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Ventilator-associated pneumonia and the importance of education of ICU nurses on prevention – Preliminary results

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Abstract: *Background and aims:* Ventilator-associated pneumonia (VAP) increases intensive care unit (ICU) length of stay, ICU mortality, the number of ventilator days, and costs. We implemented a VAP bundle and investigated its efficacy on prevention. *Materials and methods:* A prospective observational study was conducted between January 1, 2015 and December 31, 2015 in a 12-bed multidisciplinary ICU. The bundle was implemented on July 02, 2015. Comparative analysis was performed before and after the implementation of the bundle. The compliance of the nurses was also studied. *Results:* The incidence of VAP was 21.5/1,000 ventilator days (95% CI: 14.17–31.10) in the first phase and 12.0/1,000 ventilator days (95% CI: 7.2–19.49) in the second phase. Relative risk reduction was 44% (95% CI: −0.5 to 0.98). Most common bacteria identified during the first phase were *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, and *Staphylococcus aureus*; and in the second phase *P. aeruginosa*, *Acinetobacter baumannii*, and *S. maltophilia* were identified. Significant improvement was achieved in the head-of-bed elevation ($p = 0.004$), oral care ($p = 0.01$), hand hygiene ($p < 0.001$), endotracheal suctioning ($p = 0.004$), and removal of condensate ($p = 0.043$). *Discussion:* The incidence of VAP showed tendency for reduction. The prevalence of nursing-dependent bacteria decreased and compliance in following prevention methods increased. *Conclusion:* These results underline the importance of education of prevention methods.

Keywords: hospital-acquired infection, ventilator-associated pneumonia, prevention, bundle, education

Introduction

Ventilator-associated pneumonia (VAP) is defined as a pneumonia occurring over 48 h after endotracheal intubation characterized by new lung infiltrate, new onset of fever, purulent sputum, leukocytosis, and decline in oxygenation [1]. VAP is a frequent complication in critically ill patients and is among the most common hospital-acquired infections [2]. It occurs approximately in 10–20% of patients requiring mechanical ventilation and this rate has not declined over the past years [3, 4]. The incidence of VAP is 14.5 cases per 1,000 ventilator days in Europe [5]. It impacts the patient outcomes negatively, as it is associated with increased mortality, longer length of stay (LOS) intensive care unit (ICU), and higher costs [3, 6–8]. According to the previously published studies, the implementation of a VAP bundle had been proven to be efficacious in reduction of VAP rates [9–11].

Education plays an important role in the prevention of VAP [12, 13]. The importance of alternative methods including positive suggestions was also shown to be effective in reducing days on ventilator [14]. This study examined the changes in the incidence and the bacterial spectrum of VAP after the implementation of a bundle. The compliance of ICU nurses was also studied.

Materials and Methods

Study design

A prospective observational study was conducted between January 1, 2015 and December 31, 2015 in the Department of Anaesthesiology and Intensive Therapy, Semmelweis University, Budapest, Hungary. The study population included all patients treated in the 12-bed

Table I Demographic characteristics of patients before and after the implementation of the VAP bundle

	Before the implementation of the VAP bundle	After the implementation of the VAP bundle	p value
Number of patients	275	260	0.66
Male/female ratio	132/143	133/127	0.47
Mean age (SD)	69.75 years (14.32)	68.74 years (14.04)	0.41
Length of ICU stay (days)	1,833	1,814	0.79
Days on ventilator	1,117	1,249	0.08
Case-mix index	6.13	6.53	0.42

multidisciplinary ICU during the given time period without considering the patients' diagnosis. We identified and enrolled VAP patients according to the definition of VAP by the American Thoracic Society and the Infectious Diseases Society of America [1]. The diagnosis of VAP was set if the patient was intubated over 48 h, new or progressive radiographic infiltrate occurred, along with the clinical findings suggesting infection, which include the new onset of fever, purulent sputum, leukocytosis, and decline in oxygenation. Microbiological studies were performed on endotracheal aspirates and respiratory samples were obtained by bronchoalveolar lavage (BAL). The diagnostic threshold of pathogenic strains was over 10^5 colony-forming units (CFU)/ml for endotracheal aspiration and 10^4 CFU/ml for BAL. Our bundle comprised of protocolized humidification, nebulization, and 1-day nurse education. We educated all the ICU nurses on the importance of VAP prevention methods including the head-of-bed elevation, oral care, hand hygiene, cuff pressure control, aseptic endotracheal suctioning technique, and handling of respiratory equipment. The education included a "High-Fidelity" practical simulation on endotracheal suctioning, with common debriefing as well. Compliance with bundle elements was recorded by an infection control practitioner using a checklist based on 100 observations. A comparative analysis was performed before (pre-VAP bundle phase) and after the implementation of the bundle (post-VAP bundle phase). The dividing point was July 02, 2015, when the bundle was implemented.

Statistical analysis

All statistical data were analyzed on SPSS software, version 20.0 (SPSS Inc., Chicago, IL, USA). Baseline characteristics were compared using the χ^2 test for categorical variables and the t-test for continuous variables. A p value <0.05 was considered to be statistically significant.

The authors of this manuscript have certified that they comply with the principles of ethical publishing in Interventional Medicine & Applied Science [15].

Results

Demographic characteristics

A total of 535 patients were treated in the ICU during the study period. Of the 535 patients, 275 were from the pre-VAP bundle phase and 260 from the post-VAP bundle phase. Table I shows the demographic characteristics of ICU patients from both phases. There was no significant difference in the number of patients, male/female ratio, mean age, LOS, ventilator days, and case-mix index (CMI). CMI reflects the clinical complexity and severity (resource requirement) in the population of all the patients in the hospital.

Characteristics of VAP patients

Out of the 535 patients, a total of 39 met the inclusion criteria. We registered 24 VAP cases before and 15 VAP cases after the implementation of the bundle. Table II shows the demographic characteristics of VAP patients from both phases. There was no significant difference in the male/female ratio and mean age. The comorbidities of VAP patients and their risk factors for VAP development are shown in Table III. Because of the low rate of

Table II Characteristics of VAP patients before and after the implementation of the VAP bundle

	Before the implementation of the VAP bundle	After the implementation of the VAP bundle	p value
Number of VAP cases	24	15	–
Incidence of VAP (cases/1,000 ventilator days)	21.5 (95% CI: 14.17–31.10)	12.0 (95% CI: 7.2–19.49)	–
Male/female ratio	14/10	9/6	0.918
Mean age (SD)	73.25 years (9.65)	68.6 years (16.48)	0.272

Table III | Comorbidities of VAP patients and their risk factors for VAP development before and after the implementation of the VAP bundle

	Before the implementation of the VAP bundle (number of cases)	After the implementation of the VAP bundle (number of cases)
Chronic lung disease	5	3
Hypertension	18	10
Diabetes mellitus	7	5
Gastroesophageal reflux disease	4	0
Acute respiratory distress syndrome	3	0
Aspiration	2	2
Reintubation	4	7
Immunosuppression	3	4
Previous antibiotic exposure	5	7
Renal replacement therapy	3	2
Chest surgery	1	1
Abdominal surgery	7	5
Coma	4	0
Head trauma	1	0
Dementia	2	2

occurrence of individual alterations, statistical analysis was not performed.

Outcome

After the VAP bundle implementation, incidence of VAP had decreased from 21.5 (95% CI: 14.17–31.10) to 12.0/1,000 ventilator days (95% CI: 7.2–19.49). The relative risk reduction was 44% (95% CI: −0.4 to 0.97) in the post-VAP bundle phase.

Microbiological profile

The changes in the bacterial spectrum of VAP are shown in *Figs 1* and *2*. A major fraction of bacteria were multidrug resistant (MDR) in both phases. In the pre-VAP bundle phase, 66% of *Pseudomonas aeruginosa*, 30% of *Stenotrophomonas maltophilia*, and 100% of *Staphylococcus aureus* were MDR bacteria. In the post-VAP bundle phase, 100% of *P. aeruginosa*, 75% of *Acinetobacter baumannii*, 50% of *S. maltophilia*, 50% of *Klebsiella pneumoniae*, and 100% of *S. aureus* were MDR bacteria. The rate of VAP caused by
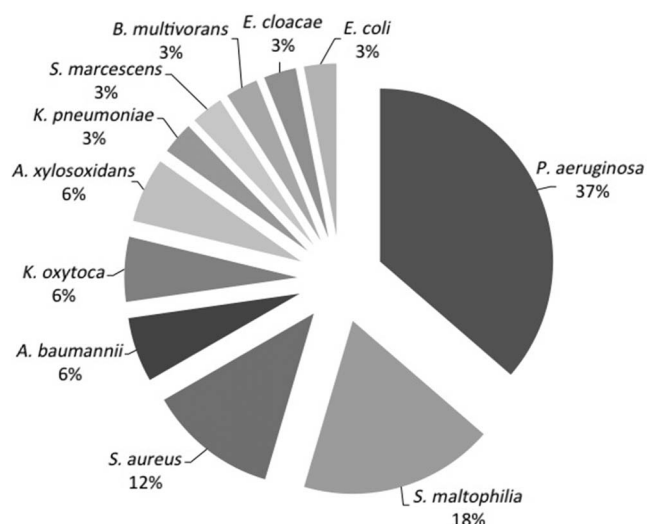

Fig. 1. | Bacterial spectrum before the implementation of the VAP bundle. *P. aeruginosa*: *Pseudomonas aeruginosa*; *S. maltophilia*: *Stenotrophomonas maltophilia*; *S. aureus*: *Staphylococcus aureus*; *A. baumannii*: *Acinetobacter baumannii*; *K. oxytoca*: *Klebsiella oxytoca*; *A. xylosoxidans*: *Achromobacter xylosoxidans*; *K. pneumoniae*: *Klebsiella pneumoniae*; *S. marcescens*: *Serratia marcescens*; *B. multivorans*: *Burkholderia multivorans*; *E. cloacae*: *Enterobacter cloacae*; *E. coli*: *Escherichia coli*

P. aeruginosa and *S. aureus* decreased, while *Escherichia coli* and *Enterobacter cloacae* infections disappeared in the post-VAP bundle phase.

Compliance with the VAP bundle

The compliance study of ICU nurses showed significant improvement in the following interventions: head-of-bed
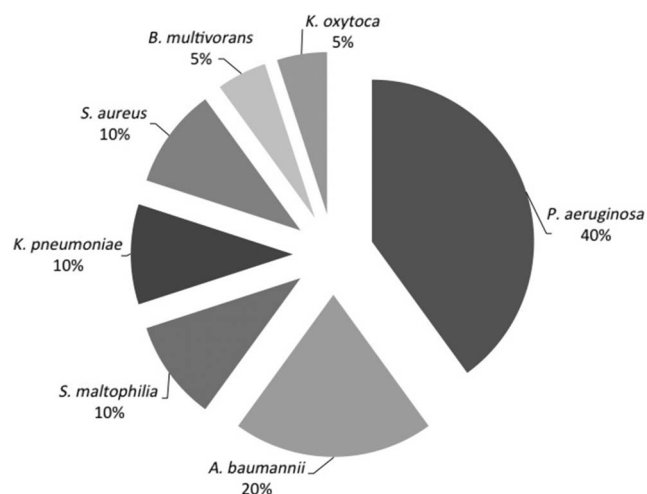

Fig. 2. | Bacterial spectrum after the implementation of the VAP bundle. *P. aeruginosa*: *Pseudomonas aeruginosa*; *A. baumannii*: *Acinetobacter baumannii*; *S. maltophilia*: *Stenotrophomonas maltophilia*; *K. pneumoniae*: *Klebsiella pneumoniae*; *S. aureus*: *Staphylococcus aureus*; *B. multivorans*: *Burkholderia multivorans*; *K. oxytoca*: *Klebsiella oxytoca*
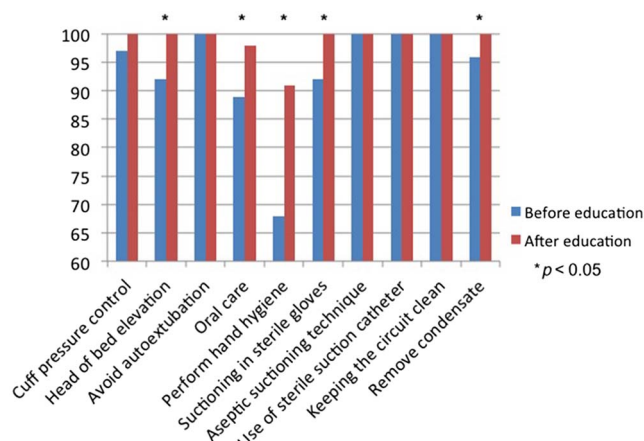
Fig. 3. | Compliance of ICU nurses in prevention methods before and after the implementation of the VAP bundle

elevation ($p = 0.004$), oral care ($p = 0.01$), hand hygiene ($p < 0.001$), endotracheal suctioning ($p = 0.004$), and removing the condensate from circuit ($p = 0.043$) *(Fig. 3)*.

Discussion

VAP cases are potentially preventable and ventilator bundles are effective to reduce the VAP rates [9–11, 16, 17]. We initiated a bundle for prevention and education on VAP for the first time in our department. This study demonstrates a reduction in the incidence and risk of VAP after the implementation of the bundle. The same trend was observed in a multicenter study by Eom et al. [9], where the incidence of VAP decreased from 4.08 to 1.16/1,000 ventilator days. However, the post-bundle phase was shorter and the number of ventilator days was lower (4 months and 6,025 ventilator days compared with 8 months and 13,937 ventilator days), and the significantly lower prevalence of VAP suggests a substantially different study environment. The bundle elements were head-of-bed elevation, peptic ulcer prophylaxis, deep venous thrombosis prophylaxis, and oral decontamination. Lim et al. [11] used a modified bundle in a surgical ICU. The incidence of VAP decreased from 13.63 to 3.94/1,000 ventilator days, although the number of ventilator days was significantly lower in the post-bundle phase.

Regarding our VAP bundle, the nurse education played an important role and we could observe a significant improvement in prevention methods. An outstanding improvement was found in hand hygiene of ICU nurses. This rate (91%) is even higher compared with the results of Lambert et al. [18], where they described a compliance rate of 57% on hand hygiene recommendations. The recently published Greek study by Parisi et al. [19] also highlighted the importance of staff education on VAP prevention. They implemented a longer educational program of 3 months every 2 weeks and the compliance

of ICU staff was also controlled. Decreased incidence rate (from 21.6 to 11.6/1,000 ventilator days), shorter mean ICU LOS (from 36 to 27 days), and lower number of ventilator days (from 26 to 21 days) were observed after the education. Viana et al. [13] introduced an educational module about VAP and used a bundle checklist in a Brazil study. The mean VAP rate before the intervention was $18.6 \pm 7.8/1,000$ ventilator days, decreasing to $11.8 \pm 7.8/1,000$ ventilator days after the intervention.

The major determinant of VAP development is the presence of the endotracheal tube and oropharyngeal colonization from endogenous and exogenous sources as well [20], thus acquiring VAP might be not only "ventilator associated." Nurses play an important role in preventing bacterial colonization of mechanically ventilated patients. Many of the prevention methods of VAP are a part of routine nursing care [21]. The altered microbiological profile may refer to a better compliance in hand hygiene, oral care, aseptic endotracheal suctioning technique, and handling of respiratory equipments. In the literature, we found no data about the changes in the bacterial spectrum of VAP after the initiation of a bundle. The observation of the microbiological profile of VAP is also a part of the infection control surveillance and can help in the development of proper prevention strategies and choosing empirical antibiotic therapy.

This study had some limitations. First, the number of enrolled patients was relatively low compared with previous studies. However, we could observe a decline in the incidence of VAP correspondingly to European epidemiologic data. Second, our results were limited to a multidisciplinary ICU of a single center. In the future, we are planning to expand this VAP bundle in more ICUs.

To our knowledge, this is the first study in Hungary that investigated the efficacy of a bundle on prevention and incidence of VAP.

In conclusion, this VAP bundle proved to be effective in reducing the incidence of VAP. This result also highlights the importance of education in more ICUs.

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References

1. American Thoracic Society (ATS) and Infectious Diseases Society of America (IDSA): Guidelines for the management of adults with

hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. Am J Respir Crit Care Med 171, 388–416 (2005)

2. Magill SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, Lynfield R, Maloney M, McAllister-Hollod L, Nadle J, Ray SM, Thompson DL, Wilson LE, Fridkin SK: Emerging infections program healthcare-associated infections and antimicrobial use prevalence survey team. Multistate point-prevalence survey of health care-associated infections. N Engl J Med 370, 1198–1208 (2014)

3. Safdar N, Dezfulian C, Collard HR, Saint S: Clinical and economic consequences of ventilator-associated pneumonia: A systematic review. Crit Care Med 33, 2184–2193 (2005)

4. Wang Y, Eldridge N, Metersky ML: National trends in patient safety for four common conditions, 2005–2011. N Engl J Med 370, 341–351 (2014)

5. Klompas M: What can we learn from international ventilator-associated pneumonia rates? Crit Care Med 40, 3303–3304 (2012)

6. Melsen WG, Rovers MM, Groenwold RH: Attributable mortality of ventilator-associated pneumonia: A meta-analysis of individual patient data from randomised prevention studies. Lancet Infect Dis 13, 665–671 (2013)

7. Muscedere JG, Day A, Heyland DK: Mortality, attributable mortality, and clinical events as end points for clinical trials of ventilator-associated pneumonia and hospital-acquired pneumonia. Clin Infect Dis 51, S120–S125 (2010)

8. Kollef MH, Hamilton CW, Ernst FR: Economic impact of ventilator-associated pneumonia in a large matched cohort. Infect Control Hosp Epidemiol 33, 250–256 (2012)

9. Eom JS, Lee MS, Chun HK, Choi HJ, Jung SY, Kim YS, Yoon SJ, Kwak YG, Oh GB, Jeon MH, Park SY, Koo HS, Ju YS, Lee JS: The impact of a ventilator bundle on preventing ventilator-associated pneumonia: A multicenter study. Am J Infect Control 42, 34–37 (2014)

10. Shitrit P, Meirson M, Mendelson G, Chowers M: Intervention to reduce ventilator-associated pneumonia in individuals on long-term ventilation by introducing a customized bundle. J Am Geriatr Soc 63, 2089–2093 (2015)

11. Lim KP, Kuo SW, Ko WJ, Sheng WH, Chang YY, Hong MC, Sun CC, Chen YC, Chang SC: Efficacy of ventilator-associated pneumonia care bundle for prevention of ventilator-associated pneumonia in the surgical intensive care units of a medical center. J Microbiol Immunol Infect 48, 316–321 (2015)

12. Biancofiore G, Barsotti E, Catalani V, Landi A, Bindi L, Urbani L, Desimone P, Stefanini A, Sansevero A, Filipponi F: Nurses' knowledge and application of evidence-based guidelines for preventing ventilator-associated pneumonia. Minerva Anestesiol 73, 129–134 (2007)

13. Viana WN, Bragazzi C, Couto de Castro JE, Alves MB, Rocco JR: Ventilator-associated pneumonia prevention by education and two combined bedside strategies. Int J Qual Health Care 25, 308–313 (2013)

14. Szilágyi AK, Diószeghy CS, Fritúz G, Gál J, Varga K: Shortening the length of stay and mechanical ventilation time by using positive suggestions via MP3 players for ventilated patients. Interv Med Appl Sci 6, 3–15 (2014)

15. Szél Á, Merkely B, Hüttl K, Gál J, Nemes B, Komócsi A: Statement on ethical publishing and scientific authorship. Interv Med Appl Sci 2, 101–102 (2010)

16. Resar R, Pronovost P, Haraden C, Simmonds T, Rainey T, Nolan T: Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. Jt Comm J Qual Patient Saf 31, 243–248 (2005)

17. Wip C, Napolitano L: Bundles to prevent ventilator-associated pneumonia: How valuable are they? Curr Opin Infect Dis 22, 159–166 (2009)

18. Lambert ML, Palomar M, Agodi A, Hiesmayr M, Lepape A, Ingenbleek A, Herrejon EP, Blot S, Frank U: Prevention of ventilator-associated pneumonia in intensive care units: An international online survey. Antimicrob Resist Infect Control 2, 9 (2013)

19. Parisi M, Gerovasili V, Dimopoulos S, Kampisiouli E, Goga C, Perivolioti E, Argyropoulou A, Routsi C, Tsiodras S, Nanas S: Use of ventilator bundle and staff education to decrease ventilator-associated pneumonia in intensive care patients. Crit Care Nurse 36, e1–e7 (2016)

20. Crnich CJ, Safdar N, Maki DG: The role of the intensive care unit environment in the pathogenesis and prevention of ventilator-associated pneumonia. Respir Care 50, 813–836 (2005)

21. Augustyn B: Ventilator-associated pneumonia: Risk factors and prevention. Crit Care Nurse 27, 32–39 (2007)