

# Rates of Ventilator Associated Pneumonia in Saudi Ministry of Health Hospitals; A Two-year Multi-Center Study

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**Abstract BACKGROUND:** Although the rates of ventilator associated pneumonia (VAP) have been estimated in Saudi Arabia, however national surveillance data for VAP has never been reported earlier. **OBJECTIVES:** To estimate VAP rates and ventilator utilization ratios in 105 Ministry of health (MOH) hospitals and to benchmark them with International Standards. **METHODS:** It was a prospective surveillance study in 15 different types of intensive care units (ICUs) between January 2018 and December 2019. The data were entered into the health electronic surveillance network (HESN) program. The methods of US National Healthcare Safety Network (NHSN) and the Gulf Cooperation Council (GCC) center for infection control were used. **RESULTS:** During two years of surveillance covering 1,469,658 patient-days and 569,961 ventilator-days, a total 1,694 VAP events were identified. The overall MOH VAP rate was 2.97 (95% confidence 2.83-3.11) per 1000 ventilator-days and the overall ventilator utilization ratio was 0.39 (95% confidence 0.387- 0.389). VAP rates were highest in adult medical (4.40), pediatric cardiothoracic (3.64), and adult medical surgical ICUs (3.61). VAP standardized infection ratio across all types of ICUs in MOH hospitals were 29% lower than GCC hospitals, 78% lower than International Nosocomial Infection Control Consortium (INICC) hospitals, and 191% higher than NHSN hospitals. Ventilator standardized utilization ratio in all types of ICUs in MOH hospitals were 19% lower than GCC hospitals, 32% higher than INICC hospitals, and 50% higher than NHSN hospitals. **CONCLUSIONS:** Using huge standardized data, the current report can serve as a unique national VAP benchmark, fostering a culture of competitiveness between the hospitals and regions.

**Keywords:** ventilator associated pneumonia, ventilator, healthcare, infection control, benchmarking, surveillance

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## 1. Introduction

Pneumonia is the most frequent healthcare-associated infection (HAI), representing approximately 27% of all HAIs [1]. Ventilator-associated pneumonia (VAP) is a serious complication that continues to affect patients on mechanical ventilation, with 5% to 40% of these patients end up developing lung infections [2]. VAP is ranked among the top most frequent HAIs in both developed and developing countries [3]. Most importantly, VAP is associated with high attributable mortality specially in developing countries [4,5]. Additionally, VAP causes a significant healthcare resource utilization due to prolonged hospitalization and associated morbidity [6]. However, up to 50% of the VAP events can be prevented [7] and implementation of

preventive bundles can significantly reduce the VAP risk in ventilated patients [8].

Regular HAI surveillance monitoring with timely reports to stakeholders is an essential component for patient safety and healthcare improvement [9]. Active VAP surveillance is critical to control VAP rates and to provide baseline data for assessing the progress of preventive measures [10,11]. Moreover, the positive impact of surveillance activities on VAP rates is believed to cofound the observed impact of these preventive programs [12]. In Saudi Arabia, multi-hospital data on VAP surveillance were released in recent years [11,13,14,15]. However, none of these reports were nationally representative to estimate the national VAP rates. Finally, the sparse nature of these reports may undermine data comparisons. As MOH hospitals started to collect standardized VAP data using the health electronic surveillance network (HESN), the current study used these

data to estimate unit-specific VAP rates and ventilator utilization ratios in MOH hospitals and compared them with recognized regional and international benchmarks of NHSN, INICC and GCC.

## 2. Methods

**Setting:** MOH is administering 284 hospitals with a total bed capacity of more than 43,000 beds. This represents almost 60% of the total number of hospitals in Saudi Arabia; 484 hospitals with a total bed capacity of more than 75,000 beds [16]. The current study was conducted in 105 MOH hospitals distributed in 20 different geographic regions across Saudi Arabia. Out of 105 hospitals, 82.9% were general or central hospitals, 12.4% were maternal and children hospitals and 4.8% were cardiac hospitals (Table 1). At the time of the study, the included hospitals had a total 26,399 beds, including 3,560 intensive care unit (ICU) beds (Table 1).

**Design:** A prospective surveillance study was conducted between 1st January 2018 and 31st December 2019, using the HESN program.

**Population:** All included hospitals had at least 100-bed capacity, one ICU, a microbiology laboratory and a full time microbiologist. The data were obtained from 15 different types of ICUs. The data were included in the analysis if at least 50 ventilator days of surveillance were reported per the reporting year; 2018 and/or 2019 in a healthcare setting.

**Methods:** The surveillance methodology followed was similar to the US National Healthcare Safety Network guidelines (NHSN) [17] and the Gulf Cooperation Council (GCC) center for infection control [18]. The surveillance was active, patient-based, prospective and targeted, that was done in some ICUs for specific duration after a local infection risk assessment was done.

**Definitions:** VAP was identified using a combination of radiologic, clinical, and laboratory criteria according to CDC Definitions. According to the type of clinical and laboratory findings, patients were further divided into (1) clinical pneumonia without laboratory confirmation of the causative pathogen, (2) pneumonia with specific laboratory findings indicating the causative pathogen, or (3) pneumonia in immunocompromised patients [17,18]. Physician's diagnosis of pneumonia that did not match the surveillance criteria was not acceptable diagnosis for VAP.

**HESN program:** It is an integrated national health electronic surveillance system that has several domains to uniformly monitor communicable diseases, disease epidemics, immunizations, and HAIs across Saudi Arabia [19]. It allows users at different hospitals to continually and uniformly report HAIs to the General Directorate of Infection Prevention and Control (GDIPC), Riyadh, Saudi Arabia. Ventilator utilization and VAP data were collected by infection control practitioners (ICPs) at respective hospitals. The data were directly entered in HESN program into two forms; ventilator form and VAP event form. The number of ventilator days were estimated using daily count at a fixed time for all patients with a ventilator or an electronic count that was within +/- 5% of the manually collected daily count. The surveillance department of GDIPC at MOH provided the included hospitals with the required training in basic surveillance definitions, surveillance methodology, use of HESN program, and information technology support. Training workshops followed by hands on training were conducted in all regions (during the year 2017) before start of the study.

**Statistical analysis:** The data from all regions were extracted from HESN program and analyzed using SPSS. Data extraction, management, analysis and interpretation were done centrally at the GDIPC. VAP rates (expressed per 1,000 ventilator days) and ventilator utilization ratios were calculated and stratified by the type of ICU and additionally by the birth weight groups in neonatal ICUs [15,20]. Confidence intervals (CIs) [15] and standard percentiles [20] were calculated for both VAP rates and ventilator utilization ratios. Percentiles were not calculated for ICU types with less than 20 data points (hospital year of surveillance). To benchmark current VAP rates and ventilator utilization ratios with regional and international benchmarks, standardized infection ratios (SIR) and standardized utilization ratio (SUR) were calculated (respectively) after adjusting for differences in ICU types (in all ICUs) and birth weight groups (in neonatal ICUs only). SIR and SUR were calculated by dividing the number of observed VAP events and ventilator days (respectively) by their expected values [17]. The expected values were calculated using the published reports of NHSN [20,21], GCC [15], and International Nosocomial Infection Control Consortium (INICC) [5]. P-values were two-tailed. P-value <0.05 was considered as significant. SPSS software (release 25.0, Armonk, NY: IBM Corp) was used for all statistical analyses.

**Table 1. Saudi Ministry of Health (MOH) hospitals enrolled in health electronic surveillance network (HESN) which contributed current VAP surveillance data, 2018-2019**

	<200 beds	200-300 beds	>300 beds	Total
<b>Type of hospital</b>				
General/central	33 (80.5%)	36 (85.7%)	18 (81.8%)	87 (82.9%)
Maternal and children	3 (7.3%)	6 (14.3%)	4 (18.2%)	13 (12.4%)
Cardiac	5 (12.2%)	0 (0.0%)	0 (0.0%)	5 (4.8%)
Total	41 (100.0%)	42 (100.0%)	22 (100.0%)	105 (100.0%)
<b>Surveillance numbers</b>				
Patient days	263400	678808	527451	1469658
Ventilator days	81323	259888	228750	569961
VAP events	335	778	581	1694
<b>Bed capacity</b>				
Total beds	4723	11385	10291	26399
ICU beds	645	1382	1533	3560

VAP, ventilator-associated pneumonia.

### 3. Results

During two years of surveillance around 1,469,658 patient-days and 569,961 ventilator-days, a total 1,694 VAP events were identified. As shown in Table 2, the overall VAP rate was 2.97 per 1000 ventilator-days with the 95% CI ranged between 2.83 and 3.11. The 50th, 75th, and 90th percentiles were 1.07, 4.15, and 9.03, respectively. Five types of ICUs contributed 96% of the ventilator-days surveyed in all types of ICUs; adult medical surgical, neonatal, adult medical, pediatric medical surgical, and pediatric medical cardiac ICU. VAP rates per 1000 ventilator-days were highest in adult medical (4.40), pediatric cardiothoracic (3.64), and adult medical surgical ICUs (3.61) but lowest in neurological, pediatric surgical, and respiratory ICUs (all were zeros).

As shown in Table 3, the overall ventilator utilization ratio was 0.39, with the 95% CI ranged between 0.387 and 0.389. The 50th, 75th, and 90th percentiles were 0.38, 0.58, and 0.69, respectively. The ventilator utilization ratios were highest in neurosurgical (0.64), surgical (0.60), respiratory (0.59), and trauma ICUs (0.59) but lowest in burn (0.11), medical cardiac (0.13), and pediatric surgical ICUs (0.15).

VAP rates and ventilator utilization ratios stratified by birth-weight groups in neonatal ICUs are shown in Table 4. The neonatal overall VAP rate was 1.88 per 1000 ventilator-days and ventilator utilization ratio was 0.23. With exception of the lowest birth-weight group, VAP rates per 1000 ventilator-days were decreasing while ventilator utilization ratios were increasing as birth weight group were increasing. For example, VAP rates were 2.47

in neonates 751-1000 g and 1.21 in neonates >2500 g while ventilator utilization ratios were 0.21 in neonates 751-1000 g and 0.30 in neonates >2500 g.

Figure 1 compares VAP rates and ventilator utilization ratios in adult, pediatric, and neonatal ICUs in MOH hospitals with other recognized benchmarking networks. VAP rates in all ICUs in MOH hospitals were higher than NHSN rates, much lower than INICC rates, and similar to or slightly lower than GCC rates. Ventilator utilization ratios in all ICUs in MOH hospitals were higher than NHSN and lower than GCC ICUs. Compared with INICC, ventilator utilization ratios in MOH hospitals were higher in adults medical-surgical and neonatal ICUs, and lower in pediatric medical-surgical ICUs.

Table 5 compares VAP rates and ventilator utilization ratios in MOH hospitals with the three benchmarks using SIR and SUR, respectively. VAP SIR across all types of ICUs in MOH hospitals were 29% lower than GCC hospitals, 78% lower than INICC hospitals, and 191% higher than NHSN hospitals. Ventilator SUR across all types of ICUs in MOH hospitals were 19% lower than GCC hospitals, 32% higher than INICC hospitals, and 50% higher than NHSN hospitals.

Table 6 compares VAP rates and ventilator utilization ratios in neonatal ICUs in MOH hospitals with the three benchmarks using SIR and SUR, respectively. VAP SIR across all birth weight groups in neonatal ICUs in MOH hospitals were 57% higher than GCC hospitals, 79% lower than INICC hospitals, and 186% higher than NHSN hospitals. Ventilator SUR across all birth weight groups in neonatal ICUs in MOH hospitals were 34% lower than GCC hospitals, 19% higher than INICC hospitals, and 52% higher than NHSN hospitals.

Table 2. VAP rates by type of ICU in Saudi MOH hospitals enrolled in HESN, 2018-2019

Type of ICU	Number of ICUs*	Ventilator days	VAP events	Mean VAP rate	95% confidence interval	Percentile**				
						10%	25%	50% (median)	75%	90%
Burn	5	1184	1	0.84	0.00-2.50					
Medical	41	50882	224	4.40	3.83-4.98	0.00	0.00	2.00	5.49	10.54
Medical cardiac	24	7223	24	3.32	1.99-4.65	0.00	0.00	0.00	5.48	12.94
Medical surgical	145	294057	1061	3.61	3.39-3.83	0.00	0.44	2.59	6.14	10.28
Neurological	1	140	0	0.00	0.00-0.00					
Neurosurgical	3	4926	8	1.62	0.00-2.75					
Neonatal	94	127951	241	1.88	0.00-2.12	0.00	0.00	0.00	1.48	4.46
Pediatric cardiothoracic	2	275	1	3.64	0.00-10.76					
Pediatric medical	18	17073	35	2.05	1.37-2.73					
Pediatric medical surgical	46	48618	64	1.32	0.99-1.64	0.00	0.00	0.51	1.75	4.36
Pediatric surgical	2	303	0	0.00	0.00-0.00					
Respiratory	1	1718	0	0.00	0.00-0.00					
Surgical	6	9139	28	3.06	0.00-4.20					
Surgical cardiothoracic	5	2932	6	2.05	0.41-3.68					
Trauma	3	3540	1	0.28	0.00-0.84					
<b>Total</b>	<b>396</b>	<b>569961</b>	<b>1694</b>	<b>2.97</b>	<b>2.83-3.11</b>	<b>0.00</b>	<b>0.00</b>	<b>1.07</b>	<b>4.15</b>	<b>9.03</b>

Abbreviations as in Table 1. \* ICUs contributing less than 50 ventilator days per year were excluded from the analysis

\*\* Standard percentiles were calculated only when at least 20 hospitals were contributing data for a specific type of ICU.

**Table 3. Ventilator utilization ratios by type of ICU in Saudi MOH hospitals enrolled in HESN, 2018-2019**

Type of ICU	Number of ICUs*	Patient days	Ventilator days	Utilization ratio	95% confidence interval	Percentile**				
						10%	25%	50% (median)	75%	90%
Burn	5	11057	1184	0.11	0.101-0.113					
Medical	41	100860	50882	0.50	0.501-0.508	0.14	0.32	0.55	0.66	0.75
Medical cardiac	24	55262	7223	0.13	0.128-0.134	0.05	0.09	0.14	0.24	0.62
Medical surgical	145	553636	294057	0.53	0.530-0.532	0.18	0.36	0.51	0.61	0.69
Neurological	1	349	140	0.40	0.350-0.453					
Neurosurgical	3	7741	4926	0.64	0.626-0.647					
Neonatal	94	550789	127951	0.23	0.231-0.233	0.07	0.12	0.21	0.32	0.44
Pediatric cardiothoracic	2	1552	275	0.18	0.158-0.196					
Pediatric medical	18	43553	17073	0.39	0.387-0.397					
Pediatric medical surgical	46	112040	48618	0.43	0.431-0.437	0.12	0.20	0.41	0.57	0.76
Pediatric surgical	2	2048	303	0.15	0.133-0.163					
Respiratory	1	2896	1718	0.59	0.575-0.611					
Surgical	6	15157	9139	0.60	0.595-0.611					
Surgical cardiothoracic	5	6754	2932	0.43	0.422-0.446					
Trauma	3	5964	3540	0.59	0.581-0.606					
Total	396	1469658	569961	0.39	0.387-0.389	0.11	0.18	0.38	0.58	0.69

Abbreviations as in Table 1. \* ICUs contributing less than 50 ventilator days per year were excluded from the analysis

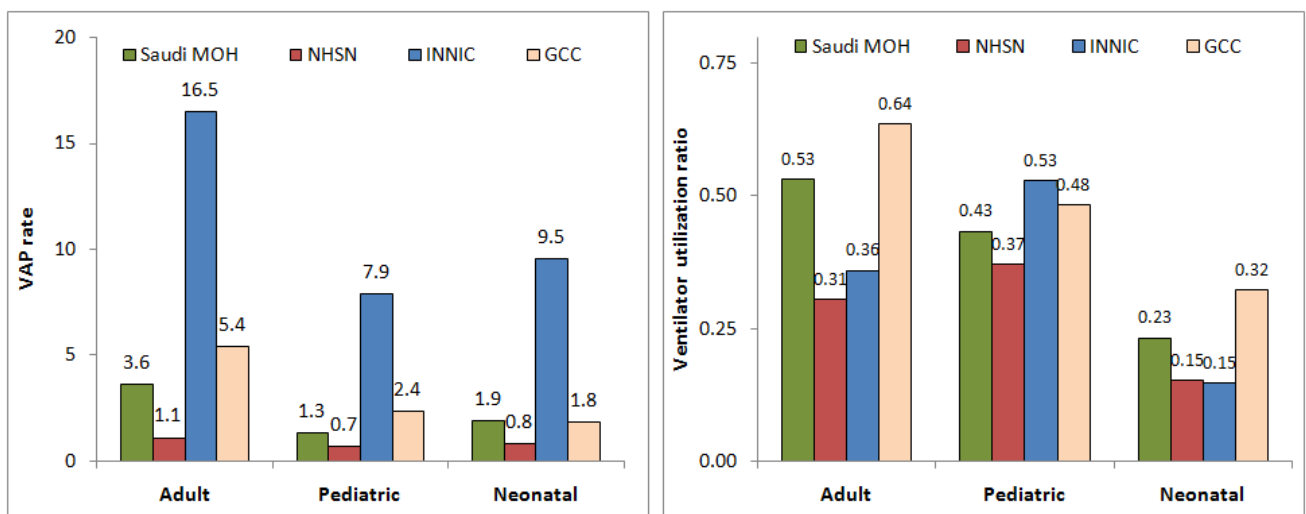
\*\* Standard percentiles were calculated only when at least 20 hospitals were contributing data for a specific type of ICU.

**Table 4. VAP rates and ventilator utilization ratio by birth weight category for level III neonatal ICUs in Saudi MOH hospitals enrolled in HESN, 2018-2019**

Birth weight category	Number of ICUs*	Patient days	Ventilator days	VAP events	Mean VAP rate	95% confidence interval	Utilization ratio	95% confidence interval
≤750 g	81	69817	17648	25	1.39	0.84-1.94	0.25	0.250-0.256
751-1000 g	76	117584	24606	61	2.47	1.85-3.10	0.21	0.207-0.212
1001-1500 g	89	133129	25277	58	2.31	1.72-2.90	0.19	0.188-0.192
1501-2500 g	94	129914	30488	61	2.00	1.50-2.50	0.23	0.232-0.237
>2500 g	89	100345	29931	36	1.21	0.82-1.61	0.30	0.295-0.301
Total	94	550789	127951	241	1.88	1.65-2.12	0.23	0.231-0.233

Abbreviations as in Table 1. \* Birth weight category with less than 50 ventilator days per year were excluded from the analysis

\*\* Standard percentiles were calculated only when at least 20 hospitals were contributing data for a specific birth weight category.



Note: Adult and pediatric ICUs were medical-surgical ICUs and neonatal ICUs were level III ICUs. NHSN, US National Healthcare Safety Network; INNIC, International Nosocomial Infection Control Consortium of developing countries; GCC, Gulf Cooperation Council countries; VAP, ventilator-associated pneumonia. Abbreviations as in Table 1.

**Figure 1.** Comparisons of VAP rates (left) and ventilator utilization ratios (right) between Saudi MOH hospitals enrolled in HESN and other recognized benchmarking networks

**Table 5. Comparisons of VAP rates and ventilator utilization ratio between Saudi MOH hospitals enrolled in HESN and other recognized benchmarking networks after adjustment for different types of ICUs**

	Saudi MOH vs. NHSN	Saudi MOH vs. INICC	Saudi MOH vs. GCC
<b>VAP rates</b>			
Number of ICU types included	15	11	7
Observed VAP events	1694	1657	1404
Expected VAP events	581.1	7593.2	1983.0
Standardized infection ratio (SIR)	2.91	0.22	0.71
95% confidence interval of SIR	2.78-3.06	0.21-0.23	0.67-0.75
P-value	<0.001	<0.001	<0.001
<b>Ventilator utilization ratios</b>			
Number of ICU types included	15	11	7
Observed ventilator days	569961	551126	488506
Expected ventilator days	380094	417030	599680
Standardized utilization ratio (SUR)	1.500	1.322	0.815
95% confidence interval of SUR	1.496-1.503	1.318-1.325	0.812-0.817
P-value	<0.001	<0.001	<0.001

Abbreviations as in [Figure 1](#).

**Table 6. Comparisons of VAP rates and ventilator utilization ratio between neonatal ICUs in Saudi MOH hospitals enrolled in HESN and other recognized benchmarking networks after adjustment for different birth weight categories**

	Saudi MOH vs. NHSN	Saudi MOH vs. INICC	Saudi MOH vs. GCC
<b>VAP rates</b>			
Number of birth weight category included	5	5	5
Observed VAP events	241	241	241
Expected VAP events	84.3	1170.1	153.9
Standardized infection ratio (SIR)	2.86	0.21	1.57
95% confidence interval of SIR	2.52-3.24	0.18-0.23	1.38-1.78
P-value	<0.001	<0.001	<0.001
<b>Ventilator utilization ratios</b>			
Number of birth weight category included	5	5	5
Observed ventilator days	127950	127950	127950
Expected ventilator days	83656	107329	168141
Standardized utilization ratio (SUR)	1.529	1.192	0.761
95% confidence interval of SUR	1.521-1.538	1.186-1.199	0.757-0.765
P-value	<0.001	<0.001	<0.001

Abbreviations as in [Figure 1](#).

## 4. Discussion

The current report is estimating VAP rates and ventilator utilization ratios in MOH hospitals. The overall MOH VAP rate was 2.97 per 1000 ventilator-days. This rate was considerably lower than previously reported VAP rates derived from multi-hospital surveillance studies in Saudi Arabia, which ranged between 4.8 and 7.8 per 1000 ventilator-days [11,14,15]. However, the difference is much reduced when comparing the current rate to the VAP rates of recent years in studies covering longer duration (2-3 per 1000 ventilator-days) [15] or post-intervention VAP rates in interventional studies (4.7 per 1000 ventilator-days) [11]. The lower rates in the current study may be explained by several reasons. First, the VAP rates were dramatically improved over the

last decade after implementation of ventilator bundle and other preventive measures. The change was evident in Saudi Arabia [11,15] and developing countries [5] had very high baseline rates. Second, the majority of the hospitals in the current study were general/central hospitals compared with secondary or tertiary hospitals in previous studies of Saudi Arabia [11,14,15]. This point was supported by the difference in ventilator utilization discussed below. Third, the variability in ICU distribution in the current study were responsible for some of the observed differences. For example, adjusting MOH VAP rates for the type of ICUs (Table 5) reduce the difference with the GCC report from 38% to 29%. Finally, VAP is the most sensitive device-associated HAI to monitor variations in surveillance methodology and definition implementation [22,23]. Therefore, comparing VAP rates

between studies with minor differences in methodology can be challenging.

The overall MOH ventilator utilization ratio was 0.39. The current ventilator utilization was considerably lower than previously reported by multi-hospital surveillance studies in Saudi Arabia, which ranged between 0.53 and 0.94 [11,13,15]. The lower ventilator utilization in the current study was consistent with the relatively lower MOH VAP rates. Additionally, the majority of the hospitals in the current study were general/central hospitals which are expected to have lower ventilator utilization compared with secondary and tertiary hospitals [11,13,15]. Finally, pediatric and neonatal ICUs which are known with their lower ventilator utilization contributed 34% of the data used in the current report compared with mainly adult ICUs in previous reports [11,13]. Therefore, when the ventilator utilization in the current study were stratified by type of ICU as in Figure 1, the overall difference in ventilator utilization between the current and GCC report become much attenuated in adult, pediatric, and neonatal ICUs [15]. Moreover, MOH ventilator utilization ratio adjusted for the type of ICUs (Table 5) was higher (not lower) than both developed and developing countries.

Internationally, the adjusted comparisons in the current report showed that MOH VAP rates were much higher than NHSN hospitals but much lower than INICC hospitals in all ICUs combined and neonatal ICUs. Similar findings were reported by a number of previous studies in Saudi Arabia [11,13,15]. For example, the GCC study reported more than 200% excess risk of VAP compared with NHSN hospitals and 70% reduced risk of VAP compared with INICC hospitals [15]. The consistent finding may be reflecting differences in infection control practices and regulations in US compared with developing countries. Additionally, the finding may indicate the need for timely implementation of infection control practices and preventive bundles to bring the rates much lower.

The current report can perfectly represent as a national benchmarking report for VAP. The benchmarking use of this report is supported by the large unprecedented number of hospitals included, the coverage of 20 geographic regions, and the use of the unified electronic data collection system. Additionally, this has been further facilitated by presenting unit-specific rates and ratios and calculating confidence intervals and standard percentiles for both rates and ratios. Moreover, the use of the same surveillance methodology and the same electronic platform ensured the homogeneity of the calculated rates and ratios. This is particularly important in VAP rates which are very sensitive to variability in implementation of VAP surveillance definitions [22,23]. Yet, several challenges still need to be overcome to further improve VAP surveillance in MOH hospitals, including data validation, site audits, and rapid turnover of infection control practitioners.

In conclusion, the current study estimated VAP rates and ventilator utilization ratios in 15 different types of ICUs in 105 MOH hospitals distributed in 20 regions. The overall VAP rate was 2.97 per 1000 ventilator-days and the overall ventilator utilization ratio was 0.39. MOH VAP rates adjusted for the type of ICUs were 29% lower than GCC hospitals, 78% lower than INICC hospitals, and

191% higher than NHSN hospitals. The last finding may indicate the need of strict adherence to the infection control practices and preventive bundles to bring the rates much lower. The current report can serve as a unique national VAP benchmark, fostering a culture of competitiveness between MOH hospitals and regions [24].

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## Disclosures

The authors report no conflicts of interest in this work.

## Statement

All authors have been acknowledged as contributors of submitted work and fulfill the standard criteria for authorship. All authors have read and approved the submission of the current version of the manuscript. The material included in this manuscript is original and it has been neither published elsewhere nor submitted for publication simultaneously.

## List of Abbreviations

GCC: Gulf Cooperation Council  
 GDIPC: General Directorate of Infection Prevention and Control  
 HAI: Healthcare associated infection  
 HESN: Health Electronic Surveillance Network  
 INICC: International Nosocomial Infection Control Consortium  
 ICP: Infection Control Practitioner  
 ICU: Intensive care unit  
 MOH: Ministry of Health  
 NHSN: National Healthcare Safety Network  
 SIR: Standardized Infection Ratio  
 SUR: Standardized Utilization Ratio  
 VAP: Ventilator Associated Pneumonia

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