Implementation of a Ventilator Associated Pneumonia Prevention Bundle in the Emergency Department

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Abstract

Background Despite the ability to save lives, mechanical ventilation places patients at an increased risk for adverse events; specifically, ventilator associated pneumonia (VAP). VAP is associated with increased duration of mechanical ventilation, hospital and intensive care unit (ICU) length of stay, hospital costs, and mortality risk. Implementing guideline directed VAP prevention bundles has been shown to reduce hospital VAP rates.

Local Problem One specific population at risk for VAP are mechanically ventilated patients in the Emergency Department (ED). Since the risk for VAP begins at the time of intubation, and patients can spend many hours in the ED waiting for bed availability, there is utility in implementing a VAP prevention bundle in this setting.

Interventions The purpose of this quality improvement project was to develop, integrate, and evaluate a VAP prevention bundle in the ED at a suburban community hospital system. The long-term goal was to decrease VAP rates in mechanically ventilated patients admitted from the ED. The short-term goal was to have a 100% compliance rate with the bundle during the six-week implementation period. The bundle was developed based on the recommendations from the Institute for Healthcare Improvement. Then, with help from a multidisciplinary team, it was incorporated into an order-set that was available in the clinical information system. The ED staff was educated during weeks one to four. The order-set was then made available at the beginning of week four and monitoring of compliance occurred from week four to week ten.

Results For education, 133 out of 142 ED nurses completed the assigned online learning module (82.1%) and 45 nurses attended the in-services hosted by the project leaders (31.2%). Eleven of the 23 ED physicians attended a formal presentation by the project leader at their departmental meeting (47.8%). During the six weeks following the order-set integration, 16 patients were recorded as being intubated, of which five were excluded because they were terminally extubated in the ED. A total of 11 patient encounters were analyzed for compliance. Sixty-four percent of the patients received all three components of the VAP prevention bundle, 90% for HOB, 64% for CHG mouth care, and 80% for oral care every two hours. There were multiple contextual barriers and limitations to implementation that could have affected the results. These included a high patient census and acuity during project implementation, a cyber-security breach, an accrediting body hospital survey, the annual hospital-wide nursing competency evaluations, a documentation related malfunction, and the process for nurses to obtain the CHG oral solution.

Conclusions This quality improvement project demonstrates the feasibility of implementing a ventilator bundle in the ED. The limitations and barriers encountered during this project are a reflection of the challenges associated with translating evidence into practice. There is a need for similar projects in the future and research regarding implementation science in general.

Mechanical ventilation can be a life-saving therapy for critically ill patients, and it is estimated that more than 300,000 patients receive mechanical ventilation each year (Centers for Disease Control and Prevention [CDC], 2018). Despite the ability to save lives, mechanical ventilation places patients at an increased risk for adverse events; specifically, ventilator associated pneumonia (VAP). VAP is associated with increased duration of mechanical ventilation, hospital and intensive care unit (ICU) length of stay, hospital costs, and mortality risk (CDC, 2018; Klompas et al., 2014). VAP is one of the most common adverse events associated with mechanical ventilation, and it is estimated that 10-20% of mechanically ventilated patients will develop VAP (Klompas et al., 2014). Numerous studies have demonstrated that implementing guideline based VAP prevention bundles, particularly in the ICU, can decrease VAP rates, and lead to improved patient outcomes (Khan et al., 2016; Okgün Alcan, Demir Korkmaz, & Uyar, 2016; Parisi et al., 2016; Rawat et al., 2017).

One specific population at risk for VAP are critically ill patients in the Emergency Department (ED). Nationally, EDs evaluate 1.8 million patients a year who require admission to critical care services (CDC, 2014). Additionally, critically ill patients can spend prolonged periods of time in the ED while waiting for bed availability. The average length of stay in the ED from door to admission for all patient populations is six hours, which does not include the potential time spent boarding in the ED as an inpatient (Centers for Medicare and Medicaid Services [CMS], 2018). While waiting for ICU bed availability, a majority of the medically complex and resource intensive care is provided to critically ill patients by the ED staff (Di Somma et al., 2015; Herring et al., 2013). Part of this care involves ventilator management, including VAP prevention. Since the risk for VAP begins at the time of intubation, and patients

can spend many hours in the ED, there is utility in implementing a VAP prevention bundle in this setting (DeLuca et al., 2017).

Purpose

The purpose of this quality improvement project was to develop, integrate, and evaluate a VAP prevention bundle in the adult EDs of a suburban community hospital system. The long-term goal of this project was to have decreased VAP rates in mechanically ventilated patients admitted from the ED. The short-term goal was to have the bundle implemented and corresponding documentation completed in the medical record for all patients who are intubated in the ED during the six-week implementation period.

Evidence-Based Practice Framework

The Knowledge to Action (KTA) framework by Graham, et al. (2006) was used to guide the implementation of this project. The purpose of the KTA framework is to help transition knowledge gained by research into the actions of practitioners, policy makers, patients, and the public (Graham, et al. 2006). There are two main concepts in the KTA framework: knowledge creation and action. Graham, et al. (2006) describes knowledge creation as a funnel; as knowledge filters downward the funnel it becomes more refined and usable. The metaphorical funnel starts with knowledge injury, then moves to knowledge synthesis, and finally into the creation of knowledge tools or products (Graham, et al. 2006).

The action part of the KTA framework is described as a cycle that encircles, and is fed by the knowledge creation funnel. This action cycle has seven iterative phases, with bidirectional movement, and is a guide for the implementation of the knowledge tool or product developed from the knowledge creation funnel (Graham, et al. 2006). The phases of the action cycle include: (1) problem identification and selection of relevant knowledge, (2) adaption of

knowledge to the local context, (3) assessment of barriers, (4) identifying and tailoring of an intervention, (5) monitoring of the intervention, (6) evaluating outcomes, and (7) ensuring the sustainability of the implementation (Graham et al., 2006). For this project, the VAP prevention bundle is the knowledge tool generated from the knowledge creation funnel. The action cycle was used to guide the implementation plan.

Literature Review

There is a great deal of literature to support the implementation of a VAP prevention bundle in the ED. There are three focus areas highlighted in this review, including a review of VAP prevention guidelines, examination of recent VAP prevention literature, and a review of the specific bundle components used in this project.

The Institute for Healthcare Improvement (IHI) developed guidelines for the prevention of VAP in the early 2000s as part of the Five Million Lives Campaign, an initiative to protect patients from incidents of medical harm (IHI, 2012). Since the original publication of the guidelines, they have been successfully incorporated as a care bundle in many ICUs to decrease VAP rates (IHI, 2012). By incorporating the guideline components as a bundle, there is greater improvement of care because multiple best practice techniques are applied together (IHI, 2012). The following are the recommended components of the IHI VAP prevention bundle: head of bed (HOB) elevation between 30 and 45 degrees, daily sedative interruption and assessment for readiness to wean from the ventilator, peptic ulcer disease (PUD) prophylaxis, deep venous thrombosis (DVT) prophylaxis, and daily oral care with chlorhexidine (CHG) solution (IHI, 2012). Of note, the IHI states that PUD and DVT may not be associated with VAP; however, incorporating prophylaxis into the bundle is important to prevent these potentially harmful consequences associated with mechanical ventilation (IHI, 2012).

As alluded to above, VAP prevention bundles have been used in the ICU setting with beneficial results, with much literature published in the 2000s to support its use (DeLuca et al., 2017; IHI, 2012; Okgün Alcan, et al., 2016; Samra, Sherif & Elokda, 2017). Presently and in the more recent past, research is on-going regarding the utility of VAP prevention bundles, particularly when applied to different settings. There have been six studies published since 2016 that relate to this quality improvement project, five pre-post implementation studies and one longitudinal quasi-experimental study. The first study is a pre-post intervention study that evaluated the feasibility of a VAP prevention bundle implemented in the ICU and ED, and the effect of this bundle on VAP rates (DeLuca et al., 2017). Of note, this study is the only one in the literature search that implemented a VAP prevention bundle in an ED setting. Their VAP prevention bundle included HOB elevation between 30 and 45 degrees, oral care every two hours, subglottic suctioning, sedation titration, spontaneous breathing trials, DVT prophylaxis, and PUD prophylaxis. DeLuca et al. first introduced the bundle in the ICU, and then in the ED. They also included staff education and utilized nurse champions to aid in the implementation process. A total of 540 patients were included. Data was obtained at three time points: pre-ICU implementation, pre-ED implementation, and post both implementations; and the VAP rates were 11.3%, 5.7%, and 3.9%, respectively. A Kaplan-Meier curve of the three measurement points illustrated a significant reduction in VAP rates between each group (χ^2 =9.16, p=.0103). This study was limited by its non-randomized design, which reduced the control of compounding variables. Additionally, Deluca et al. used strict diagnostic criteria for VAP, which could have underestimated the true VAP rate. However, this study was strengthened by sound methodology and large sample size per the reported power analysis.

The next pre-post implementation study evaluated the effectiveness of a VAP prevention bundle on all mechanically ventilated patients admitted to an ICU (Khan, et al., 2016). This bundle included HOB elevation 30 to 45 degrees, daily sedation vacation and assessment for extubations, PUD prophylaxis, DVT prophylaxis, oral care with chlorhexidine, endotracheal intubation with in-line suction and subglottic suctioning, and maintenance of ETT cuff pressures between 20 to 30mmHg. A multidisciplinary VAP team was created to aid in the implementation and to monitor for staff compliance with the bundle. A total of 3665 patients were included in the study. Khan et al. reported a significant decrease VAP after the implementation of their bundle; 8.6 to 2 events per 1000 ventilator days ($p<.0001$).

Okgün Alcan, et al. (2016) conducted a similar pre-post intervention study using a VAP prevention bundle that consisted of HOB elevation 30 to 45 degrees, daily sedative interruption and readiness to extubate, PUD prophylaxis, DVT prophylaxis, daily oral care with chlorhexidine, hand hygiene, and ETT cuff pressure monitoring. Okgün Alcan et al. also included mandatory staff education and compliance monitoring. After the implementation period, there was a significant reduction is VAP density from 15.91 to 8.5 events per 1000 ventilator days ($p=.0001$).

The fourth pre-post implementation study, conducted by Parisi, et al. (2016), also implemented a VAP prevention bundle in an ICU setting. The bundle was comprised of elevation of the HOB, daily sedation vacations and assessment of readiness to extubate, PUD prophylaxis, DVT prophylaxis, and oral care with sodium bicarbonate. Similar to the other studies, Parisi et al. incorporated education to help with the bundle implementation. 362 patients were enrolled in the study. VAP density was significantly reduced from 21.6 to 11.6 events per 1000 ventilator days ($p=.01$).

The fifth pre-post implementation study, by Samra, Sherif, and Elokda (2016), aimed to evaluate the adherence to a VAP prevention bundle, and its effect on mortality and VAP rates. This study was completed in a 14-bed medical-surgical adult ICU. The implemented bundle included: HOB elevation, DVT prophylaxis, PUD prophylaxis, oral care with CHG twice a day, and daily sedation interruption and assessment for readiness to wean. Samra, et al. measured 94 to 100 percent compliance with the bundle during the implementation period, no statistically significant difference in mortality, and a significant reduction is VAP rates. The VAP rate decreased from 18.3% to 9% from pre to post implementation ($p<.05$; Samra et al., 2016).

The last study in this review is a longitudinal quasi-experimental study conducted by Rawat et al. (2017). The purpose was to evaluate the implementation of a multifaceted intervention aimed at reducing ventilator associated events (VAE), which includes VAP. The intervention included the establishment of a unit-based quality improvement team, and the education and coaching of providers on the best practice interventions for the prevention of VAE. The best practice interventions included: HOB elevation, use of subglottic suctioning for ETT, oral care six times per day, CHG mouth care two times a day, and performance of spontaneous awakening and breathing trials (Rawat et al., 2017). This intervention was implemented in 56 ICUs from 38 hospitals located in Pennsylvania and Maryland (Rawat et al., 2017). The researchers observed a significant decrease in VAEs (7.34 to 4.48 events per 1,000 ventilator days, $p=0.007$), including a significant decrease in probable VAP (1.41 to 0.31 events per 1,000 ventilator days, $p=0.012$; Rawat et al., 2017).

Overall, reducing VAP is achievable with the use of bundled interventions and staff education (DeLuca, et al., 2017; Khan, et al., 2016; Okgün Alcan et al., 2016; Parisi et al., 2016; 2014; Rawat, et al., 2017; Samra, et al., 2016). While the settings in many of the studies

reviewed took place in an ICU, it is important to note that the patient population was consistent, mechanically ventilated adults. Furthermore, the risk for VAP begins when a patient begins mechanical ventilation, including patients in the ED. Additionally, each study used a different variation of the ventilator bundle, which is a reflection of how researchers adapted and tailored the guidelines to their individual study sites for feasibility and longevity.

After considering the recommendations from the IHI, the synthesis of the reviewed articles, and the needs and resources of the project site, the following was included in this project's bundle: (1) HOB elevation between 30 and 45 degrees, (2) oral care every two hours, and (3) one time oral rinse with chlorhexidine solution. To encourage bundle use, the following orders were also included: post-intubation chest x-ray, arterial blood gas, insertion of an oral-gastric tube, and optional orders for restraints and urinary catheter insertion. Additionally, there was education for ED staff and the incorporation of nurse champions to aid in the implementation process.

Implementation Plan

Project Description

This quality improvement project focused on the development, implementation, and evaluation of a VAP prevention bundle in the adult EDs of a suburban community hospital system. The two EDs are run by the same medical and nursing administration. Additionally, the physician staff, and some of the nursing and respiratory staff work in both EDs. The VAP prevention bundle was developed based on the recommendations from the IHI, described in the literature review, and was incorporated into the clinical information system (CIS) as an ED specific ventilator order-set (appendix A). The order-set was available for ED providers to order,

and the ED nurses were primarily responsible for performing the bundle components. Eligibility to receive the bundle included patients who were 18 years or older and intubated in the ED.

Procedures and Timeline

Prior to the implementation, the project leader obtained approval and support from multiple organizational stakeholders. First, the project leader presented the literature review and project proposal to the ED Medical Director and the Director of Critical Care and Emergency Nursing for their approval. The information was also presented to the hospital's Chief Nursing Officer and Accreditation Committee for approval.

Throughout the pre-implementation period, the project leader created an interdisciplinary team who aided in the development and implementation of the project. The hospital's Process Improvement Team provided insight and guidance to ensure that hospital guidelines and policies for the incorporation of a new order-set were followed. The nursing information systems analyst was an essential team member who built the order-set into the CIS. Members from the pharmacy department helped to make the CHG oral solution available in the ED medication dispense machine. The ED nurse educator helped to make educational materials available to ED nurses. The Respiratory Therapy (RT) manager was consulted to verify that there were not barriers or additional needs for RTs associated with the new order-set. Lastly, the hospital's Nurse Practice Council approved revisions to the oral care policy to reflect the new oral care orders for vented patients in the ED.

Education about the new order-set was provided to the ED providers and nurses for four weeks prior to implementation. The providers were educated at two of their departmental meetings via a formal presentation by the project leader. The project leader and the ED Medical Director also individually and informally educated some providers in the clinical setting. Nurses

were educated through an assigned learning module via the hospital's online educational forum, in-services hosted by the project leader, a presentation provided at a monthly ED Nurse Practice Council meeting, and information posted on the unit's education bulletin board. Additionally, 14 nurses volunteered to be project champions during the implementation period. The nurse champions were given additional education about the project and served as an available resource for staff during the implementation period. They also were responsible for communicating any barriers to the project leader.

The order-set went live in the CIS at the beginning of the fourth week of the implementation period. Availability of the new order-set was announced via email to all staff and there were reminders during nursing shift change huddle. Active monitoring of compliance and data collection occurred from week four to week ten. The project leader was available via phone or email, and made at least one personal appearance a week on the unit during this six-week time.

Human Subjects Protection and Approval Process

The project proposal was submitted to the University of Maryland Baltimore (UMB) Institutional Review Board (IRB) and granted Non-Human Subjects Research (NHSR) determination. To protect the patient identity during data collection, the recording document was kept in a locked cabinet at the charge nurse's desk. For the retrospective chart review, patients were assigned a code to replace their identity and the project leader did not store patient identifiers to Excel.

Data Collection and Analysis

Due to limitations with the CIS, data was collected manually. During the six-week implementation period, ED charge nurses recorded the name, date of birth, encounter date, and

the medical record number of patients 18 years or older who were intubated in the ED. Patients who were terminally extubated and/or converted to palliative care in the ED were excluded from data collection. Then, a retrospective, manual chart review was completed to evaluate compliance with the bundle and the following individual components: HOB elevation, oral care with CHG, and oral care every two hours.

Data collected from the chart review was transcribed into Excel for analysis. Descriptive statistics were used to analyze this data. Compliance with the bundle as a whole and each component was measured as a percentage.

Results

For education, 133 out of 142 ED nurses completed the assigned online learning module (82.1%) and 45 nurses attended the in-services hosted by the project leaders (31.2%). Eleven of the 23 ED physicians attended the a formal presentation by the project leader at their departmental meeting (47.8%). All physicians received an email with the departmental meeting minutes.

During the six-week monitoring period, 16 patients were recorded as being intubated in the two EDs. Five of those patients were terminally extubated and/or converted to palliative care in the ED. Therefore, a total of 11 patient encounters were analyzed for compliance. Sixty-four percent of the patients received all three components of the VAP prevention bundle. Compliance with individual components was as follows: 90% for HOB, 64% for CHG mouth care, and 80% for oral care every two hours. The long-term goal of this project was to decrease VAP rates in mechanically ventilated patients admitted from the ED. However, data regarding hospital VAP rates was unobtainable due to technical difficulties related to data retrieval from the CIS.

There were a few unforeseen barriers encountered during implementation. First, the ED experienced high patient volumes and increased patient acuity during weeks three through ten. Next, the following unexpected events occurred during weeks one through three: a cyber-security breach that created an unplanned shut down of the entire computer system, an accrediting body hospital survey, and the annual hospital-wide nursing competency evaluations. Lastly, during week four, there was a malfunction with the CIS resulting in the nurse's inability to document the CHG oral care.

Discussion with Limitations

To evaluate the integration of the VAP prevention bundle into this practice setting compliance rates were measured. While the desired goal was 100% compliance, achieving compliance rates ranging from 64 to 90% is an indicator of project success, for VAP prevention was a new concept and process for the ED staff. The relative success of the project could be attributed to the unit culture of the implementation site. At this location, ED staff are accustomed to and acceptant of practice changes. The staff are also familiar with the use of electronic order-sets, making it easier for them to adopt this ventilator order-set into practice. Additionally, the incorporation of the nurse champions and involvement of multiple stakeholders helped facilitate the integration of the bundle.

There were a few factors that may have contributed to sub-optimal compliance rates. First, education for all staff through the online nursing module, in-services, and formal presentations was 82.1%, 31.2%, and 47.8%, respectively. Education coupled with implementation of the bundle is key to reducing VAP rates (DeLuca, et al., 2017; Khan, et al., 2016; Okgün Alcan et al., 2016; Parisi et al., 2016; 2014; Rawat, et al., 2017; Samra, et al., 2016). In hindsight, a more robust educational plan that included more staff participation could

have improved bundle compliance. In addition, it would be helpful to subjectively measure staff's knowledge of VAP before and after educational materials were provided to evaluate efficacy of the education provided.

Next, compliance with the CHG oral care component of the bundle was the lowest of all the bundle components at 64%. This low compliance rate could be attributed to the counterintuitive process for retrieving the CHG oral solution. Nurses had to obtain the solution from the medication dispense machine as a cabinet override, then document it under nursing care, not in the medication administration record. In the future, a more streamlined approach could be utilized to reduce the burden associated with this task and thus increase compliance.

Lastly, during implementation there was a surge in the patient volume and acuity. This influx of patients was demanding for the ED staff and increased nursing workload. Unfortunately, additional nursing workload is associated with decreased quality of care (Qureshi, Purdy, Mohani, & Neumann, 2019). Therefore, this increase in workload could have hindered the nurse's ability to implement the bundle.

The long-term project goal of reduction in VAP rates of patients admitted from the ED was not measured, as the process for extracting VAP rates in the CIS is exceedingly complex. However, inability to capture this outcome is not a reflection of project success, because the VAP prevention measures that were successfully implemented in this project are already linked to reduced VAP rates in the literature.

Limitations

There were several limitations to this quality improvement project. First, the project was implemented in one hospital system with an intervention that was tailored to this specific location, which limits the generalizability of this work. However, the process leading to

implementation can serve as a guide for implementing similar projects in other ED settings. Second, the process of manual data tracking and chart review increased the risk of data collection error. Additionally, there may have been lost data due to the documentation related malfunction during the week four of implementation.

Lastly, there were confounding contextual variables that influenced the implementation process. These variables include: patient volume and acuity during project implementation, the cyber-security breach, the accrediting body hospital survey, the annual hospital-wide nursing competency evaluations, and the process for nurses to obtain the CHG oral solution.

Conclusion

VAP is a costly hospital-acquired complication that is associated with unfavorable patient outcomes and occurs in 10-20% of mechanically ventilated patients (IHI, 2012; Klompas, 2014). The importance and efficacy of implementing the IHI recommended VAP prevention bundle to decrease VAP rates has been well documented (DeLuca, et al., 2017; IHI, 2012; Khan, et al., 2016; Okgün Alcan et al., 2016; Parisi et al., 2016; 2014; Rawat, et al., 2017; Samra, et al., 2016). Mechanically ventilated patients in the ED have the same risk of developing VAP as those in the ICU. This quality improvement project demonstrates the feasibility of implementing a ventilator bundle in the ED to reduce VAP rates.

Due to the importance of VAP prevention and the favorable compliance ratings achieved through this project, plans for sustainability were crucial. The incorporation of the bundle into the CIS as an order-set was the primary mechanism used to achieve sustainability. Furthermore, it was recommended that there should be continued monitoring of bundle compliance and feedback to staff until this process becomes the standard of care in the ED. The project leader

also recommended that ED staff receive continued education regarding VAP either through the monthly educational luncheons or through the annual nurse competency evaluations.

This project has the potential to work in other acute care settings. Information about this project will be disseminated at two different poster presentations and results have been communicated to organizational leaders. While this project adds to the body of literature that supports implementing VAP prevention in the ED, there is a need for future projects to examine the impact of implementing VAP prevention in this setting. There is also on-going need for research regarding best practices in implementation science. Moreover, the limitations and barriers encountered during this project are a reflection of the challenges associated with translating evidence into practice.

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Appendix A

ED Specific Ventilator Order-Set

Activity

- ☑ Elevate HOB/Patient Position greater than or equal to 30 degrees
- ☐ Restraints, non-violent safety

Laboratory

- ☑ ARTERIAL BLOOD GAS obtain 30 min after initial placement on the ventilator

Imaging/Diagnostic Tests

- ☑ RAD Chest Portable, STAT * [obtain after initial placement on the ventilator]

Nursing Interventions

- ☑ Oral Hygiene Every 2 Hours PRN
- ☑ Suction airway and mouth PRN
- ☑ Oral care with 0.12% chlorhexidine oral solution, x1 NOW

Tubes and Drains

- ☑ Insert OG/NT tube, if not already in place
- ☐ Insert urinary catheter; Reason: Hourly intake and output with intervention

Table 1.

Evidence Table

Author(s) and year	**Study objective/intervention or exposures compared**	**Design**	**Sample (n)**	**Outcomes (and how measured)**	**Results**	**Level and Quality Rating**
DeLuca, L. A., Walsh, P., Davidson, D. D., Stoneking, L. R., Yang, L. M., Grall, K. J. H., … Denninghoff, K. R. (2017)	To assess VAP prevalence in patients intubated in the ED, the feasibility of ED VAP prevention bundle, and the effect of ED VAP prevention bundle on VAP rates. VAP prevention bundle included: of HOB elevation 30°-45°, oral care every 2 hours, subglottic suctioning, sedation titration, sedation vacations or spontaneous breathing trials as appropriate, DVT prophylaxis, and stress ulcer prophylaxis. Researchers also incorporated VAP prevention champions to aid in the implementation process.	Pre-post intervention study	n=540	• VAP rates were retrospectively measured before and after ICU implementation of the VAP bundle • VAP rates were then prospectively measured after the ED implemented the same VAP bundle. • Compliance with the VAP bundle components • Illness severity, measured using SOFA, APACHE, and CPIS scores. • Mortality, defined as portion of patients who died before discharge • Ventilator days, ED LOS, ICU LOS, hospital LOS	• No significant difference between severity of illness in patients who did and did not develop VAP • VAP rates decreased from 11.3% (PRE-1) to 5.7% (PRE-2) after implementing the VAP bundle in the ICU. Then decreased to 3.9% (POST) after implementing the bundle in the ED. • A nonparametric Kaplan-Meier curve of the PRE1, PRE2, and POST groups illustrates an overall statistically significant reduction in VAP rates (log-rank test difference in VAP; $\chi^2 = 9.16$, $P = .0103$) • Mortality rate was 32% for the PRE1 cohort, 26% for the PRE2 cohort, and 25% for the POST cohort • The addition of an RN VAP champion increased compliance with bundle usage.	IIIA
Institute for Healthcare Improvement, 2012	Ventilator Associated Pneumonia Prevention Bundle was created by the IHI, originally was part of the 5 Million Lives Campaign. This is what many bundles used in the	Clinical Practice Guideline	VAP Bundle components: • HOB elevation • Daily sedative interruption and assessment of readiness to extubate • Peptic ulcer disease prophylaxis			VIIA

	literature are based on.		• DVT prophylaxis • Daily oral care with CHG			
Khan, R., Al-Dorzi, H. M., Al-Attas, K., Ahmed, F. W., Marini, A. M., Mundekkadan, S., … Arabi, Y. M. (2016)	To evaluate the effectiveness of a VAP prevention bundle on all mechanically ventilated patients in the ICU of a 1000 bed tertiary medical center in Saudi Arabia. VAP prevention bundle included: HOB elevation 30°-45°, daily sedation vacations and assessment of readiness to wean, PUD prophylaxis, DVT prophylaxis, oral care with CHG solution, endotracheal tube cuff pressures 20-30 mmHg, and ETT with in-line suction system and subglottic suctioning. There was also the creation of a multidisciplinary VAP team that helped implement the project and monitor compliance.	Pre-post intervention study	Mechanically Vented Patients: n=4743 Events monitored for bundle compliance: n=9085	• Bundle compliance • Number of VAP episodes • VAP rate per 1000 ventilator days • ICU LOS (days) • Ventilator days • ICU mortality (%) • Hospital mortality (%)	• Total bundle compliance was 90.7% before initiation of the VAP team and 94.2% after (P < .0001). • There were 144 episodes of VAP pre-implementation and 14 in the post-implementation (p<0.0001) • There was a VAP rate of 8.6 per 1000 vent days pre-implementation and 2.0 per 1000 vent days post-implementation (p<0.001) • ICU LOS and mortality increased from pre-intervention to post intervention. This could be attributed to the higher acuity of the post-implementation group. • There was no significant change in number of ventilator days between the two groups	IIIA
Okgün Alcan, A., Demir Korkmaz, F., & Uyar, M. (2016).	To evaluate the effect of using a customized VAP bundle on VAP rates in the Anesthesia ICU of a Turkish University Hospital. The VAP bundle consisted of HOB elevation 30°-45°, daily sedative interruption and daily assessment of readiness to extubate, PUD prophylaxis, DVT prophylaxis, daily oral care for CHG, hand hygiene, and ETT cuff pressure monitoring.	Pre-post intervention	n=128	• Bundle compliance (%) • ICU LOS (days) • Ventilator days • ICU VAP rates	• Length of ICU stay (*P* = 0.003) and duration of ventilation (*P* =0.0001) correlated with increased the VAP rates. • Overall compliance with VAP bundle improved significantly after implementation (10.8% to 89.8%, p=0.0001) • There was a significant reduction in VAP rates post implementation, 15.91 cases	IIIA

					of VAP per 1000 ventilator-days pre-implementation to 8.50 cases of VAP per 1000 ventilator-days post-implementation (U=0.00, P= 0.0001)	
Parisi, M., Gerovasili, V., Dimopoulos, S., Kampisiouli, E., Goga, C., Perivolioti, E., … Nanas, S. (2016)	To measure the effect of implementing a ventilator bundle with staff education on VAP incidence. VAP Bundle included elevation of the head of the bed, daily "sedation vacations" and assessment of readiness to extubate, PUD prophylaxis, DVT prophylaxis, and oral care with sodium bicarb. Education included lectures given to medical staff and nurse leaders, posters, and informational leaflets handed out to staff.	Pre-post intervention	n=362	• VAP bundle adherence. • VAP incidence/rate • Days of mechanical ventilation. • ICU LOS	• VAP incidence had a significant reduction from 23.4 to 15.4 case per 100 patients. • VAP rates also had a significant reduction from 21.6 to 11.6 events per 1000 ventilator days (p=0.01). • Days of MV decreased, but were not statistically significant. • ICU LOS decreased from 36 days before the intervention to 27 after the intervention (p=0.04) • Adherence to the basic VAP bundle improved significantly from 13% before to 28% after the intervention (*P* = .02).	IIIA
Rawat, N., Yang, T., Ali, K. J., Catanzaro, M., Cohen, M. D., Farley, D. O., … Berenholtz, S. M. (2017)	To evaluate the impact of a multifaceted intervention on ventilator-associated events (VAE), which includes VAP, in 56 different ICU's located in Maryland and Pennsylvania. The multifaceted intervention included adherence to evidence-based practices for VAE reduction, implementation of the Comprehensive Unit-Based Safety Program, and the measurement and feedback of performance. Using the Delphi method a bundle of six	Longitudinal, quasi-experimental study.	n=416 unit-quarters * Out of the 56 ICUs that collaborated, full data was collected on 52 of them. Information analyzed was broken into quarterly increments.	• VAE rate • Compliance with bundle	• The quarterly mean VAE rate significantly decreased from 7.34 cases per 1,000 ventilator-days during the first study quarter to 4.58 cases after 24 months of implementation ($p = 0.007$) • Compliance with each of the six interventions significantly increased from early to late phase; 14% to 20% ($p < 0.024$)	IIIA

	interventions was created, which included: HOB elevation, use of subglottic suctioning for ETT, oral care six times a day, CHG mouth care two times a day, and performance of spontaneous awaking and breathing trials.					
Samra, S. R., Sherif, D. M., & Elokda, S. A. (2016)	To evaluate the adherence to a VAP prevention bundle and its effect on mortality and VAP rates. The study was conducted in a 14 bed medical-surgical adult ICU. The bundle included: HOB elevation, DVT prophylaxis, PUD prophylaxis, oral care with CHG twice a day, and daily sedation interruption and assessment for readiness to wean.	Pre-post intervention	n= 380	• VAP rates • Bundle compliance • Mortality	• Pre vs. post implementation, VAP rate decreased from 18.3% to 9% ($p< 0.05$) • The mean VAP rate was 25 per 1000 vent days pre implementation and decreased to 8.5 per 1000 vent days a year post implementation ($p=.007$), then continued to decrease to 6 per 1000 vent days two years post implementation ($p=.001$) • There was a non-significant decrease in mortality rate from pre-implementation to post implementation • During the implementation period compliance with the ventilator bundle was achieved in 94-100% of patient	IIIA

*APACHE= acute physiology and chronic health evaluation; CHG=chlorhexidine; CPIS=clinical pulmonary infection score; DVT=deep vein thrombosis; ED=emergency department; ETT= endotracheal tube; HOB=head of bed; ICU=intensive care unit; IHI=Institute for Healthcare Improvement; MV=mechanical ventilation; PUD= peptic ulcer disease; SOFA=sequential organ failure assessment; VAE= ventilator associated events; VAP=ventilator associated

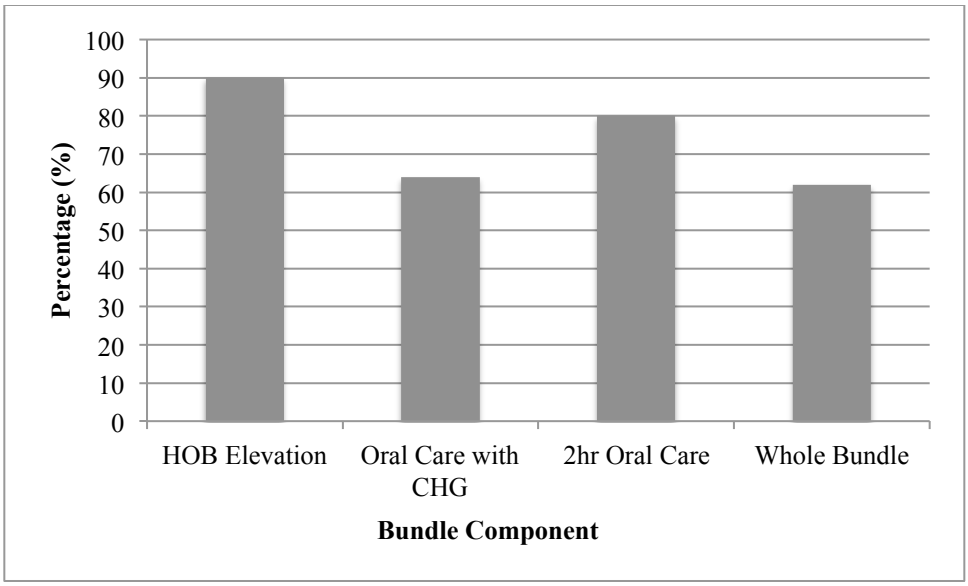

Figure 1. Bar graph depicting compliance with individual bundle components and compliance with all components of the bundle.