The Brazilian Journal of
INFECTIOUS DISEASES

www.elsevier.com/locate/bjid

Original Article

Assessment of the effectiveness of a ventilator associated pneumonia prevention bundle that contains endotracheal tube with subglottic drainage and cuff pressure monitorization

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ARTICLE INFO

Article history:
Received 1 September 2016
Accepted 13 January 2017
Available online 11 February 2017

Keywords:
Ventilator associated pneumonia
VAP prevention bundles
Subglottic secretion drainage
Cuff pressure monitorization

ABSTRACT

The effectiveness of prevention bundles on the occurrence and mortality of ventilator associated pneumonia (VAP) was evaluated in many studies. However, the effectiveness of endotracheal tube with subglottic secretion drainage (ETT-SD) and cuff pressure monitorization in VAP bundles have not been adequately assessed. In this study, we aimed to evaluate the effectiveness of VAP bundle containing ETT-SD and cuff pressure monitorization. This was a prospective, controlled study that was carried out between March 2011 and April 2012 including intubated patients. The study was conducted at the Anesthesiology Intensive Care Unit 1 and 2 (10 beds each) in a 898-bed university hospital. Occurrence of VAP and compliance with the parameters of the VAP prevention bundles were assessed daily. Patients intubated with the standard endotracheal tube were recruited as controls, mainly in the first six months of the study as ETT-SD and cuff pressure monometer had not yet been implemented. In the second term, patients intubated with ETT-SD were included as cases. Occurrence of VAP, mortality, and compliance with VAP prevention bundles were monitored. A total of 133 patients, 37 cases and 96 controls were recruited. VAP incidence declined from 40.82 to 22.16 per 1000 ventilator days among controls and cases, respectively ($p < 005$). On average, VAP occurred 17.33 ± 21.09 days in the case group and 10.43 ± 7.83 days in the control group ($p = 0.04$). However, mortality of cases and controls at the 14th and 30th days was not different. VAP prevention bundles including the utilization of ETT-SD, monitoring cuff pressure, and oral care with chlorhexidine were efficient in reducing the rate of VAP.

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http://dx.doi.org/10.1016/j.bjid.2017.01.002

Introduction

VAP is a preventable nosocomial infection with high mortality and morbidity associated with medical instruments and health care, and increases hospital costs.[1] Ventilator associated pneumonia (VAP) incidence is 1–4/1000 ventilator days, but it can be high as 10/1000 ventilator days.[2]

Considering the risk factors associated with VAP, evidence-based guidelines have been published for many years aiming to reduce VAP incidence.[3,4] VAP is mainly caused by pathogens to lower respiratory tract that colonizes the oropharynx and trachea. Therefore, restraining this colonization is the first step in the prevention of VAP. Prevention strategies of VAP includes surveillance, hand hygiene, isolation measures to reduce cross contamination of resistant bacteria, keeping the head position elevated, oral care with chlorhexidine, and utilization of endotracheal tube which allows the aspiration of subglottic secretions (ETT-SD) and monitoring the cuff pressure. In recent years, it has been observed that the application of these measures individually is not sufficient. The target is zero infection with a synergistic effect by creating the "VAP prevention bundle" of preventive measures.[5] Thus, VAP prevention bundles may include many possible measures and the Institutions usually select three to six of them. The inclusion of ETT-SD and cuff pressure monitorization in bundles brings about additional economic burden to hospitals. However, the importance of these two parameters have been evaluated in just a few studies.[6,7] This study was carried out to assess the effectiveness of VAP prevention bundles that contain ETT-SD and cuff pressure monitorization in terms of incidence and mortality of VAP.

Material and methods

Hospital setting and study design

This was a prospective, controlled study carried out at the two 10-bed Anesthesiology Intensive Care Units (ICU-1 and ICU-2) of a 898-bed University Hospital between March 2011 and April 2012.

Patients aged 18 years and more referred from the emergency room, clinical or surgical wards who were intubated for more than 48 h at the participating ICUs were recruited for the study.

Patients were followed up until hospital discharge or death even if transferred to another clinic. Patients with chronic tracheostomy and those intubated for more than one day in another center were excluded from study.

The included patients were assessed daily in terms of VAP occurrence and compliance with the measures of the VAP prevention bundle and recorded at the standardized follow-up form.

The study consisted of two periods: the first period lasted six months and the second seven months. As there were no ETT-SDs and cuff pressure monometer in our hospital and in order to avoid ethical problems related to randomization, the patients recruited in the first 6-month period were considered the control group. In the second period ETT-SDs and cuff pressure monometers were obtained with the support of the Scientific Research Projects Unit (SRPU) of Inonu University. ETT-SDs (Coviden, Mallinckroth™) and manual cuff pressure monometers (Coviden, Mallinckroth™) were made available to the Emergency Services and ICUs. The health professionals of these units were trained in the use of these two parameters that were recently added to VAP prevention bundle of the ICUs. To evaluate the effectiveness of this VAP prevention bundle, the patients intubated with ETT-SD, considered cases, were compared to the patients intubated with standard ETT, the control group.

VAP was diagnosed according to the nosocomial PNU 1 criteria in line with the suggestions of the Centers for Disease Control (CDC).[1]

Pneumonia diagnosed in the first four days after the intubation were classified as early onset pneumonia and those pneumonias diagnosed after four days were classified as late onset pneumonia.[1,4,8]

VAP bundle included the following interventions:

1. Utilization of subglottic secretion drainage endotracheal tube (ETT-SD);
2. Monitorization of endotracheal cuff pressure and maintenance at 20–30 cm H_2O;
3. Oral care with chlorhexidine (0.12–0.2%);
4. Semi-recumbent position, head position at 30–45°;
5. Daily sedation break;
6. Prophylaxis of peptic ulcer;
7. Utilization of orogastric (OG) feeding catheter instead of nasogastric (NG) feeding catheter;
8. Prophylaxis of deep vein thrombosis (DVT).

Identity, underlying diseases, risk factors, compliance with the components of the VAP prevention bundle, clinical and laboratory information, and APACHE II scores were used. APACHE II scores were calculated according to the worst parameters within the first 24 h of patients admission to the ICUs.

Occurrence of VAP and compliance with the components of the VAP prevention bundle were monitored daily. Bundle compliance was recorded as positive or negative for each bundle component and the compliance ratio was calculated for each component in every patient. "The compliance ratio" for each component was calculated as the percentage of the patient' hospitalization days with positive compliance.

Compliance ratio: [the number of days with full compliance/hospitalization time (days)] × 100.[9]

VAP rate: (number of VAP/ventilator days) × 1000.

VAP attack rate: total VAP attacks/number of patients with VAP.

Crude mortality and mortality rate in the first 14 and 30 days were recorded for cases and controls.

Statistical analyses

Data were entered in SPSS 16.0 for Windows for statistical analysis. Arithmetic mean and standard deviation (mean ± SD) were used for numeric variables, and number (*n*) and percentage (%) parameters were used for categorical

variables in descriptive statistics. Pearson Chi Square and Fishers Exact Test were used for the calculation of p-value for categorical and Student's t test for continuous variables. Statistical significance was considered at $p < 0.05$.

Results

A total of 133 patients, 37 patients cases and 96 controls entered the study between March 2011 and April 2012. Two patients with ETT-SD presented stridor, foaming of mouth, and wheezing and the tubes were replaced by standard ETT. These two patients were not excluded from the study.

Mean age of cases was 60.32 (mean ± 21.6) and 61.34 (mean ± 19.8) of control patients ($p = 0.7$) (Table 1). There was no significant difference between APACHE II score of cases (29.35 ± 6.3) and controls (28.98 ± 7.1) ($p = 0.7$).

The most common admission diagnosis to ICU was respiratory disorders (22 cases and 32 controls), followed by cardiovascular diseases (5 and 34), and trauma (5 and 17).

There was no significant subgroup difference between cases and controls regarding underlying diseases.

A total of 133 patients and 2657 ventilator days were followed-up during the 13 months of the study. Mean hospitalization time, length of stay in ICUs, and mortality rate are presented in Table 1. Crude mortality was 70% and 64.65 for cases and controls, respectively, with no statistically significant difference between two groups ($p = 0.54$). Mean mortality time was 25.77 ± 28.6 days and 23.03 ± 20.21 days among cases and controls, respectively ($p = 0.61$) (Table 1). However, the first episode of VAP diagnosis was on average seven days earlier among controls (10.4 days) than among cases (17.3 days) ($p = 0.04$).

In the control group, 1935 ventilator days were recorded in 96 patients intubated with standard ETT and 79 VAP episodes were diagnosed in 60 (62.5%) patients of this group. Seven hundred twenty-two ventilator days were recorded in 37 patients with ETT-SD (case group). Sixteen (43.2%) VAP episodes were diagnosed in 15 (40.5%) patients among cases. Early onset pneumonia was seen in 14 (14.58%) patients and late onset pneumonia in 65 control patients. However, early onset VAP was diagnosed in only one (2.7%) patient and late onset in 15 (40.5%) case patients in the group. VAP rate in 1000 ventilator days was 40.82 and 22.16 in controls and cases, respectively.

VAP ratio/1000 ventilator days was significantly higher among controls (40.8) than among cases (22.1) ($p < 0.05$). Data associated with ventilator days and VAP in both groups are presented in Table 2.

Total VAP prevention bundle compliance could not be calculated as no patient had a compliance over 90% or 100% with all components comprised in the VAP prevention bundle. There was statistically significant increase in use of cuff

Table 1 – Demographic and other variables, mean hospitalization time, length of stay in intensive care unit, mean intubation time (days), mean ventilation time (days), and mortality rates among cases and controls.

	Case ($n = 37$)	Control ($n = 96$)	p-Value
Male gender (n, %)	28 (75.68)	52 (54.17)	0.023
Age (year, mean ± SD)	60.32 ± 21.55	61.34 ± 19.78	0.7
Admission APACHE II score	29.35 ± 6.32	28.98 ± 7.13	0.7
Estimated mortality	65.51 ± 16.8	64.25 ± 20.7	0.7
Mean hospitalization time	28.54 ± 23.98	30.22 ± 30.10	0.76
Mean length of stay in intensive care unit	23.70 ± 24.33	23.75 ± 20.55	0.99
Mean ventilator time	19.51 ± 19.56	20.16 ± 15.74	0.844
Day of first VAP diagnosis (mean)*	17.33 ± 21.09	10.43 ± 7.83	0.04
Day of first VAP diagnosis (mean)**	20.56 ± 24.13	13.75 ± 10.19	0.07
Mean mortality time	25.77 ± 28.6	23.03 ± 20.21	0.61
Mortality at 14th day (n, %)	16 (43.24)	34 (35.42)	0.17
Mortality at 30th day (n, %)	19 (51.35)	47 (48.96)	0.25
Total mortality (n, %)	26 (70.3)	62 (64.6)	0.54

* First attack was taken in patients with more than one attack.
** All of the attacks were taken in patients with more than one attack.

Table 2 – Ventilator days, number of ventilator associated pneumonias, number of episodes, ratio of early onset and late onset ventilator associated pneumonia in the study groups.

	Total	Cases ($n = 37$)	Controls ($n = 96$)	p-Value
Monitored ventilator days	2657	722	1935	0.456
Number of patients with VAP*, n (%)	75 (56.4)	15 (40.5)	60 (62.5)	0.031
Number of VAP episodes**, n (%)	95 (71.4)	16 (43.2)	79 (82.29)	0.003
Early onset VAP, n (%)	15 (11.3)	1 (2.7)	14 (14.58)	0.006
Late onset VAP, n (%)	80 (60.2)	15 (40.5)	65 (67.7)	0.008
Ratio of VAP in 1000 ventilator day	35.76	22.16	40.82	<0.05***

* The first attack of patients with more than one attack was included.
** All attacks of patients with more than one attack were included.
*** The difference between two percentages was assessed by significance test (t-test, $t = 2322$).

Table 3 – Compliance ratios with the components of the VAP prevention bundle in the study groups.

Parameters in VAP prevention bundle	Compliance ratios, % (mean ± SD)		*p*-Value
	Case group *n*: 37	Control group *n*: 96	
Cuff pressure measurement	50.1 ± 31.4	6.6 ± 19.5	0.00
Head position	66.8 ± 33.3	75.1 ± 25.5	0.13
Oral care with chlorhexidine	37.4 ± 46.9	18.6 ± 33.6	0.01
Peptic ulcer prophylaxis	99.8 ± 1.3	96.2 ± 18.1	0.23
Orogastric feeding catheter	51.8 ± 38.4	47.8 ± 36.6	0.59
Deep vein thrombosis prophylaxis	66.8 ± 32.9	68.7 ± 30.4	0.98
Daily break of sedation	57.9 ± 28.9	66.3 ± 27.0	0.12

pressure monometer, and oral care with chlorhexidine among cases compared to controls. Other than these three components, there was no other significant difference between two groups.

Ratio of compliance with the components of the VAP prevention bundle is presented in Table 3.

Discussion

Ventilator associated pneumonia rates differ according to the centers and wards and the ratio of VAP is reported between 10 and 25% in the studies.[10] Prevention of VAP has become the priority of ICUs all around the world, and in America in particular.[11–13] Since 2005, the rate of VAP had a significant decline as a result of the implementation of VAP prevention bundles.[9,13–16] Reduction of VAP as a result of prevention efforts have been reported as 1–4/1000 ventilator days.[2] In national studies, the ratio of VAP has changed in the range of 13–27/1000 ventilator days.[17–21] According to the National Hospital Infection Surveillance Network (UHESA) 2011 data, the incidence density of VAP is reported as 19.7 in 50% percentile in Anesthesiology and Reanimation Intensive Care Units of University Hospitals in Turkey.[22]

In our study the ratio of VAP was 40.82/1000 ventilator day in the control group and 22.16/1000 in the case group ($p < 0.05$). The high rate of VAP should be pointed out even among cases who presented a 50% decline in the rate of VAP. The main cause for the high VAP rate is considered to be the exclusion of patients who were intubated for less than 48 h. Most of the studies have included all patients admitted to the ICU; in our study, patients with short term intubation were excluded so that the groups would be more homogenous and the effectiveness of the various measures could be made more accurately. This resulted the decline of ventilator days and the inclusion of more seriously ill patients. Furthermore, the VAP incidence reported by Valles et al. who used a similar study design was 39.6 and 19.9 among controls and cases, respectively.[23]

The lack of significant difference in a several components, particularly in APACHE-II scores and estimated mortality among cases and controls showed the homogeneity and comparability of the groups.

There was no full compliance with all components of the VAP prevention bundle in neither group.

Only the ratio of compliance of peptic ulcer was ≥90% in both groups among the five components comprising semi sitting head position, peptic ulcer prophylaxis, preference of OG feeding catheter to NG feeding catheter, performance of DVT prophylaxis, and break of sedation. Although these components have been implemented for so many years in the units, it is interesting that the observed compliance ratio was so low. As there was a correlation between the compliance with the VAP prevention bundle and the incidence of VAP,[9] it was thought that not achieving the targeted compliance ratio except with these three components could explain the high rate of VAP in our study when compared to the literature.

In literature, the duration of the studies ranges between 2 and 7 years with a prior preparation period.[13] One of the important limitations of our study is the short duration of the study, which could have contributed to the observed low compliance ratio. We would have thought that to assess the increment in the compliance ratio accurately the implementation should follow a process.

Team work must be strengthened for VAP prevention bundles to work. Cocanour et al. reported that the decline in VAP was not only the result of the implementation of VAP prevention bundles but also the daily assessment of the compliance with the components of the VAP prevention bundle and weekly feedback to the health professionals.[24] For the prevention of VAP, the efforts of all hospital management, physicians, staff of the ICU are necessary, and internalization by the ICU staff and recording are also important. In our study compliance was assesses but the weekly feedback was not done. This could have been the reason why the compliance ratio had no significant increment during the study.

Notwithstanding, the duration of the mechanical ventilation was reduced in four days, the length of hospital stay decreased six days, and the occurrence of VAP was delayed in 6–9 days on average as a result of full compliance with the three components of the VAP prevention bundle, namely hygiene of hands, control of cuff pressure, and sedation break.[14] In our study, though none of the patients from both groups had a compliance >90% with all components, except use of ETT-SD in the case group, VAP rate declined approximately 50% and hospitalization time decreased by two days.

Bird et al. reported that the most effective component of VAP prevention bundles is the position of the bedhead.[9] In our study though the ratio of the compliance with the position of the head was rather low, the percentages were calculated as 66.8 ± 33.3 in case group meanwhile 75.1 ± 25.5 in control group ($p = 0.13$). We considered the position of the head as one of the most effective method for preventing VAP. Furthermore,

ETT-SDs and monitoring of the cuff pressure can be critical for the prevention of aspiration to the airways in the cases the head position cannot be kept high.

The aspiration of subglottic secretion is suggested to prevent early onset pneumonia in VAP prevention guidelines.[3,4,25,26] In a meta-analysis performed by Defluzian et al. in 2005, the utilization of ETT-SD prevented early onset VAP in a significant level.[27] In the same line with the literature a significant delay in the time of occurrence of VAP in patients with ETT-SDs was observed in our study. Time of the first episode of VAP was 17.33 days among cases and 10.43 days among controls ($p = 0.04$), a significant seven-day delay. While patients with ETT-SD had 16 (43.2%) VAP episodes, and only one (2.7%) early onset VAP, control patients with standard ETT had 79 (82.29%) VAP episodes, and 14 (14.58%) early onset VAP. There was a statistically significant difference in number of VAP episodes and occurrence of early onset VAP between the two groups.

Lorente et al. used different techniques for the prevention of the late onset pneumonia as ETT-SD is effective in preventing early onset pneumonia, but it was insufficient to prevent the late onset pneumonia.[28] They reported that the utilization of ultra-thin polyurethane cuff concomitantly with SSD could minimize the leakage of the secretion which might decline the incidence of both early and late onset VAP.

Two patients using ETT-SD presented stridor, foaming of the mouth, and wheezing during the study and had their tubes replaced by standard ETT. Some studies reported the occurrence of stridor after extubation with the utilization of ETT-SD.[29,30]

To maintain the target cuff pressure value (20–30 cm H_2O) by the measurement of cuff pressure, which is one of the important components of the VAP prevention bundle, is a precaution that prevents micro aspiration that causes VAP. Some of the investigators determined the cuff pressure under 20 cm H_2O more frequently by manual cuff pressure monometer than the continuous pressure monometer.[31] Nonetheless, there was no impact on the frequency of VAP and time in ICU and mortality. Also, in our study the intermittent manual cuff pressure monometer was used. Compliance with the cuff pressure measurement was 50.1% among cases. It was observed that the first measured cuff pressure value was frequently under the 20 cm H_2O although the cuff pressure measurement was controlled regularly in every four hours. So, it is possible to fail in prevention of micro aspirations despite the monitoring of cuff pressure measurements. Manual cuff pressure monometer was preferred because of its cost-effectiveness and this could have been a limitation factor of our study.

While it was shown that, the ETT-SDs reduced morbidity, two separate studies reported that there was no statistically significant effect on mortality.[30,32] In our study, the average day of death among cases and controls was 26 and 23 days, respectively, and the effect of the VAP prevention bundle on mortality was not statistically significant ($p = 0.61$). However, we would have thought that the small size of the case group could have lowered the power for detecting a clinically relevant difference. Larger studies with longer follow-up are warranted. In addition, it should be noticed that there are very few nursing homes in Turkey. As a result, long term care patient hospitalization continues in acute intensive care units, which may help explain the observed high mortality rates.

As a conclusion, significant decline in VAP rate can be achieved with the implementation of a VAP prevention bundle that includes the measurement of cuff pressure, oral care with chlorhexidine, and full utilization of ETT-SD. On the other hand, the effect on mortality could not be demonstrated. The ratio of compliance with the VAP prevention bundles are low and compliance must be increased with the health team, collaboration of the institution, education and feedbacks.

Funding

This study was supported by Inonu University Scientific Research Projects Unit [project number: 2011/56].

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

We thank Prof. Dr. Gülsen Güneş from the Department of Public Health, Inonu University School of Medicine, for her efforts on performing statistical analyses.

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