. VAP surveillance is mandatory in Pennsylvania, but optional in other states. Increasing the surveillance on VAP is crucial to individual hospital and national quality improvement programs [5].

2.1.1 Infection Prevention

Infection Prevention teams actively monitor the progress of ventilated patients admitted to the healthcare facility they work to keep safe. The teams survey records and laboratory results updated by attending physicians and technicians for evidence of an HAI until discharge. Then, they submit reports on the infected patient's demographic data, HAI type, and pathogens to the

NHSN [8]. This quality improvement project takes the information one step further to evaluate the compiled data within and between the hospitals in the TCH system. By identifying risk factors, Infection Prevention members could come together to adjust their protocols in order to make their infection prevention efforts specifically adjusted for ventilated individuals with increased risk factors.

2.2 VENTILATOR ASSOCIATED PNEUMONIA

2.2.1 History

Prior to 2013, VAP was the only ventilator-associated infection that the NHSN monitored. In the past, about 10-20% of patients placed on a ventilator were deemed to have a pneumonia condition [3]. Recent research showed that chest radiographs and other clinical symptoms can be subjective and inconsistent [2]. For example, patients on a ventilator that developed a fever would fit one criteria of the VAP definition. However, if the patient had a severe underlying illness, it cannot be determined if the fever is from a new infection or the previous condition [10]. Screening a patient's daily ventilator settings for lung stability can be used to better predict adverse VAE outcomes [5].

2.2.2 Definition

In January 2013, the CDC changed their NHSN reporting definition of VAP to make the guidelines more objective, structured, and reproducible for all hospital settings [2]. It was

created to include quantitative physiological complications known to lead to any type of VAE [5]. By creating a broad definition of VAE, surveillance has expanded to include all ventilator-associated complications, not just pneumonia [3] (for a complete definition, see Appendix A).

The new algorithm has a nested hierarchy where each rank becomes more specific as scaling down the tier:

1) Ventilator-Associated Condition (VAC),

2) Infection-related Ventilator-Associated Complication (IVAC), and

3) Possible and Probable VAP

Although the definition change was made in an effort to attain more specific representation of VAP rates, the new criteria is significantly more complicated. In simple terms, a VAE is identified by the Infection Prevention team using this definition: deterioration in respiratory status after a period of stability or improvement while on a ventilator.

2.2.3 VAP Timeline

The day the patient is intubated and mechanical ventilation has begun is considered day one of the ventilator period. After the initial intubation, 2 or more calendar days of stability or improvement of lung health ventilation must pass before the patient is considered to potentially have a VAE **[**2]. Following the algorithm, an HAI must first be deemed a Ventilator-Associated Condition (VAC) and tracked down the tiers to meet the VAP criteria [11]. Therefore, the earliest day on which VAE criteria can be fulfilled is day 3 of mechanical ventilation [2]. The actual date of VAE onset in this study is the day 1 (D1) when all criteria for the condition have been met. Clinical data from day 0 (D0), the day before the event, have also been included for comparison.

The area where the patient was diagnosed with VAE is known as the location of attribution. However, if the D1 occurs on the day of a transfer between locations, the VAP is said to be attributed to the new location the patient is transferred to. A new VAE cannot be established until 14 days after D1 [2]. However, if a patient were to be reintubated onto a ventilator after stopping ventilation for one full day, an entirely new VAE window period would begin.

The new VAE definition utilizes quantitative measurements of both Positive End-Expiratory Pressure (PEEP) and Fraction of Inspired Oxygen (FiO2) to monitor lung health [2]. PEEP can be adjusted on the ventilator as needed to achieve airway pressure greater than atmospheric pressure at the end of exhalation. Following a period of stability, if PEEP or FiO2 needs to be increased to meet the patient's needs, there is a possibility of a ventilator complication. Daily PEEP and FiO2 values in this study are defined as the highest value during a calendar day that is maintained for at least one hour [2]. PEEP values from 0 to 5 cmH2O are considered equivalent. If the PEEP or FiO2 increases $\geq$ 3 cmH2O or 20% respectively to at least 8 cmH2O or 50%, the individual is monitored for VAE development.

2.2.4 Demographic Risk Factors

Depending on the population, VAP incidence can range between 9% and 27% of patients on mechanical ventilation for more than 24 hours [4, 13, 14]. The literature on VAP risk factors presents conflicting data. In a recent retrospective review to assess early risk factors of trauma patients who developed late VAP, risk factor analysis demonstrated that age, race, sex, ethanol status, and smoker status did not have an impact [14, 15]. However, other investigators have

found a risk correlation with certain patient demographics. For instance, one study found chronic alcoholism was common among middle-aged patients with VAP [16].

There is controversy as to which sex presents more risk for the development of VAP. Several studies have identified female sex as a predominant factor in VAP patients [14,16, 17] However, others found male sex to be a significant, independent risk factor for the development of VAP [4]. In yet another study, sex differences were statistically insignificant [4]. Studies showing sex influence include those with and without control groups.

Some investigators have found that age is associated with VAP, while others did not. Studies have shown a wide age range of individuals who develop VAP with a median age around 65 [14, 18]. However, some studies have found that older age is not a risk factor for VAP [16]. One study even deemed a significant correlation between younger male patients and VAP events [4].

2.2.5 Clinical Risk Factors

A number of host factors, clinical factors, and certain ICU locations increase the risk of VAP [19]. In a study evaluating a network of nonteaching community hospitals, small hospitals had a higher VAP incidence rate than medium or large hospitals despite having lower ventilation rates [14]. The evaluation confirmed a relationship between poor outcomes among ventilated patients and the inexperience of small hospitals with low bed counts. In addition, VAP rates at trauma ICU can be significantly high and vary among centers [4, 20]. Various trauma patient studies have demonstrated that VAP prolongs the duration of mechanical ventilation [15].

Evidence of infection includes increased patient body temperature above 37.5^{o}C, evidence of inflammation including white blood cell (WBC) counts above 3.5-10.5 billion, and

laboratory evidence of respiratory infection [2]. Increased patient body temperature has been shown to be less frequent among very old patients [16]. An incidence of VAP is considered when a patient has secretions, sputum, or positive cultures. Incidents of psVAP are defined as cases when the patient does not necessarily have a positive culture for pathogenic organisms [5]. Cases of prVAP must meet all of the previous criteria in addition to evidence of positive quantitative cultures for pathogenic organisms or respiratory viruses [5].

Any and all organism isolated from cultures of lung tissue or pleural fluid could be reported as pathogens for psVAP or prVAP. Patients with viral pneumonia, such as H1N1, are often difficult to diagnose with VAP as they may not have typical or significant symptoms [12]. The most common microorganisms linked with mechanical VAP are: *Staphylococcus aureus, Pseudomonas aeruginosa, Acinetobacter baumannii, Escherichia coli,* and *Enterobacter* species [4, 5]. VAP can develop within 48 hours of ventilation and risk rises as ventilation increases. Pseudomonas aeruginosa, Acinetobacter spp, and Staphylococcus aureus are the most common causative agents in late-onset nosocomial pneumonia, and Streptococcus pneumoniae and Hemophilus influenzae are more commonly found in early-onset pneumonia [19, 4]. VAP patients infected with antibiotic-resistant bacteria or given inappropriate initial antibiotic treatment have an increased risk of mortality [4].

2.2.6 VAP Patient Outcomes

One independent risk factor for VAP is the length of mechanical ventilation [4, 16]. Patients with VAP have greater number of days in ICU, a longer hospital length of stay, higher costs, and higher mortality compared to patients without VAP [4, 18].

ICU mortality rates of 24% to 76% have been reported for VAP [10, 13]. VAP patients can have a 2 to 10-fold higher risk of death compared to ventilated, VAP-negative patients. Death rates have been associated with the severity of the infecting pathogen [10, 16]. Sixty percent of elderly patients, 85 years of age and older, placed on a ventilator after acute lung injury will spend their last days in the hospital [2, 16].

3.0 METHODS

3.1 STUDY OBJECTIVES

The purpose of this study is to identify demographic characteristics of patients at the TCH system associated with the development of VAP infection. Additional aims include detecting the prevalence of psVAP and prVAP at the TCH system, and make comparisons between urban and suburban hospital groups within the TCH system for related factors.

3.2 STUDY DESIGN

To address these objectives, a systematic retrospective review was designed to include all reported VAP events and corresponding patient details to the NHSN from the academic TCH system between January 1, 2013, and August 1, 2014.

3.3 STUDY AREA

The chosen TCH system is a large network of hospitals (A-I) in Western Pennsylvania which includes acute care hospitals, long term acute care hospitals, and inpatient rehabilitation

facilities. The healthcare facilities B, C, E, and F are all located within a 2 mile radius of each other. These hospitals were grouped together as urban locations with patients of similar demographics and social standings. All other surrounding healthcare facilities (A, D, and G) were classified as suburban.

3.4 STUDY POPULATION

3.4.1 Inclusion Criteria

Adult patients at least 18 years old and deemed by Infection Prevention teams to have been infected with VAP while admitted to the TCH system sometime between January 1, 2013 and August 31, 2014 were included in this study. There were a total of 190 patients detected with VAP between the chosen date range. Patients on Airway Pressure Release Ventilation are included in the study, but only changes in FiO2 were monitored [2]. Patients being weaned from a ventilator are also included in the study because they spent at least a portion of a day on a ventilator where contamination was possible [2]. One patient was recorded twice for more than one VAP event per admission as per reporting criteria [5].

3.4.2 Exclusion Criteria

Patients who may have been clinically diagnosed with pneumonia, but did not meet the criteria for the NHSN definition were excluded from the study. Patients on high frequency ventilation or extracorporeal life support are also excluded from VAE surveillance [2]. Ventilated children and

neonates were excluded as the VAE algorithm used is only applicable to adult mechanically ventilated patients [2].

3.5 DATA COLLECTION

Clinical as well as demographic risk factor information were extracted and organized from the NHSN surveillance data already being collected. In addition, the TCH medical record system, Cerner, was utilized via PowerChart and Theradoc. Patient information, clinician history and physical examination notes, social history, patient vital reports, laboratory and microbiology database, and discharge and death summaries were utilized to obtain pertinent data not included in NHSN reports. All collected information was organized into one Excel data extraction form.

3.5.1 NHSN Data Collection

Upon request, a summary of NHSN data for all VAP patients was provided by a UPMC System level data analyst. The analyst then matched the NHSN material to patient medical record data and highlighted any inconsistencies. The summary delivered to me included: the hospital the patient was admitted to, age, sex, race, length of stay in the hospital, length of stay in an ICU, number of days patient was on a ventilator, VAP type, pathogens reported in association with diagnosis, and second and third HAI diagnosis. It is important to note that the ICU type listed is not necessarily the location of VAP attribution.

3.5.2 Cerner Data Collection

This study used the electronic health records of adult patients to identify criteria that may have contributed to the VAP. Electronic patient medical records included reports of abuse or even slight use of illicit drugs, tobacco, or alcohol upon hospital admission were considered in this analysis. Previous histories of use were not considered. Reports from family members were considered if patients were not able to communicate social histories themselves. Demographic data collected incorporated admission dates and hospital summaries of discharge or death reports. The hospital length of stay and vent day data for certain patients had to be verified by the number of bed days and number of ventilator setting data recorded respectively.

Laboratory information included vital reports of body temperature, WBC counts, daily ventilator settings and culture results from the hospital's microbiology database. The cultures of blood, pleural fluid, sputum, and urine samples often grew multiple organisms. For this study, only the pathogen with the heaviest growth counts were included. Charts were also consulted for any missing information from NHSN reports.

3.6 DATA ANALYSIS

By using the clinical evidence that Infection Prevention teams have collected and reported to NHSN, an insight into each patient's VAP experience was revealed. The patterns and distribution of those with the highest risk of infection were examined through frequency distributions using SAS 9.3 software. Fischer's Exact tests were used to analyze this descriptive information per hospital locations.

4.0 ETHICS

Approval for this study was provided by the Total Quality Council/Quality Improvement Review Committee for the TCH system. All medical record numbers, and patient and hospital names were removed from this analysis to preserve patient confidentiality in accordance with HIPAA policy.

5.0 RESULTS

5.1 OVERALL DATA

5.1.1 Patient Demographics

Altogether, 159 of the 190 VAP patients were included in the analysis. A total of 31 patients including 2 hospitals (H & I) were excluded from analysis: 15 patients from one hospital (H) due to the inability of the UPMC System level data analyst to match the patient details, and 16 other patients from several hospitals – including the only patient from hospital I – due to incomplete data to confirm VAP infection or data suggested the patient did not fit the criteria for VAP.

As shown in Table 1, out of the 159 patients included in this study, 120 (75.5%) were male. Seven patients were not willing to report their race, and a social history was not available for every patient due to their mental status during admission, unavailable records, or attending physicians failing to report the history. Out of 152 patients willing to report their race, 133 (87.5%) reported being Caucasion while only 19 (12.5%) were African American. The median age was 58 with a range of 19 to 85 years (Table 1). A total of 85 (53.5%) individuals were within the age range of 50 to 70 years of age. Only 24 patients were between 71 and 90 years of age. Out of 133 patients, 36.8% reported current use of tobacco or smoking upon admission.

Out of 127 patients, a little less than half (48.0%) reported current use of alcohol upon admission. Out of 104 patients, 13.5% reported illicit drug use.

Table 1. Demographic Characteristics of All VAP Patients in the TCH System

Variable	Total (n=159)
Male sex	120 (75.5%)
Age	50-70 (53.5%
***Race:**	-
White	133 (87.5%)
African American	19 (12.5%)
***Social history:**	-
Alcohol	61 (48.0%)
Tobacco	49 (36.8%)
Illicit drugs	14 (13.5%)

** Race n=152, Social history: Alcohol n=127, Tobacco n=133, Illicit drugs n=104*

There urban hospitals (B, C, E, and F) had a VAP incidence rate of 1.8 per 1,000 vent days within the study period. There were a total of 142 (89.3%) VAP patients admitted to urban hospitals. All other suburban hospitals (A, D, and G) had a VAP incidence rate of .84 per 1,000 vent days. Suburban locations contained 17 (10.7%) of the VAP patients. The number of patients attributed to each specific hospital can be found in Table 2. Hospital E has a large bed count of 720 where 69.2% of the total VAP patients were admitted. Hospitals B and G each held only 1 patient diagnosed with VAP.

Table 2. Percentage of VAP Patients Admitted to Urban and Suburban Hospitals

Hospital Code	Bed Count	Location	Incidence Rate (per 1,000 vent days)	Total Patients	Percent
A	446	Suburban	0.77	9	5.7%
B	310	Urban	0.58	1	0.6%
C	488	Urban	0.72	9	5.7%
D	424	Suburban	1.2	7	4.4%
E	720	Urban	2.2	110	69.2%
F	520	Urban	1.4	22	13.8%
G	249	Suburban	0.41	1	0.6%
Urban	2038	4	1.8	142	89.3%
Suburban	1119	3	.84	17	10.7%

5.1.2 Clinical Characteristics

Patients were admitted to their respective ICU locations with 15 (9.4%) to the medical/surgical, 38 (23.9%) to trauma, 41 (25.8%) to medical, and 65 (40.9%) to the surgical ICU. The ICU location of the patient is not necessarily the location of intubation or attribution of VAP.

Table 3 displays the urban and suburb ICU subtype differences. In suburban locations specifically, medical/surgical and trauma ICU patients had equivalent (3.8%) VAP events with surgical ICU only representing 1.3% of cases. 39.6% of all VAP events were due to patients in urban hospitals placed in surgical ICU. In suburban hospitals, medical/surgical and trauma ICU locations accounted for 35.3% of all the 17 VAP events.

Table 3. Frequency of VAP Events per ICU Type in Urban and Suburban Hospitals

ICU Type	Suburb	Urban	Total
Medical/Surgical	6 (35.3%)	9 (6.3%)	15 (9.4%)
Medical	3 (17.7%)	38 (26.8%)	41 (25.8%)
Surgical	2 (11.8%)	63 (44.4%)	65 (40.9%)
Trauma	6 (3.8%)	32 (20.1%)	38 (23.9%)
Total	17 (10.7%)	142 (89.3%)	159 (100.0%)

The lowest, median, and highest measurements of clinical variables affecting VAP patients are listed in Table 4 for D1. In comparison, measurements for D0 are also included in the table. Patient body temperature before and during VAP events ranged from 33.9ºC to 41.3ºC. PEEP was only recorded for 55 of the 159 patients on D1. However, FiO2 values were recorded for every patient both on D0 and D1. WBC counts varied considerably between patients. The only statistically significant increase from D0 to D1 was WBC counts (t-test p=0.032).

Table 4. Range of Clinical Characteristics of VAP Patients in the TCH System

Variable	N Variable Reported	Minimum	Median	Maximum
Temp (ºC) D0	159	33.9	38.0	40.7
Temp (ºC) D1	159	36.0	38.0	41.3
FiO2 (%) D0	159	30.0	70.0	100.0
FiO2 (%) D1	159	40.0	70.0	100.0
PEEP (cmH2O) D0	67	5.0	15.0	44.0
PEEP (cmH2O) D1	55	5.0	15.0	46.0
WBC D0	155	2.0	11.4	52.5
WBC D1	158	1.4	12.5	41.0

TEMP, body temperature. D0, day before the event. D1, date of VAP onset. FiO2, Fraction of Inspired Oxygen. PEEP, Positive End-Expiratory Pressure. WBC, white blood cell.

The most frequent VAP pathogens reported to the NHSN were *Staphylococcus aureus* (23.27%), *Pseudomonas aeruginosa* (8.81%), *Escherichia coli* (8.18%), and *Enterobactor aerogenus* (5.66%). However, there was a large variety of additionally reported microorganisms throughout all VAP patients.

5.1.3 Patient Outcomes

The median length of stay in each ICU was 21 days with a wide range of 1 to 242 days. Similarly, the median length of stay at the hospital was 24 days with a range of 6 to 142 days. The median duration of mechanical ventilation was 18 days with a minimum of 6 and a maximum of 186 days. Maximum ICU and vent days are greater than the total length of stay due to the fact that total days in the hospital could not be recorded for two of the VAP patients as they were still admitted to the hospital upon data collection. These patients could potentially have more ICU or vent days that are not included this analysis.

A total of 50 patients developed at least one additional HAI during the same hospital stay as incurring the VAP infection (Table 5). Of the additional HAI events, 41 had a second event while 9 even had a third. The most common additional HAI other than VAP was a urinary tract infection affecting 24 (48.0%) patients, followed by surgical site infections at 8 (16.0%), and gastrointestinal infection at 7 (14.0%) events. This data does not reflect concurrent general infections also at the time of VAP events.

Table 5. Distribution of Additional HAI Events in TCH System

HAI Type	Total (n=50)
Second HAI	41
Third HAI	9
Bloodstream Infection	5 (10.0%)
Eye, Ear, Nose and Throat	1 (2.0%)
Gastrointestinal	7 (14.0%)
Pneumonia	3 (6.0%)
Skin and Soft Tissue	2 (4.0%)
Surgical Site Infection	8 (16.0%)
Urinary Tract Infection	24 (48.0%)

Excluding the two patients not yet discharged, 59 (37.6%) of the patients succumbed to their health complications during hospital admission. Of the 100 safely discharged, 55 (56.1%) patients were readmitted: 47 (85.5%) within 1-30 days, 5 (9.1%) within 31-60 days, and 3 (5.5%) within 61-90 days. Of the 55 patients readmitted within 90 days, only 2 died.

5.2 POSSIBLE AND PROBABLE VAP

5.2.1 Incidence Rate

A little more than half of the patients, 57.9%, were diagnosed with psVAP while the other 42.1% were deemed prVAP events (Table 6). Urban locations contained 85.9% of all psVAP infections and 94.0% of the total prVAP events. Thirteen of the 17 total suburban VAP patients (76.5%) were psVAP cases.

Table 6. Percent of psVAP and prVAP per Suburban and Urban VAP Patients

Variable	Suburban	Urban	Total
psVAP	13 (76.5%)	79 (55.6%)	92 (57.9%)
prVAP	4 (23.5%)	63 (44.4%)	67 (42.1%)

5.2.2 Clinical Characteristics

Table 7 lists the clinical variables, other than pathogens, that may have been indicative of VAP type. There is no statistically significant difference in WBC or FiO2 from D0 to D1 but change in temp was different between the groups (p=0.036). All PEEP values were within the range of 5 to 46 cmH2O.

Table 7. Clinical Variables Affecting psVAP and prVAP Events

VAP Type	Total Patients	Variable	N Variable Reported	Minimum	Median	Maximum
psVAP	92	Temp (^{o}C) D0	92	35.9	38.2	40.6
		Temp (^{o}C) D1	92	36.1	37.9	41.3
		FiO2 (%) D0	92	30.0	60.0	100.0
		FiO2 (%) D1	92	40.0	70.0	100.0
		PEEP (cmH2O) D0	32	5.0	23.5	41.0
		PEEP (cmH2O) D1	28	5.0	18.0	46.0
		WBC D0	88	2.0	10.6	34.5
		WBC D1	91	1.4	11.5	34.9
prVAP	67	Temp (^{o}C) D0	67	33.9	37.9	40.7
		Temp (^{o}C) D1	67	36.0	38.1	41.3
		FiO2 (%) D0	67	40.0	80.0	100.0
		FiO2 (%) D1	67	40.0	80.0	100.0
		PEEP (cmH2O) D0	35	5.0	10.0	44.0
		PEEP (cmH2O) D1	27	5.0	15.0	45.0
		WBC D0	67	3.6	12.9	52.5
		WBC D1	67	2.6	14.2	41.0

TEMP, body temperature. D0, day before the event. D1, date of VAP onset. FiO2, Fraction of Inspired Oxygen. PEEP, Positive End-Expiratory Pressure. WBC, white blood cell.

5.2.3 Patient Outcomes

The median duration of mechanical ventilation for psVAP was 17 days with a wide range of 6 to 123 days (Table 8). Similarly, the median vent days for prVAP was 21 with a range of 6 to 186 days. One patient developed VAP after only 1 day spent in the ICU. Total ICU days and length of stay were not available for the two prVAP patients not yet discharged from their respect hospitals.

Table 8. Duration of Patient Hospital Stay per psVAP and prVAP Events

VAP Type	Total Patients	Variable	N Variable Reported	Minimum	Median	Maximum
psVAP	92	Vent Days	92	6.0	17.0	123.0
		ICU Days	92	1.0	19.0	131.0
		Total Length of Stay	92	6.0	23.5	142.0
prVAP	67	Vent Days	67	6.0	21.0	186.0
		ICU Days	65	2.0	25.0	242.0
		Total Length of Stay	65	6.0	31.0	106.0

5.3 VAP BY URBAN AND SUBURBAN LOCATIONS

5.3.1 Clinical Characteristics

Table 9 shows the specific indicators, other than pathogens, of VAP that may be affecting specific urban or suburban locations. There were no statistically significant differences between variables from D0 to D1 in either suburban or urban groups. PEEP was only recorded for 4 of the 17 suburban VAP patients and less than half of urban patients on both D0 and D1. The

median FiO2 values for VAP patients on D1 in suburban hospitals was 80% and only 70% in urban locations.

Table 9. Clinical Variables Involved with VAP at Suburban and Urban Hospitals

Location	Total	Variable	N	Minimum	Median	Maximum
Suburb	17	Temp (ºC) D0	17	36.4	37.6	39.3
		Temp (ºC) D1	17	36.3	38.0	41.3
		FiO2 (%) D0	17	30.0	100.0	100.0
		FiO2 (%) D1	17	50.0	80.0	100.0
		PEEP (cmH2O) D0	4	5.0	23.0	41.0
		PEEP (cmH2O) D1	4	5.0	28.5	46.0
		WBC D0	17	3.3	12.1	52.5
		WBC D1	17	3.4	13.6	41.0
Urban	142	Temp (ºC) D0	142	33.9	38.0	40.7
		Temp (ºC) D1	142	36.0	38.0	41.3
		FiO2 (%) D0	142	40.0	70.0	100.0
		FiO2 (%) D1	142	40.0	70.0	100.0
		PEEP (cmH2O) D0	63	5.0	12.0	44.0
		PEEP (cmH2O) D1	51	5.0	15.0	45.0
		WBC D0	138	2.0	11.3	34.5
		WBC D1	141	1.4	12.4	35.5

TEMP, body temperature. D0, day before the event. D1, date of VAP onset. FiO2, Fraction of Inspired Oxygen. PEEP, Positive End-Expiratory Pressure. WBC, white blood cell.

The most common VAP pathogens associated within urban locations were *Staphylococcus aureus* (19.5%), *Pseudomonas aeruginosa* (6.9%), and *Escherichia coli* (7.6%). While the suburban hospitals had similar pathogens to protect against, β-hemolytic *Streptococci* (1.9%) caused more infections than *Escherichia coli* (0.6%). There were three viral H1N1 cases which were all associated with urban hospitalization. Again, there were a large variety of pathogens associated with VAP between suburban and urban hospitals.

5.3.2 Patient Outcomes

Table 10 shows both suburban and urban locations kept patients on a ventilator for a median of 18 days. The maximum duration of ventilation for suburban hospitals was 50 days while at least one patient in an urban hospital had 186 vent days. Median ICU days and total length of hospital stay for urban patients was slightly higher than suburban, but maximum days in urban locations (242 and 142 respectively) greatly outnumbered the maximum of suburban hospitals (46 and 50 days).

Table 10. Range of Days VAP Patients Spent in Suburban and Urban Hospitals

Location	Total	Variable	N	Minimum	Median	Maximum
Suburb	17	Vent Days	17	9.0	18.0	50.0
		ICU Days	17	10.0	19.0	46.0
		Total Length of Stay	17	10.0	22.0	50.0
Urban	142	Vent Days	142	6.0	18.0	186.0
		ICU Days	140	1.0	22.0	242.0
		Total Length of Stay	140	6.0	25.5	142.0

A total of 52 (88.1%) of the 59 patient deaths upon initial admission occurred within urban hospitals. Of suburban patients, 41.2% died on initial admission, and 60.0% were readmitted within 90 days. Only 37.14% of the 142 urban patients passed away, and 49 (55.7%) were readmitted after initial discharge.

Table 11. VAP Patient Outcomes in Suburban and Urban Hospitals

Outcome	Suburban	Urban	Total (n=157)
Mortality	7 (41.2%)	52 (37.1%)	59
Readmission	6 (60.0%)	49 (55.7%)	55

Of the additional HAI infections, 47 occurred in urban locations. Within Hospital F alone, 6 of the 22 patients had one additional HAI while 2 others had three total HAI events. All of the suburban additional HAIs in Hospital A. The only two HAI events occurring in addition to VAP in suburban locations were bloodstream and urinary tract infections. The most common HAI, accounting for 41.03% of the total second HAI events, at urban TCHs was urinary tract infections, as shown in Table 12.

Table 12. Percent of Additional HAI Events per Suburban and Urban VAP Patients

HAI	Suburban	Urban
Second HAI	2	39
Third HAI	1	8
Bloodstream Infection	2 (66.7%)	3 (6.4%)
Eye, Ear, Nose and Throat	0	1 (2.1%)
Gastrointestinal	0	7 (14.9%)
Pneumonia	0	3 (6.4%)
Skin and Soft Tissue	0	2 (4.3%)
Surgical Site Infection	0	8 (17.0%)
Urinary Tract Infection	1 (33.3%)	23 (48.9%)
Total	3	47

6.0 DISCUSSION

While the literature does not provide a definitive list of risk factors, this analysis shows a clear relationship between VAP events and certain patient demographics. This study demonstrates that white males are the majority of patients who develop VAP infection while on a mechanical ventilator within this TCH system. Patients of this background within the age range of 50 to 70 made up over half of the study population. There seemed to be no association between recent patient social history and VAP incidence.

This study shows that patient social history of tobacco or drug use may not be associated with pneumonia development while on a ventilator. However, alcohol use may have an influence. Previous research has shown a discrepancy between the correlation of VAP development and social history [14, 15]. While some studies have shown no correlation, others have found a high ethanol status in certain VAP patients [16].

It has been 1.5 years since the implementation of the latest VAP definition which has increased the objectivity of HAI diagnosis by adding quantitative PEEP and FiO2 values to criteria [2]. These results indicate that patient vital signs are indeed subjective, and consistent ventilator setting data should be recorded. However, in this study PEEP values were only recorded for 55 of the 159 VAP events. PEEP and FiO2 values, while similar, are the only quantifiable components directly associated with lung health.

In accordance with criteria, it only takes a short amount of ventilation time, in this case 6 days, to become infected with VAP. The results were also consistent with previous reports that VAP infections caused longer ventilation time, ICU days, and total days admitted to the hospital [4, 16, 18]. The length of stay in each ICU, on a ventilator, and in a hospital consisted of a wide range between 1 and 242 days. Initial overall mortality and readmission rates of VAP patients was high, but readmission mortality was low. Overall mortality counts were similar to previously published data from teaching hospitals [10, 13].

As predicted, cases of psVAP were more common than prVAP in both urban and suburban locations. Between VAP types, both showed a wide range of total days spent in the healthcare facility including ICU and vent days. Individuals with prVAP had a higher median length of vent days, ICU days, and total stay in the healthcare facility. Patients with prVAP also had an increased WBC count on D1 compared to psVAP. These results suggest that there is a difference between psVAP and prVAP, and that prVAP may be more severe.

For suburban hospitals, trauma and med/surgical ICU wards were tied for highest number of VAP cases. Consistent with the overall data, surgical ICUs had the highest association with VAP events in the urban hospital group. Over half of the VAP infections, no matter the ICU ward location, were caused in urban hospitals. The most common microbial pathogens affecting VAP patients within this TCH system are consistent with published data [4, 5]. The most common pathogens found in this TCH system were *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Enterobactor aerogenus*. The most frequent pathogens associated with VAP did not differ between locations.

The VAP patients from this TCH system suffered a large number of additional HAIs. These infections should especially be monitored in surgical ICU wards. Of the additional HAI

events, the most common incident was a urinary tract infection. It cannot be determined if the additional infections aided in VAP development. However, additional HAI events, especially urinary tract infections, need to be significantly reduced.

Although there were no significant demographic differences of patients admitted between urban or suburban hospital, VAP outcomes were affected by the size and experience of hospitals. Patients admitted to suburban locations had a higher mortality and readmission rate than urban VAP patients. However, there was no significant difference in duration of mechanical ventilation, and each location had more psVAP than prVAP.

6.1 STRENGTHS AND LIMITATIONS

The strengths of this study include the use of a national database with sequential information specific to VAP events, and the ability to match the data with existing medical records. This study gives a base line of modifiable variables to prevent VAP events, and warns of outcome risks should these events continue. The database used provides many more variables to potentially study in the future including underlying health conditions, infections upon admission, and antibiotic use before admission. Ongoing surveillance also allows for a similar data review in the future to identify any trends.

All included patients were located within a similar region of western PA, and were all from the same hospital system under one protocol to prevent VAP. The sample size was still large after the elimination of unmatched patients. The results were consistent with what previous studies have reported.

Limitations of this study include the retrospective nature of the data collection. Reporting of valid data was only as efficient as the patient's clinicians to record data. Therefore, missing data from the variables this study considered was to be expected. We can assume, because the data was collected from one TCH system, that there are little differences between the hospitals in terms of mechanical ventilation methods, weaning strategies, or laboratory protocols [5]. However, the results may not be generalizable to community hospitals.

The analysis of patient demographics was limited by the large number of missing social history data for the patients included in the analysis. In addition, there were suggestions of reporting bias as patients questioned multiple times for a social history during the same admission period resulted in varying answers. Furthermore, since the patients included in this study may have had multiple health conditions, it is impossible to say with certainty that specific symptoms or mortality were caused by VAP alone.

7.0 CONCLUSION

Despite its limitations, this study succeeded in providing baseline data of VAP epidemiology in the TCH system. VAP incidence greatly affects patient safety and health. Effective strategies for preventing VAP and other HAI events must be implemented.

Surprisingly, white males of middle age are at greatest risk of developing VAP infection while on a mechanical ventilator within this TCH system. It is not clear why this demographic characteristic is so prevalent among infected patients. By using this information to prevent psVAP and prVAP cases, this TCH system could use special techniques to increase ventilated patient safety overall. Future studies should include a comparison group of matched ventilated but pneumonia negative patients to prove that patient characteristics are specifically associated with VAP infection or merely mechanical ventilation.

This review shows that daily PEEP values are not being monitored by most hospitals. In many cases, only FiO2 ventilator settings were recorded for each mechanically ventilated patient. This difference in protocol vs. practice reduces the neutrality of the diagnosis by causing Infection Prevention teams to rely solely on FiO2 values and arbitrary symptoms. Utilizing all standardized care processes and regularly monitoring each patient's progress is vital for prevention [3]. It is important that practice and procedure match when recording ventilated patient data. Both PEEP and FiO2 should be monitored in order to ensure that VAP cases are

acknowledged at the earliest possible date. Furthermore, monitoring ready values for any decrease in lung health could prompt early demands for sputum cultures.

It is important that procedures be developed to protect against additional HAI events, especially urinary tract infections. Cultures of potential infection should especially be monitored in surgical ICU wards. Hospitals of smaller size and with less experience at safe ventilation protocols, evidently require further education and guidance. Suburban hospitals should be closely monitored in order to decrease VAP incidence, mortality, and readmission rates.

The findings of this quality improvement project help distinguish common patient characteristics which local hospitals could adjust for in the future. In addition to the current basic quality improvement strategies, it would be interesting to utilize a specialized oral care approach for individuals with a higher risk of developing VAP such as during and after surgery. The use of oral health care techniques has been moderately shown to decrease the amount of VAP [3]. This project hopefully will encourage the TCH system to continue studies that evaluate how current ventilation practices could be improved.

The lifesaving benefits of mechanical ventilation for thousands of American citizens have been fraught with frequent VAP and other HAI events, resulting in excess admission days and costs of treatment. With the population continually living longer and the need for ventilation potentially increasing, surveillance tools must continually be used to monitor VAP events, and Infection Prevention teams must constantly evaluate protocol to provide a safe environment for ventilated patients as a public health priority.

APPENDIX: 2013 NHSN VENTILATOR ASSOCIATED EVENT DEFINITIONS

Ventilator-Associated Condition (VAC): [21]

Patient has a baseline period of stability or improvement on the ventilator, defined by ≥ 2 calendar days of stable or decreasing daily minimum* FiO2 or PEEP values. The baseline period is defined as the two calendar days immediately preceding the first day of increased daily minimum PEEP or FiO2.

and

After a period of stability or improvement on the ventilator, the patient has at least ONE of the following indicators of worsening oxygenation:

1.) Increase in daily minimum* FiO2 of ≥ 0.20 (20 points) over the daily minimum FiO2 in the baseline period, sustained for ≥ 2	***or***	2.) Increase in daily minimum* PEEP values of ≥ 3 cmH2O over the daily minimum PEEP in the baseline period†,

*Daily minimum defined by lowest value of FiO2 or PEEP during a calendar day that is maintained for at least 1 hour.

†Daily minimum PEEP values of 0-5 cmH2O are considered equivalent for the purposes of VAE surveillance.

Infection-related Ventilator-Associated Complication (IVAC):

Patient meets criteria for VAC

and

on or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, the patient meets both of the following criteria:

1.) Temperature > 38 °C or < 36°C, OR white blood cell count ≥ 12,000 cells/mm3 or ≤ 4,000 cells/mm3.

and

2.) A new antimicrobial agent(s)* is started, and is continued for ≥ 4 calendar days.

Possible Ventilator-Associated Pneumonia (psVAP):

Patient meets criteria for VAC and IVAC

and

on or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, one of the following criteria is met:

1.) Purulent respiratory secretions (from one or more specimen collections): defined as secretions from the lungs, bronchi, or trachea that contains > 25 neutrophils and < 10 squamous epithelial cells per low power field [lpf, x100] • See additional instructions for using the purulent respiratory secretions criterion in the VAE Protocol.	***or***	2.) Positive culture (qualitative, semi-quantitative or quantitative) of sputum*, endotracheal aspirate*, bronchoalveolar lavage*, lung tissue, or protected specimen brushing* *Excludes normal respiratory/oral flora, mixed respiratory/oral flora or equivalent, *Candida* species or yeast not otherwise specified, Coagulase-negative *Staphylococcus* species, *Enterococcus* species

Probable Ventilator-Associated Pneumonia (prVAP):

Patient meets criteria for VAC and IVAC

and

on or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, ONE of the following criteria is met:

1.) Purulent respiratory secretions (from one or more specimen collections—defined as for possible VAP)

and

ONE of the following:

- Positive culture of endotracheal aspirate*, $\geq 10^5$ CFU/ml or equivalent semi-quantitative result
- Positive culture of bronchoalveolar lavage*, $\geq 10^4$ CFU/ml or equivalent semi-quantitative result
- Positive culture of lung tissue, $\geq 10^4$ CFU/g or equivalent semi-quantitative result
- Positive culture of protected specimen brush*, $\geq 10^3$ CFU/ml or equivalent semi-quantitative result

*Same organism exclusions as noted for Possible VAP.

or

2.) ONE of the following (without requirement for purulent respiratory secretions):

- Positive pleural fluid culture (where specimen was obtained during thoracentesis or initial placement of chest tube and NOT from an indwelling chest tube)
- Positive lung histopathology
- Positive diagnostic test for Legionella spp.
- Positive diagnostic test on respiratory secretions for influenza virus, respiratory syncytial virus, adenovirus, parainfluenza virus, rhinovirus, human metapneumovirus, coronavirus

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