Analysis of Ventilator Associated Pneumonia Patients’ Hospital and Intensive Care Charges, Length of Stay and Mortality

Thesis

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By

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Abstract

This research investigated the amount of potential increase in charges, mortality and length of stay of patients with Ventilator Associated Pneumonia (VAP) over non-VAP patients at the Wexner Medical Center between the dates of 11/1/2011 and 12/31/2012.

VAP patients were identified and matched with a non-VAP patient using a 1:1 ratio. There were a total of 45 matches achieved, therefore the study and control groups each had 45 patients init, with like admitting diagnosis as identified per ICD 9 code, gender, and ± 5 years of age. The control and study groups were examined individually, compared with each other, and then several subgroups were identified and compared. Those subgroups were the patients who were admitted to and discharged form the ICU more than once during a single hospital admission, those patients who were under the age of 50, and those who were older than 80 years of age.

This research found that the charges from the ICU and non-ICU days were increased as was the length of stay both in the ICU and hospital for the patients who had VAP over their non-VAP counterparts. There were not significant difference between the study and control groups in terms of mortality.
Dedication

To the love of my life, my late husband Stephen. Without your love, encouragement, support and example, I would not be who I am today. Until we meet again, Gods speeds.
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The first thank you’s go to my family and children who have supported me through this long and rocky road. Without the love and support I have received from them I am not sure I would have come to the end of this journey successfully. Thank you Mom, Dad, Ruth, Drew, Issac, Jami, Holly, Meghan, and Christopher. I love you!! I also want to send a very special thank you to the best friend that a girl could have, Lori Branscome Ray!

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Major Field: School of Health and Rehabilitation Services
Table of Contents

Abstract .............................................................................................................. ii
Dedication ......................................................................................................... iii
Acknowledgements ............................................................................................ iv
Vita ...................................................................................................................... v
List of Tables ...................................................................................................... vii
Chapter 1: Introduction ..................................................................................... 1
Chapter 2: Review of the Literature ................................................................. 11
Chapter 3: Methodology .................................................................................. 34
Chapter 4: Results ........................................................................................... 37
Chapter 5: Discussion ...................................................................................... 46
References ......................................................................................................... 55
Appendix A ......................................................................................................... 59
List of Tables

Table 1: Mean Days in Hospital, ICU and Total Charges for the Study Group and Control Group ................................................................. 38
Table 2: Mean Differences between the Control and Study Groups and Statistical Significance ........................................................................ 39
Table 3: Results of the Individual Pairs Mortality .............................................. 40
Table 4: Study and Control Group patients readmitted to the ICU during a single hospital admission against their overall group means ........................................... 41
Table 5: Comparison of the 80+ year old patients to their group means and comparing the Control and Study Groups .............................................. 43
Table 6: Difference between the Control and Study Groups means for the patients who were under 50 years of age .............................................. 44
Chapter 1: Introduction

Background of the Problem:

Healthcare Associated Infections (HAIs), infections that occur during or as a consequence of healthcare, are a major public health concern in Ohio. Based on national estimates, “HAIs affect 5 to 10 percent of hospitalized patients in the United States annually, resulting in approximately 99,000 deaths in 2002, and may account for nearly $45 billion in direct annual hospital costs” (Krein, page 773, 2011). According to the Center of Disease Control, for Ohio, this translates into “over 80 thousand infections, nearly 4 thousand deaths and adds $180 to $230 million to healthcare costs.” Consequently, Ventilator Associated Pneumonia (VAP), the number one type of HAI, is a major concern to both the critical care and respiratory communities. “VAP is defined as pneumonia in patients receiving mechanical ventilation that was neither present, or developing, at the time of intubation” (Munro, page 428, 2009). It contributes to the health care cost increases, antibiotic use, mortality and an increased length of stay for patients in the hospital. There are some methods of decreasing VAP in
patients such as keeping the head of the bed elevated a minimum of 30 degrees, stress ulcer prophylaxis, and doing daily spontaneous breathing trials, DVT (deep vein thrombosis) prophylaxis and regular emptying of condensate from the ventilator tubing. These things are now widely practiced in ICU’s throughout the Wexner Medical Center and are part of the ventilator bundle.

It is also known that some things increase the likelihood of developing VAP. They are: “previous antibiotic use, improper hand washing by the staff, patients laying on their backs without the head of the bed elevated, presence of a nasal gastric tube, gastric alkalization, and colonization of the oropharynx with potential pathogens. Those pathogens include Staphlococcus Aureus, Streptococcus, MRSA, and Pseudomonas Aeruginosa.” (Munro, page 429, 2009)

Patients who are on mechanical ventilation are intubated with an Endotracheal tube. This tube goes directly into the patients lungs, providing a direct route for pathogens to gain access to the lungs from either the gastro-intestinal tract, the upper respiratory tract, or from the oral cavity. It is also known, that “within 48 hours of intubation, and/or, admission to the ICU, the oral flora changes and becomes more virulent and a breeding ground for gram negative associated pneumonias” (Munro, page 429, 2009).
It is the dental plaque that becomes the location for these bacteria to fester. The Endotracheal tube then becomes a direct transmitter of these pathogens to the lungs, and consequently, VAP is born.

Significance of the Problem:

As the cost of healthcare continues to rise, hospitals are being held more responsible for the care they deliver and the associated costs. While in the past hospitals were paid based on Diagnosis, they are now being penalized, and not being paid the same amount, when patients develop conditions like VAP and HAI’s. “Three of the 10 hospital-acquired conditions covered by the new Center for Medicare and Medicaid Services policy involve HAI’s, which are common, expensive and often preventable cause of inpatient morbidity and mortality” (Stone, page 2, 2010). These changes are a result of the Deficit Reduction Act of 2005 which required the Secretary of Health and Human Services to identify high cost and high volume preventable conditions that result in higher payments. Following this directive, the Centers for Medicare and Medicaid Services promulgated regulations denying payment for claims occurring after October, 1, 2008, in
which selected conditions occurred during the hospital stay and were not present on admission. "CMS prohibits the hospital from billing the beneficiary for the difference between the lower and higher payment rates. The intended net effect of this change is that claims would be paid as though the secondary diagnosis were not present" (Stone, page 2, 2010). As hospitals are ultimately businesses, these changes affect their bottom lines. Several studies have been done looking at these costs. The National Institute for Health (NIH 2010) did one such study looking at patients from all across the United States. Total inpatient costs were between 2.6 and 6 times higher in patient with HAI compared with patients without HAI’s. “Patients with pneumonia ($77,393) had the highest median cost compared with control patients ($12,849). Inpatients with HAI’s had a nearly 3 to 4-fold higher length of stay (LOS) compared with patients without HAIs” (NIH). In a review completed by Ashraf (2012), he states, "patients with VAP had a longer ICU length of stay (26 versus 4 days) and hospital length of stay (38 versus 13 days) when compared to uninfected intubated patients” (page 4). The Ashraf, et al, study found that the increase in costs for VAP patients was $11,897 after adjusting severity of illness. The median hospital costs for VAP patients and non - VAP patients were $70,568 and $21,620 respectively.

The National Institute for Health has set forth very strict guidelines
that patients are evaluated against, to determine if they do in have an HCAP, or VAP. This is the standard used in evaluating the patients here at the Wexner Medical Center, at The Ohio State University. Any patient suspected of having a VAP is evaluated by Clinical Epidemiology. The Clinical Epidemiologists are ultimately responsible for making the final determination. Patients charts are scrutinized very closely before responsibility is accepted.

Respiratory Therapies involvement with VAP:

Respiratory Therapists are intimately involved with these patients. They evaluate them, take care of their ventilators, deliver their medications, assist with their bronchoscopies, and suction them as well. They are in and out of these patients’ rooms, around the clock, every day. Consequently, their actions are of utmost importance.

They are expected to wash their hands, upon entering and exiting their patients’ rooms, wear gowns, gloves, and masks as needed, and to wipe down the patients’ ventilators daily. These things are done to minimize the cross transfer of bacteria and germs from one patient to another.

Another part of the patients’ care directly involving the respiratory
therapist is the spontaneous breathing trial. Nurses are asked to give patients a sedation holiday every morning to the patients that meet the criterion. That holiday entails the nurses turning off their patients’ sedation and allowing the patients to wake up. It is during this awake period the respiratory therapists initiate the spontaneous breathing trial, again on those meeting specific criterion. The patients’ ventilators settings are changed to simulate the patients breathing on their own. How well the patients tolerate these changes determines whether the patient can be extubated and the ventilator discontinue, or not. This trial is very important, as the sooner the patient can be liberated from the ventilator, the less likely they are to develop a VAP.

The critical care nurses and respiratory therapists are the primary people responsible for suctioning patients. They are often the first ones who notice changes in patients’ sputum. The changes can be in the amount, color, consistency, or any combination thereof.

The Wexner Medical Center at The Ohio State University holds interdisciplinary rounds every day in the ICUs. All facets of the medical team are involved including: Hospitalists, the Pulmonary team, Registered Nurse responsible for the patient, Pharmacist, Respiratory Therapist, Dietician, Social Worker, Charge Nurse and the Patient Care Resource Manager (discharge planner). These rounds take place once every day at a
set time. It is during this time that the patient’s case is reviewed, discussed and input is obtained from all involved. This is when changes in sputum, ability to wean, progress, or the patients’ problems are discussed, and a plan for the next 24 hours is put in place.

Purpose of the study:

The following questions will be investigated.

1) How many patients have been diagnosed with VAP at the Wexner Medical Center, between the dates of 11/1/2011 and 12/31/2012.

2) Of those diagnosed, what was the associated increase in mortality, length of stay, and charges in the ICU and for their overall hospital stay, if any? Are there any subgroups with interesting finding, such as those with more than one admission to ICU during a single hospital admission, those over the age of 80, or those under the age of 50?

These charges are very important to the hospital as these are charges that the hospital cannot recoup. This study will be retrospective in nature. De-identified information will be obtained through the Information Warehouse. Information obtained will include; admitting diagnosis, age,
gender, ICU dates of admission and discharge, dates of admittance and discharge from the hospital, and their total ICU costs, and hospitalization costs. Data will be requested based on ICD-9 codes which are specific to VAP’s. These patients will be used to form the study group. The same data will be requested for all patients who were mechanically ventilated for more than 48 hours who did not develop VAP. These patients will be used to form the control group.

**NHSN definitions, guidelines and protocols:**

For the purposes of NHSN (National Healthcare Safety Network) surveillance in the acute care setting, the CDC defines an “HAI as a localized or systemic condition resulting from an adverse reaction to the presence of an infectious agent(s) or its toxin(s). There must be no evidence that the infection was present or incubating at the time of admission to the acute care setting” (Horan, 2008, page 309). HAI’s may be caused by two sources; endogenous and exogenous. Endogenous sources are the mouth, skin, gastrointestinal tract, and others, where bacteria normally occur, but are now causing infections since they have traveled to another area of the body where they are not naturally occurring. Exogenous sources are things that are in the acute care setting outside of the patient’s body, such as
medical equipment, staff, visitors and the hospital environment.

The NHSN has three classifications of pneumonia clinically diagnosed pneumonia (PNU 1), pneumonia with specific laboratory findings (PNU 2), and pneumonia in immunocompromised patients (PNU 3). The NHSN has some criteria/comments that apply to all three types of pneumonia. They are noted below.

General Comments:

1) Physician diagnosis alone is not an acceptable criteria for HCAP.

2) Ventilator associated pneumonia should be designated as such.

3) When assessing a patient for pneumonia, it is important to distinguish between changes in clinical status due to other conditions such as, myocardial infarction, pulmonary embolism, respiratory distress syndrome, atelectasis, malignancy, chronic obstructive pulmonary disease etc. Also, care must be taken when assessing intubated patients to distinguish between tracheal colonization, upper respiratory tract infections and early onset pneumonia.

4) Finally, it may be difficult to determine HCAP in the elderly and immunocompromised because such conditions may mask the signs or symptoms associated with pneumonia.

5) Pneumonia due to gross aspiration is considered HCAP if it meets
the criteria of not clearly present or incubating at the time of admission to the hospital.

6) Multiple episodes of HCAP may occur in critically ill patients. To determine if it is one episode with a change of pathogen, or several, is decided by whether or not there was a clear resolution to the initial infection. The addition or change in pathogen alone is not indicative of a new episode of pneumonia. The combination of new signs and symptoms and radiographic evidence or other diagnostic testing is required.

Horan, 2008, page 327. see appendices 1-5 (pages 328-332)
Chapter 2: Review of Literature


There are three main categories of pneumonias: community acquired pneumonias (CAP), healthcare associated pneumonias (HCAp), and hospital acquired pneumonias (HAP). Community acquired pneumonias are just that; pneumonias that occur while the patients are living their lives. HCAP is a relatively new classification. “These are pneumonias that occur while people are involved in the healthcare community but not hospitalized; such as people who are receiving outpatient chemotherapy, immunosuppressed, long term dialysis patients, patients living in nursing homes, outpatient intravenous drug therapy, or are receiving care for extensive wounds” (Grenier, 2011, page 1617). Although not hospitalized, these patients are in and out of contact with the healthcare industry routinely, leaving them exposed to many multi-drug resistant bacteria. HAP are those pneumonias that occur while a patient is in the hospital.

"Pneumonia is the second most common nosocomial infection in the United States and is a leading cause of death due to hospital - acquired
infections" (Augustyn, 2007, page 32). Ventilator associated pneumonias (VAP) are just one type of HAP.

According to the CDC/NHSN patients are diagnosed with VAP using the following criterion; a temperature greater then 38 degrees Celsius with no other recognized cause, a WBC greater then 12,000/microliter or less than 4,000/microliter,for adults 70 years or older altered mental status with no other recognized cause, and at least 2 of the following, new onset purulent secretions or change in character or amount of secretions that developed greater than 48 hours after admission to the ICU, worsening hypoxemia, rales or bronchial breath sounds, or finally, new onset or worsening cough, dyspnea or tachypnea. (Horan, 2008, page 328) Prior to July 1, 2012 there was one additional criteria which was a new persistent alveolar infiltrate on a chest x-ray.

VAP occurs because the intubated patients’ body’s natural defense mechanisms have been bypassed. First, when a patient inhales through his/her nose, the air they are breathing is warmed, humidified and filtered by the nasal hairs. Second, the endotracheal tube (ETT) compromises the patients' ability to utilize their cough reflex effectively. Lastly, the upper airways of the lungs have small hair-like protrusions called cilia. The cilia’s job is to catch and trap foreign particles and/or bacteria headed into the lungs. The cilia then move these objects up to the back of the throat where most are swallowed, and therefore, do no harm. Also, dental plaque can harbor bacteria, and having an endotracheal tube
going through the mouth directly into the lungs becomes a direct route for these bacteria to travel. Therefore, for all the above reasons, an endotracheal tube increases the likelihood of VAP.

“Within 48 hours of admission to the ICU, oral flora of the critically ill patient undergoes a change to predominately gram-negative flora that includes more virulent organisms” (Munro, 2009, page 429). Patients that are at especially high risk for the development of VAP include trauma, burn, neurosurgery and surgery patients. There are other risk factors that also contribute to VAP which are, “inadequate hand washing by the staff, supine positioning of the patient, previous and repeated antibiotic use, use of a nasogastric tube, gastric alkalization, and colonization of the oral pharynx with potential pathogens of Staphlococcus aureus, Streptococcus pneumonia, gram negative rods, and Pseudomonas aeruginosa.” (Munro, 2009, page 429) “Timely administration of antibiotics for the treatment of pneumonia has been suggested as an important factor in decreasing morbidity and mortality” (Sikka, 2011, page 1).

Certain actions have become part of the standard of care in many hospitals in the hopes of preventing VAP from occurring. They are part of the Wexner Medical Center VAP bundle, which are; elevation of the head of the bed to a minimum of 30 degrees, a daily Spontaneous Breathing trial unless contraindicated, stress ulcer prophylaxis, and deep vein thrombosis prophylaxis. All patients should also have the condensate from the ventilator tubing emptied as often as needed.
The Deficit Reduction Act of 2005 required the Secretary of Health and Human Services to identify high cost and high volume preventable conditions that result in higher payments. If these conditions were not present on admission, as a primary or secondary diagnosis, the Center for Medicare and Medicaid Services (CMS), did not allow payment for the treatment of these conditions. Three of the 10 hospital-acquired conditions covered by the new CMS policy involve healthcare-associated infections, which are a "common, expensive, and often preventable causes of inpatient morbidity and mortality" (Stone, 2010, page 434).

"Medicare will be reduced only in instances where the HAI (hospital acquired infection) codes are the only factor causing a case to be reclassified into a more expensive payment. That is, if a patient has many complications, the exclusion of the HAI from the payment formula will have zero consequences. Thus, in most cases, it is expected that the policy change will affect only a small portion of hospital reimbursement, and the magnitude of the financial incentive remains relatively small for most hospitals" (Stone, 2010, page 436).

**Costs, Mortality and the increase in Length of Stay:**

Multiple studies have evaluated the increases in costs, mortality, and the length of stay in patients with hospital acquired pneumonias and ventilator associated pneumonias. All are retrospective in nature.

The question becomes, what is the financial cost of CAP, HCAP, and
HAI's, specifically VAP. "Approximately 2 million patients per year develop HAIs, or about 5% of acute hospital admissions. The last decade alone has seen an estimated 36% increase in HAIs. The estimated 100,000 deaths per year associated with HAIs rank this as the sixth leading cause of death in the United States. The excess hospital cost of HAIs across the nation was estimated to be between 28 and 45 billion dollars annually" (Stone, 2010, page 434). According to Colice, et al, (2004) there are between 5-6 million cases of CAP pneumonia each year in the United States. This leads to approximately 1 million hospital admissions and 10 million doctor visits. This leads to an estimated cost of $8.4 billion per year and an estimated mortality rate of between 8-15%. The treatment costs for the inpatient and outpatient management of CAP were obtained from a claims database of employed people and their dependents <65 years of age. “This estimate is substantially higher than previously reported but still might underestimate the actual annual impact of CAP.” (Colice, 2004, page 2145)

Patients with VAP had a longer ICU length of stay (26 versus 4 days) and hospital length of stay (38 versus 13 days) when compared to uninfected intubated patients (Ashraf, 2012, page 4). Warren, et al, found that the cost of VAP after adjusting for potential confounders was approximately $11,897. They also found that patients with VAP had higher hospital costs ($70, 568 versus $21,620) when compared with uninfected ventilated patients, even after adjusting for the underlying severity of illness.

pneumonia from two vantage points, that of costs and outcomes. Patients were located in both the ICU and on medical floors. Patients were randomly divided into two groups which were, noninvasive management (NIM) and invasive management (IM) which was guided by the results obtained from a protected brush specimen (PSB) or bronchial alveolar lavage samples. Criterion for inclusion in the study were as follows; “recent and persistent infiltration on the chest radiograph and at least two of the following-body temperature between ≥ 38°C or < 36°C, abnormal leukocyte count, purulent tracheobronchial secretions, and symptom onset either after 72 hours of hospitalization or on admission to Forsilles hospital following a long stay in another hospital.”(Herer, page 166, 2009). Exclusion criteria included the following patients, those who were immunosuppressed, patients considered unsuitable for bronchoscopy by the attending physician and patients with a life expectancy of < 3 months (page 166). Demographics collected were: age, gender, comorbid illnesses, length of hospitalization before nosocomial pneumonia onset, body temperature, prior antibiotic treatment including the compound used, or the period without antibiotic use, leukocyte count, time from symptom onset to antibiotic therapy, extent of radiographic chest abnormalities, PaO2, FiO2, the PaO2/FiO2 ratio and the presence and aspect of respiratory secretions. (Herer, page166, 2009) The resulting costs did not vary significantly between the two groups. “The 28 day clinical cure rate did not differ statistically either, but, the 28 day mortality rate
tended to be lower with the non invasive management strategy (10.0% versus 21.9% in the invasive management group), but the difference did not reach statistical significance.” (Herer, page 170, 2009).

The National Institute of Health conducted a study, with the objective of exploring “the clinical impact and economic burden of HAI’s in trauma patients using a nationally representative database.” The database was the Nationwide Inpatient Sample which is “the largest all-payer hospital inpatient database in the United States and includes data from a 20% stratified sample of US hospitals.” (NIH, 2008, page 2) The population studied was patients admitted with a principle diagnosis of trauma, and LOS more than 3 days. Some patients were excluded, which included patients with burns, unspecified injuries, hip fractures and burns. The final study sample was comprised of 155,691 patient records. The researchers collected the following pieces of data; mortality, LOS, and hospital cost. They also looked at the patients’ demographics, co-morbidities, diagnostic codes, ICD-9 codes, length of stay and the patient conditions on discharge, and what type of hospital. The hospitals were found in all areas of the country; 80% were non-teaching hospitals, and 62% were located in urban America.

They found that patients with HAI’s had a higher crude mortality rate (without adjusting for severity of illness, or co-morbidities), costs and LOS than those without. “The overall mortality rate for control patients (those without HAI’s) was 1.99%, compared with 10.6% for patients with pneumonia” (Glance, 2012,
The patients’ hospital costs were between 2.6 and 6 times more expensive, for those with HAI’s, than those who did not have an HAI. Patients with pneumonia had the highest median costs ($77,393) compared with control patients ($12,849).” Inpatients with a HAI had nearly 3 to 4 fold higher LOS compared with patients without HAI’s.” (NIH, 2008, page 5)

Thomas, et al, (2012) did a study looking at the costs of pneumonia versus non-pneumonia patients’ in the Medicare population between the years of 2005 and 2007. They used a 5% random sample from these patients. Data from 2004 was used as baseline data. Pneumonia - related services were identified using International Classification of Disease, ninth revision (ICD-9) codes, as primary on admission, pneumococcal septicemia (only when pneumonia was the secondary), or any of the above pneumonias primary or secondary on an outpatient claim. Patients were case matched based on multiple criteria into the control (no pneumonia) and study (with pneumonia) groups which were; “the quarter-year the pneumonia hospitalization occurred; age, gender, race; low-income; ESRD (end stage renal disease) or disabled; 37 conditions associated with pneumonia in the past three and 12 months” (Thomas, page 8, 2012). Age variance was ± 2 years. The costs were calculated using the Medicare allowable charges. During 2005-2007, the average cumulative annual incidence of any pneumonia episode was 47.4/1000 beneficiaries. Pneumonia occurred in 2.9% of beneficiaries age 65-74, increasing to 8.7% in those 85 years and older. (see Thomas, 2012, page 16, table 2). “An important finding of this study is the major
impact that pneumonia has in the elderly, in excess mortality and excess direct medical costs. The excess mortality was four times higher that matched controls in the initial quarter with mortality differences remaining after two years. The excess cost of pneumonia was also higher than pneumonia hospitalization costs in previous cited studies. (Thomas, page 12, 2012). This excess cost of pneumonia has significance on our overall health care spending. "Applying our annual cumulative incidence of inpatient primary pneumonia (13.3/1000) to 29.29 million aged Medicare fee-for-service beneficiaries in 2010, we estimate 390,000 annual hospitalizations in persons age 65+, with annual excess medical costs in 2010 dollars of $7.3 billion" (Thomas, 2012, page 13).

Koffel, et al. (2012) conducted a study looking specifically at the economic affect of VAP. They used a large matched cohort. Their data came from the Premier research database, which includes data from approximately 400 of the >2500 hospitals in the Premier healthcare alliance. The data was de-identified patient information. This study spanned October 1, 2008 through December 31, 2009. For a patient to be included, the patient had to spend a minimum of 1 day in the ICU, and be on a MV (Mechanical Ventilator) for ≥ 2 calendar days. Information was obtained via billing codes and ICD-9 codes. VAP was identified strictly by the ICD-9 code 997.31. The patients' billing statements were acquired through the different hospital accounting departments. “Actual costs were available for each revenue department as well as for each billing item. Patient billing codes for products and services received during hospitalization were
captured. In-hospital mortality was indicated by a discharge status of expired." (Koffel, page 252, 2012). Patients were matched 1:1 between those with, and those without VAP, with a total of 2,144 patients per group. Patient characteristics used for comparison were, age, gender, race or ethnic background, attending physician specialty, admission type (elective, urgent or emergency), all patients' severity of illness, and the patient's condition at discharge (alive or expired). Hospital characteristics were geographic region, bed size, urban or rural and teaching status. In this study there were 88,689 patients who had been MV for ≥ 2 calendar days. Of those patients 2,238 had the ICD-9 code for VAP, which equates to a rate of 1.27 cases per 1,000 MV days. They found that the patients with VAP were older and more likely male. “Patients with VAP were more likely to have been transferred from another healthcare facility and to have been discharged to skilled nursing or rehabilitation facilities. (Koffel, 2012, page 253). This occurs because patients with VAP, and therefore often longer LOS, are frequently debilitated from their extensive hospitalizations. Patients are transferred to these alternate facilities to allow the patients time to regain their strength and stamina through rehabilitation.

Koffel, et al, (2012) found that, “Patients with VAP had higher mean costs for hospitalization, pharmacy, antibiotics, vancomycin, propofol, ventilation both overall and in the ICU, respiratory therapy, and chest x-rays. For example, mean hospitalization costs were $99,598 for patients with VAP and $59,770 for patients without VAP, resulting in an absolute difference of $39,828 between these
matched cohorts” (page 253, 2012). Oddly, they also found that those “patients with VAP had a lower overall in-hospital mortality rate than patients without VAP (22.5% versus. 29.4%). There were no between-group differences in 30-day all-cause readmissions, excluding mortality (which was higher in the VAP group).” (Koffel, 2012, page 252). This is unusual as most studies have shown that those with VAP had higher mortality rates.

This study also looked at the differences in costs between the VAP and non-VAP groups. The VAP group had consistently higher costs in the following areas, respiratory therapy, MV, pharmacy and chest x-rays. The difference in costs was a minimum of 40%.

Rello, et al. (2002) “performed a study involving a large US database with two main goals: to identify risk factors associated with the development of VAP among patients admitted to ICU’s, and to assess the influence of VAP on patient outcomes, including attributable hospital mortality, inpatient resource utilization, and medical care costs.” (Rello, 2002, page 2116). This study was done retrospectively using a matched cohort style.

The data for this study comes from the MediQual Profile database. This database is maintained by the Cardinal Information Corporation (CIC). The data is submitted by more than 100 U.S. acute care hospitals which are similar in both bed size and region. These hospitals submit de-identified information on all of their patients to the database so that biases do not occur. The database collects
information on each patient to include patients demographics, ICU LOS and type, procedure and diagnostic codes, hospital bills for total costs as well as ancillary charges, and the patients' conditions on discharge.

First, they identified which patients had been admitted to an ICU and on MV for >24 hours. If a patient had been admitted to the ICU more than once during a single admission, only data from the first admission was analyzed. All patients who were admitted to the ICU's with a diagnosis of pneumonia were excluded, because those patients already had a pneumonia and therefore likely had a CAP or HCAP, not a HAP, or VAP pneumonia. From this remaining group, the case group (those with HAP or VAP) was developed and those without formed the control group. The VAP cases were confirmed by a diagnosis of either bacterial pneumonia, or, by an “event code indicative of pneumonia, such as an abnormal chest radiographic finding, documentation of hospital-acquired pneumonia in physician progress notes, and/or positive respiratory culture finding VAP.” (Rello, 2002, page 2116-2117). The control group were the patients who had no documentation of viral, fungal, bacterial or unspecified pneumonia. They also did not have any event codes that would give credence to a pneumonia as well.

The database had 9,080 patients who met all the needed criteria. Out of that group, 842 developed VAP (9.3%). “Patients with VAP were significantly younger, more likely to be male, had intermediate deciles of illness severity, had a greater incidence of coma and stupor, and were more frequently admitted for
trauma compared to patients without VAP." (Rello, 2002, page 2117). The researchers found that 603 patients had positive respiratory cultures. The most common bacteria was Staphylococcus aureus in the patients who developed VAP within the first 4 days after intubation. Pseudomonas aeruginosa was the most commonly cultured bacteria in patients developing VAP 4 or more days after intubation. In the final analysis, Rello, et al, (2002) found that there was no increased risk of mortality for those with VAP versus those without VAP. However the results did show that the patient with VAP averaged an additional 9.6 days on mechanical ventilation. They also had an increased average stay of 6.1 days in the ICU and 11.5 days in the hospital over the non-VAP patients. The VAP patients had a median increased hospital cost of $40,000 over the patients without VAP. Although, those with VAP did not have higher mortality rates, being hospitalized longer, and in ICU longer leads to a higher level of debilitation. They are often weaker than their non-VAP counterparts, leading to an increased risk of further problems. Another interesting finding was that those patients with intermediate underlying illness severity, who developed VAP, had the highest mortality rate, versus those with either high or low underlying illness severity.

Patients who come in with a very low severity of illness and then acquire a HAP/VAP often show significant changes in their conditions. Patients who are admitted with a high severity of illness present with significant symptoms. These patients are started on antibiotics and other therapies immediately, often even before physicians are aware of the cause of their illnesses. This early intervention is
considered the reason these patients do not have a higher mortality rate.

Restrepo, et al, (2010) conducted a retrospective study using a matched cohort design. There were 524 patients who had medical insurance claim information. These records included certain ICD-9 codes indicating the patients had been mechanically ventilated. Thirty of these patients had VAP confirmed microbiologically. These patients were matched against 90 patients who were mechanically ventilated but did not contract VAP, yet had the same diagnostic codes. There were no significant statistical differences between the two groups. Using a very detailed formula, “median hospital charges were compared between groups at baseline. Costs were estimated by applying hospital specific cost to charge ratios based on all payor in patient costs.” (Restrepo, 2010, page 510).

The financial burden was found to be quite high. Median total hospital charges were $198,200 for the patients with VAP and $96,540 for control patients without VAP. “The average derived cost-to-charge ratios were similar for study patients and control patients, resulting in median costs of $76,730 for the study patients and $41,250 for control patients. After adjusting for DRG payments, median losses to hospitals were $32,140 for case patients and $19,360 for control patients” (Restrepo, 2010, page 510).

The hospital median costs were higher for the study group in all of the following instances, “hospital services, pharmacy services, laboratory services, and respiratory therapy. Additional services with higher median costs for case
patients than for control patients included cardiology services, operating room services, electrocardiogram services, nuclear medicine services and recovery room services.” (Restrepo, page 511, 2010). They also found that the length of ICU stay, time being MV, and the overall hospital stay medians were longer in the case versus control group.

Warren, et al, (2003) studied a group of 819 patients who were mechanically ventilated in one of the ICU’s at the Missouri Baptist Medical Center, a non-teaching facility. This hospital is a 500 bed facility and has a 10-bed surgical ICU, and a 10-bed medical ICU. During their study, 127 patients developed VAP while in the ICU’s. Comparison was made between the VAP group and the 692 patient vented but non-VAP group. Their VAP rate was 21 cases per 1000 ventilator days in their ICU’s. They found that the, “Patients with VAP had a significantly longer duration of mechanical ventilation compared with uninfected patients (15 versus 2 days)” (Warren, 2003, page 1314). They also found that the VAP group had overall longer LOS, the patients were more likely to have sepsis and a longer stay in ICU, and that the VAP group was more likely to die.”Patients with VAP incurred on average, $48,948 in additional hospital costs compared with uninfected patients.” (Warren, 2003, page 1314). The formula they used was primarily; “Cost of VAP= (total hospital cost)VAP patients - (total hospital cost) from non-VAP patients” (Warren, 2003, page 1313). The additional costs were incurred because the VAP group had a higher pharmacy and respiratory therapy, costs, although, nursing costs, and longer hospital and ICU
stays are the primary reasons for the increased costs.

Several studies were also done that looked specifically at patients who had superinfections, or infections caused by multi-drug resistant (MDR) bacteria. These bacteria are believed to lead to even higher mortality rates, longer LOS, and even higher costs per patient than the patients with HAP or VAP that are antibiotic susceptible. MDR bacteria requires the use of more broad spectrum antibiotics in the hopes that these antibiotics will kill off the infection. Unfortunately, the best antibiotics for the given bacteria are resistant, or, not effective, therefore, other less desirable medications are used.

Maudlin, et al, (2009) looked specifically at gram negative (GN) bacteria. The study was conducted only at the University of South Carolina hospital located in Charleston, South Carolina. They did a “retrospective, observational comparative cohort study that included patients with HAI’s due to GN bacteria.” (Maudlin, page 110, 2009). Patients who had HAI’s caused by a GN bacterium were divided then into two groups, those with MDR GN bacteria, and those who had a GN bacteria that was susceptible to antibiotics. The sample pool comprised 662 patients, hospitalized between January 2000 and June 2008, approximately half of whom had MDR GN bacteria. Patients with either multiple infections during a single admission, or those with incomplete data were excluded from the study.

Although this study looked at all HAI’s causes, they found that pneumonia comprised 34% of their patient population. Hospital costs and LOS were higher in
those with resistant bacteria over the nonresistant group. The median difference in cost was $38,121, which was a mean difference of 29.3%, and with a median difference in LOS of 5 days. Things that had an impact on the difference in cost, was length of time the patients spent in ICU, use of MV, and a receipt of TPN.

“This implies that for this sample of patients when all other independent covariates are held constant, having an HAI caused by a resistant GN pathogen was associated with a 29.3% higher total hospital cost for each admission and a 23.8% increase in the LOS than those for patients with HAI’s caused by nonresistant pathogens.” (Mauldin, 2009, page 112). “Pneumonia was associated with a 43.8% and 38.2% increases in total hospital cost and LOS, respectively compared to the total hospital costs and LOSs for other types of infections. (Mauldin, 2009, page 112)

Eagye, et al, (2009) did a study looking at superinfections and their impact. This study was done with a retrospective cohort design, at an urban 840 bed, not-for-profit teaching hospital. The study went from January 2004 until July 2005. For a patient to be included in the study, a patient had to be ventilated for a minimum of 48 hours, a new persistent infiltrate on a chest radiograph, “plus at least two of the following: (1) body temperature of <36 °C or >38.3°C; (2) white blood count (WBC) >10,000/mm$^3$ or <5000/mm$^3$; or (3) macroscopically purulent tracheal aspirate.” (Eagye, page 117, 2009). “Patients were excluded if the causative pathogen was determined to be nonbacterial (e.g. fungi, molds, or
viruses) or if tracheobronchitis was strongly suspected (i.e., no antibiotic therapy was initiated or an infectious diseases physician noted indicated a diagnosis of tracheobronchitis.) (Eagye, 2009, page 117).

The medical records were the source of information, and were reviewed for the following information; personal demographics, comorbidities, dates of admission and discharge from both the ICU and hospital, clinical and microbiological data including the patients culture results, as well as antibiotic therapy given before and after the development of VAP.

“A superinfection was defined by the presence of both of the following; (1) isolation of a new organism while receiving antibiotic therapy for VAP, and (2) a change in therapy to an agent with a broader spectrum of coverage within ≤4 days after the superinfection culture, suggesting the covering intensivist acknowledged this isolation as a new infection.” (Eagye, 2009, page 118).

For a bacteria to be considered multi-drug resistant, the bacteria had to be resistant to minimum of 3 classifications of antibiotics, “was an Escheria coli or Klebsiella and noted to possess an extended spectrum B-lactamase; or it was classified by the microbiology laboratory as MRSA.” (Eagye, 2009, page 118).

The researchers looked at “crude mortality, infection-related mortality, LOS in the hospital and ICU, and total costs after the initial VAP identification.” (Eagye, 2009, page 118).

Two hundred patients were found to be positive for VAP, of which, 74 had superinfections. There was no difference between the groups in terms of
mortality or inappropriate therapy on the LOS in the hospital or ICU stay. “Our results indicate that the development of a superinfection was independently associated with a 1.6 fold increase in LOS once VAP had been contracted compared with VAP patients who did not develop such infections; furthermore, total hospital costs after VAP was contracted were 1.7 times greater for patients who developed superinfections than for those who did not” (Eagye, 2009, page 121). “Attributable LOS and cost of developing a superinfection was 15.6 days and $48,527, respectively.” (Eagye, 2009, page 121).

Ott, et al, (2010) did a study at a German hospital in Hannover, Germany. They specifically studied patients who had MRSA (Methicillin Resistant Staphlococcus Aureus) versus those who had MSSA (Methicillin Susceptible Staphlococcus Aureus) that was Methicillin susceptible using a case-control study respectively. This type of HAP, has increased from 8% of the total VAPs in 1997, to 35% in 10 years. Ott initiated the study at the Hannover Medical School, which is a 1398-bed facility which has a total of 124 ICU beds.

The case and control patients were identified by searching through the hospitals microbiology laboratory records, as well as, the medical record clinical descriptions. For all patients included in this study, the following information was obtained; demographics, LOS in the hospital and ICU, length of time in the hospital after the diagnosis of VAP/HAP, length of time on MV, and patients’ condition at the time of discharge. The researchers also accessed the hospital financial records, which were broken down into different groups. Using DRG’s
and reimbursement records patients' total cost vs. reimbursement was analyzed to see what the financial loss was, if any, to the hospital. Despite this study being done in Germany, the CDC guidelines for positive identification of pneumonia were used, which means the patient had to be hospitalized a minimum of 48 hours before developing pneumonia for it to be considered nosocomial. Case patients (MRSA) were matched 1:1 against control patients who had MSSA who were similar in age, admitted and discharged within the same year, LOS before the onset of MRSA, and whether the patient was on a floor or in the ICU when the infection occurred. Ott, et al, also adjusted for co-morbidities and underlying disease states.

They found 53 patients who had MRSA, and had been hospitalized for 48 hours prior to the onset and therefore had a nosocomial MRSA. Out of the 53 patients they were able to match 41 patients with a MSSA patient. They found that there were no significant differences between the case and control groups with the exception of LOS and mortality.

There was a median cost for MRSA patients of €60,684 ($77,068), and €38,731 ($49,188) for MSSA patients, or a difference of €21,953 ($27,880). They found that the median loss of MRSA patients to the hospital was €11,701 ($14,860) and €2,762 ($3,507). The exchange rate was €1 = $1.27, on 11/11/2012. The increase in costs was attributable to significant differences for nursing staff, pharmacy, medical products and more. This study shows that the superinfections that are resistant to antibiotics are even more costly than those
which are susceptible to them, making these the most costly of all infections.

Summary:

Throughout this literature review there were three main focuses; (1) Does the length of stay increase in patients with VAP/HAP? (2) Is there an increase in cost as a result of having either a VAP/HAP? and (3) Is there an increase in the mortality rate of those with VAP/HAP over those without? Each of the above foci will be looked at individually.

There seems to be little doubt that the length of stay increases for patients with VAP. The NIH (2010) looked specifically at trauma patients and reported that the LOS increased by 3-4 fold. Rello (2002), Warren (2003) and Ashraf (2012) all looked at patients who were MV and developed VAP versus those who were MV but did not develop VAP. Rello states that the LOS increased by 6.1 days on average in the ICU and the hospital LOS increased by an average of 11.5 days. Warren found the LOS to be an average of 13 days longer for VAP patients, and Ashraf found that the average hospital LOS was 25 days longer, and the average ICU stay was 22 days longer for patients with VAP. Although the LOS increases varied, the consensus is certainly that VAP will increase the LOS in both the ICU and the hospital.

Costs is the other foci in which there is little variance. Herer, et al, (2009) found that there was not a difference in cost between the groups studied, which focused primarily on different methods of managing VAP. Although the researchers framed things differently, every other study showed that the
patients with VAP had higher costs in terms of their overall hospital bills, respiratory therapy charges and pharmacy charges. Three studies (Koffel (2012), Rello (2002) and Warren (2003)) even stated that the average increase shown in their research was a median of $40,000-$50,000 per hospital stay. Thomas (2012) stated that the United States spends approximately $7.3 billion a year in the treatment of 390,000 cases of VAP.

Mortality is the area of study in which there were the greatest differences. Several researchers found that the mortality increased when patients developed VAP, one said the mortality decreased, and one said that there was not a difference at all. The NIH (2010) looked specifically at trauma patients. They found that the presence of an HAI, specifically VAP, increased the mortality rate by 5 fold. Thomas (2012) and Warren (2003) both found that VAP increased the patients’ mortality rate by approximately 4x’s. Rello (2002) found that VAP in MV patients did not increase, or decrease the patients' likelihood of dying. Oddly, Herer (2009) and Koffiel (2012) found that VAP decreased the likelihood of patient mortality while hospitalized. They differed however after the patients had been discharged for 30 days. Koffel found that after 30 days those who had VAP had a higher incidence of mortality over those who did not. Herer, on the other hand, found that the group with invasive management of pneumonia had a higher incidence of death after 30 days, although the difference was not considered to be statistically significant.

Superinfections are in a group all their own. They are infections that are
resistant to more than 3 classifications of antibiotics. They are the most expensive group of all VAP/HAP patients. Maudlin (2009) and Eagyre (2009) found that patients with superinfections had a greater cost, and longer a LOS for those patients who had superinfections that were MDR, then those who did not have superinfections. Ott concurred with this. His research showed that MRSA was a lot more expensive than MSSA. Maudlin did not look at the aspect of mortality; however, Eagyre and Ott (2010) did. Eagyre found no difference in mortality between those with and those without superinfections. Ott, found that the mortality rate was quite different. The case group (MRSA) had 13 deaths (32%), and the control group of MSSA only had 1 death (2%).

Overall, it seems that for the largest majority of patients, VAP/HAP increases your LOS, cost and in many cases mortality.
Chapter 3: Methodology

The data was obtained through a written request from the Information Warehouse. The data is all de-identified information of patients that were admitted to the Wexner Medical Center at The Ohio State University between the dates of November 1, 2011, and December 31, 2012. Each of the following types of data was obtained on its own separate spread sheet and contained information on only patients mechanically ventilated for 48 hours or longer, admitting diagnosis, ICU charges, ICU dates, and one titled cohort. The cohort spread sheet listed all the patients’ age, gender, total hospital charge, and dates of admission to and discharge from the hospital. Patients who had developed VAP during their hospitalization were clearly indicated by a “Y” in a column marked VAP patients on the cohort spreadsheet. The VAP patients were determined by ICD 9 code. There were over 3300 patients in the cohort of which 121 (approximately 3.5%) were identified as having VAP.

A matched cohort was created. The VAP patients were isolated from the larger list and listed by patient identification number. The spreadsheet was then created by compiling data from the provided spreadsheets to include age, gender, ICD 9 code (International Classification of Diseases, ninth
revision), admitting diagnosis, dates the patient entered the hospital and was
discharged from the hospital, date of admittance to and discharge from the ICU,
total ICU charge, and total hospital charge. This created the study group. Once
completed, the patients were matched against other mechanically ventilated
patients who did not develop VAP during their hospital stay, and they became the
control group. The patients were matched on the following criteria, ± 5 years in
age, gender and like admitting diagnosis and ICD 9 codes. In several instances,
the ICD 9 codes were identical although the stated diagnosis associated with it
was different. Patients were only considered a match if the ICD 9 code and the
listed admitting diagnosis was identical.

Population and Sample Size:

There were 121 known cases of VAP between 11/1/2011 and 12/31/2012.
After the matching process was complete, there were 45 patients in the control
and study groups. When the original request was submitted to the IRB, the
following patient groups were excluded from the possible patient pool, prisoners,
neonates, pregnant women, patients with Acute Respiratory Distress Syndrome
identified by ICD 9 code as well as burn and trauma patients, also identified via
ICD 9 code. How many patients were excluded is not known. The IRB
determined this research did not need a human subjects review. Patients were
disqualified for multiple reasons. Some did not have an admission to the ICU,
and several did not have a listed admitting diagnosis. As stated earlier, even if the ICD 9 codes were identical, but the stated admitting diagnosis was different, those patients were not considered to be a match. Some just did not have a match based on age and/or gender. Also, despite requesting that certain patient groups be excluded when the data was obtained, several patients had to be excluded because they were in the excluded categories, such as a neonate with respiratory distress, and a pregnant woman with placental previa.

Data Analysis

The study and control groups are very similar in content. The study group averaged 61.6 years of age with 67% of the patients being male and 33% female. The control group averaged 61.2 years of age, with 67% of the patients being male and 33% female. There were a total of 14 patients who expired in the study group and 12 patients who expired in the control group. T tests were performed on the 6 variables that were investigated in reference to the patients’ length of stay and charges in both the ICU and hospital, and their average per day charges both in the ICU and for their non-ICU days. A McNemar Chi Square test was performed on the mortality data comparing both groups. Descriptive statistics were completed.
Chapter 4: Results

The Wexner Medical Center had over 3300 patients who were mechanically ventilated for greater than 48 hours between the dates of November 1, 2011 and December 31, 2012. Of those patients, 121 developed VAP which is approximately 3.5%.

The study group (VAP patients), consisted of 45 patients, 30 (67%) of which were male and 15 (33%) were female. Their mean age was 61.6 years old. The study patients averaged 24.9 days in the ICU and averaged 30.2 days total in the hospital. They also had a higher mean overall charge in the ICU of $417,203.65, and $495,382.85 mean total hospital charge. Their overall average charge per ICU day was $16,732.77, and their overall average non-ICU charge per day was $14,844.15. Patients were in the hospital for a range of 3 to 92 days, and in the ICU for a range of 1 to 86 days. A total of 31 patients (69%) were alive at discharge from the hospital and 14 patients (31%) expired during their hospital stay.

The control group also consisted of 45 patients, 30 (67%) of which were male and 15 (33%) were female. The mean age for this group was 61.2 years old. Each patient within this group was matched by ICD 9 code and written diagnosis to a patient within the study group. The average number of days that
this group was in the ICU was 11.33, and in the hospital an average of 18.67 days. The average daily ICU charge per day was $20,480.80, and the average cost of a non-ICU day $10,280.54. Patients were hospitalized between 2 and 49 days and in the ICU between 1 and 35 days. A total of 33 patients (73%) were alive upon discharge from the hospital, and 12 patients (27%) expired during their hospital stay. Age is listed on the table below to show similarity between the groups, but was not analyzed. See table below.

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Study Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>61.2 years</td>
<td>61.6 years</td>
</tr>
<tr>
<td><strong>Days in the ICU</strong></td>
<td>11.33 (SD= 9.75)</td>
<td>24.9 (SD= 16.99)</td>
</tr>
<tr>
<td><strong>ICU charges</strong></td>
<td>$232,115.77 (SD= $235,063)</td>
<td>$417,203.65 (SD= $363,498)</td>
</tr>
<tr>
<td><strong>Days in the Hospital</strong></td>
<td>18.67 (SD= 12.441)</td>
<td>30.2 (SD= 18.92)</td>
</tr>
<tr>
<td><strong>Overall Hospital Charges</strong></td>
<td>$307,506.42 (SD= $235,874)</td>
<td>$495,382.85 (SD= $413,255)</td>
</tr>
<tr>
<td><strong>Number of Patients who Expired in the Hospital</strong></td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>

*Table 1: Mean Days in Hospital, ICU and Total Charges for the Study Group and Control Group*
Table showing the mean differences between the groups

<table>
<thead>
<tr>
<th>Pair</th>
<th>Parameter</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
<th>95% CI of the difference Lower</th>
<th>95% CI of the difference Upper</th>
<th>t-test</th>
<th>df</th>
<th>Sig. of 2 tailed t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total days in the Hospital</td>
<td>11.53</td>
<td>20.63</td>
<td>3.08</td>
<td>5.34</td>
<td>17.73</td>
<td>3.75</td>
<td>44</td>
<td>0.001</td>
</tr>
<tr>
<td>2</td>
<td>Total days in the ICU</td>
<td>13.6</td>
<td>20.17</td>
<td>3.01</td>
<td>7.54</td>
<td>19.86</td>
<td>4.52</td>
<td>44</td>
<td>0.001</td>
</tr>
<tr>
<td>3</td>
<td>Total Hospital Charges</td>
<td>$196,453</td>
<td>$433,838</td>
<td>$64,673</td>
<td>$66,114</td>
<td>$326,792</td>
<td>3.04</td>
<td>44</td>
<td>0.003</td>
</tr>
<tr>
<td>4</td>
<td>Total ICU charges</td>
<td>$211,218</td>
<td>$402,470</td>
<td>$59,997</td>
<td>$90,303</td>
<td>$332,134</td>
<td>3.52</td>
<td>44</td>
<td>0.001</td>
</tr>
<tr>
<td>5</td>
<td>Non-ICU charges/day</td>
<td>$4447</td>
<td>$12,101</td>
<td>$2852</td>
<td>-$1571</td>
<td>$104,643</td>
<td>1.56</td>
<td>17</td>
<td>0.137</td>
</tr>
<tr>
<td>6</td>
<td>ICU-charges/day</td>
<td>-$6687</td>
<td>$17281</td>
<td>$2576</td>
<td>-$11,879</td>
<td>-$1,495</td>
<td>-2.60</td>
<td>44</td>
<td>0.013</td>
</tr>
</tbody>
</table>

Table 2: Mean differences between the control and study groups and statistical significance

Table 2 above shows the mean differences between the study and control groups. Five out of the six parameters show statistical significance. The one that does not show any significance is the Non-ICU day charges.

There were also only 18 matched pairs where both patients had days outside of the ICU. The other 27 pairs had one patient that did not have a stay outside of the ICU. This also decreases the power of this paired t-test.
McNemar's Chi Square p=0.527

<table>
<thead>
<tr>
<th></th>
<th>VAP</th>
<th>PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ALIVE</td>
<td>EXPIRED</td>
</tr>
<tr>
<td>CONTROL PATIENTS</td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td>ALIVE</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>31</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 3: Results of the individual pairs mortality.

This study was completed by matching VAP and non-VAP patients 1:1. Those two patients form a pair. Table 3 above shows the outcomes of the pairs. In other words, there were 27 pairs in which both patients were alive at discharge, and 8 pairs in which both patients expired. Therefore, there were a total of 35 patient pairs whose outcomes was the same for both the VAP and non-VAP patient. There were 10 pairs in which one patient expired and one was alive at discharge. McNemar's test was performed. The p= 0.527 value shows that there is not a statistical difference in mortality between the control and study group. McNemar's Chi Square value was 0.4.

Both groups had several patients who were admitted to, discharged from, and then readmitted to the ICU during a single hospital admission. The control group had 8 patients in this category and the study group had 7. The study group’s readmitted patients had an average age of 64.97 years of age, with 5 (72%) of the patients being male, and 2 (28%) being female. Two patients (29%) within this group expired during their hospitalization. They were 2 males aged 55.3 and 80.9 years old, both having been diagnosed with Pulmonary disease.
due to other mycobacterium. The two patients who expired were the only two with like diagnoses. The other diagnoses were hepatitis, HIV, Post concussion syndrome, Mosquito borne hemorrhagic fever, and other specified diseases of the appendix. Amongst the control group’s readmitted patients there was only one patient (12.5%) who expired, a 55.2 year old male who was admitted with Tick borne hemorrhagic fever. Within this group there were 2 patients with Post concussion syndrome, 2 patients with Mosquito borne hemorrhagic fever, one with Brucella Suis, one with antepartum hemorrhage due to coagulation defects, and lastly, one with malignant neoplasm of the cervix, uteri, unspecified.

       The control group’s readmitted patients had an average age of 67.2 years and included 6 males (75%) and 2 females (25%) in it. Each group’s overall length of stay in the hospital increased. The control group’s readmitted patients increased to an average of 29.1 days, and the study group’s readmitted patients increased to an average of 34.9 days. Ultimately, amongst the control group’s readmitted patients, the largest difference is the average length of stay. This subgroup averaged 29.1 days which was 10.43 days longer than the group as a whole. See table below.
### Control and Study Groups Readmitted Patients

<table>
<thead>
<tr>
<th>Mean</th>
<th>Control Group</th>
<th>Study Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age - Overall Group Mean</td>
<td>61.2</td>
<td>61.6</td>
</tr>
<tr>
<td>Age - Readmitted Patients Mean</td>
<td>67.2</td>
<td>64.7</td>
</tr>
<tr>
<td>Length of Stay - Overall Group hospital days mean</td>
<td>18.67</td>
<td>30.2</td>
</tr>
<tr>
<td>Length of Stay - Readmitted patients hospital days mean</td>
<td>29.1</td>
<td>34.9</td>
</tr>
</tbody>
</table>

**Table 4:** Study and control group patients readmitted to the ICU during a single hospital admission against their overall group means.

There are several other sub groups that had some interesting findings. First is the group of patients that are over the age of 80 of which there were 4 in each group. All the older patients in both the study and control groups were men and were alive at discharge except for one man in the study group. He expired after a 57 day hospitalization which was the longest of all the 80+ year old patients. The study group's average overall charge was higher amongst these 4 patients than the group as a whole by $32,335 with an average overall cost of $528,667. The 4 patients who comprised the control older subgroup had an overall hospital charge average of $241,675. This is an average of $65,831 less than their group as a whole. The control group's older patients had an average hospital length of stay of 20.4 days, which is an increase of 1.73 days over the
group as a whole (18.67 days). However, with the 4 patients who were 80+ within the study group the average hospital length of stay was 37.2 days which is a full 7 days longer than their group as a whole. See table 5 below.

Comparison of the 80+ year old to their group means

<table>
<thead>
<tr>
<th></th>
<th>Control group - 4 patients</th>
<th>Study Group - 4 patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number alive at discharge</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Mean group hospital charges</td>
<td>$307,506.42</td>
<td>$495,382.85</td>
</tr>
<tr>
<td>80+ mean hospital charges</td>
<td>$241,675.18</td>
<td>$528,667.85</td>
</tr>
<tr>
<td>Difference in hospital charges</td>
<td>-$55,831.24</td>
<td>+33,205.00</td>
</tr>
<tr>
<td>Average Group Length of Stay</td>
<td>18.67 days</td>
<td>30.2 days</td>
</tr>
<tr>
<td>Average 80+ group Length of Stay</td>
<td>20.4 days</td>
<td>37.2 days</td>
</tr>
<tr>
<td>Difference in Length of Stays</td>
<td>+1.73 days</td>
<td>+7 days</td>
</tr>
</tbody>
</table>

Table 5: Comparison of the 80+ year old patients to their group means and comparing the control and study groups.

Lastly, is the subgroup of patients who were under the age of 50. There were 7 in each group with 3 males and 4 females. Here again all the patients were alive at discharge except for one woman in the control group. She expired after a 9 day hospitalization. There were several large differences between these two younger subgroups. The control subgroup’s averages were very similar to their group as a whole. Their average length of stay in the ICU was 10.85 days.
and 18.57 overall hospital stay. Their average ICU charges were $230,334.90
(group average $232,115.77), and their overall hospital charges averaged
$302,159.95 (group average $307,506.42). Here again, their charges did not
vary much from their groups as a whole. However, the study group’s younger
patients’ length of stay in the ICU and hospital were very similar, with a median
stay of 36.86 days in the hospital and 34.57 days in the ICU. Out of the 7
patients in the study younger subgroup 5 remained in the ICU for their entire
hospital stay. The remaining two were quite different with one being outside the
ICU only a portion of one day, and the last patient was in the ICU 12 days of her
28 day hospitalization. The study group’s younger patients’ overall ICU charge
average and overall hospital charge average were substantially higher than their
group as a whole with a mean ICU charge of $592,585.68 and a mean hospital
charge of $615,863.59. This shows an increase in charges over the entire group
mean of $175,382.03 in ICU charges and $120,480.74 in overall hospital
charges. See the table 6 below for a comparison between the groups of patients
under the age of 50.
Comparison of the Control and Study Groups Patients under the age of 50

<table>
<thead>
<tr>
<th>Means</th>
<th>Control Group - 7 patients</th>
<th>Study Group - 7 patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups overall ICU Length of Stay</td>
<td>11.33 days</td>
<td>24.9 days</td>
</tr>
<tr>
<td>Under 50 years old ICU Length of Stay</td>
<td>10.87 days</td>
<td>34.6 days</td>
</tr>
<tr>
<td>Groups overall ICU charges</td>
<td>$232,225.77</td>
<td>$417,203.65</td>
</tr>
<tr>
<td>Under 50 years old ICU charges</td>
<td>$230,334.90</td>
<td>$592,585.68</td>
</tr>
<tr>
<td>Groups overall hospital Length of Stay</td>
<td>18.67 days</td>
<td>30.2 days</td>
</tr>
<tr>
<td>Under 50 years old hospital Length of Stay</td>
<td>18.57 days</td>
<td>30.86 days</td>
</tr>
<tr>
<td>Groups overall hospital charges</td>
<td>$307,506.42</td>
<td>$495,382.85</td>
</tr>
<tr>
<td>Under 50 years old hospital charges</td>
<td>$302,159.95</td>
<td>$615,863.59</td>
</tr>
<tr>
<td>Number of patients alive at discharge</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 6: Difference between the control and study groups means for the patients who were under 50 years of age.
Chapter 5: Discussion

The focus of this research was to determine what effect VAP had on patients and their outcomes and hospital charges. The objective was to examine the overall charge, and the length of stay increase in both the ICU and hospital and to determine whether VAP patients were more likely to expire over their non-VAP counterparts.

The largest differences between the two groups is in their length of stay in both the hospital and ICU. The study group averaged 24.9 days in the ICU and 30.2 days in the hospital. The control group averaged 11.33 (45% of the study group average length of stay) days in the ICU, and 18.67 (62% of study group average length of stay) days in the hospital. These increases were shown to be statistically significant. This increased length of stay seems to have the greatest effect on their final costs. The control group averaged an ICU charge of $232,115.77 (56% of study groups' charge), with a total hospital average of $313,003.48 (63% of study group charge). The study group’s averages were substantially higher, with an average ICU charge of $417,203.65, and overall hospital charge of $495,382.85. These increased charges were also shown to be statistically significant. The patients had a wide range of diagnoses, but two were the most prevalent. They were Mosquito borne hemorrhagic fever (9), and Post
conussion syndrome (9), which comprised 18 (40%) out of the 45 patients diagnoses. Although not explored in this research, it would be an interesting future study to find out why these patients may be more susceptible to developing a VAP.

Within the control group there were 19 (42%) patients with a total hospital bill of less than $200,000 and only one patient with a total hospital bill of greater than $1,000,000. Within the study group, there were 8 patients (18%) with a total hospital bill of less than $200,000 and 3 patients that had a total bill of greater than $1,000,000; one had a total bill of $2,353,750.

When the cost per day was averaged for the ICU, the control group had a higher average cost by $3748 per day over the study group. Why that is is unknown. However, when the average non-ICU costs were calculated, the study group had a higher daily average cost of $4563. Therefore, the total costs averaged per day were very similar from the control to study group as seen below.

There were 3 subgroups that were examined. They were those patients admitted to and discharged from the ICU more than once during a single hospital admission, those over the age of 80, and those who were less than 50 years of age.

The patients who were admitted to the ICU more than once during their hospitalization all showed an increased length of stay. The control groups
readmitted patients hospital length of stay increased by 10.43 days, while the study groups readmitted patients hospital length of stay increased by 4.7 days. The reason for this is unknown.

The control and study groups over 80 years of age patients had an interesting finding. The control groups older patients despite having a 1.73 day longer stay in the hospital had a mean hospital charge of $65,831 less than their group as a whole. The older patients in the study group had an increase mean hospital charge of $32,335 even though their length of stay was a full 7 days longer than their overall group. This seems to imply that being over 80 and developing VAP increases your charges and length of stay even further. It may also imply that those patients over the age of 80 who did not develop VAP were healthier individuals to begin with which is why their total charges were less than their overall group means.

Those under the age of 50 had an interesting finding. The control groups under 50 patients charges and length of stay were very similar to their overall group. However, the study groups patients under the age of 50 had a mean increase length of stay of 10.85 days longer in the ICU and 18.57 days in the hospital longer than their overall group mean. They also had a substantial increase in charges. Their ICU charges increased by $175,382 and their hospital charges increased by $120,480. This implies that if you are under 50 and develop VAP, the sicker you are and the higher your charges become.

Ultimately, this study shows that the charges incurred from VAP are high,
probably due to the increased length of stay in primarily the ICU. Overall, the total hospital charges were an average of $187,876 per admission more than those in the control group. Most of this charge is incurred during their time in the ICU, where the study group's average length of stay was 12.87 days longer. The average charges of the control and study patients non-ICU charges were $75,390 and $78,179 respectively, even though the control groups average non-ICU length of stay averaged 7.34 days and the study groups was 5.3 days.

An interesting finding is that there was very little difference between the groups in terms of mortality. The control group had a total of 12 patients expire while the study group had 14 patients expire. Those who expired within the control group were 8 males (66%) and 4 females (34%). This is consistent with the general make-up of both groups. Those who expired within the study group were 11 males (79%) and 3 females (21%). Within the study group, the percentage of males who expired was 13% higher, and the females were 13% lower than the make-up of the groups. Perhaps, another interesting topic for future research because it suggests that males with VAP have a higher likelihood of dying in the hospital than females with VAP do.

Limitations

There are several limitations involved with this study. First, the data was
only collected at one hospital, the Wexner Medical Center at The Ohio State University, between the very specific dates of, November 1, 2011, and December 31, 2012 (14 month period). The Wexner Medical Center has many patients who are transferred from smaller hospitals because those hospitals are unable to care for the complexity of their cases or due to the uniqueness of their illnesses. The Wexner Medical Center is a teaching regional hospital. This may help to explain the odd mixture of diagnoses found within this study.

There were 45 patients per group after excluding all of those for whom there was no match. This is a relatively small sample of patients. The question then becomes whether the results of this study are generalizable to other institutions. This research does show that there is definitely an increase in ICU charges and length of stay when one develops VAP as well as overall hospital charges and length of stay.

The patients in each group were only matched by primary admitting diagnosis without concern of what other diagnoses they may have had on admission. This research did not investigate what caused the patients’ VAP so it is not known if any of these patients had a superinfection. It is also possible that several patient were transferred from other institutions and therefore did not develop their VAP at the Wexner Medical Center. However, the patients were all mechanically ventilated at the Wexner Medical Center for greater than 48 hours in order for them to be included in this study.

On July 1, 2012 there was a change made by the CDC in their definition of
VAP. The requirement for a new persistent alveolar infiltrate on a chest x-ray was eliminated. It is unknown what effect that change may have made to the number of VAP cases being diagnosed with VAP before and after that date.

The Wexner Medical Center underwent a large change in their charting procedures on 10/11/2011. That is the date they switched to strictly computer based charting from paper charting. What impact that may have had on this study is unknown. However, this study encompasses only patients who were admitted after that date.

Implications for Practice

As the culture of health care is continually changing, the costs will become increasingly more of a focus. This is because of the increasing costs of health care. As it stands now, VAP is one of the HAI’s for which the CMS has determined that payment will no longer be made for the services rendered. This is because the CMS views VAP as preventable. In 2002, Rello, et al, found that the total billed hospital charges were greater than $40,000 more for a patient with VAP over a similar patient without VAP. This research done 10 years later shows the mean hospital billed charges to be $187,876.43 more than for non-VAP patients. This appears to be a substantial increase in charges in just 10 years. Prevention seems to be the key. It needs to be the focus, as once VAP is
acquired the costs escalate. Educating the staff to new research findings will help keep them abreast of changes that can be implemented to make their practice safer for patients and therefore help to further decrease the incidence of VAP.

Abiding by known isolation techniques and hand washing by the staff are protocols that need to be followed by everyone all the time. Implementation of the VAP bundle recommended by the CDC has proven to decrease the number of patients that develop VAP at the Wexner Medical Center and needs to be strictly adhered to as well. The VAP bundle has been in place at the Wexner Medical Center since early 2007 and revised in 2012 to remain current with the newest research findings. The Wexner Medical Center VAP bundle includes, deep vein thrombosis prophylaxis, stress ulcer prophylaxis, head of the bed at a 30 degree angle minimum, an oral hygiene program, a daily sedation interruption and a daily spontaneous breathing trial. This bundle has proven to decrease VAP, as per a conversation with the Clinical Epidemiologist, it can be difficult to implement because some patients’ conditions prevent its implementation, such as, someone with low blood pressure not being able to tolerate having the head of the bed at a minimum of 30 degree angle.

Oral care is also being focused on as a way of preventing VAP. Recently researchers have been investigating different oral care routines and the use of Chlorhexadine Gluconate. The Wexner Medical Center has implemented the use of Chlorhexidine Gluconate at the suggestion of the American Thoracic Society for open heart patients only (Ashraf, 2012, page 7). Ashraf also states that
Chlorhexadine 2% is showing promising results in other populations (2012, page 7), therefore its usage may become more widespread. There is also research being done on different types of Endotracheal Tubes (ETT). Some are being coated with different substances to see whether those substances decrease the frequency of VAP by decreasing the amount of bacteria present. Other ETT have a port added so that the port can be attached to continual suctioning. This is done in the hopes that fewer secretions will get into patients lungs and therefore decrease VAP.

Future Research

It would be interesting to see what other factors/conditions the VAP patients may have had, if any, that increased their length of stay in the ICU, and therefore, their total charges. This could be accomplished by looking at the patient’s individual billed charges. Did these expenses come from procedures, medications, additional laboratory and/or medical diagnostic tests, or a combination of things? Did these patients have more co-morbidities than the control group or were they just more infirm from the beginning?

Are there tests, procedures, or medications that could be performed earlier, more aggressively, or eliminated, that would shorten the VAP patient’s LOS, and therefore decrease their total charges? Was it necessary that these patients remained in the ICU as long as they did, or would it have been possible
to discharge them from the ICU sooner, and therefore decrease their total charges? If these patients were discharged sooner from the ICU &/or the hospital would it have any negative outcomes?

Overall, this research shows that in this Medical Center ICU charges and hospital charges are higher on the average for the VAP patients over their non-VAP counterparts. Their hospital and ICU stays are also longer. Mortality did not show any significance from the study to the control group.
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Appendix A: Flowsheets
Pneumonia flow diagram alternate criteria for infants and children.

Abbreviations:
- BAL: bronchoalveolar lavage
- EIA: enzyme immunoassay
- FAMA: fluorescent-antibody staining of membrane antigen
- IFA: immunofluorescent antibody
- LRT: lower respiratory tract
- PCR: polymerase chain reaction
- PMN: polymorphonuclear leukocyte
- RIA: radioimmunoassay

Reporting instructions:
- There is a hierarchy of specific categories within the major type pneumonia (PNUL). Even if a patient meets criteria for more than 1 specific site, report only 1:
  - If a patient meets criteria for both PNUL and PNU2, report PNU2.
  - If a patient meets criteria for both PNU2 and PNU3, report PNU3.
  - If a patient meets criteria for both PNUL and PNU3, report PNU3.
  - Report concurrent lower respiratory tract infection (e.g., abscess or empyema) and pneumonia with the same organism(s) as pneumonia.
  - Lung abscess or empyema without pneumonia are classified as LUNG.
  - Bronchitis, tracheitis, tracheobronchitis, or bronchiolitis without pneumonia are classified as BRON.
Algorithms for clinically defined pneumonia (PNU1)

<table>
<thead>
<tr>
<th>Signs/Symptoms</th>
<th>Radiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOR ANY PATIENT, at least 1 of the following:</td>
<td>Two or more serial chest radiographs with at least 1 of the following&lt;sup&gt;1,2&lt;/sup&gt;:</td>
</tr>
<tr>
<td>- Fever (&gt;38°C or &gt;101.4°F) with no other recognized cause</td>
<td>- New or progressive and persistent infiltrate</td>
</tr>
<tr>
<td>- Leukopenia (&lt;4000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) or leucocytosis (≥15,000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) and left shift (≥10% band forms)</td>
<td>- Consolidation</td>
</tr>
<tr>
<td>- For adults ≥70 years old, altered mental status with no other recognized cause</td>
<td>- Cavity</td>
</tr>
<tr>
<td>and at least 2 of the following:</td>
<td>- Pneumatoceles, in infants ≤1 year old</td>
</tr>
<tr>
<td>- New onset of purulent sputum&lt;sup&gt;3&lt;/sup&gt; or change in character of sputum&lt;sup&gt;4&lt;/sup&gt; or increased respiratory secretions or increased suctioning requirements</td>
<td>NOTE: In patients without underlying pulmonary or cardiac disease (eg, respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), a definitive chest radiograph is acceptable.&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>- New onset or worsening cough, or dyspnea, or tachypnea&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>- Rates&lt;sup&gt;4&lt;/sup&gt; or bronchial breath sounds</td>
<td></td>
</tr>
<tr>
<td>- Worsening gas exchange (eg, O₂ desaturations [eg, PaO₂/FiO₂ ≤240], increased oxygen requirements, or increased ventilator demand)</td>
<td></td>
</tr>
<tr>
<td>ALTERNATE CRITERIA, for infants ≤1 year old:</td>
<td></td>
</tr>
<tr>
<td>Worsening gas exchange (eg, O₂ desaturations, increased oxygen requirements, or increased ventilator demand) and at least 3 of the following:</td>
<td></td>
</tr>
<tr>
<td>- Temperature instability with no other recognized cause</td>
<td></td>
</tr>
<tr>
<td>- Leukopenia (&lt;4000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) or leucocytosis (≥15,000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) and left shift (≥10% band forms)</td>
<td></td>
</tr>
<tr>
<td>- New onset of purulent sputum&lt;sup&gt;3&lt;/sup&gt; or change in character of sputum&lt;sup&gt;4&lt;/sup&gt; or increased respiratory secretions or increased suctioning requirements</td>
<td></td>
</tr>
<tr>
<td>- Apneoa, tachypnea&lt;sup&gt;4&lt;/sup&gt; nasal flaring with retraction of chest wall or grunting</td>
<td></td>
</tr>
<tr>
<td>- Wheezing, rales&lt;sup&gt;4&lt;/sup&gt; or rhonchi</td>
<td></td>
</tr>
<tr>
<td>- Bradycardia (&lt;100 beats/min) or tachycardia (&gt;170 beats/min)</td>
<td></td>
</tr>
<tr>
<td>ALTERNATE CRITERIA, for child &gt;1 year old or ≥12 years old, at least 3 of the following:</td>
<td></td>
</tr>
<tr>
<td>Fever (&gt;38.4°C or &gt;101.1°F) or hypothermia (&lt;36.5°C or &lt;97.7°F) with no other recognized cause</td>
<td></td>
</tr>
<tr>
<td>Leukopenia (&lt;4000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) or leucocytosis (≥15,000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;)</td>
<td></td>
</tr>
<tr>
<td>New onset of purulent sputum&lt;sup&gt;3&lt;/sup&gt; or change in character of sputum&lt;sup&gt;4&lt;/sup&gt; or increased respiratory secretions or increased suctioning requirements</td>
<td></td>
</tr>
<tr>
<td>New onset or worsening cough or dyspnea, apnea, or tachypnea&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Rates&lt;sup&gt;4&lt;/sup&gt; or bronchial breath sounds</td>
<td></td>
</tr>
<tr>
<td>Worsening gas exchange (eg, O₂ desaturations [eg, pulse oximetry &lt;94%], increased oxygen requirements, or increased ventilator demand)</td>
<td></td>
</tr>
</tbody>
</table>

Footnotes to Algorithms:

1. Occasionally, in nonintubated patients, the diagnosis of health care–associated pneumonia may be quite clear on the basis of symptoms, signs, and a single definitive chest radiograph. However, in patients with pulmonary or cardiac disease (for example, interstitial lung disease or congestive heart failure), the diagnosis of pneumonia may be particularly difficult. Other noninfectious conditions (for example, pulmonary edema from decompensated congestive heart failure) may simulate the presentation of pneumonia. In these more difficult cases, serial chest radiographs must be examined to help separate infections from noninfectious pulmonary processes. To help confirm difficult cases, it may be useful to review radiographs on the day of diagnosis, 3 days prior to the diagnosis and on days 2 and 7 after the diagnosis. Pneumonia may have rapid onset and progression, but does not resolve quickly. Radiographic changes of pneumonia persist for several weeks. As a result, rapid radiographic resolution suggests that the patient does not have pneumonia but rather a noninfectious process such as atelectasis or congestive heart failure.

2. Note that there are many ways of describing the radiographic appearance of pneumonia. Examples include, but are not limited to, "air-space disease," "pulmonary infiltrate," "patchy areas of increased density." Although perhaps not specifically delineated as pneumonia by the radiologist, in the appropriate clinical setting these alternative descriptive words should be seriously considered as potentially positive findings.

3. Purulent sputum is defined as secretions from the lungs, bronchi, or trachea that contain ≥25 neutrophils and ≥10 squamous epithelial cells per low power field (≥100). If your laboratory reports these data quantitatively (eg, "many WBCs" or "few squamous"), be sure their descriptors match this definition of purulent sputum. This laboratory confirmation is required because written clinical descriptions of purulence are highly variable.

4. A single notion of either purulent sputum or change in character of the sputum is not meaningful; repeated notions over a 24-hour period would be more indicative of the onset of an infectious process. Change in character of sputum refers to the color, consistency, odor, and quantity.
### Algorithms for pneumonia with common bacterial or filamentous fungal pathogens and specific laboratory findings (PNU2)

<table>
<thead>
<tr>
<th>Radiology</th>
<th>Signs/Symptoms</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two or more serial chest radiographs with at least 1 of the following:</td>
<td>At least 1 of the following:</td>
<td>At least 1 of the following:</td>
</tr>
<tr>
<td>- New or progressive and persistent infiltrate</td>
<td>- Fever (&gt;38°C or &gt;100.4°F) without other recognized causes</td>
<td>- Positive growth in blood culture&lt;sup&gt;5&lt;/sup&gt; not related to another source of infection</td>
</tr>
<tr>
<td>- Consolidation</td>
<td>- Leukopenia (&lt;4000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) or leukocytosis (&gt;12,000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>- Positive growth in culture of pleural fluid</td>
</tr>
<tr>
<td>- Cavitation</td>
<td>- For adults ≥70 years old, altered mental status with no other recognized cause and at least 1 of the following:</td>
<td>- Positive quantitative culture&lt;sup&gt;6&lt;/sup&gt; from minimally contaminated LRT specimen (eg, BAL or protected specimen brushing)</td>
</tr>
<tr>
<td>- Pneumatoceles, in infants ≤1 year old</td>
<td>- New onset of purulent sputum&lt;sup&gt;7&lt;/sup&gt; or change in character of sputum&lt;sup&gt;7&lt;/sup&gt; or increased respiratory secretions or increased suctioning requirements</td>
<td>≥5% BAL-obtained cells contain intracellular bacteria on direct microscopic exam (eg, Gram stain)</td>
</tr>
<tr>
<td>NOTE: In patients without underlying pulmonary or cardiac disease (eg, respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), a definitive chest radiograph is acceptable.&lt;sup&gt;1&lt;/sup&gt;</td>
<td>- New onset or worsening cough or dyspnea or tachypnea&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Histopathologic exam shows at least 1 of the following evidences of pneumonia:</td>
</tr>
<tr>
<td></td>
<td>- Worsening gas exchange (eg, O&lt;sub&gt;2&lt;/sub&gt; desaturations [eg, PaO&lt;sub&gt;2&lt;/sub&gt;/FiO&lt;sub&gt;2&lt;/sub&gt; ≤240]&lt;sup&gt;2&lt;/sup&gt;, increased oxygen requirements, or increased ventilator demand)</td>
<td>- Abscess formation or foci of consolidation with intense PMN accumulation in bronchiectasis and alveoli</td>
</tr>
</tbody>
</table>

### Algorithms for pneumonia with viral, Legionella, Chlamydia, Mycoplasma, and other uncommon pathogens and specific laboratory findings (PNU2)

<table>
<thead>
<tr>
<th>Radiology</th>
<th>Signs/Symptoms</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two or more serial chest radiographs with at least 1 of the following:</td>
<td>At least 1 of the following:</td>
<td>At least 1 of the following:</td>
</tr>
<tr>
<td>- New or progressive and persistent infiltrate</td>
<td>- Fever (&gt;38°C or &gt;100.4°F) without other recognized causes</td>
<td>- Positive culture of virus or Chlamydia from respiratory secretions</td>
</tr>
<tr>
<td>- Consolidation</td>
<td>- Leukopenia (&lt;4000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;) or leukocytosis (&gt;12,000 WBC/mm&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>- Positive detection of viral antigen or antibody from respiratory secretions (eg, EIA, FAMA, shell vial assay, PCR)</td>
</tr>
<tr>
<td>- Cavitation</td>
<td>- For adults ≥70 years old, altered mental status with no other recognized cause and at least 1 of the following:</td>
<td>- Four-fold rise in paired sera (lgG) for pathogens (eg, influenza viruses, Chlamydia)</td>
</tr>
<tr>
<td>- Pneumatoceles, in infants ≤1 year old</td>
<td>- New onset of purulent sputum&lt;sup&gt;7&lt;/sup&gt; or change in character of sputum&lt;sup&gt;7&lt;/sup&gt; or increased respiratory secretions or increased suctioning requirements</td>
<td>- Positive PCR for Chlamydia or Mycoplasma</td>
</tr>
<tr>
<td>NOTE: In patients without underlying pulmonary or cardiac disease (eg, respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), a definitive chest radiograph is acceptable.&lt;sup&gt;1&lt;/sup&gt;</td>
<td>- New onset or worsening cough or dyspnea or tachypnea&lt;sup&gt;8&lt;/sup&gt;</td>
<td>- Positive micro-IF test for Chlamydia</td>
</tr>
<tr>
<td></td>
<td>- Worsening gas exchange (eg, O&lt;sub&gt;2&lt;/sub&gt; desaturations [eg, PaO&lt;sub&gt;2&lt;/sub&gt;/FiO&lt;sub&gt;2&lt;/sub&gt; ≤240]&lt;sup&gt;2&lt;/sup&gt;, increased oxygen requirements, or increased ventilator demand)</td>
<td>- Positive culture or visualization by micro-IF of Legionella spp, from respiratory secretions or tissue</td>
</tr>
<tr>
<td></td>
<td>- New onset or worsening cough or dyspnea or tachypnea&lt;sup&gt;8&lt;/sup&gt;</td>
<td>- Detection of Legionella pneumophila serogroup 1 antigens in urine by RIA or EIA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Fast-fold rise in L. pneumophila serogroup 1 antibody titer to 1:128 in paired acute and convalescent sera by indirect IFA</td>
</tr>
</tbody>
</table>

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5. In adults, tachypnea is defined as respiratory rate >25 breaths per minute. Tachypnea is defined as >75 breaths per minute in premature infants born ≤37 weeks gestation and until the 40th week; >60 breaths per minute in infants <2 months old; >50 breaths per minute in infants 2 to 12 months old; and >30 breaths per minute in children >1 year old.

6. Rates may be described as "crackles."

7. This measure of arterial oxygenation is defined as the ratio of the arterial tension (PaO<sub>2</sub>) to the inspiratory fraction of oxygen (FiO<sub>2</sub>.

8. Care must be taken to determine the ediology of pneumonia in a patient with positive blood cultures and radiographic evidence of pneumonia, especially if the patient has invasive devices in place such as intravascular lines or an indwelling urinary catheter. In general, in an immunocompetent patient, blood cultures positive for coagulase-negative staphylococci, common skin contaminants, and yeasts will not be the etiologic agent of the pneumonia.

9. Refer to threshold values for cultured specimens (Table 8). An endotracheal aspirate is not a minimally contaminated specimen. Therefore, an endotracheal aspirate does not meet the laboratory criteria.

10. Once laboratory confirmed due to pneumonia because of respiratory syncytial virus (RSV), adenovirus, or influenza virus have been identified in a hospital, clinicians may make a presumptive diagnosis of these pathogens in subsequent cases with similar clinical signs and symptoms is an unacceptable criterion for presence of health care-associated infection.
### Algorithms for pneumonia in immunocompromised patients (PNU3)

<table>
<thead>
<tr>
<th>Radiology</th>
<th>Signs/Symptoms</th>
<th>Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two or more serial chest radiographs with at least 1 of the following:</td>
<td>Patient who is immunocompromised has at least 1 of the following:</td>
<td>At least 1 of the following:</td>
</tr>
</tbody>
</table>
| • New or progressive and persistent infiltrate | • Fever (>38°C or >100.4°F) with no other recognized cause | • Matching positive Blood and sputum cultures with Candida spp.
| • Consolidation | • For adults ≥70 years old, altered mental status with no other recognized cause | • Evidence of fungi or Pneumocystis carinii from minimally contaminated LRT specimen (eg, BAL or protected specimen brushing) from 1 of the following: |
| • Cavitation | • New onset of purulent sputum or change in character of sputum or increased respiratory secretions or increased suctioning requirements | • Direct microscopic exam
| • Pneumatoceles, in infants ≤1 year old | • New onset or worsening cough or dyspnea or tachypnea | • Positive culture of fungi |
| **NOTE:** In patients without underlying pulmonary or cardiac disease (eg, respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary edema, or chronic obstructive pulmonary disease), a definitive chest radiograph is acceptable.4 | **NOTE:** | Any of the laboratory criteria defined under PNU2 |

11. Sputum or watery sputum is commonly seen in adults with pneumonia due to viruses and Mycoplasma although sometimes the sputum may be mucopurulent. In infants, pneumonia due to RSV or influenza yields copious sputum. Patients, except premature infants, with viral or Mycoplasma pneumonia may exhibit few signs or symptoms, even when significant infiltrates are present on radiographic exam.

12. Few bacteria may be seen on stains of respiratory secretions from patients with pneumonia due to Legionella spp, mycoplasma, or viruses.

13. Immunocompromised patients include those with neutropenia (absolute neutrophil count <500/mm³), leukemias, lymphomas, HIV with CD4 count <200, or splenomegaly; those who are early posttransplantation, on cytotoxic chemotherapy, or on high-dose steroids (eg, >40mg of prednisone or its equivalent >160mg hydrocortisone, >32mg methylprednisolone, >4mg dexamethasone, >200mg cortisone) daily for >2 weeks).

14. Blood and sputum specimens must be collected within 48 hours of each other.

15. Semiquantitative or nonquantitative cultures of sputum obtained by deep cough, induction, aspiration, or lavage are acceptable. If quantitative culture results are available, refer to algorithms that include such specific laboratory findings.

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### Threshold values for cultured specimens used in the diagnosis of pneumonia

<table>
<thead>
<tr>
<th>Specimen collection/technique</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung parenchyma*</td>
<td>≥10⁴ cfu/g tissue</td>
</tr>
<tr>
<td>Bronchoscopically obtained specimens</td>
<td></td>
</tr>
<tr>
<td>Bronchoalveolar lavage</td>
<td>≥10⁴ cfu/mL</td>
</tr>
<tr>
<td>Protected BAL</td>
<td>≥10⁴ cfu/mL</td>
</tr>
<tr>
<td>Nonbronchoscopically obtained (blind) specimens</td>
<td></td>
</tr>
<tr>
<td>Bronchoalveolar lavage</td>
<td>≥10⁴ cfu/mL</td>
</tr>
<tr>
<td>Protected BAL</td>
<td>≥10⁴ cfu/mL</td>
</tr>
</tbody>
</table>

*cfu, colony-forming units.

*Open-lung biopsy specimen and immediate post-mortem specimens obtained by transthoracic or transbronchial biopsy.