Journal of Microbiology, Immunology and Infection (2019) 52, 592–597

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jmii.com

Original Article

# National bundle care program implementation to reduce ventilator-associated pneumonia in intensive care units in Taiwan

Chin-Chuan Kao [a,w], Hsiu-Tzy Chiang [b,w], Chih-Yu Chen [c,w], Ching-Tzu Hung [d], Ying-Chun Chen [e], Li-Hsiang Su [f], Zhi-Yuan Shi [g], Jein-Wei Liu [h], Chang-Pan Liu [b,i], Yin-Ching Chuang [k], Wen-Chien Ko [l,m], Yen-Hsu Chen [d,n,o], Shu-Hui Tseng [p], Chun-Ming Lee [b,q,r,*], Min-Chi Lu [s,t,**], Po-Ren Hsueh [u,v,***], for the Infection Control Society of Taiwan

[a] *Division of Infectious Disease, Department of Internal Medicine, Tungs' Taichung Metroharbor Hospital, Taichung, Taiwan*
[b] *Infection Control Centre, MacKay Memorial Hospital, Taipei, Taiwan*
[c] *Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, China Medical University Hospital, Taichung, Taiwan*
[d] *Center of Infection Control, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*
[e] *Center of Infection Control, Taichung Veterans General Hospital, Taichung, Taiwan*
[f] *Center of Infection Control, Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan*
[g] *Department of Internal Medicine, Taichung Veterans General Hospital, Taichung, Taiwan*
[h] *Department of Internal Medicine, Kaohsiung Chang Gung Memorial Hospital, Kaohsiung, Taiwan*
[i] *Division of Infectious Disease, Department of Internal Medicine, MacKay Memorial Hospital, Taipei, Taiwan*
[k] *Department of Internal Medicine, Chi Mei Hospital, Liouying, Taiwan*
[l] *Department of Internal Medicine, National Cheng Kung University Medical College and Hospital, Tainan, Taiwan*
[m] *Center of Infection Control, National Cheng Kung University Medical College and Hospital, Tainan, Taiwan*
[n] *Division of Infectious Diseases, Department of Internal Medicine, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*

* Corresponding author. Department of Internal Medicine, St. Joseph's Hospital, Yunlin County, Taiwan.
** Corresponding author. Department of Microbiology and Immunology, School of Medicine, China Medical University, Taichung, Taiwan.
*** Corresponding author. Departments of Laboratory Medicine and Internal Medicine, National Taiwan University Hospital, National Taiwan University College of Medicine, No. 7 Chung-Shan South Road, Taipei 100, Taiwan.
*E-mail addresses:* leecm4014@yahoo.com.tw (C.-M. Lee),. luminchi@outlook.com (M.-C. Lu), hsporen@ntu.edu.tw (P.-R. Hsueh).
[w] These authors contributed equally to this work.

https://doi.org/10.1016/j.jmii.2017.11.001

[o] School of Medicine, Graduate Institute of Medicine, Sepsis Research Centre, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan
[p] Center for Disease Control, Ministry of Health and Welfare, Taiwan
[q] Department of Internal Medicine, St. Joseph's Hospital, Yunlin County, Taiwan
[r] MacKay Junior College of Medicine, Nursing, and Management, Taipei, Taiwan
[s] Division of Infectious Diseases, Department of Internal Medicine, China Medical University Hospital, Taichung, Taiwan
[t] Department of Microbiology and Immunology, School of Medicine, China Medical University, Taichung, Taiwan
[u] Department of Laboratory Medicine, National Taiwan University Hospital, National Taiwan University College of Medicine, Taipei, Taiwan
[v] Department of Internal Medicine, National Taiwan University Hospital, National Taiwan University College of Medicine, Taipei, Taiwan

Received 12 October 2017; received in revised form 1 November 2017; accepted 1 November 2017
Available online 2 December 2017

**KEYWORDS**
Ventilator-associated pneumonia;
Bundle care;
Infection rate;
Taiwan

**Abstract** *Background/purpose:* This study investigated the impact of implementing ventilator-associated pneumonia (VAP) bundle care on the rates of VAP in intensive care units (ICUs) in Taiwan.
*Methods:* A total of 10 ICUs (bed number, 170), including surgical (SICUs) (n = 7), cardiovascular/surgical (CV/S-ICUs) (n = 1), and medical ICUs (MICUs) (n = 2) from 10 hospitals (7 medical center hospitals and 3 regional hospitals) were enrolled in this quality-improvement project. This study was divided into the pre-intervention phase (1st January, 2012—31st July, 2013) and the intervention phase (1st August, 2013—31st October, 2014).
*Results:* Among the 10 hospitals, the overall rates (cases per 1000 ventilator-days) of VAP declined significantly ($p = 0.005$; rate ratio, 0.71) from 1.9 in the pre-intervention period to 1.5 in the intervention period. Significant difference in VAP rates between these periods was found in the regional hospitals (from 1.6 to 0.7; $p < 0.001$) and the SICUs (from 2.1 to 1.4; $p < 0.001$), but not in the medical centers (2.0 vs. 1.9; $p = 0.0667$) or CV/S-ICUs (4.5 vs. 4.5; $p = 0.5391$). However, VAP rate increased significantly (cases per 1000 ventilator-days) in the MICUs between the two periods (from 0.5 to 1.0; $p = 0.0489$). For the VAP bundle care elements, the overall compliance rate was 87.7% with 83.6% and 97.9% in the medical centers and regional hospitals, respectively.
*Conclusions:* Implementing VAP bundle care has effectively reduced VAP in Taiwanese ICUs, but differences in performance and compliance rates of VAP bundle care among the different ICUs and hospital categories did exist.


## Introduction

Ventilator-associated pneumonia (VAP) is associated with poor clinical and economic outcomes.[1] The overall mortality attributed to VAP was 13%, with higher rates for surgical patients and patients with a mild-range severity score upon admission.[2] In the United States, nosocomial pneumonia (31%) was the most common type of healthcare-associated infections (HAIs), followed by urinary tract infection (UTI, 23%) and primary bloodstream infection (BSI, 14%).[3] Of the patients with nosocomial pneumonia, 83% were associated with the use of mechanical ventilators.[3] In developing countries, VAP was the second most common HAI (25%).[4] The VAP rate in intensive care units (ICUs) was 50.87 per 100 ventilator-days with attributed mortality of 35% and 10 attributed additional days of hospitalization.[4]

Data obtained from the Taiwan Nosocomial Infection Surveillance (TNIS) program which collected the relevant information of HAIs in ICUs of medical centers and regional hospitals in 2011, UTI, BSI, and lower respiratory tract infections were the top three types of HAIs. More than 70% of patients with HAIs were related to catheter interventions, which were commonly used in ICUs. Ventilators were the most important equipment in ICUs for supporting patients in respiratory failure.

Some evidence-based studies have applied effective methods, particularly bundle care interventions, to reduce catheter-related infections. In addition, the bundle may improve the quality of medical services with limited

resources.[5–11] Many groups have reported reductions in VAP rates through bundle care intervention.[12,13] In Boston, a medical center hospital reduced the VAP rate in the surgical intensive care unit (SICU) from 10.2 cases over 1000 ventilator-days to 3.4 cases over 1000 ventilator-days by improving adherence to VAP bundles over 38 months.[14] Unsurprisingly, the VAP rate was reduced from 11.05 cases over 1000 ventilator-days to 2.81 cases over 1000 ventilator-days through a bundle care intervention at a regional hospital in southern Taiwan.[15] Although it is an effective way to reduce the rates of VAP and ensure patient safety, different VAP bundle cares include varied elements in different studies.

The purpose of this VAP bundle care intervention project coordinated by the Centers for Disease Control of Taiwan (Taiwan CDC) and the Infection Control Society of Taiwan (ICST) was intended to reduce the rates of VAP in ICUs in Taiwan.

## Residents and methods

### Study design, setting, and participants

In this prospective study, a total of 170 beds from 10 intensive care units (ICUs), including seven surgical ICUs (SICUs), two medical ICUs (MICUs), and one cardiovascular/surgical ICU (CV/S-ICU), were recruited from 10 hospitals (7 medical center hospitals and 3 regional hospitals). The seven ICUs from seven medical centers (two in each were located in northern, middle, and southern Taiwan), consisted of four SICUs (bed numbers of 10, 20, 22, and 30, respectively), two MICUs (bed numbers of 10 and 20, respectively), and one CV/S-ICS (bed number of 10). The three ICUs from three regional hospitals, one was located in northern Taiwan and two in southern Taiwan, were all SICUs with bed numbers of 15, 16, and 17, respectively. This study was divided into two periods: pre-intervention period (1st January, 2012—31st July, 2013) and intervention period (1st August, 2013—31st October, 2014). In the pre-intervention period, several educational programs related to VAP bundle cares were developed by a professional committee (the Committee) that was organized by Taiwan CDC and ICST for all participating hospitals. The rates of VAP in the pre-intervention period and intervention period were collected. During both two periods, members of the Committee provided counseling and inspected the adherence and performance of VAP bundle care in the participating hospitals. This study was approved by the Institutional Review Boards of all participating hospitals.

### VAP definitions

VAP was diagnosed only if it occurred 48 h after the endotracheal tube was inserted with a mechanical ventilator and was based on radiological evidence (new or progressive infiltration on chest radiography or computed tomography images), clinical condition (body temperature over 38 °C or below 36 °C, tachypnea, hypoxia/desaturation, respiratory distress, and purulent sputum), and laboratory data (abnormal white blood cell count, C-reactive protein, and gas exchange).[16,17]

### Ventilator-associated pneumonia bundle cares

The five bundle elements of VAP bundle care were selected based on the systemic review on VAP management and prevention guidelines by the Committee.[16,18] The five elements included (1) assessment of intubation daily, (2) interruption or lightening of sedation daily, (3) daily routine oral hygiene by 0.12%—0.2% chlorhexidine gluconate (CHG), (4) semi-recumbent position/head-of-bed (SRP/HOB) elevation (30—45°), and (5) evacuation of water in the circuit. Performance of hand hygiene before suction and post procedures and maintenance of cuff pressure around the endotracheal tubes at 20—25 $cmH_2O$ were also evaluated.[19]

Prior to intervention, the Committee provided (1) a checklist of the elements, (2) daily care assessment forms, (3) training materials for all elements in the bundle cares, including video, step-by-step working handbooks and standard operating procedures, (4) relevant publications and posters related to VAP bundle care to promote awareness among all involved staffs, (5) process and outcome measurement indicators and definitions, (6) common issues with implementing bundle care interventions, (7) handbooks for VAP bundle cares, and (8) protocols for implementing VAP bundle cares.

### Statistical analysis

Data were collected through the Infection Control Society of Taiwan's website by the respective usernames for each hospital. Results were presented as the rate ratio (IRR) and 95% confidence interval (CI) with accompanying $p$ values. Analyses were performed using Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA, USA), and a $p$ value $< 0.05$ was considered significantly different.

## Results

### VAP rates

During the 34-month study period (1st January 2012—31st October 2014), a total of 142 VAP cases were identified from 10 hospitals with a total of 81,027 ventilator-days from 170 beds of the different ICUs (Table 1). Fig. 1 shows the significantly decreasing trend of rates of VAP ($p = 0.0058$) by a six-month breakdown (only four months in the end of the intervention, July to October in 2014) during the pre-intervention and intervention periods. VAP rate decreased starting in the pre-intervention period from 2.84 per 1000 ventilator-days between January and June in 2012 to 1.31 per 1000 ventilator-days from January to June in 2013. Among the 10 hospitals, the overall VAP rates (cases per 1000 ventilator-days) declined significantly ($p = 0.005$; IRR, 0.71; CI 0.59—0.86) from 1.9 in the pre-intervention period to 1.5 in the intervention period. Significant differences in the VAP rates (cases per 1000 ventilator-days) between the pre-intervention and intervention periods occurred in the regional hospitals (from 1.6 to 0.7; $p < 0.001$) and SICUs (from 2.1 to 1.4; $p < 0.001$). VAP rates (cases per 1000 ventilator-days) between the pre-intervention and intervention periods were not significantly

**Table 1** Ventilator-associated pneumonia (VAP) rates (cases per 1000 ventilator-days) categorized by hospital scale and intensive care unit (ICU).

| Hospitals and ICUs (no. of hospitals or beds) | VAP | Pre-intervention (1st Jan., 2012—31st July, 2013) | Intervention (1st Aug. 2013—31st Oct., 2014) | *p* Value[a] | Rate ratios (95% confidence interval) |
|---|---|---|---|---|---|
| All hospitals (10) | Infection rate | 1.9 | 1.5 | **0.005** | 0.71 (0.59—0.86) |
| | No. of cases | 97 | 45 | | |
| | Ventilator-days | 51,363 | 29,664 | | |
| Medical centers (7) | Infection rate | 2.0 | 1.9 | 0.0667 | 0.82 (0.66—1.01) |
| | No. of cases | 73 | 39 | | |
| | Ventilator-days | 36,500 | 21,010 | | |
| Regional hospitals (3) | Infection rate | 1.6 | 0.7 | **<0.0001** | 0.71 (0.26—0.65) |
| | No. of cases | 24 | 6 | | |
| | Ventilator-days | 14,858 | 8654 | | |
| SICUs (7) | Infection rate | 2.1 | 1.4 | **<0.0001** | 0.41 (0.45—0.73) |
| | No. of cases | 80 | 32 | | |
| | Ventilator-days | 38,538 | 22,071 | | |
| CV/S-ICUs (1) | Infection rate | 4.5 | 4.5 | 0.5391 | 0.89 (0.62—1.28) |
| | No. of cases | 12 | 7 | | |
| | Ventilator-days | 2692 | 1556 | | |
| MICUs (2) | Infection rate | 0.5 | 1 | **0.0489** | 1.9 (1.00—3.60) |
| | No. of cases | 5 | 6 | | |
| | Ventilator-days | 10,133 | 6037 | | |

SICUs, surgical ICUs; CV/S-ICUs, cardiovascular/surgical ICUs; MICUs, medical ICUs.
[a] *p* values in boldface indicate significant differences in VAP rates (cases per 1000 ventilator-days) between pre-intervention and intervention phases.

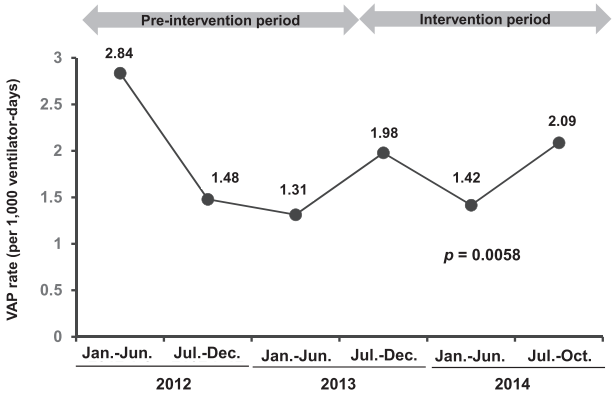


**Figure 1.** Trend of rates (cases per 1000 ventilator-days) of ventilator-associated pneumonia (VAP) from 10 intensive care units from January 2012 to October 2014.

different in the medical centers (2.0 vs. 1.9; $p = 0.0667$) and CV/S-ICU (4.5 vs. 4.5; $p = 0.5391$). However, VAP rates (cases per 1000 ventilator-days) significantly increased in the MICUs between the two periods (0.5 vs. 1.0; $p = 0.0489$) (Table 1).

## Compliance with hand hygiene and bundle care practice elements

Table 2 shows the overall compliance with hand hygiene, cuff pressure attainment, and 5 other practice elements of VAP bundle care in the participating hospitals and ICUs. The overall hand hygiene compliance rate in all participating ICUs was high, at 95.2% among 2855 hand hygiene opportunities: 92.84% (1803) in medical centers and 99.53% (1052) in regional hospitals. In general, compliance rates for hand hygiene, sufficient cuff pressure maintenance, and practice of the five bundle care elements were better in the regional hospitals than in the medical centers, except for the hand hygiene adherence rate by nurses, which was lower in regional hospitals than that in medical centers (Table 2).

## Discussion

In this study, the overall VAP rate of 1.5 per 1000 ventilator-days after bundle care intervention was lower than that in other studies.[5,8] Recent studies with different bundle care items for VAP reduction report that they reduced the VAP rate from 8.6 per 1000 ventilator-days to 2.0 per 1000 ventilator-days.[7] One study reported that the annual VAP rate was reduced to between 1.3 and 2 per 1000 ventilator-days and even zero for several months while VAP bundle compliance was over 90%.[20]

In this study, the overall VAP infection rate (cases per 1000 ventilator-days) was significantly reduced after bundle care intervention, especially in the regional hospitals (from 1.6 to 0.7) and SICUs (from 2.1 to 1.4). Patients in different ICU types were reported to have different VAP rates, which could be related to many factors. SICU patients had a greater risk of VAP than MICU patients, and VAP rates went up over time.[21] Through adherence to VAP bundle care management, VAP rates dropped in the SICU from 10.2 per 1000 ventilator-days to 3.4 per 1000 ventilator-days.[22] In this study, VAP rates in the SICU significantly decreased

**Table 2** Compliance with bundle care elements for ventilator-associated pneumonia (VAP) in the intervention period among different hospital categories and intensive care units (ICUs).

| Practices and elements of bundle care | Compliance, % (no. of opportunities) | | | | | |
|---|---|---|---|---|---|---|
| | Medical centers | Regional hospitals | SICUs | CV/S-ICUs | MICUs | Overall |
| Overall | 92.84 (1803) | 99.53 (1052) | 95.23 (2254) | 97.02 (163) | 94.4 (438) | 95.20 (2855) |
| Hand hygiene | | | | | | |
| Physicians | 96.6 (1876) | 100.0 (1057) | 97.47 (2307) | 97.02 (163) | 99.78 (463) | 97.8 (2933) |
| Nurses | 97.06 (1,1885) | 99.91 (1056) | 97.55 (2309) | 100.0 (168) | 100.0 (464) | 98.07 (2941) |
| Respiratory therapists | 93.05 (1807) | 99.72 (1054) | 95.35 (2257) | 98.81 (166) | 94.4 (438) | 95.4 (2861) |
| Sufficient cuff pressure (20—25 $cmH_2O$) | 97.01 (1884) | 99.91 (1056) | 97.51 (2308) | 100 (168) | 100 (464) | 98.03 (2940) |
| All elements | 83.60 (11,909) | 97.7 (5722) | 86.26 (12,813) | 97.93 (1133) | 90.05 (3685) | 87.7 (17,631) |
| Daily extubation assessment | 89.64 (12,744) | 99.81 (5846) | 90.77 (13,483) | 100 (1157) | 96.53 (3950) | 92.47 (18,590) |
| Interruption or lightening of sedation | 93.46 (13,315) | 98.05 (5743) | 94.91 (14,098) | 98.44 (1139) | 93.38 (3821) | 94.8 (19,058) |
| Oral hygiene with CHG | 99.91 (14,233) | 99.95 (5854) | 99.97 (14,849) | 100 (1157) | 99.73 (4081) | 99.92 (20,087) |
| SRP/HOB elevation (30—45°) | 99.35 (14,154) | 99.81 (5846) | 99.52 (14,782) | 98.96 (1145) | 99.54 (4073) | 99.49 (20,000) |
| Evacuation of water in the circuit | 99.84 (14,223) | 99.97 (5855) | 99.91 (14,840) | 100 (1157) | 99.73 (4081) | 99.88 (20,078) |

SICUs, surgical ICUs; CV/S-ICUs, cardiovascular/surgical ICUs; MICUs, medical ICUs; CHG, chlorhexidine gluconate; SRP/HOB, semi-recumbent position/head-of-bed elevation (30—45°); ISSD, intermittent subglottic secretion drainage.

from 2.1 per 1000 ventilator-days to 1.4 per 1000 ventilator-days. The scenario was also found in a study of 5 SICUs of a medical center in northern Taiwan that the VAP rate decreased from 3.3 per 1000 ventilator-days to 1.4 per 1000 ventilator-days through VAP bundle cares.[8]

Patients undergoing heart surgery were associated with a high frequency of VAP and poor attributable outcomes related to VAP.[23] In this study, VAP rates in the CV/S-ICU from a medical center remained the same (4.5/per 1000 ventilator-days) during the two periods. A prospective study demonstrated that 7.9% of all patients who underwent major heart surgeries had at least one episode of VAP (34.5 cases per 1000 ventilator-days) and the mortality of these patients was high (57.1%).[23]

In MICUs, the VAP rates increased significantly after bundle care intervention, but infection rate remained much lower than that in SICU patients. We did not collect APACHEII or SOFA scores for disease severity adjustment. For developing countries, the VAP rate is reported to be from 10 to 41.7 per 1000 ventilator-days, which is higher than in our study.[24] An epidemiology study reported the HAP rate to be as low as 0.5—0.85 per patient-days in Taiwan, but VAP rate was reported.[25]

In this study, 75% of ventilator-days were from SICUs, and 82.5% of VAP cases were from SICUs during pre-intervention, decreasing to 71.1% during intervention. During the VAP bundle care intervention period, the VAP rate markedly declined in SICUs compared to other ICUs, indicating that bundle care was more effective in SICUs than in other ICUs.

In this study, VAP rate decreased obviously in the pre-intervention period only after education. Until the project ended, the VAP rate was sustained at a lower level although a mild elevation of VAP rate was noted just after intervention and before the end of the project (Fig. 1). In general, most recruited hospitals showed a decrease in VAP rates since a series of educational programs. In fact, improvement starts before the true intervention period but with initial 6 months after the education instead. Comparing the VAP rate of the initial 6 months with the residual period, the VAP rate dropped from 2.83 to 1.58 per 1000 ventilator-days, which is a little higher than the average of VAP rate in the intervention period.

In conclusions, implementing VAP bundle care has effectively reduced VAP in Taiwanese ICUs, but differences in performance and compliance rates of VAP bundle care among the different ICUs and hospital categories did exist.

## Funding

This study was supported by a grant provided by the Centers for Diseases Control of Taiwan (MOHW104-CDC-C-114-112402).

## Conflict of interest

There is no conflict of interest.

## Ethical approval

This study was approved by the Institutional Review Boards of the National Taiwan University Hospital (201502026RINB), Chung Shan Medical University Hospital (CSMUH No: CS15022) and Mackay Memorial Hospital (15MMHIS016e). Signed consent forms were obtained from all enrolled subjects.

## References


1. Rello J, Ollendorf DA, Oster G, Vera-Llonch M, Bellm L, Redman R, et al. Epidemiology and outcomes of ventilator-associated pneumonia in a large us database. *Chest* 2002;**122**:2115—21.
2. Melsen WG, Rovers MM, Groenwold RH, Bergmans DC, Camus C, Bauer TT, et al. Attributable mortality of ventilator-associated pneumonia: a meta-analysis of individual patient data from randomised prevention studies. *Lancet Inf Dis* 2013;**13**:665—71.
3. Rello J, Lode H, Cornaglia G, Masterton R, Contributors VAPCB. A European bundle care for prevention of ventilator-associated pneumonia. *Intensive Care Med* 2010;**36**:773—80.
4. Rosenthal VD, Guzman S, Orellano PW. Nosocomial infections in medical-surgical intensive care units in Argentina: attributable mortality and length of stay. *Am J Infect Control* 2003;**31**: 291—5.
5. Eom JS, Lee MS, Chun HK, Choi HJ, Jung SY, Kim YS, et al. The impact of a ventilator bundle on preventing ventilator-associated pneumonia: a multicenter study. *Am J Infect Control* 2014;**42**:34—7.
6. Ferreira CR, de Souza DF, Cunha TM, Tavares M, Reis SS, Pedroso RS, et al. The effectiveness of a bundle in the prevention of ventilator-associated pneumonia. *Braz J Infect Dis* 2016;**20**:267—71.
7. Khan R, Al-Dorzi HM, Al-Attas K, Ahmed FW, Marini AM, Mundekkadan S, et al. The impact of implementing multifaceted interventions on the prevention of ventilator-associated pneumonia. *Am J Infect Control* 2016;**44**:320—6.
8. Lim KP, Kuo SW, Ko WJ, Sheng WH, Chang YY, Hong MC, et al. Efficacy of ventilator-associated pneumonia bundle care for prevention of ventilator-associated pneumonia in the surgical intensive care units of a medical center. *J Microbiol Immunol Infect* 2015;**48**:316—21.
9. Marini AL, Khan R, Mundekkadan S. Multifaceted bundle interventions shown effective in reducing VAP rates in our multidisciplinary ICUs. *BMJ Qual Improv Rep* 2016:5.
10. Mathru M. Reducing ventilator-associated pneumonia in intensive care: impact of implementing a bundle care. *Yearb Anesthesiol Pain Manag* 2012;**2012**:265—7.
11. Zilberberg MD, Shorr AF, Kollef MH. Implementing quality improvements in the intensive care unit: ventilator bundle as an example. *Crit Care Med* 2009;**37**:305—9.
12. 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* 2005;**31**:243—8.
13. Speck K, Rawat N, Weiner NC, Tujuba HG, Farley D, Berenholtz S. A systematic approach for developing a ventilator-associated pneumonia prevention bundle. *Am J Infect Control* 2016;**44**:652—6.
14. Bird D, Zambuto A, O'Donnell C, Silva J, Korn C, Burke R, et al. Adherence to ventilator-associated pneumonia bundle and rate of ventilator-associated pneumonia in the surgical intensive care unit. *Arch Surg* 2010;**145**:465—70.
15. Liu WL, Lin HL, Lai CC, Hsueh PR. A multidisciplinary team bundle care for reducing ventilator-associated pneumonia at a hospital in southern Taiwan. *J Microbiol Immunol Infect* 2013; **46**:313—4.
16. American Thoracic S, Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *Am J Respir Crit Care Med* 2005;**171**:388—416.
17. Kuo LC, Yu CJ, Kuo ML, Chen WN, Chang CK, Lin HI, et al. Antimicrobial resistance of bacterial isolates from respiratory care wards in Taiwan: a horizontal surveillance study. *Int J Antimicrob Agents* 2008;**31**:420—6.
18. Tablan OC, Anderson LJ, Besser R, Bridges C, Hajjeh R, CDC, et al. Guidelines for preventing healthcare-associated pneumonia, 2003: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee. *MMWR Recomm Rep* 2004;**53**:1—36.
19. Nseir S, Zerimech F, Fournier C, Lubret R, Ramon P, Durocher A, et al. Continuous control of tracheal cuff pressure and microaspiration of gastric contents in critically ill patients. *Am J Respir Crit Care Med* 2011;**184**:1041—7.
20. Caserta RA1 MA, Durão MS, Silva CV, Pavao dos Santos OF, Neves HS, Edmond MB, et al. A program for sustained improvement in preventing ventilator-associated pneumonia in an intensive care setting. *BMC Infect Dis* 2012;**29**:234.
21. Cunnion KM, Weber DJ, Broadhead WE, Hanson LC, Pieper CF, Rutala WA. Risk factors for nosocomial pneumonia: comparing adult critical-care populations. *Am J Respir Crit Care Med* 1996;**153**:158—62.
22. Dorothy B, Amanad Z, Charles O. Adherence to ventilator-associated pneumonia bundle and rate of ventilator-associated pneumonia in the surgical intensive care unit. *Arch Surg* 2009;**144**:656—62.
23. Bouza E, Perez A, Munoz P, Jesus Perez M, Rincon C, Sanchez C, et al. Ventilator-associated pneumonia after heart surgery: a prospective analysis and the value of surveillance. *Crit Care Med* 2003;**31**:1964—70.
24. Arabi Y, Al-Shirawi N, Memish Z, Anzueto A. Ventilator-associated pneumonia in adults in developing countries: a systematic review. *Int J Infect Dis* 2008;**12**:505—12.
25. Chawla R. Epidemiology, etiology, and diagnosis of hospital-acquired pneumonia and ventilator-associated pneumonia in Asian countries. *Am J Infect Control* 2008;**36**:S93—100.