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Application of a Real-Time Dashboard to Reduce Ventilator-Associated Pneumonia in Intensive Care Units



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Abstract

Introduction and Purpose: Ventilator-associated pneumonia is the second most common nosocomial infection that develops in patients admitted to the intensive care unit. The mortality rate for VAP ranges from 24% to 76% and is even higher than the primary illness. Based on the importance of this issue, many organizations have focused on strategies and guidelines to reduce the occurrence of complications such as ventilator associated pneumonia. Despite these guidelines, due to multi orders with different conditions and time periods, multi caregivers in the intensive care unit and human mistakes, still there are high rates of VAP. The purpose of this study is to provide an overview of real-time dashboards applications which were designed and implemented as a solution to reduce Ventilator-associated-pneumonia in Intensive Care Unit.

Background: The VAP reduction dashboards in different research studies are implemented with real-time and visual data display features which help caregivers to know the existing condition. So they can do the necessary tasks. Besides, alerts and reminders are among the effective features of this software.

Findings: Because of the representing order lists and the way tasks are done, VAP reduction dashboards, will reduce human mistakes regarding the time consumed and the way it is done. Also, representing history of finished tasks prevents mistakes caused by coordination between multiple caregivers, and finally clinicians begin to understand the importance of consistency in the clinical documentation templates and practices.

Conclusion: Finally, using mobile or web based version, connecting dashboard to patient medical record, representing management information, using sensor and hardware for data entry and connecting dashboard to decision support system make VAP reduction dashboards more effective.

Keywords: Ventilator-associated pneumonia; VAP dashboard; Intensive Care Unit

Abbreviations: CDC: Centers for Disease Control and Prevention; CPOE: Computerized Provider Order Entry; EMR: Electronic Medical Record; HAIs: Hospital-Acquired Infections; ICU Intensive Care Unit; INICC: International Consortium Controlling Hospital Infections; LOS: Lengths of Stays; MDR: Multi-Drug-Resistant; VAP: Ventilator-Associated Pneumonia

Introduction

Ventilator-associated pneumonia is the second most common nosocomial infection that develops in patients admitted to the intensive care unit. VAP is the most common nosocomial infection in the ICU [1,2]. Ventilator-associated pneumonia is the second most common nosocomial infection which contains 86% of nosocomial pneumonia [3]. Furthermore, VAP is usually acquired in hospital settings approximately 48-72 hours after

mechanical ventilation. VAP occurs in patients who are ventilated either by an endotracheal tube or tracheostomy [4,5]. It is worth mentioning that the mortality rate associated with VAP ranges from 24 to 76%, and is even higher among critically ill patients [5,6]. In addition to the increased risk of death, the disease causes increase ICU lengths of stays (LOS) from 4 to 13 days [3]. It also increases the hospital costs and the need for extra hospital care procedures indirectly [1].

According to the published report in 2014 by the International Consortium Controlling Hospital Infections (INICC), the overall rate of ventilator-associated pneumonia was also higher (16.8 per 1000 days using a ventilator). Using such an index to measure the risk is due to the fact that if patients use a ventilator more than two days, they will suffer from VAP [1].

VAP is categorized into two kinds of early-onset VAP and late-onset VAP. Early-onset VAP occurs during the first four days of mechanical ventilation and is usually caused by antibiotic sensitive bacteria. Late-onset VAP develops five or more days after the initiation of mechanical ventilation and is caused by multidrug-resistant (MDR) pathogens [4,5].

The main causes of VAP include: bacterial colonization of the aero digestive tract and aspiration of contaminated oral secretions into the lower airways because endotracheal tubes used to ventilate neonates which are not cuffed [4]. The major causes of acquiring endemic VAP is oropharyngeal colonization by the endogenous flora or by pathogens acquired exogenously from the intensive care unit environment, especially the hands or apparel of health-care workers, contaminated respiratory equipment, hospital water or air. The stomach represents a potential site of secondary colonization and reservoir of nosocomial Gram-negative bacilli. Absorption of microbe-laden oropharyngeal, gastric or tracheal secretions around the cuffed endotracheal tube into the normally sterile lower respiratory tract results in most cases of endemic VAP [1,7,8].

In order to control and reduce the incidence of VAP, numerous institutions have attempted to give medical guidelines. The United States Centers for Disease Control and Prevention (CDC) has also published a guide entitled "A Guide to prevent nosocomial pneumonia" in 2003. Some of the guidelines for the prevention of VAP are listed in the mentioned guide include: The angle of the head of the bed, the cuff pressure inside the tracheal tube, the ventilator circuit changes, oral care (including brushing teeth, using Chlorhexidine, applying water soluble mouth moisturizer), rotating the position of oral endotracheal tube, sedation reduction, consuming stress ulcer prophylaxis drugs, consuming venous thrombo embolism Prophylaxis drugs, suctioning contaminated secretions, evaluating the patient's readiness daily to wean them off the ventilator, using and changing antibacterial filter, and heat and moisture exchangers [9].

The guidelines are used as a combination of a number of guidelines in the intensive care unit, and the results have been effective in reducing the incidence of VAP. Despite such guidelines, the rate of the incidence of VAP is still significant. On the one hand, the number of different guidelines and implementation of each of them in different hours and conditions, and human error in remembering responsibilities increase the probability of not implementing the guidelines correctly and timely. On the other hand, due to the constant shifts of the staff in the intensive care unit, and lack of coordination between staff and not informing each other of carrying out the guidelines and the time

of their implementation, the incidence of ventilator-associated pneumonia is inevitable [10].

Some of the possible errors include: not changing the ventilator circuit and antibacterial filter timely, ignoring the guidelines for cleaning patients' mouth, and not adjusting the angle of the head of the bed.

One of the strategies to reduce human errors and create coordination among the staff in order to perform accurate and timely guidelines is the use of informatics tools such as dashboard software, reminders and alarms. The purpose of this study was to use dashboard software to reduce ventilator-associated pneumonia.

This study was conducted through a library method and searching the databases of PubMed, Science Direct, Google Scholar and the key words of dashboard, ventilator associated pneumonia, VAP reduction dashboard, VAP dashboard, pneumonia, alert, ICU, ventilator and monitoring software. A total number of 58 articles were available. After investigating the quality of the articles based on the references and conforming their objectives with the present study, 23 articles published from 2003 to 2014 were chosen.

The present study first identified different kinds of dashboards in the field of health and the studies providing dashboards to prevent ventilator-associated pneumonia in the ICU were studied in terms of the design, sample, intervention, prominent features of the dashboard software of the studies, the results of the application of dashboard and its impacts to reduce ventilator-associated pneumonia.

Background

Increasingly the healthcare organizations define dashboard software as a means to measure and improve care quality. Dashboard software allows easy access to various databases in a single display format [11]. The superiority of the display format of the data to their numerical format and providing real-time information are the most important features distinguishing between dashboard software and decision support systems in the field of health. In such applications, the data related to the patients, health care professionals and equipment in the field of healthcare used [12].

Dashboard applications in the field of health are used in the two forms of "Quality dashboard" and "Clinical dashboard". Quality dashboard is a visual display of the quality indices that allows managers to identify areas needing improvement [13]. For example, in England quality dashboard is established by the Ministry of Health to evaluate the performance of health care providers including the ratio of the nurses to the beds for patients, the ratio of physicians to the number of beds, the results of the staff audit and patients and the incidence of nosocomial infections and mortality rate [14]. Ultimately, the information is used by senior authorities to decide on the quality and output of health service providers [13].

Clinical dashboard applications are used with the aim of providing practical and timely information in order to create the right conditions to decide on the daily performance of health staff improving the quality of care for the patients [13]. Such tools help the health care staff to do and record the procedures of medical guidelines and protocols in detail and when it is required [10].

The ICU is also one of the subordinate vital health areas of the users of dashboard applications in a way that the processes of the ICU done by service providers and the management of its resources can be efficiently managed through dashboard application. For example, beds in the ICU are considered as one of the crucial sources of the hospital. Thus, the following problems occur: the timely rejection of or early discharge of the current ICU patients to accept new emergency patients. In order to reduce such problems, it is so helpful to monitor and manage the beds through dashboard in a network of municipal and provincial hospitals [15].

The dashboard software for the prevention of ventilator-associated pneumonia is also one of the varieties of dashboard applications used in ICU. The application provides a real-time and graphic display of the information (a combination of text and image) so that the ICU staff can be informed of the existing condition with a glance and take the necessary measures. In addition to mentioned items, reminders and alarms in due time of the guidelines are effective features of the application.

Numerous studies have been conducted to evaluate the application of dashboard and its effectiveness to prevent ventilator-associated pneumonia which has been dealt with in the following paragraphs.

A Real-time ventilator management dashboard: "Toward Hardwiring Compliance with Evidence-based Guidelines" is the title of a study done by Starmer, et al. [10] in 2007. In this study, a ventilator management dashboard application is designed to display the patient's condition by using the guidelines provided by the Center for Disease Control and Prevention such as the prevention of DVT Prophylaxis, stress ulcer prophylaxis, sedation management and daily assessment of readiness to exudate, adjusting the head of the bed at the angle of 35-45°, brushing the teeth and hypo pharyngeal suctioning. Each guideline based on its nature is done by several employees of the ICU at different times. Therefore, the dashboard application coordinates the individuals and also shows proper colors for the status of doing the guidelines. The dashboard utilizes data from various source systems already in use by clinical personnel, including clinical documentation systems and computerized provider order entry (CPOE). These systems pass results through an interface engine which in turn routes the results to subscriber systems. The system also provides the possibility of reporting based on the individuals and processes. By September 2007, dashboard software was installed on all adult intensive care units which increased the number of procedures [10].

"Implementation of a Real-time Compliance Dashboard to Help Reduce SICU Ventilator-Associated Pneumonia with the Ventilator Bundle" is the title of the study by Zaydfudim, et al. [16] through the dashboard application in a previous study in 2009. During the study, guidelines for the prevention of VAP improved from 39% in 2007 to 89% in 2008. In addition, the incidence of VAP reduced by 39 percent from 15.2 to 9.3 cases per 1,000 days using a ventilator in the intensive care unit [16].

"Real-Time, Right Care" is the title of a study carried out by Debra, et al. [17] in 2013 with the support of Health East institution and provision of dashboard application to manage guidelines for the prevention of VAP. The Ventilator-Associated Pneumonia (VAP) Quality Monitor is a software tool that monitors clinical transactions as they occur within Health East's electronic medical record (EMR) system and uses embedded logic to evaluate the transactions against pre-defined processes of care related to preventing VAP. The information is constantly available via a wall-mounted monitor, or it can be displayed on demand at any user's desktop.

For instance, nurses may take a quick glance at the monitor and see status. Such immediate feedback helps the nurses to take measures when necessary. The guidelines of adjusting the head of the bed, daily sedation vacations and the assessment of readiness to exudate, consuming anticoagulants and drugs preventing peptic ulcer disease prophylaxis, venous thrombosis prophylaxis, daily oral care with Chlorhexidine were considered in this study. In the year prior to the pilot project, the pilot ICU had 3.07 cases of VAP per 1,000 ventilators. In the year after the onset of the project, there were 0 cases of VAP [17].

"Infection Control for Critically Ill Trauma Patients" is the title of a study by Heather in 2012, conducted through describing a comprehensive multi-disciplinary approach for VAP focused on prevention, diagnosis and appropriate management. For the trauma surgical population, VAP continues to be one of the most challenging hospital-acquired infections (HAIs), with the incidence rate of the highest in the burn (7.4 cases per 1000 days using a ventilator), trauma (6.5 cases per 1000 days using a ventilator), and neurosurgical (3.8 cases per 1000 days using a ventilator) intensive care units (ICUs) compared with an overall pooled mean rate of 2.2 cases per 1000 days using a ventilator.

Regarding the issue that the prevention of VAP requires coordinated efforts between providers, nursing staff and respiratory therapists, in this study, the elements of adjusting the head of bed at more than 30°, a daily sedation awakening trial and the assessment of readiness to exudate, oral care with Chlorhexidine, peptic ulcer disease prophylaxis and deep vein thrombosis prophylaxis were considered. The quality dashboard application is accessible through the electronic medical record of the patient and the status of doing the guidelines is shown on monitors mounted throughout the ICUs. The result of the study indicates a 63% reduction in the absolute number of VAP cases and also a reduction in the treatment period from 12 days to

10 days during the 4 years of using the dashboard application [18].

Two more studies on the clinical dashboard applications of the ICU processes are provided: "Clinical Dashboards: Impact on Workflow, Care Quality, and Patient Safety" is the title of a study performed by Egan, the researcher of Massachusetts General Hospital in 2006. In the same year, Massachusetts General Hospital used the dashboard application in the operating room in order to monitor and display essential data of the patients automatically on the screen. Moreover, the application receives processes, integrates, and shows a wide range of the data of patients on the screen. During the study, the mentioned idea of using the dashboard application was extended to the ICU. According to Egan there are not only many similarities between the workflow of the ICU and the workflow of operating room, but also more complexities in many cases; therefore, providing dashboard management application is required for the ICU.

The following features are considered for the proposed application:

Making a coordination among the health care team, data management of the patient such as allergies, daily status of the patient, medical history, medication regimen, the dose of injections, the results of tests, prescribed treatment plan, adjusting devices such as a ventilator and displaying the data depending on the user (doctor, nurse and anesthesiologist) [19].

"Designing and evaluating an electronic application of nursing process: a step to improve learning and nursing care" is the title of a study conducted by Mazloum, et al. [20] in Mashhad in 1393. Mazloum has expressed the reason of performing the study was that there is a need for the nursing field to use an electronic application of nursing process-mail software to use the nursing process and expressed the mismatch between external applications but the available foreign applications are not suitable for the country in terms of language, cultural and social factors and clinical conditions. The study was conducted in two parts: designing and evaluating the application. The first part of the study was carried out in the four stages of "developing nursing process in accordance with the application", "designing algorithm", "test run" and "final reform". The second part is also done with the participation of 20 students and nurses in the ICU at Ghaem Hospital of Mashhad. They did the nursing processes through the designed application for 3 patients and their views have been collected by the questionnaire of application evaluation.

The application includes the menus of reference information, recording background information of the patient, recording the nursing process, setting, alerts and the guide. The results of the evaluation show that 81.3% of the research units evaluated the application as good or very good generally. The most important advantage of the application according to 90% of the nurses is the accuracy of the electronic information compared with the handwritten form helping to organize the problems of the

patients. According to 100% of the students, the most important advantages of the application are its simplicity, helping the division of responsibility, evaluating the warning signs and preventing errors; therefore, it is possible to design a native application for nursing processes in accordance with the health care system with which the nurses and students are satisfied. Moreover, the implementation of such an application helps to increase the accuracy and reduce the errors and division of responsibility. Such factors improve the patient care [20]. The summary of the conducted studies is provided in Table 1.

Findings

This study was conducted to investigate the effect of the dashboard application to reduce ventilator-associated Pneumonia. Four investigated studies are completely in line with the objective of the present study and two studies provide a dashboard application to do the ICU processes. The uses of the dashboard application based on the conducted studies in this study suggest that the use of the dashboard application can help to remove the factors causing VAP in ICU.

Failing to remember the guidelines and doing them properly due can cause the colonization of bacteria in the oral mucosa and tracheal secretions and aspiration to the lower part of the pharynx of the patient due to the large number of guidelines and thus cause the patient to get VAP. The dashboard application displays a list of guidelines and information, such as the angle of the head of the bed, and the name and dose of drugs to ensure the nurse so that the guidelines are done with the minimum mistake in terms of forgetting the number of times. The change of shifts by the specialists and nurses of the health care unit causes them to be unaware of the status of the guidelines for the prevention of VAP in the previous shift. So, displaying the history and status of the current guidelines on the dashboard application due to its information giving nature helps the nurses and specialist prevent the errors and improves teamwork. However, if there is not such an application, many of the members of the team would deny the responsibility even though they are informed of the status of the guidelines.

Dashboard application uses user accounts and controls the access levels clarifying the mentioned cases. Doing VAP prevention guidelines is not among the responsibility of the nurses to document which increases the human error. Dashboard application makes it possible to record the time of doing the guidelines and provide a suitable environment for documentation which will subsequently lead to doing the guidelines timely and reducing ventilator-associated pneumonia. In addition to the effect of dashboard application on reducing ventilator-associated pneumonia, the continued use of the application and the observation of positive effects make the staff aware of the importance of documentation.

Another outcome of the use of dashboard for the prevention of VAP is to train people in doing the guidelines timely. In fact, emphasizing the reason to do the guidelines and its effect on

the quality of services provided by the health care staff due to instructions, will pass better training in this regard.

the service providers provide systematic strategies to ensure that all patients receive all the best care; therefore, it reduces ventilator-associated pneumonia.

Ultimately, since the focus of the application is on patients,

Table 1: Summary of the conducted studies.

Study	Design	Sample	Intervention	control	Results	Distinctive features
Starmer et al. [10]	Before and after the study	not clear (presumably the nursing staff)	Ventilator management dashboard, presented as a screensaver and accessible from EMR with indicators for each patient for each element of ventilator management bundle	none	Increasing compliance with bundle elements (RASS score, weaning, Head of Bed adjustment, OB, oral care). Nurse Managers and Charge Nurses note that dashboard allows them to more quickly see when a nurse is overloaded with patient and can divert resources.	Each indicator has traffic light status (green done, yellow imminent, red overdue/not done). Indicators are not always up to date as reliant on timely documentation – problematic if workflow uses 'batch' Documentation
Zayfudin et al. [16]	Interrupted time series analysis Pre-intervention period January 2005-june 2007 (30 Months), implementation in July 222007, post-intervention period August 2007- July 2008 (12 Months)	Nursing and medical staff	Ventilator management dashboard, presented as a screensaver with indicators for each patient for each element of ventilator management bundle	none	Average compliance with ventilator bundle improved from 39% in August 2007 to 89% in July 2008 (P < .001). Rates of ventilator- associated pneumonia(VAP) decreased from a mean(SD) of 15.2(7.0) to 9.3(4.9) events per 1000 ventilator days after introduction of the dashboard (P = .01). Quarterly VAP rates were significantly reduced in the November 2007 through January 2008 and February through April 2008 periods (P < .05). For the August through October 2007 and May through July 2008 quarters, the observed rate reduction was not statistically significant.	Use of color coding for indicators; green = incompliance, red = out of compliance, yellow = soon due Managers received daily reports on compliance levels
Debra [17]	Before and after the intervention, the implementation of the project was conducted since October 2009. The time interval of before and after is not clear.	Nursing and medical staff	Ventilator management dashboard, presented as a screen, provided through an electronic health record for each patient as well as the management of pre-defined guidelines relating to the ventilator.	none	In the year prior to the pilot project, the pilot ICU had 3.07cases of VAP per 1000ventilator.In the year after the onset of the project, there were 0 cases of VAP	an individual nurse may take a quick glance at the monitor and see that one of his assigned ventilated patients has a “green” status for periodic wean assessment and therefore does not need immediate attention, but another ventilated patient may show a “red” status for daily oral care, meaning the nurse needs to complete that activity..
Heather [18]	Before and after the intervention. The implementation of the project was conducted since 2007 to 2010.	Nursing and medical staff	The quality dashboard connected to the medical records of a patient displaying the status of doing the guidelines on the monitor in the ICU.	none	This had led to a 63% reduction in the number of VAP cases over the past 4 years although improving our management of those cases that occur through appropriate antimicrobial therapy based on local microbiology.	No cases have been mentioned.

Discussion and Conclusion

Investigating the results of the performance of the dashboard application in studied investigations, it can be said that in the study conducted by Zaydfudim, et al. [16] in 2007, VPA was reduced by 38 percent (from 15.2 to 9.3 cases per 1,000 days of using a ventilator) as reported. In the study carried out by Debra, et al. [17] in 2013, VPA was reduced by 100 percent (from 3.07 to 0 cases) as reported and it seems that it is possible to display the dashboard on the monitor mounted in the ICU at every moment. The long duration of the study, the high number of nurses and its connection to patients' medical records increase the impacts of using dashboard application in reducing ventilator-associated pneumonia. The environment of the study and the work discipline of the mentioned studies were involved in the effectiveness of the use of dashboard application to reduce ventilator-associated pneumonia, since increasing the work discipline in an environment makes it more difficult to change.

Due to the increasing development of IT and the influence of information systems in the field of health and clinical care, adding more features to the dashboard application to provide health services in a better way and focus more on patients. The mobile version of the dashboard application can be used on the nurses' tablets or cell phones and makes it possible to use it immediately beside patients' bed. In such a condition, the time of doing the guidelines is recorded with less time error and also more quickly and easily.

Connecting the dashboard application to patients' medical file allows you to get the information and makes it possible to record the summary of the data of doing the guidelines in the medical file. Providing high-rank managers with the management information of the trend graphs of the incidence of disease makes them aware of the effectiveness of the nursing processes done in the health care units and proper decision making. Since the number of health care nurses is not usually equal to the number of nurses, it is quicker to enter the data into the application through hardware systems such as the use of sensors to check the angle of the head of the bed or data transfer technologies of NFC on the ventilator circuit and heat and moisture exchangers that can be helpful in recording the time of change.

Furthermore, connecting the dashboard application to DSS systems can help to change the number of times the guidelines are practiced and the way to do it based on the condition of patients.

Providing a web-based dashboard application facilitates the access and online use and can be used to improve the application.

Finally, using the dashboard application can reduce the rate of the incidence of different infections and do the management processes in the field of health in a better way. For example, the dashboard application can also be effective in preventing other infections such as catheter-related urinary tract infections, the most common nosocomial infections.

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