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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences of Emory University in partial fulfillment
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Abstract

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This study attempts to evaluate the impact of the utilization of the ventilator bundle checklist on health outcomes such as VAP, mortality, readmission, and general complications. In order to achieve this study's overall purpose, an extensive medical chart review was conducted at one hospital. Data on patient demographics and health outcomes was collected from ventilator patient records before and after the checklist was implemented. Upon a full regression analysis, this study found that the ventilator checklist significantly reduces the probability of readmission and mortality among all ventilator patients by 19 and 16 percentage points respectively.

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I: Introduction

According to the American College of Physicians, “the cost of healthcare poses the greatest single threat to the fiscal health of the United States” (2011). It has been estimated that healthcare expenditure will represent approximately 20% of the GDP in 2017, which means that the overall cost of healthcare will total to over 4 trillion dollars by the end of this decade (Callahan, 2009). Thus, the overarching question in most health economics based research is: how can we create a sustainable healthcare system that will allow the most consumers access to affordable medical care while also allowing suppliers to be adequately compensated?

In order to do answer this question, many researchers have attempted to identify the shortcomings of different types of healthcare systems. The general consensus among healthcare professionals and economists seems to be that the root cause of the American medical system’s shortcomings is the vast inefficiency in the manner that healthcare is provided. One study estimates that in 2011 “avoidable complications and unnecessary hospital readmissions” led to a total of 24 to 45 billion dollars in wasteful spending (Burton, 2012). As a result, much research has focused on improving and modifying the best practices implemented in medical facilities.

One relatively recent modification implemented by many hospitals is the use of checklists before, during, and after all medical procedures. There has been a large push in the medical community to further develop standardized best practices and to implement these methods by using checklists that articulate a step-by-step list of requirements for different types of medical procedures. In the past couple of years, researchers have developed a checklist for procedures like central line insertion, cardiac catheters, and general surgeries. One checklist that has been recently developed is the ventilator bundle checklist. This particular checklist has been used to decrease the large number of complications and deaths associated with the improper care of patients on medical ventilators. The medical community refers to the checklist as a "bundle" checklist due to the fact that it has grouped many individual methods of best practices into one overall endeavor to improve health outcomes. Past studies have evaluated the success of ventilator checklists by examining whether or not the checklist successfully decreases the prevalence of ventilator-associated pneumonia (VAP). VAP is one of the most common hospital acquired illnesses. Some studies have reported that the checklist decreases the VAP rate by 50% or higher (Dubose, 2008).

In this paper, I further evaluate if the implementation of ventilator bundle checklists has significantly improved additional health outcomes among ventilator patients. This paper is intended to be a case study and specifically analyzes data on the changes of health outcomes among ventilator patients before and after the implementation of a ventilator specific checklist. Due to the fact that patient specific data regarding the ventilator bundle checklist is not available to the public, I obtained and reviewed patient records to collect data on health outcomes and patient demographics from one hospital. After completing an extensive medical chart review, this study concluded that the use of ventilator checklists improves health outcomes among all ventilator patients by decreasing the likelihood of hospital readmission and mortality by 19 percentage points and 16 percentage points respectively.

II. Contribution

This study attempts to evaluate the broader effects of the ventilator bundle checklist by analyzing mortality, readmission, and general complications. Previous studies have focused solely on using the VAP rate to assess the difference in health outcomes after implementing the ventilator checklist. It should be noted that studies evaluating the effect of other types of medical checklists (surgical, central line, etc.) have considered its impact on these health outcomes. While VAP is the most prominent risk of the improper use of medical ventilators, ventilators can also cause complications like tracheal stenosis, perforation of the stomach lining, and pneumothorax. Also, because the incidence of VAP is already relatively low, it is difficult to prove that the implementation of the ventilator bundle checklist has led to a statistically significant decrease in the occurrence of ventilator-associated pneumonia. By including more variables to estimate health outcomes, this study provides a more thorough evaluation of the full benefits of the ventilator bundle checklist.

This study also attempts to improve upon past methodology by including patient demographics, initial medical condition, type of medical condition the patient was being treated for (admit reason), and the medical service that was responsible for treating the patient while evaluating health outcomes. Most previous studies on this topic have been clinical studies that simply measured the difference in the VAP rate before and after the implementation of the checklist. These studies often failed to consider other variables that may lead to a change in health outcomes. In addition, by conducting a retrospective medical record review, this study also hopes to remove the potential sampling bias that could occur in clinical studies of checklist implementation.

Despite the large number of studies proving the benefits of implementing medical checklists, many hospitals still refuse to adopt the policy. Only 25% of American hospitals have implemented Atul Gawande’s renowned surgical checklist (Clark, 2011). Many critics of the medical checklist system claim that the policy is unnecessary and wastes medical staffs' time and efficiency. However, no scientific study has been able to dispute the benefits of implementing a standard checklist for medical procedures. As a result, the World Health Organization and many other American healthcare agencies have tried to encourage the use of checklists in hospitals for all medical procedures. This paper ultimately hopes to offer necessary support in favor of the implementation of medical checklists.

III. Background

A. Literature Review of Medical Checklists

The idea of using checklists in hospital operating rooms first stemmed from a 2006 study by Pronovost et al. to reduce the number of central line catheter associated bloodstream infections in hospitals. In this study, researchers came up with a set of methods and procedures to reduce the central line infection rate. Pronovost et al instructed the healthcare staff on how to reduce the central line infection rate by doing things like increasing the number of times they washed their hands, monitoring the exact time antibiotics were given, changing the method in which patients were "draped" prior to inserting the central line, etc. The doctors and nurses were then each provided with a checklist (Figure 2) and told to implement them in their clinics.

After 3 months of implementation, the doctors and nurses were asked to monitor and report the central line infection rate back to the research group. In this study, the researchers found that the central line infection rate decreased by a dramatic 66%. As a result of avoiding treatment for these potential cases of central line infections, the hospitals saved an aggregate amount of 175 million dollars. In conjunction with this study, Pronovost and Hales (2006) published another article discussing the checklist as a means of improving performance and diminishing error in many different fields. In this study, the two authors asserted that the clearly apparent benefits of utilizing checklists in fields such as aviation and product manufacturing could also be applied to medicine.

Dr. Atul Gawande most famously introduced this method in his book, *The Checklist Manifesto (2008)*. According to Gawande (2008), due to the complicated yet often repetitive steps in medical procedures, “it is easy to overlook routine matters under the strain of [other] pressing immediate demands.” Borrowing the concept of implementing checklists from the Pronovost et al study and the aviation industry, Gawande went on to develop a checklist (Figure 1) to reduce improve health outcomes for surgeries. Gawande recognized that the idea of implementing checklists in operating rooms to improve health outcomes seemed rather far-fetched. Thus, in order to test his theory, he implemented a surgical checklist in 8 different hospitals around the world. In a follow up study published in 2009, Gawande announced that the implementation of the surgical checklists resulted in a 36% decrease in surgical complications, a 47% decrease in amenable deaths, and a 50% decrease in surgery related infections.

It is worth pointing out that a major criticism of Gawande’s studies have been that his data combines information from third world countries with first world countries and then goes onto make broad generalizations about improving healthcare systems as a whole. It seems rather obvious that implementing a checklist in a third world hospital with few regulations would result in a drastically large improvement in health outcomes. However, implementing the checklist in s first world hospital that already has a large number of other regulations may result in few and diminishing marginal benefits.

Another study conducted by Semel et al. (2010) used Gawande's data to evaluate whether the implementation of the checklist resulted in a decrease in the cost of healthcare. From their analysis, they found that within the 4 hospitals in high-income countries, the implementation of the checklist led to a 30% reduction in "major complications." Semel et al. focused on the use of the checklists within non-cardiac operations in American hospitals for a one-year time period. To determine the costs of implementing the checklist, the researchers calculated the health care professionals' opportunity costs of implementing and learning about the checklist. Based on this, they estimated that the total cost of implementing the checklist was $12,635 per hospital. The cost of implementing the checklist "per-use" was predicted to be $11. According to the study, "for every averted complication, there is a net savings of $8,652." Thus, assuming a surgical complication rate of 17%, a hospital could save as much as $2.7 million dollars a year by implementing the ventilator bundle checklist (Semel et al. 2010).

Many other studies have focused on expanding the surgical checklist and adding more checkpoints and standards to Gawande's checklist. For example, Vries et al. (2010) added more variables to measure health outcomes the checklist and found similar results as Gawande when the implemented the checklist in 6 different hospitals around the world. Few other studies that took issue with Gawande's measures of health outcomes tried changing the variables used to measure health outcomes. For example, Van Klei et al. (2012) used infant mortality rate as a measure of health quality and found a statistically significant decrease in the infant mortality rate when the checklist was used.

Past studies have also focused on developing checklists for other medical procedures. For example, one study examined benefits of a checklist developed for oxytocin administration procedure in mothers and newborns (Clark 2007). Another study developed a checklist in order to improve care for patients with cardiac catheterization (Regueriro 2013). Both of these studies reported an improvement in outcomes as a result of these checklists.

There has been a large problem within the medical community about compliance with these checklists. Although the checklist has shown to have great benefits if used properly, the use of the checklist is often forgotten or disregarded soon after implementation of the policy (Conley, 2010). Thus, many other studies have also focused on improving checklist compliance. For example, one study reported that mandating a verbal review of the checklist rather than a non-verbal review improves compliance by 7% (Byrnes 2007).

B. Background on Ventilators and the Ventilator Bundle Checklist

Since this study focuses on ventilator bundle checklists, it is important to first discuss some background information on medical ventilators and the development of this particular checklist. Medical ventilators are used for patients with serious medical issues who cannot properly breathe on their own. They are designed to flow air in and out of a patient's lungs. Ventilators provide patients with oxygen and carry out carbon dioxide and other "waste gas" (NHLBI, 2011). The modern medical ventilator essentially consists of an electronically controlled pump, an oxygen reservoir, multiple types of pressure valves, air filters, and a "circuit," which is a set of tubes that are connected to the ventilator pump and inserted into the patient. There are multiple methods of inserting the circuit tubes into the patient. The most common is the endotracheal method in which the circuit tubes are inserted into the nasal cavity and then positioned into the throat. An alternative method, called a tracheostomy, is often used in emergency cases or when the patient needs to be ventilated for a longer amount of time. In this procedure, a hole is surgically made in the neck and the circuit tubes are placed directly into windpipe. While ventilators are essential to the medical field, they have also posed many problems due to the large amount of complications associated with them.

The most direct risk of medical ventilator use is ventilator-associated pneumonia (VAP). Although studies have shown that VAP is highly preventable, it is one of the most common hospital acquired infections. Approximately 8-28% of patients on ventilators contract VAP (Chastre and Fagon 2002). VAP poses a serious risk to the patient's health. The mortality rate for patients who contract VAP is approximately 46%. On the other hand, the mortality rate for ventilator patients who do not contract VAP is roughly 32% (Abed and Al-Tawfiq 2010). Although any type of bacteria that cause other types of pneumonia can cause VAP, VAP can also result from many unique types of bacteria that are usually associated only with medical ventilator. The bacteria accumulate within the circuit tubes and the patient's mouth and ultimately travel into the lungs where they can take advantage of the patient's already weak immune system and multiply. By this mechanism, other types of infections and diseases can also occur. Because many of the VAP bacterial strains are multidrug resistant, it is difficult and costly to treat VAP. One study estimates the cost of treating VAP to be approximately 30,000 dollars per patient (Bird, 2010). As a result, much research on cost reductions in healthcare has focused on preventing VAP.

The ventilator checklist was developed as the result of many independent studies on methods to improve the complication and VAP rate for ventilator patients. The study site's ventilator checklist (Figure 3) involves 12 overall measures for improving health outcomes in ventilator patients. The first measure included on the checklist is head of bed elevation to a 30° to 45° angle. Studies have shown that head elevation can help prevent stomach acid from travelling up through the esophagus and into the patient's mouth (Keeley, 2007). This acid "backflow" often occurs in ventilated patients due to the fact they are sedated and cannot properly keep the esophageal sphincter closed. Many bacterial strains prefer to colonize in highly acidic environments thus, in order to prevent infection; it is vital to prevent the environment from turning acidic. Another measure, PUD (peptic ulcer disease) prophylaxis, is also included on the checklist to help reduce buildup of an acidic environment in the patient's mouth. Under this measure, the patient is given drugs like esomeprazole (Nexium) or omeprazole (Pepcid) to reduce the acid production in the stomach so that less acid will ultimately accumulate in the mouth. (NHLBI, 2011).

The next set of measures on the checklist is designed to remove the possible build up of hospital-acquired microbes in the patient's mouth and lungs. Because ventilator patients are usually sedated and kept within the ICU, it is quite easy for bacterial and viral strains from nearby patients to accumulate in the patient's mouth and lungs. One measure designed to decrease the build up of bacteria is simple oral care. This involves brushing the patient's teeth, swabbing the inside of the patient's mouth with hydrogen peroxide, etc. In addition to this, subglottic (area underneath the opening of the vocal chords), oral, and ballard suction are all measures included on the checklist in order to help remove harmful mucus, secretions and any possible build up of viruses or bacteria. The checklist also mandates that each type of suction be conducted by a different suction pump in order to avoid cross contamination. In addition to this, the checklist also includes a safety measure called a "sedation vacation." Under this measure, the patients are temporarily removed from their sedated state so that they can cough out any additional secretions/mucus that was not picked up by the different suction techniques. During this time, the checklist also mandates that the patient undergo speech therapy. Due to the positioning of the circuit tubes and the long length of sedation required for ventilator patients, a common side effect of medical ventilation is weakening of the oropharyngeal (throat) muscles. By conducting speech therapy, the strength of these muscles is maintained. This will allow the patient to cough out any secretions that may cause pneumonia or other infections (Hutchins 2009).

Due to the fact that the ventilated patients are temporarily immobilized, blood clots can form in the veins of the patient's leg and travel to different parts of the body, causing serious complications. Pulmonary embolism (blockage of pulmonary arteries) and stroke are just a few of the risk factors associated with blood clots. To avoid this complication, another measure included on included is DVT (deep vein thrombosis) prophylaxis. Under this measure, blood thinners like Heparin are given to the patient to avoid blood clot formation (Wip 2009)

Finally, some of the last measures on the checklist involve sputum (mixture of saliva and mucus) samples and chest-x rays. After a patient is placed on the ventilator, sputum samples from the patient are taken at regular intervals in order to diagnose potential infections as quickly as possible. Usually, earlier infection diagnosis leads to better health outcomes for the patient. Finally, the checklist mandates that an initial chest x-ray be taken after the patient is placed on the ventilator to ensure that the tube has been correctly positioned. Incorrect positioning can lead to issues like minor patient discomfort or serious medical complications like pneumothorax (collapsed lung). Chest x-rays can also help diagnose any lung infections that a patient may have contracted before being placed on the ventilator.

C. Literature Review on Ventilator Bundle Checklists

Improving health outcomes for ventilator patients has been a topic of research ever since the use of medical ventilators began. Many studies have shown that compliance with these individual best practices has been rather low. Thus, the new ventilator bundle checklist is unique in that it aims to provide healthcare professionals with a quick, simple tool to ensure that all of the necessary procedures have been followed (NHLBI, 2011). An approach to implement all of these individual methods together in a "bundle" was first introduced in 2002. The Institute for Healthcare Improvement (IHI) then heavily publicized the method in 2006. The IHI study compiled all past research on best practices and recommended the use of a checklist with a standard set of best practices to improve healthcare for ventilator patients.

After the IHI's publication of the ventilator bundle checklist, many clinical studies focused on quantifying the benefits of using the ventilator bundle checklist. While most studies differ over the exact quantitative benefits of implementing the ventilator checklist, all agree that the checklist causes a significant decrease in the VAP rate. One study reported that introducing the ventilator checklist improved compliance with the ventilator bundle measures by over 50%, which in turn led to a decrease in the VAP rate by 50% (Dubose, 2008). Another study that monitored the joint effectiveness of central line checklists and ventilator checklists found that compliance with ventilator bundle practices improved from 50% to 82% within 3 months of the introduction of the checklist in 9 individual study sites. The study also reported that the VAP rate for all study sites decreased by 41% within the same time frame (Bonello 2008). Finally, there has also been a large issue in healthcare professionals' compliance with the ventilator bundle checklist. As a result, many studies have focused on improving compliance with the ventilator checklist. For example, one study found that dedicating a team of nurses to strictly monitor checklist compliance led to an improvement in the compliance rate for each best practice measure by 9% (Mendez 2013).

Another study that completed a systematic literature review on many past ventilator checklist studies found that due to the "lack of methodological rigor," issues with bias and confounding variables, the results from most previous studies should not be used as evidence to implement the ventilator bundle checklist in hospitals (Zilberberg 2009). Furthermore, very few previous studies have controlled for patient demographics or initial medical condition while evaluating the effectiveness of the ventilator bundle checklist. One study attempted to evaluate the ventilator checklist in a busy trauma ICU by controlling for possible confounding factors such as age, injury mechanism, injury severity score (ISS) and the Glasgow Coma Scale (GCS) score. The ISS and GCS are standard practices used by healthcare professionals to evaluate the severity of a patient's initial medical condition. The study concluded that due to a 24% decrease in the VAP rate, hospitals were able to save 400,000 dollars as a result of the ventilator checklist implementation (Dubose, 2010). It should be noted that this decrease in the VAP rate was much smaller than the decrease in VAP rates reported by studies that did not control for confounding variables. Thus, in hopes of coming to a reasonable conclusion of the effectiveness of the ventilator checklist, this study also attempts to improve upon the methods used in previous literature.

II. Methods

A. Data Collection

Having discussed the relevant background, we may now turn to the methodology used in this particular study. As stated earlier, the purpose of this study is to evaluate if the implementation of ventilator specific medical checklists has significantly improved health outcomes in ventilator patients. In order to be able to control for other effects that may have an impact on health outcomes, this study chose to gather data on patient demographics, initial condition of the patient, reason for admission, and service responsible for ventilating the patient. In order to gather the relevant data, an extensive medical chart review was conducted on ventilator patients before and after the implementation of the checklist.

I obtained and reviewed a total of 296 patient records to collect data on health outcomes and patient demographics from the study site. A random sample of 116 ventilator patients was taken from a total of roughly 200 ventilator patients in 2007. Another random sample of 180 patients was taken from a total of roughly 240 ventilator patients in 2009. In order to obtain this random sample, every patient from every other month was selected. Due to the fact that the study site implemented the ventilator checklist in early 2008, patient information was gathered from 2007 and 2009. Ventilator patients from 2007 are patients on which the ventilator checklist was not used. Ventilator patients from 2009 are patients on which the checklist was used. Past studies have shown that for physicians and nurses take approximately 3-4 months to get accustomed to using medical checklists (Pronovost, 2006). Thus, by not collecting data from 2008, this study hopes to avoid a potential skew in results and evaluate the true effectiveness of the checklist. A healthcare specialist from the study site generated the random sample of the patients whose records were used in this study from the Eclipsys electronic medical record system.

At the study site, most patient information is recorded on the Eclipsys electronic medical record system. This electronic record contains basic information such as patient demographics, length of patient stay, readmission, and a general overview of the patient's visit. More detailed information on medication and complications is kept in the patients' paper record files that are stored in the study site's medical record storage facility. In order to gather the relevant information, I utilized both aspects of the patients' medical record. From each patient record, I gathered information in order to answer the following questions:

1) Did the patient suffer from complications like fever, infection, etc. that did not result in immediate death? (Yes or No)
2) Did the patient die? (Yes or No)
3) Was the patient readmitted to the hospital for an illness within 0-6 months? (Yes or No)
4) Did the patient contract a VAP? (Yes or No)
5) What was age of the patient at the time they were placed on the ventilator?
6) What type of service was the patient admitted to? (Medical, Emergency, ICU)
7) What was the race of the patient? (Black, White, Other)
8) What was the gender of the patient? (Male or Female)
9) What type of insurance did the patient use? (Private or Public)
10) Was the patient employed? (Yes or No)
11) What number of days was the patient kept on the ventilator?
12) Was the ventilator checklist used? (Yes or No)

The de- identified information gathered per patient was stored in an excel file according to a code that corresponded to the patient's medical record number. Due to the fact that most of the data collected was categorical (with the exception of ventilator days and age), dummy variables were created from the data in order to perform a statistical analysis and quantitatively evaluate the benefits of using the ventilator specific checklist.

Finally, it should be noted that Emory University and the study site gave IRB approval and a partial HIPPA waiver for the review of confidential patient records and data collection in this study. No information on the patients' HIPPA identifiers was ever collected or recorded during the course of the study and only de-identified data was included in this paper. Furthermore, in order to protect the patients' medical privacy, the list of patients whose records were used was promptly destroyed after the completion of the data collection stage of this study.

B. Empirical Strategy for Health Outcomes

To measure health outcomes, this study evaluates the individual impact of the usage of ventilator checklists on the likelihood of a ventilator patient dying, being readmitted, suffering from a general complication, and suffering from ventilator associated pneumonia. As discussed in the background section, the checklist is designed to not only help reduce the VAP rate but also to reduce the occurrence of other infections and complications. Even if the ventilator checklist succeeds in lowering the VAP rate, it may not be an efficient practice if it increases or does not change the rate of other infections or complications. The reverse relationship also holds: if the VAP rate is not significantly diminished, the ventilator checklist may still be of value if it leads to a lower general complication rate. Thus, this study evaluates the occurrence of complications among all patients who did not expire while on ventilators. It takes a broad approach to the definition of complications in that it includes all minor complications such as fever and nausea as well as all major complications such as a pneumothorax and deep vein thrombosis. Although improper ventilation may not necessarily lead to a patient's medical complications, this measure was included in order to capture the full potential benefits of the ventilator checklist. It is often not possible to determine from a medical record whether a certain complication arose due to improper ventilation. Thus, this study includes all complications with the assumption that the control variables in the estimation models will account for other potential causes of the complications.

This study also includes mortality rate as a measure of health outcomes for ventilator patients. Because most patients who are placed on ventilators already have extremely poor health and weak immune systems, the mortality rates for ventilator patients are relatively high. The ventilator checklist is also designed to reduce the mortality rate of ventilator patients by reducing the ventilator associated complication rate and improving the overall healthcare quality. Patient mortality was included in addition to complication rate because mortality is clearly caused by complications that were ultimately untreatable. The complication rate measures only the incidences in which the complication was nonterminal and the patient was discharged from the hospital. Patient mortality can also be caused by a number of reasons other than improper ventilation however; this study relies upon the control variables to account for these other causes.

The final measure that we include in order to measure health outcomes for ventilator patients is the readmission rate for all patients who were ultimately discharged from the hospital. In this study, any ventilator patient who is re-admitted to the hospital anytime within 6 months of their initial stay is considered to be a readmission. The average readmission rate for ventilator patients is roughly 38% (Douglas 2001). Re-admission within a short time period after an initial hospital stay is often avoidable and occurs if a patient suffers from complications due to the fact that the initial medical treatment was not properly conducted. It should be noted that readmission could also be a result of medical issues unrelated to the initial visit. While there has been some debate in the medical community about whether or not it is an accurate measure of healthcare quality, it still remains one of the most common measures to evaluate health outcomes (Milne and Clarke, 1990). For this reason, this study also includes the readmission rate as a measure for health outcomes.

C. Empirical Strategy for Control Variables

This study controls for the patient's age, race, gender, type of insurance used, employment, initial medical condition, and the medical "service" responsible for the patient's care. Clearly, patient demographics such as age, race, and gender can have a large effect upon health outcomes. Age is the largest concern for this study as past literature has shown that while the mortality rate for ventilator patients 65 or younger is roughly 11.7%, the mortality rate drastically increases to 72.1% for ventilator patients 85 years or older. Studies have also shown a similar increase in readmission and complication rates as age increases. Thus, age is included as a control variable for all health outcomes (Feng, 2009). There has been no documented relationship between gender and race to health outcomes of ventilator patients specifically. However, gender and race are included as controls in this study as a precaution as they have shown to have a large impact on health outcomes in other medical instances.

Due to the well-documented positive correlation between economic status and health outcomes, this study attempts to control for the patient's financial information (Deaton, 2003). Because a patients' income is not reported on medical records, this study chooses to instead control for the patients' employment status and health insurance type in order to indirectly control for the patients' financial status. This study makes the assumption that patients who are unemployed and/or use public health insurance are most likely of a lower socioeconomic class than those who are employed and/or use private health insurance.

In order to consider the impact of initial medical condition, this study has controlled for the number of ventilator days. It is necessary to control for a patient's initial medical condition due to the fact that patients with poor initial health are less likely to have positive health outcomes (Naessens and Huschka, 2004). Previous literature has shown that the length of time a patient is kept on the ventilator increases as the severity of the initial medical condition increases (Feng, 2009). Thus, we use ventilator days as a proxy variable for the patient's initial medical condition. In addition, this study also controls for the type of medical issue the patient was initially admitted for in order to control for other medical causes that may have an impact on the patient's overall health. For example, a patient admitted for cardiac arrest would most probably have different medical concerns and outcomes from a patient admitted for a respiratory condition. Due to the large variety in admission reasons, it is not possible to include a control variable for each different type of reason for admission. To cope with this limitation, this study groups the different types of medical issues into 5 major groups: cardiac, respiratory, renal (kidney), abdominal, and other.

Finally, this study also controls for the service or "medical team" in charge of the patients' care. This study recognizes that different healthcare professionals could use different methods and techniques that could ultimately have an impact on health outcomes. Thus, this study identified 3 different types of medical services at the study site that could be in charge of a ventilator patient's medical care: ICU, emergency, and medical. It should be noted that each of these medical teams employs a different set of nurses and doctors. The service that a patient is ultimately admitted to depends on the patient's initial condition and type of initial medical issue. For example a non-emergency cardiac patient would be admitted to a medical service where as a non-emergency patient with a respiratory condition would be admitted to the ICU service. It should also be noted that there are many different types of medical services such as cardiology, neurology, pulmonology, etc. however, due to our small sample size, it is not feasible to control for each different type of medical service, thus they have all been grouped under "medical service" in this study.

D. Hypotheses

Having discussed the empirical strategy and data collection, we may now discuss the hypotheses tested in this study. In order to achieve this paper's overall purpose of identifying whether or not the implementation of the checklist improve health outcomes, the following 4 hypotheses were tested.

1. H_o: The likelihood of patient readmission after the implementation of the ventilator bundle checklist is higher or equal to the likelihood of patient readmission before the implementation of the ventilator bundle checklist.

   H_a: The likelihood of patient readmission after the implementation of the ventilator bundle checklist is lower than the likelihood of patient readmission before the implementation of the ventilator bundle checklist

2. H_o: The likelihood of patient complications after the implementation of the ventilator bundle checklist is higher or equal to the likelihood of patient complications before the implementation of the ventilator bundle checklist

H_a: The likelihood of patient complications after the implementation of the ventilator bundle checklist is lower than the likelihood of patient complications before the implementation of the ventilator bundle checklist

3. H_o: The likelihood of a patient contracting a ventilator associated pneumonia after the implementation of the ventilator bundle checklist is higher or equal to the likelihood of a patient contracting a ventilator associated pneumonia before the implementation of the ventilator bundle checklist

   H_a: The likelihood of a patient contracting a ventilator associated pneumonia after the implementation of the ventilator bundle checklist is lower than the likelihood of a patient contracting a ventilator associated pneumonia before the implementation of the ventilator bundle checklist

4. H_o: The likelihood of a patient dying after the implementation of the ventilator bundle checklist is higher or equal to the likelihood of a patient dying before the implementation of the ventilator bundle checklist

   H_a: The likelihood of a patient dying after the implementation of the ventilator bundle checklist is lower than the likelihood of a patient dying before the implementation of the ventilator bundle checklist

It should be noted that because all outcome variables were categorical binary variables, the linear probability model was used to estimate the effect of the checklist on the individual health outcomes. A full description of the variables created from the data is included in Table 2.

III. Results and Discussion

This section reports the trends and results from a regression analysis on each of the 4 health outcomes listed above. Each outcome table includes a regression of the health outcome among all ventilator patients and regressions among individual patient subgroups (i.e. all female patients, all male patients, all unemployed patients, etc.) This section will also discuss the limitations in this study and possible alternative causes for the results found. Again, it should be noted that due to the fact that the dependent variables (health outcomes) are all categorical binomial variables, the LPM model was used to interpret the data collected. Table 1 provides a simple summary of the mortality rate, VAP rate, complication rate, and readmission rate before and after the implementation of the checklist. From this data it is appears as though the implementation of the ventilator checklist had a clear benefit in health outcomes for ventilator patients. A closer analysis of the regression results provides further conclusive evidence that the implementation of the ventilator checklist significantly improved the mortality and readmission rate.

Table 1

	2007 - No Checklist	2009 - Checklist Used
Mortality Rate	28%	12%
VAP Rate	3%	1%
Complication Rate	26%	22%
Readmission Rate	38%	21%

A. Readmission

Tables 3 and 3.1 display results from the different regressions that were analyzed in order to evaluate the effect of the checklist on the likelihood of readmission. From regression 1, we can see that that the use of the checklist decreases the likelihood of all ventilator patients being readmitted by 19 percentage points (pp.). This relationship is significant at the 1% level thus, we can be quite certain in rejecting the 1st null hypothesis to come to the conclusion that the use of the checklist does in fact correlate with a decrease in the likelihood of readmission.

Regressions 2 through 12 represent an analysis of the likelihood of readmission within specific subgroups. From these regressions, we can see that the use of the checklist leads to a significant decrease in the likelihood of readmission among male patients, patients with private insurance, white patients, and patients whom were admitted to an emergency or medical service.

From regression 3, we can see that males seem to benefit more from the checklist as the likelihood of readmission among male patients decreases by 26 pp. when the checklist is used. In addition, regression 8 reports that checklist utilization correlates with a 21 pp. decrease in the probability of readmission among white patients. One potential explanation for this pattern could be that healthcare professionals felt a greater need or desire to follow the checklist protocol while treating white and/or male patients, this would in turn improve the checklist's effect on readmission. This pattern could also occur if white patients or male patients benefit more from the checklist due to biological or genetic differences from their counterparts. For example, if males tend to produce more stomach acid than females, male ventilator patients could have a greater oral acid build up during ventilation. As a result, the checklist's measures to reduce the acid build up in ventilator patients could lead to a greater overall benefit for male patients.

As shown in regression 4, there is a 27 pp. decrease in likelihood of readmission for all those whom used private insurance. This result implies that the checklist had higher benefit among patients of a higher socioeconomic background. As discussed earlier, patients with a higher socioeconomic status tend to have better health outcomes due to the fact that they also tend to have better initial medical conditions. This pattern could also possibly stem from the fact that patients of higher socioeconomic statuses tend to be more willing and able to spend more on healthcare. Thus, one explanation for this pattern may be that wealthier patients chose to pay more for higher quality healthcare professionals who take greater care in complying with the ventilator checklist. This increased ventilator checklist compliance could in turn yield to fewer errors and thus a lower readmission rate among patients with private health insurance.

Perhaps the most interesting pattern in the data can be seen from regressions 11 and 12, which analyze the likelihood of readmission among ventilator patients that have been admitted into emergency and medical services respectively. From regression 11, we see that the use of the checklist led to a 32 pp. decrease in the likelihood of readmission among emergency service patients. On the other hand, regression 12 shows that the likelihood of readmission for medical service patients decreased by 22 pp., which is significantly lower than the reduction in likelihood of readmission for the emergency service patients. As discussed earlier, the checklist has shown to benefit health outcomes due to the fact that it serves as a reminder of the best practices that healthcare professionals often forget or disregard when under strict time constraints and in high-pressure environments. The emergency service most often handles patients with the most pertinent life threatening illnesses and is undoubtedly the service that faces the most time constraints and pressure. Thus, it logically follows that the checklist would have a much larger benefit among patients admitted to the emergency service.

It should be noted that readmission could occur for a number of non-ventilator associated medical reasons. If one of these other reasons was the true cause of the change in likelihood of patient readmission, it is possible that a Type 1 error could have made in our analysis. Avoidable complications, negligent post-discharge care by the patient, new illnesses, etc. are just a few examples of other causes that could cause a patient to be readmitted. As such, one limitation of this study is the inability to control for such variables. However, because the frequency of these issues has very little cause for change within the relatively short time frame of this study, these issues should most likely be captured by the constant term.

B. Complication

Tables 4 and 4.1 display the regression results used to analyze the effect of checklist utilization on the likelihood of complications. As shown in regression 1, this study found that the utilization of the ventilator checklist led to a 2 pp. increase in the likelihood of a patient suffering from complications at the 1% significance level. As a result, we cannot reject our 2nd null hypothesis and have no significant evidence to show that the checklist decreases the likelihood of complications among ventilator patients. The positive relationship in between checklist implementation and the likelihood of complications was unexpected due to the fact that the raw data from Table 1 displays a decrease in the complication rate after the checklist was implemented at the study site.

Upon further analysis within different subgroups, it was noted that the coefficient for the variable controlling for the number of ventilator days per patient ("VentDays") falls within the 1% and 5% significance level for 7 of the 11 subgroups. These results indicate that the number of ventilator days explain the likelihood of complication more than the use of the checklist. Among all of the subgroups, the coefficient controlling for subgroups is positive. This indicates that as the number of ventilator days increases, the likelihood of complication also increases. Recall that the number of ventilator days was controlled in order to indirectly account for a patient's initial medical condition. Thus, one potential explanation for these results is that the patient's initial medical condition has more of an effect on the likelihood of complications than checklist utilization. Another possible explanation is that medical complications actually cause the number of ventilator days per patient to increase. This would mean that the ventilator days would always show a strong positive correlation with the likelihood of patient complication.

Because accounting for the number of ventilator days may introduce a bias into the regression analysis, we also regressed each health outcome without this control variable. From regression 2 on Table 7, we ultimately conclude that the checklist implementation did not have any significant impact on the likelihood of patient complications. It is also important to note that due to the relatively small sample size, a Type 2 error may influence our results in this case.

It is also interesting to note that only patients who did not die were considered in this particular regression analysis. In other words, this study measures the likelihood of complication only among living patients. The medical records of expired patients do not often include information about complications. As a result, it was not possible to identify which expired patient suffered from a complication and which did not. Due to this limitation, it may be possible that the checklist could have actually decreased complications among patients who died. If the checklist helps significantly reduce complications among critically ill patients, it could cause the likelihood of mortality to decrease without causing the likelihood of complication among living patients to change. This explanation is further supported by the results (Table 6) that show that the likelihood of mortality did significantly decrease after the implementation of the checklist.

C. Ventilator Associated Pneumonia

Table 5 and 5.1 show the results of the regression analysis of VAP on checklist utilization. From these results, we cannot reject our 3rd null hypothesis and have do not have significant evidence to support the theory that checklist utilization decreases the likelihood of contracting VAP. This result was expected due to the extremely small incidence of VAP within our sample population. Only 4 patients in 2007 contracted a VAP and only 2 patients contracted a VAP in 2009.

It is interesting to note that despite the small incidence of VAP, the number of ventilator days significantly accounts for the likelihood of contracting VAP. As discussed in the previous section, the ventilator day control variable poses a problem in this study since the large number of ventilator days seems to be an indicator of poor initial medical condition and a byproduct of certain health outcomes. In regression 3 from Table 7, we analyze the effect of the checklist utilization on VAP without controlling for the number of ventilator days. From these results, we can also come to the conclusion that the checklist utilization does not lead to any significant change in a patient's likelihood of contracting VAP. Due to the small sample size, it is quite likely that a Type 2 error could have been made in this case.

D. Mortality

The results of a regression analysis of mortality on checklist utilization are displayed in Tables 6 and 6.1. Regression 1 shows that use of the checklist decreased the likelihood of mortality by 16 pp. at the 1% significance level. Thus, we have enough evidence to reject the null hypothesis and support the conclusion that the implementation of the checklist correlates with a lower likelihood of mortality for all ventilator patients.

Regression 2 and regression 3 show that the checklist tends to benefit males more than females. Checklist utilization decreases the likelihood of mortality by 10 pp. more among males than females. This pattern may be a result of the medical staff's increased compliance with the checklist when treating male patients. As discussed earlier, a more likely explanation for this pattern may stem from biological or genetic differences among different sexes.

Regressions 4 and 6 indicate that the checklist tends to yield to a much greater benefit among employed patients and patients with private health insurance. When the checklist was implemented, employed patients had a 21 pp. lower probability of mortality and patients with private insurance had a 34 pp. lower probability of mortality. These patterns also indicate that patients of a higher socioeconomic status tend to benefit more from the checklist.

The results from regression 11 and 12 show that patients from the emergency service had a much lower probability of mortality than patients admitted to medical services when the checklist was implemented. As discussed earlier, this pattern is to be expected as the checklist is especially designed to improve health outcomes in high-pressure environments.

It should be noted that ventilator related medical issues are not the only cause of patient mortality. Surgical complications and negligence by hospital staff are just a few examples of factors that may instead cause patient mortality. However, as previously discussed, the frequency of these issues has very little cause for change within the relatively short time frame of this study. As a result, the constant term will most likely account for these additional issues.

E. Limitations

One limitation in this study is that the sample population comes from only one hospital. Thus, the results from this study may not necessarily be applicable to ventilator patients in hospitals around the rest of the world. Furthermore, the limited sample size also made it difficult to properly analyze trends within the data and increased the likelihood of a Type 2 error in the analysis of the checklist's effect on VAP and complication.

In addition, the limited sample size forced us to group control variables for medical service and admission reason. These variables should ideally have been separated into multiple categories. For example, in this study all patients who were admitted for any type of cardiac problem were lumped under the “Cardiac” variable that controlled for all cardiac admission reasons. However, there are many different types of cardiac medical illnesses with different levels of severity. Although these different conditions could have very different impacts on health outcomes, these specific factors were not accounted for in this study. As a result, this lowers the explanatory power of the empirical models used to estimate health outcomes in this study.

This study was also limited by the amount of information available on the patient’s medical records. Ideally, this study should have used a better method to control for the patients’ initial medical condition. As discussed earlier, a patient’s initial medical condition can have a very large impact on health outcomes. Controlling for ventilator days proved to be somewhat biased as it often correlated with the dependent health outcome variables.

Finally, another limitation of this study is that it did not control for the other best practice measures that the hospital introduced within the timeframe of this study. As discussed in the literature review Pronovost and Gawande’s early work in 2006 instigated a large effort within the medical community to develop best practice methods for all different types of medical procedures. One major best practice initiative that this hospital launched in 2007 was called SCIP (Surgical Care Improvement Protocol). This initiative was designed to improve health outcomes for all surgical patients. Similar initiatives like Pronovost’s central line checklist may also have been adopted during this time. Thus, the improvement in readmission and mortality may not necessarily be a result of the ventilator checklist exclusively. Instead, it may be the result of a joint effort to improve healthcare quality.

IV. Conclusion

Despite the limitations previously discussed, this study finds consistent evidence that the implementation of the ventilator bundle checklist improves health outcomes for ventilator patients. The ventilator checklist has shown to significantly reduce the probability of readmission and mortality among all ventilator patients by 19 pp. and 16 pp. respectively. Furthermore the checklist also proves to be even more beneficial among patients admitted to the emergency service. Within this service, the checklist reduced the probability of readmission by 32 pp. and also decreased the likelihood of mortality by 24 pp. Although this study found no significant statistical evidence to support the theory that the checklist decreases the likelihood of a patient contracting VAP or other complications, trends in the raw data indicate that the checklist could have at least made a minor improvement upon these two health outcomes.

While the implementation of the ventilator checklist has clear benefits, we must be wary of the fact that great cooperation from hospital staff is required in order to reap the full rewards of the checklist. If healthcare staff is unwilling to utilize the checklist (previous literature shows this is often the case), the costs of checklist utilization can outweigh the benefits. Furthermore, it is interesting to note that the checklist might add to the cost of hospital administration. In order for the checklist to be used in hospitals, approval must first be given by the hospital's legal/administrative departments. In addition, many hospitals that use medical checklists often designate one or more healthcare professional(s) to solely monitor and enforce compliance with the checklist. Without this administrative measure, many hospitals have found that the medical checklists are ignored or forgotten. Thus, it is interesting to note that while the checklist may reduce the cost of avoidable medical complications and readmission, there may be a slight trade off since it also causes an increase in administrative costs.

Perhaps the largest benefit of the checklist is the potential reduction in the cost in patient readmission. Avoidable hospital readmission is thought to be one of the greatest costs to our healthcare system. One study estimates that the total cost of hospital readmissions was 16.3 billion dollars. The Medicare Payment Advisory Commission (2007) reported that each hospital readmission costs approximately 7,200 dollars. As a result, since the checklist decreases the likelihood of readmission by 19 pp. within our total sample size, the study site could have potentially saved about (.19*243*7200) 330,000 dollars as a result of implementing the checklist.

A simple cost benefit analysis also shows that even if the checklist can cause a statistically insignificant improvement in the likelihood of VAP and other complications, it can still have a large-scale impact on reducing healthcare costs. Assuming that the per use cost of the ventilator checklist is roughly the same as Gawande's surgical checklist, the cost of implementing the checklist within this sample size is approximately (11*180) 1,980 dollars (Semel, 2010). Previous literature has shown that the cost of treating one VAP is 30,000 dollars. Thus, even if the checklist implementation is successful in preventing 1 VAP, this study site saved a potential 28,000 dollars by avoiding the treatment costs. In addition, the cost of other ventilator related complications are also quite high. For example, the cost of treating one pulmonary embolism is roughly 10,000 dollars and the cost of treating one moderate infection is 12,500 dollars (Fuller, 2009). Thus, as long as the checklist can simply prevent one occurrence of these avoidable consequences, the benefits of the checklist will far outweigh the costs.

For the reasons discussed above, this study strongly recommends all hospitals to utilize the ventilator bundle checklist in order to improve health outcomes and cut costs. All in all, the ventilator checklist serves as an excellent example of how innovative thinking can lead to vast improvements in the medical industry.

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Table 2: Summary Statistics

Variable	Description	Obs.	Mean	Std. Dev.	Min	Max
Age	Age measured in years	296	62.92	24.91	7	105
Vent Days	Number of days patient was placed on ventilator	296	4.24	4.55	1	34
Black	Dummy: 1 If patient identifies as black; 0 if not	296	0.27	0.45	0	1
Other Race	Dummy: 1 If patient does not identify as black or white; 0 if patient does	296	0.07	0.25	0	1
White	Dummy: 1 If patient identifies as white; 0 if not	296	0.66	0.47	0	1
Abdominal	Dummy: 1 If patient was admitted for abdominal related reasons; 0 if not	296	0.18	0.38	0	1
Cardiac	Dummy: 1 If patient was admitted for cardiac related reasons; 0 if not	296	0.23	0.42	0	1
Other Admit	Dummy: 1 If patient was admitted for other medical reasons; 0 if not	296	0.20	0.40	0	1
Renal	Dummy: 1 If patient was admitted for renal related reasons; 0 if not	296	0.12	0.32	0	1
Respiratory	Dummy: 1 If patient was admitted for respiratory related reasons; 0 if not	296	0.28	0.45	0	1
Emergency	Dummy: 1 If patient was admitted to the emergency room service; 0 if not	296	0.28	0.45	0	1
ICU	Dummy: 1 If patient was admitted to the ICU service; 0 if not	296	0.23	0.42	0	1
Medical	Dummy: 1 If patient was admitted to another medical service; 0 if not	296	0.49	0.50	0	1
Female	Binary: 1 If patient is female, 0 if male	296	0.55	0.50	0	1
Private	Binary: 1 If patient used private insurance to pay for hospital stay; 0 if public	296	0.63	0.48	0	1
Employed	Binary: 1 If patient is employed; 0 if not	296	0.25	0.18	0	1
Checklist	Binary: 1 If checklist was used on patient; 0 if not	296	0.61	0.49	0	1
Readmitted	Binary: (Excludes patients who died) 1 if patient was re-admitted within 0-6 months; 0 if not	243	0.27	0.44	0	1
VAP	Binary: 1 If patient had a VAP; 0 if not	296	0.02	0.14	0	1
Death	Binary: 1 If patient died; 0 if not	296	0.18	0.38	0	1
OnlyComp	Binary: (Excludes patients who died) 1 if patient had a complication; 0 if not	243	0.23	0.42	0	1

Table 2.1: Comparative Summary Statistics

	2007: No Checklist		2009: Checklist Used	
Variable	# Obs.	Mean	# Obs.	Mean
Age	116	69.3	180	58.78
VentDays	116	4.88	180	3.83
Black	116	0.26	180	0.28
Other Race	116	0.09	180	0.05
White	116	0.65	180	0.67
Abdominal	116	0.19	180	0.17
Cardiac	116	0.22	180	0.23
Other Admit	116	0.22	180	0.18
Renal	116	0.09	180	0.13
Respiratory	116	0.28	180	0.28
Emergency	116	0.31	180	0.26
ICU	116	0.25	180	0.21
Medical	116	0.44	180	0.53
Readmitted	84	0.38	159	0.21
Female	116	0.53	180	0.56
Private	116	0.57	180	0.66
Employed	116	0.39	180	0.5
VAP	116	0.03	180	0.01
Death	116	0.28	180	0.12
OnlyComp	84	0.26	159	0.22

Table 3: Effect of Checklist Utilization on Readmission

	(1)		(2)		(3)		(4)		(5)		(6)	
	Readmission		Readmission		Readmission		Readmission		Readmission		Readmission	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	-0.19*	0.00	-0.16	0.09	-0.26*	0.01	-0.27*	0.00	-0.13	0.28	-0.20	0.08
VentDays	0.01	0.28	0.02	0.07	0.00	0.74	0.01	0.48	0.01	0.56	0.01	0.26
Age	0.00	0.62	0.00	0.00	0.00	0.96	0.00	0.64	0.00	0.20	0.00	0.30
Black	-0.08	0.21	0.01	0.10	-0.11	0.27	-0.09	0.29	-0.08	0.58	-0.04	0.72
Other Race	-0.17	0.17	-0.22	0.17	-0.05	0.80	-0.19	0.25	-0.21	0.33	-0.21	0.22
Abdominal	-0.11	0.23	0.01	0.14	-0.24	0.08	-0.16	0.14	-0.08	0.68	-0.17	0.23
Cardiac	-0.04	0.60	-0.06	0.11	-0.05	0.73	-0.11	0.29	0.07	0.64	-0.17	0.18
Other Admit	-0.05	0.58	0.11	0.12	-0.20	0.13	-0.08	0.44	0.00	0.99	0.08	0.58
Renal	-0.09	0.41	-0.09	0.15	-0.07	0.64	-0.15	0.22	-0.02	0.92	-0.21	0.20
Emergency	-0.04	0.55	-0.02	0.10	-0.01	0.93	-0.11	0.21	0.07	0.63	-0.12	0.29
ICU	-0.03	0.67	-0.05	0.11	-0.07	0.58	-0.20	0.05	0.20	0.16	-0.12	0.35
Female	0.02	0.68					0.05	0.48	-0.06	0.56	0.21	0.03
Private	-0.01	0.81	0.02	0.09	-0.03	0.75					0.01	0.91
Employed	0.06	0.31	0.18	0.08	-0.05	0.56	0.13	0.10	0.00	0.99		
cons	0.47*	0.00	0.34	0.21	0.64*	0.00	0.48*	0.00	0.51	0.07	0.57**	0.03

(1) All subgroups, N = 243; (2) Female, N = 135; (3) Only Male, N = 108; (4) Only Private, N = 159; (5) Only Public, N = 84; (6) Only Employed, N = Only 113; * Significant at 1%; ** Significant at 5%

Table 3.1: Effect of Checklist Utilization on Readmission

	(7) Readmission		(8) Readmission		(9) Readmission		(10) Readmission		(11) Readmission		(12) Readmission	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	-0.19**	0.02	-0.21*	0.01	-0.12	0.39	0.05	0.77	-0.32**	0.02	-0.22**	0.02
VentDays	0.01	0.34	0.02	0.06	-0.01	0.33	0.02	0.10	0.00	0.82	0.00	0.73
Age	0.00	0.90	0.00	0.28	0.00	0.62	0.00	0.72	0.00	1.00	0.00	0.92
Black	-0.16	0.09					-0.06	0.72	-0.04	0.77	-0.07	0.41
Other Race	-0.13	0.49					-0.05	0.85	-0.37	0.11	-0.16	0.47
Abdominal	-0.08	0.53	-0.07	0.57	-0.16	0.41	-0.08	0.73	0.18	0.53	-0.21	0.11
Cardiac	0.05	0.65	-0.05	0.61	-0.05	0.75	-0.05	0.80	0.10	0.48	-0.14	0.32
Other Admit	-0.09	0.45	0.00	1.00	-0.03	0.86	-0.18	0.25	0.06	0.74	-0.13	0.40
Renal	0.01	0.92	-0.10	0.44	0.11	0.65	0.03	0.25	0.14	0.57	-0.18	0.20
Emergency	0.07	0.50	-0.01	0.93	-0.03	0.85						
ICU	0.02	0.86	-0.05	0.66	-0.04	0.79						
Female	-0.10	0.21	-0.02	0.83	0.07	0.55	0.00	1.00	-0.01	0.92	0.03	0.69
Private	-0.03	0.67	0.00	0.97	-0.12	0.43	-0.22	0.14	0.03	0.84	0.09	0.31
Employed			0.04	0.64	-0.12	0.39	0.11	0.41	0.01	0.95	0.11	0.22
cons	0.46*	0.01	0.52*	0.01	-0.01	0.33	0.05	0.77	0.45	0.15	-0.22**	0.02

(7) Only Unemployed N, = 130; (8) Only White, N = 165; (9) Only Black, N = 64; (10) Only ICU, N = 54; (11) Only Emergency, N = 67; (12) Only Medical, N = 122; * Significant at 1%; ** Significant at 5%

Table 4: Effect of Checklist Utilization on Complication

	(1) OnlyComp		(2) OnlyComp		(3) OnlyComp		(4) OnlyComp		(5) OnlyComp		(6) OnlyComp	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	0.02*	0.00	0.02	0.01	0.10	0.14	0.07	0.23	-0.07	0.38	0.02	0.78
VentDays	0.00	0.37	0.00	0.36	0.02*	0.01	0.02*	0.00	0.02*	0.00	0.01	0.33
Age	0.09	0.14	-0.02	0.86	0.00	0.96	0.00	0.88	0.00	0.19	0.00	0.27
Black	0.09	0.43	-0.16	0.32	0.15	0.04	0.08	0.26	0.05	0.56	0.16	0.06
Other Race	0.02	0.83	-0.07	0.58	0.21	0.09	-0.11	0.38	0.18	0.20	-0.06	0.66
Abdominal	0.06	0.45	-0.05	0.62	0.07	0.50	-0.06	0.49	0.23	0.06	0.03	0.76
Cardiac	-0.07	0.40	-0.25	0.03	0.11	0.24	0.04	0.64	0.18	0.10	0.08	0.46
Other Admit	0.04	0.72	0.12	0.42	0.08	0.38	-0.10	0.24	0.13	0.25	-0.12	0.28
Renal	0.06	0.39	-0.02	0.81	-0.04	0.70	0.11	0.31	0.01	0.92	0.19	0.16
Emergency	0.05	0.53	0.12	0.26	0.11	0.20	0.06	0.40	0.04	0.71	0.09	0.31
ICU	0.07	0.19	0.00		-0.05	0.55	0.09	0.26	-0.06	0.57	0.14	0.17
Female	0.02	0.76	0.09	0.30			0.13	0.03	0.00	0.99	0.10	0.17
Private	-0.01	0.92	0.03	0.69	-0.04	0.53					0.00	0.96
Employed	0.08	0.51	0.24	0.19	-0.05	0.44	0.01	0.86	-0.06	0.45		
cons	0.02	0.00	0.02	0.01	-0.05	0.72	-0.04	0.79	0.12	0.50	-0.15	0.42

(1) All subgroups, N = 243; (2) Only Female, N = 135; (3) Only Male, N = 108; (4) Only Private, N = 159; (5) Only Public, N = 84; (6) Only Employed, N = 113; * Significant at 1%; ** Significant at 5%

Table 4.1: Effect of Checklist Utilization on Complication

	(7) OnlyComp		(8) OnlyComp		(9) OnlyComp		(10) OnlyComp		(11) OnlyComp		(12) OnlyComp	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	0.04	0.56	-0.03	0.64	0.04	0.68	0.01	0.91	-0.03	0.75	0.03	0.65
VentDays	0.03*	0.00	0.02*	0.00	0.02	0.06	0.02**	0.03	0.02	0.21	0.03*	0.00
Age	0.00	0.15	0.00	0.31	0.00	0.40	0.00	0.48	0.00	0.72	0.00	0.06
Black	0.04	0.59					0.10	0.37	0.18	0.13	0.01	0.88
Other Race	0.27	0.06					0.29	0.15	-0.20	0.34	0.16	0.22
Abdominal	0.07	0.46	0.05	0.59	-0.09	0.60	-0.15	0.39	0.06	0.79	0.08	0.38
Cardiac	0.09	0.29	0.05	0.53	0.14	0.33	-0.19	0.22	0.22**	0.05	0.08	0.45
Other Admit	0.04	0.62	-0.06	0.44	-0.10	0.50	-0.25	0.03	0.13	0.38	0.00	1.00
Renal	-0.02	0.88	0.13	0.20	-0.14	0.45			-0.08	0.71	0.10	0.32
Emergency	0.01	0.89	0.03	0.70	0.11	0.41					0.00	
ICU	-0.07	0.40	0.02	0.78	0.03	0.80					0.00	
Female	0.02	0.78	0.14	0.01	-0.07	0.50	0.21	0.04	0.00	0.98	0.11	0.11
Private	0.01	0.87	0.04	0.52	-0.02	0.88	0.09	0.40	0.08	0.44	-0.01	0.83
Employed			-0.01	0.87	0.10	0.40	0.11	0.31	0.08	0.45	-0.08	0.25
cons	0.09	0.53	0.05	0.71	0.04	0.68	-0.15	0.58	-0.09	0.70	0.12	0.40

(7) Only Unemployed, N = 130; (8) Only White, N = 165; (9) Only Black, N = 64; (10) Only ICU, N = 54; (11) Only Emergency, N = 67; (12) Only Medical, N= 122; * Significant at 1%; ** Significant at 5%

Table 5: Effect of Checklist Utilization on VAP

	(1)		(2)		(3)		(4)		(5)		(6)	
	VAP		VAP		VAP		VAP		VAP		VAP	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	-0.02	0.36	0.00	0.86	-0.03	0.32	-0.02	0.11	0.00	1.00	0.00	0.94
VentDays	0.01*	0.00	0.01*	0.00	0.01	0.14	0.01*	0.00	0.01	0.07	0.01*	0.01
Age	0.00	0.19	0.00**	0.03	0.00	0.86	0.00	0.03	0.00	0.90	0.00	0.77
Black	0.02	0.27	0.03	0.14	0.04	0.21	-0.01	0.43	0.09	0.07	0.03	0.29
Other Race	0.04	0.25	0.00	0.95	0.09	0.14	0.00	0.86	0.09	0.29	0.09**	0.02
Abdominal	0.00	0.92	-0.01	0.79	0.00	0.99	-0.02	0.19	0.05	0.45	0.02	0.45
Cardiac	-0.03	0.21	-0.02	0.33	-0.04	0.33	-0.02	0.21	-0.04	0.50	-0.01	0.74
Other Admit	-0.01	0.76	0.03	0.29	-0.04	0.38	-0.01	0.45	-0.01	0.91	0.03	0.43
Renal	-0.01	0.80	-0.01	0.78	0.01	0.80	-0.02	0.21	0.02	0.76	0.02	0.62
Emergency	-0.03	0.18	0.00	0.88	-0.04	0.31	-0.01	0.25	-0.03	0.56	0.00	1.00
ICU	-0.02	0.35	0.01	0.79	-0.06	0.18	-0.01	0.37	-0.01	0.82	0.03	0.32
Female	0.00	0.83					0.02	0.12	-0.03	0.46	0.01	0.71
Private	-0.04	0.04	0.00	0.85	-0.06	0.06					-0.05**	0.04
Employed	-0.01	0.49	0.00	0.98	-0.01	0.72	-0.02	0.14	0.02	0.65		
cons	0.07	0.09	0.02	0.70	0.07	0.31	0.03	0.20	-0.01	0.92	0.00	0.99

(1) All subgroups, N = 296; (2) Only Female, N = 162; (3) Only Male, N = 134; (4) Only Private, N = 185;
(5) Only Public, N = 111; (6) Only Employed, N = 135; * Significant at 1; ** Significant at 5%

Table 5.1: Effect of Checklist Utilization on VAP

	(7) VAP		(8) VAP		(9) VAP		(10) VAP		(11) VAP	
Variables	β	p	β	p	β	p	β	p	β	p
Checklist	-0.02	0.33	-0.02	0.18	0.03	0.54	0.00	0.95	-0.04	0.19
VentDays	0.01*	0.00	0.01*	0.00	0.00	0.49	0.00	0.51	0.01*	0.00
Age	0.00	0.29	0.00	0.21	0.00	0.27	0.00	0.40	0.00	0.28
Black	0.02	0.38					0.06	0.08	0.03	0.38
Other Race	-0.01	0.79					0.01	0.85	0.05	0.38
Abdominal	-0.02	0.63	-0.05	0.04	0.13	0.10	0.01	0.93	-0.01	0.87
Cardiac	-0.05	0.12	-0.04	0.04	0.03	0.68	-0.01	0.92	-0.05	0.31
Other Admit	-0.04	0.30	-0.03	0.22	0.04	0.52	0.03	0.42	-0.07	0.20
Renal	-0.04	0.44	-0.05**	0.04	0.10	0.25	0.01	0.53	-0.03	0.55
Emergency	-0.05	0.11	-0.03	0.06	-0.01	0.85				
ICU	-0.06	0.10	-0.04	0.07	0.05	0.44				
Female	-0.02	0.53	0.00	0.92	0.00	1.00	0.03	0.43	-0.03	0.38
Private	-0.03	0.24	-0.01	0.49	-0.10**	0.05	-0.04	0.21	-0.05	0.12
Employed			-0.02	0.31	-0.01	0.92	0.04	0.25	-0.05	0.13
cons	0.11**	0.05	0.08*	0.02	0.08	0.42	0.01	0.92	0.12	0.08

(7) Only Unemployed, N = 161; (8) Only White, N = 195; (9) Only Black, N = 81; (10) Only ICU, N = 67; (11) Only Emergency, N = 83; (12) Only Medical, N = 146; * Significant at 1%; ** Significant at 5%

Table 6: Effect of Checklist Utilization on Mortality

	(1) Death		(2) Death		(3) Death		(4) Death		(5) Death		(6) Death	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	-0.16*	0.00	-0.13**	0.03	-0.23*	0.00	-0.21*	0.00	-0.10	0.29	-0.34*	0.00
VentDays	-0.01*	0.01	-0.01	0.10	-0.02	0.06	0.00	0.80	-0.03	0.07	0.00	0.84
Age	0.00	0.97	0.00	0.83	0.00	0.97	0.00	0.73	0.00	0.82	-0.01*	0.01
Black	0.06	0.22	0.10	0.18	0.05	0.54	0.00	0.97	0.17	0.09	-0.03	0.65
Other Race	0.10	0.27	0.04	0.76	0.22	0.11	0.12	0.29	0.09	0.58	0.10	0.36
Abdominal	-0.10	0.17	-0.06	0.56	-0.14	0.19	-0.17**	0.04	0.07	0.64	-0.11	0.22
Cardiac	-0.08	0.21	-0.10	0.21	-0.04	0.69	-0.04	0.58	-0.08	0.51	-0.04	0.69
Other Admit	-0.08	0.21	-0.19	0.04	0.02	0.82	-0.05	0.48	-0.13	0.33	-0.05	0.58
Renal	-0.09	0.25	-0.13	0.24	-0.03	0.82	-0.17	0.05	0.01	0.93	-0.20	0.08
Emergency	-0.01	0.92	0.01	0.92	0.00	1.00	-0.04	0.50	0.07	0.53	-0.09	0.27
ICU	-0.01	0.83	0.10	0.25	-0.15	0.11	-0.08	0.26	0.10	0.39	0.01	0.89
Female	-0.01	0.75					-0.03	0.60	0.01	0.92	-0.05	0.40
Private	-0.10	0.03	-0.10	0.13	-0.09	0.20					0.00	0.97
Employed	0.00	0.98	-0.05	0.39	0.06	0.45	0.07	0.22	-0.06	0.55		
cons	0.45*	0.00	0.40*	0.01	0.48*	0.00	0.33*	0.01	0.35	0.09	0.79*	0.00

(1) All subgroups, N = 296; (2) Only Female, N = 162; (3) Only Male, N = 134; (4) Only Private, N = 185; (5) Only Public, N = 111; (6) Only Employed, N = 135; * Significant at 1%; ** Significant at 5%

Table 6.1: Effect of Checklist Utilization on Mortality

	(7) Death		(8) Death		(9) Death		(10) Death		(11) Death		(12) Death	
Variables	β	p	β	p	β	p	β	p	β	p	β	p
Checklist	-0.08	0.21	-0.14**	0.02	-0.17	0.11	-0.07	0.58	-0.24**	0.02	-0.16*	0.01
VentDays	-0.02**	0.03	-0.01**	0.03	-0.01	0.50	-0.01	0.31	-0.01	0.41	-0.02*	0.01
Age	0.00	0.30	0.00	0.99	0.00	0.62	0.00	0.24	0.00	0.71	0.00	0.09
Black	0.10	0.17					0.15	0.22	0.05	0.65	0.06	0.32
Other Race	0.07	0.64					-0.03	0.88	-0.12	0.54	0.28	0.02
Abdominal	-0.11	0.32	0.00	1.00	-0.12	0.46	0.15	0.42	-0.14	0.50	-0.19	0.03
Cardiac	-0.10	0.25	-0.07	0.36	0.04	0.77	0.16	0.34	-0.04	0.69	-0.19	0.06
Other Admit	-0.12	0.18	-0.08	0.32	0.06	0.66	0.10	0.42	-0.17	0.24	-0.25	0.07
Renal	-0.08	0.47	-0.07	0.49	0.08	0.65	0.00	0.45	-0.17	0.45	-0.14	0.14
Emergency	0.05	0.55	0.05	0.46	0.07	0.59						
ICU	-0.04	0.64	0.02	0.77	0.07	0.61						
Female	0.03	0.60	-0.02	0.67	0.05	0.65	0.07	0.56	-0.07	0.49	-0.05	0.37
Private	-0.16	0.01	-0.07	0.22	-0.12	0.27	-0.17	0.16	-0.04	0.71	-0.07	0.24
Employed			0.00	0.99	-0.03	0.83	0.04	0.74	-0.09	0.34	0.01	0.81
cons	0.33*	0.02	0.37*	0.01	0.44*	0.05	0.38	0.18	0.58*	0.01	0.41*	0.00

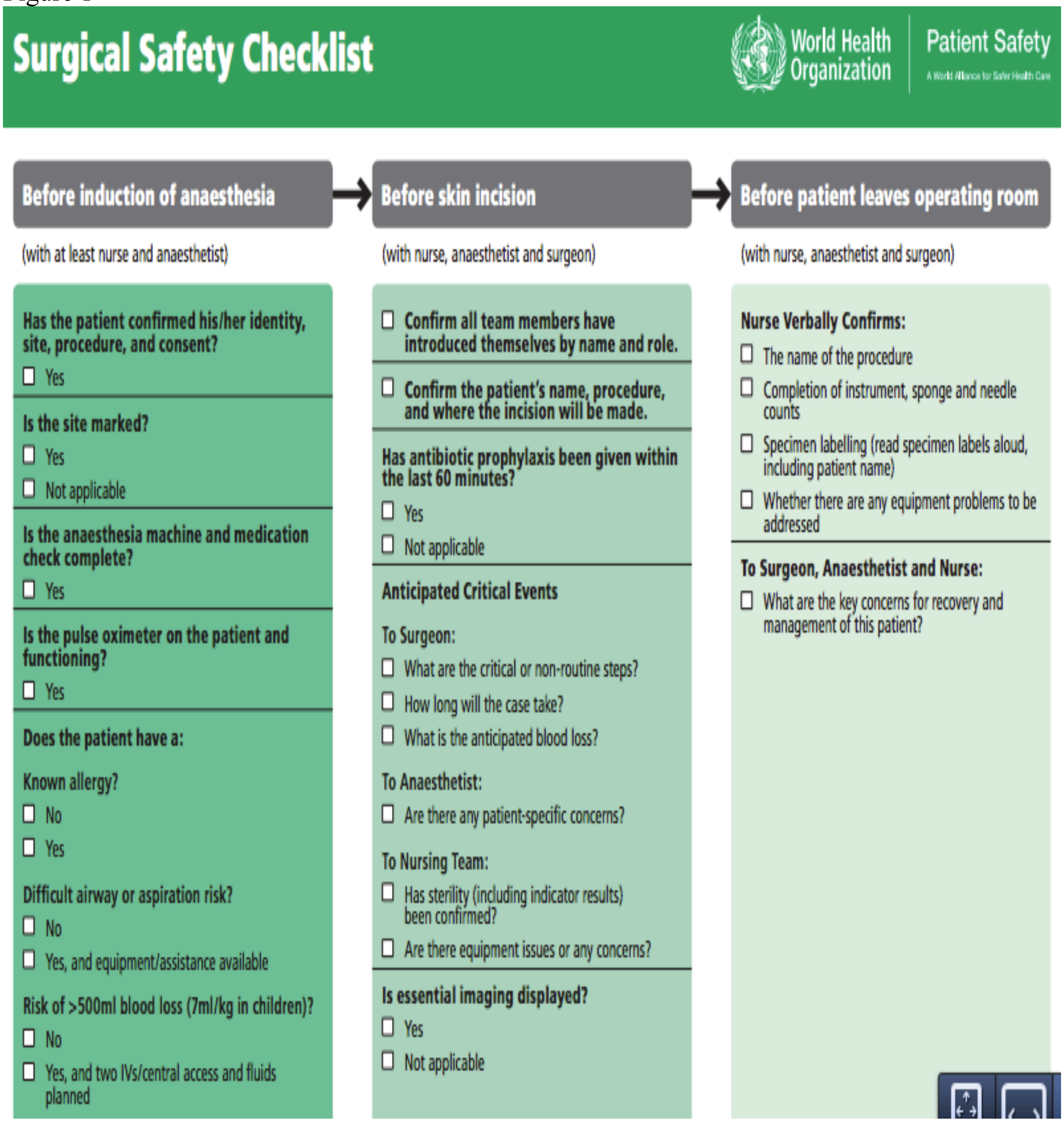
(7) Only Unemployed, N = 161; (8) Only White, N = 195; (9) Only Black, N= 81; (10) Only ICU, N = 67; (11) Only Emergency, N = 83; (12) Only Medical, = 146; * Significant at 1%; ** Significant at 5%

Table 7: Effect of Checklist Utilization on Health Outcomes: Not Controlling for VentDays

	(1)		(2)		(3)		(4)	
	Death		OnlyComp		VAP		Readmission	
Variables	β	p	β	p	β	p	β	p
Checklist	-0.15*	0.00	-0.06	0.31	-0.02	0.17	-0.20*	0.00
Age	0.00	0.92	0.00	0.50	0.00	0.29	0.00	0.67
Black	0.05	0.29	0.10	0.11	0.02	0.20	-0.08	0.22
Other Race	0.11	0.21	0.06	0.62	0.03	0.40	-0.18	0.15
Abdominal	-0.09	0.21	0.00	1.00	0.00	0.92	-0.12	0.21
Cardiac	-0.07	0.24	0.06	0.47	-0.03	0.18	-0.04	0.59
Other Admit	-0.07	0.29	-0.10	0.24	-0.01	0.58	-0.06	0.52
Renal	-0.08	0.32	0.01	0.88	-0.01	0.63	-0.09	0.38
Emergency	0.00	0.97	0.03	0.64	-0.03	0.13	-0.05	0.49
ICU	-0.01	0.92	0.03	0.75	-0.02	0.28	-0.04	0.61
Female	-0.01	0.82	0.07	0.25	-0.01	0.73	0.02	0.71
Private	-0.10	0.05	-0.01	0.86	-0.04	0.02	-0.02	0.70
Employed	-0.01	0.89	0.01	0.92	-0.01	0.64	0.06	0.28
cons	0.38*	0.00	0.25	0.06	0.11*	0.01	0.51*	0.00

* Significant at 1% ** Significant at 5%

Figure 1



Surgical Safety Checklist

World Health Organization | Patient Safety — A World Alliance for Safer Health Care

Before induction of anaesthesia

(with at least nurse and anaesthetist)

Has the patient confirmed his/her identity, site, procedure, and consent?

- ☐ Yes

Is the site marked?

- ☐ Yes
- ☐ Not applicable

Is the anaesthesia machine and medication check complete?

- ☐ Yes

Is the pulse oximeter on the patient and functioning?

- ☐ Yes

Does the patient have a:

Known allergy?

- ☐ No
- ☐ Yes

Difficult airway or aspiration risk?

- ☐ No
- ☐ Yes, and equipment/assistance available

Risk of >500ml blood loss (7ml/kg in children)?

- ☐ No
- ☐ Yes, and two IVs/central access and fluids planned

Before skin incision

(with nurse, anaesthetist and surgeon)

- ☐ **Confirm all team members have introduced themselves by name and role.**
- ☐ **Confirm the patient's name, procedure, and where the incision will be made.**

Has antibiotic prophylaxis been given within the last 60 minutes?

- ☐ Yes
- ☐ Not applicable

Anticipated Critical Events

To Surgeon:

- ☐ What are the critical or non-routine steps?
- ☐ How long will the case take?
- ☐ What is the anticipated blood loss?

To Anaesthetist:

- ☐ Are there any patient-specific concerns?

To Nursing Team:

- ☐ Has sterility (including indicator results) been confirmed?
- ☐ Are there equipment issues or any concerns?

Is essential imaging displayed?

- ☐ Yes
- ☐ Not applicable

Before patient leaves operating room

(with nurse, anaesthetist and surgeon)

Nurse Verbally Confirms:

- ☐ The name of the procedure
- ☐ Completion of instrument, sponge and needle counts
- ☐ Specimen labelling (read specimen labels aloud, including patient name)
- ☐ Whether there are any equipment problems to be addressed

To Surgeon, Anaesthetist and Nurse:

- ☐ What are the key concerns for recovery and management of this patient?

Figure 2

Appendix J

Central Line Insertion

Care Team Checklist

- If any item on the checklist is **not** adhered to or there are any concerns, contact the ICU attending

Purpose:	To work as a team to decrease patient harm from catheter-related blood stream infections
When:	During **all** central venous or **central** arterial line insertions or re-wires
By whom:	Bedside nurse

If there is an observed violation of infection control practices, line placement should stop immediately and the violation should be corrected. If a correction is required, mark yes to question #6 *and explain violation at the bottom of the page and what corrections were made*

Patient's name or Room Number____

1. Today's date _____ / _____ / ________

2. Is the procedure: ☐ Elective ☐ Emergent

3. Procedure: ☐ New line ☐ Rewire

4. Site Rite Used: ☐ Yes ☐ No ☐ Internal Jugular ☐Subclavian ☐ Femoral

If equipment is available, ultrasound guidance should be used for all non-emergent internal jugular line placements. (Optional for subclavian and femoral line placement.)

	Yes	**Yes After correction**	**Don't Know**
5. Before the procedure, did the house staff:			
Perform a **"time-out"**	☐	☐	
Wash hands (chlorhexidine or soap) immediately prior	☐	☐	**(ask if needed)**
Was hand washing directly observed?	☐	☐	
Place pt in trendelenburg position (< 0 degrees)	☐	☐	to prevent air embolism
Sterilize procedure site (chorhexidine)	☐	☐	☐
Drape entire patient in a sterile fashion	☐	☐	☐
During the procedure, did the house staff:			
Use hat, mask, sterile gown and gloves	☐	☐	☐
Maintain a sterile field	☐	☐	☐
Did all personnel assisting follow the above precautions	☐	☐	☐
Ensure line aspirates blood to prevent hemothorax	☐	☐	
Transduce CVP or estimate CVP by fluid column	☐	☐	
After the procedure:			
Was a sterile dressing applied to the site	☐	☐	☐
6. Was a correction required to ensure compliance with Safety & Infection control practices? Explain.	**Yes**	**No**	

Please return completed form to the designated location in your area

Figure 3

2013-04-06 14:04 ICU N.station 770 719 6814 >> 8665216324 P 1/2

Mechanical Ventilated Concurrent Assessment

Patient: ____________________

Admit Date: ____________________

Date & Time intubated: ____________________

Physician Managing Ventilator: ____________________

ICU DAY	1/ 7A	1/ 7P	2/ 7A	2/ 7P	3/ 7A	3/ 7P	4/ 7A	4/ 7P
Date								
HOB elevated 30-45^0								
Oral Care done								
Ballard and Oral Suction are separate								
Daily Sedation Vacation and assessment of readiness for extubation								
PUD Prophylaxis (H2 Blocker: i.e., Nexium, Pepcid, Nutrition: i.e., TPN)								
DVT Prophylaxis (Anticoags: i.e., Lovenox, Heparin, Increased PT/INR, SCM/Plexipulses)								
Speech Therapy Consulted (Trach pt)								
Ambu bag and Neb in bags								
Gloves worn for patient care and hands washed before and after contact								
Subglottic Suction performed Q-12 and prior to Et-Tube Repositioning								

Ventilator order set utilized on admission? Yes or No

Sputum culture ordered and obtained following initiation of mechanical vent? Yes or No? If yes,

Initial Sputum Results: ____________________

____

Initial X-Ray Results after Intubation:

____