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Risk factors for mortality in ICU patients in 10 middle eastern countries: The role of healthcare-associated infections

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ABSTRACT

Purpose: The International Nosocomial Infection Control Consortium (INICC) found a high mortality rate in ICUs of the Middle East (ME). Our goal was to identify mortality RF in ICUs of the ME.
Materials: From 08/01/2003 to 02/12/2022, we conducted a prospective cohort study in 236 ICUs of 77 hospitals in 44 cities in 10 countries of ME. We analyzed 16 independent variables using multiple logistic regression.
Results: 66,440 patients, hospitalized during 652,167 patient-days, and 13,974 died.

We identified following mortality RF: Age (adjusted odds ratio (aOR):1.02;$p < 0.0001$) rising risk 2% yearly; length of stay (LOS) (aOR:1.02;$p < 0.0001$) rising the risk 2% per day; central line (CL)-days (aOR:1.01;$p < 0.0001$) rising risk 1% per day; mechanicalventilator (MV) utilization-ratio (aOR:14.51;$p < 0.0001$); CL-associated bloodstream infection (CLABSI) acquisition (aOR):1.49;$p < 0.0001$); ventilator-associated pneumonia (VAP) acquisition (aOR:1.50;$p < 0.0001$); female gender (OR:1.14;$p < 0.0001$); hospitalization at a public-hospital (OR:1.31;$p < 0.0001$); and medical-hospitalization (aOR:1.64;$p < 0.0001$). High-income countries showed lowest risk (aOR:0.59;$p < 0.0001$).
Conclusion: Some identified RF are unlikely to change, such as country income-level, facility ownership, hospitalization type, gender, and age. Some can be modified; LOS, CL-use, MV-use, CLABSI, VAP. So, to lower the mortality risk in ICUs, we recommend focusing on strategies to shorten the LOS, reduce CL and MV-utilization, and use evidence-based recommendations to prevent CLABSI and VAP.

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1. Introduction

The goals of medicine encompass alleviating pain and suffering, promoting health and preventing disease, forestalling death, promoting a peaceful death, curing disease when possible, and caring for the incurable [1]. The International Nosocomial Infection Control Consortium (INICC) is dedicated to promoting these goals through the surveillance and prevention of healthcare-associated infections (HAIs) worldwide [2]. It is a multinational multicenter HAI research network working internationally since 2002 [2]. Its main objective is to promote evidence-based infection prevention practices to reduce the incidence of HAIs and their associated mortality, bacterial resistance, excess length of stay (LOS) and costs [2].

INICC has published international reports providing data on HAIs and related mortality in 2006 [3], 2008 [4], 2010 [5], 2012 [6], 2014 [7], 2016 [8], 2019 [9], and 2021 [10]. These INICC findings show that HAI rates in the Middle East [11-19], and in low and middle countries (LMIC) are 3 to 5 times higher than in the rate at high income countries [3-10]. INICC published in 2021 that the mortality rate in ICU patients in LMICs without HAI it is 17.12% (95% CI = 16.93–17.32), for those with one HAI is 30.15% (95% CI = 27.70–32.77) to 48.21% (95% CI = 45.57–50.96), and for those with 3 simultaneous HAIs it is 63.44% (95% CI = 55.99–71.60) [10].

Different studies have analyzed the impact of severity of illness score [20,21], such as SOFA [20] and APACHE II [20,21], age [21], gender [22], mechanical ventilator (MV)-use [20,21,23], central line (CL)-use [21], HAIs [23], diabetes [23], severe pulmonary hypertension [20], lower mean arterial pressure [20], cardiac index [20], vasopressors [20], pulmonary vascular resistance index [20], and several others on ICU mortality. However, as of the time of this publication, no study has analyzed multiple countries simultaneously to identify mortality RF in ICUs of the Middle East [24]. Additionally, no study has been conducted prospectively over 19 years. No study has analyzed any of the following variables and their association with mortality: Income level classifications according with World Bank (WB) (Low, Lower-middle, Upper-middle, High), Hospital Ownership (publicly owned facilities, not-for-profit privately owned facilities, for-profit privately owned facilities, university hospitals) [25], type of hospitalization (medical, surgical), ICU type (cardio-thoracic, coronary, medical, medical-surgical, neuro surgical, neurologic, adult oncology, pediatric oncology, pediatric, respiratory, surgical, trauma, burn), device days (CL-days, MV-days, urinary catheter [UC]-days), device-utilization ratio as a marker of severity of illness of patients [30] (CL-utilization ratio, MV-utilization ratio, UC-utilization ratio). The goal of the present study is to analyze the impact of these variables and others as independent mortality RF.

2. Methods

2.1. Study population and design

This multinational, multicenter, prospective observational cohort study was performed on patients admitted to 236 ICUs of 77 hospitals in 44 cities in 10 Middle Eastern countries [24] throughout 19 years, between 08/01/2003 to 02/12/2022.

2.2. Prospective cohort in ICUs and surveillance of health care associated infections

Each patient's data was gathered at the time of ICU admission. Infection prevention professionals (IPP) visited each patient's bedside daily from the time of admission until discharge. This analysis prospectively included all adult and pediatric patients hospitalized to an ICU with or without HAIs, and their data were gathered from admission to discharge utilizing the INICC Surveillance Online System (ISOS) [2]. IPPs bring a tablet to each hospitalized patient's bedside in the ICU, sign in to ISOS, and simultaneously upload the patient's data [2].

This information is provided at the time of admission and includes information about the setting, such as the nation, city, name of the hospital, and the ICU type, as well as information about the patient, such as age, type of hospitalization (medical or surgical), use of invasive devices (CL, MV, UC), and presence of infection [2]. Every day up until the patient is discharged, IPPs upload details on invasive devices (such as a CL, MV, UC), and positive cultures (such as blood, urine, and respiratory samples) for each patient [2].

If the patient has signs or symptoms of infection, an infectious diseases specialist approach the patient to determine the presence of an HAI (CLABSI, VAP, CAUTI). According to the Centers for Disease Control and Prevention/National Healthcare Safety Network (CDC/NHSN), IPPs look at a patient's signs and symptoms, cultures, X-rays, and other described criteria to fulfill definitions of HAI [26,27]. When IPPs upload the results of a culture to the ISOS, the ISOS immediately displays a message and directs the IPP to an online module of the ISOS where the IPP can check all the CDC NHSN criteria to determine the presence of a HAI and the kind of HAI (CLABSI, VAE, CAUTI) [2].

Daily device utilization checks are performed by ISOS. When a bias in patient-days or device use is detected from admission to discharge, the ISOS notifies the IPPs. The patient will be hospitalized in the ICU without any devices in place most likely because IPP forgot to upload to ISOS the use of devices or forgot to upload to ISOS the discharge of the patient. If ISOS notices lack of use of any kind of device on any given day, it will send a message to the IPP to remind him or her to upload missing devices or upload the discharge of the patient. In other words, ISOS asks IPPs to look into why a patient in an ICU doesn't have any devices in place [2]. This approach significantly reduces biases associated with device utilization, patient-days, and discharge conditions [2].

Patients with missing data were excluded from this study. The Institutional Review Boards of the participating hospitals provided their approval for this study. Patients' and hospitals' identities are treated with confidentiality.

2.3. INICC Surveillance Online System

Standard CDC/NSHN methodologies state that HAI denominators are device-days gathered from all patients as pooled data, without mentioning the characteristics of particular patients or the quantity of device-days associated with particular patients [26,27]. INICC HAI surveillance is carried out through the use of an online platform, the INICC Surveillance Online System (ISOS), which includes CDC NHSN criteria and methods [26,27].

Additionally, ISOS includes the gathering of patient-specific information on all patients, including those with and those without HAI, with a several variables per patient [2]. The ability to match data from all patients admitted to the ICU by different variables allows for the estimation of the mortality RFs.

The CDC/NHSN criteria and methods are used in the data uploaded to ISOS to identify HAIs, estimate HAI rates, and determine DU-ratio [26,27].

2.4. Study definitions

World Bank country classifications by income level: The WB assigns the world's economies to four income groups—low, lower-middle, upper-middle, and high-income countries. The classifications are based on GNI per capita in current USD. Low income are those countries with gross national income (GNI) less than USD 1045. Lower-middle income

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those with GNI from 1046 to 4095. Upper-middle income those with GNI from 4096 to 12,695. High income those with GNI >12,695 [28].

Facility/institution ownership type: Publicly owned facilities owned or controlled by a governmental unit or another public corporation (where control is defined as the ability to determine the general corporate policy); ***not-for-profit privately owned*** facilities that are legal or social entities created for the purpose of producing goods and services, whose status does not permit them to be a source of income, profit or other financial gain for the unit(s) that establish, control or finance them; and, ***for-profit privately owned facilities*** that are legal entities set up for the purpose of producing goods and services and are capable of generating a profit or other financial gain for their owners [25].

Patient-day: A count of the number of patients in a patient care location during a defined time period [29].

Device-utilization: DU was calculated as a ratio of device-days to patient-days for each location type. As such, the DU of a location measures the use of invasive devices and constitutes an extrinsic RF for HAI. DU may also serve as a marker for severity of illness of patients (i.e. severely ill patients are more likely to require an invasive device) which is an intrinsic RF for HAI [30].

Ventilator: Any device used to support, assist, or control respiration through the application of positive pressure to the airway when delivered via an artificial airway, specifically an oral/nasal endotracheal or tracheostomy tube.

Definitions of HAI (VAP, CLABSI, CAUTI) used during surveillance were those published by CDC in 1991 [26] and their subsequent updates through 2022 [29].

Ventilator-associated pneumonia (VAP): A pneumonia where the patient is on MV for >2 consecutive calendar days on the date of event, with day of ventilator placement being Day 1, **AND** the ventilator was in place on the date of event or the day before [29].

Clinically Defined Pneumonia: Two or more serial chest imaging test results with at least **one** of the following: New and persistent **or** Progressive and persistent; Infiltrate; Consolidation; Cavitation; Pneumatoceles, in infants ≤1 year old. For ANY PATIENT, at least **one** of the following: Fever; Leukopenia; or leukocytosis; For adults ≥70 years old, altered mental status with no other recognized cause. And at least **two** of the following: New onset of purulent sputum or change in character of sputum, or increased respiratory secretions, or increased suctioning requirements; New onset or worsening cough, or dyspnea, or tachypnea; Rales or bronchial breath sounds; Worsening gas exchange; increased oxygen requirements; or increased ventilator demand [29].

Pneumonia with Common Bacterial or Filamentous Fungal Pathogens and Specific Laboratory Findings: Two or more serial chest imaging test results with at least **one** of the following: New and persistent **or p**rogressive and persistent Infiltrate; Consolidation; Cavitation; Pneumatoceles, in infants ≤1 year old. At least **one** of the following: Fever; Leukopenia or leukocytosis; For adults ≥70 years old, altered mental status with no other recognized cause. And at least **one** of the following: New onset of purulent sputum or change in character of sputum, or increased respiratory secretions, or increased suctioning requirements; New onset or worsening cough, or dyspnea, or tachypnea; Rales or bronchial breath sounds; Worsening gas exchange; increased oxygen requirements; or increased ventilator demand. At least **one** of the following: Organism identified from blood; Organism identified from pleural fluid; Positive quantitative culture or corresponding semi-quantitative culture result from minimally-contaminated LRT specimen; ≥5% BAL-obtained cells contain intracellular bacteria on direct microscopic exam; Positive quantitative culture or corresponding semi-quantitative culture result of lung tissue; Histopathologic exam shows evidences of pneumonia [29].

Central line (CL): An intravascular catheter that terminates at or close to the heart, **or** in one of the great vessels **AND** is used for infusion, withdrawal of blood, or hemodynamic monitoring. The following are considered great vessels: Aorta, pulmonary artery, superior or inferior vena cava, brachiocephalic veins, internal jugular veins, subclavian veins, external iliac veins, common iliac veins, femoral veins, in neonates, the umbilical artery/vein [31].

Primary bloodstream infection (BSI): A Laboratory Confirmed Bloodstream Infection (LCBI) that is not secondary to an infection at another body site [31].

Central line-associated BSI (CLABSI): A LCBI where an **eligible BSI organism** is identified, and an **eligible CL** is present on the LCBI or the day before [31].

Laboratory-Confirmed Bloodstream Infection 1: Patient of any age has a recognized bacterial or fungal pathogen, not included on the NHSN common commensal list: Identified from one or more blood specimens obtained by a culture OR Identified to the genus or species level by non-culture based microbiologic testing methods. **AND** Organism(s) identified in the blood are not related to an infection at another site [31].

Laboratory-Confirmed Bloodstream Infection 2: **A** patient of any age has at least ***one*** of the following signs or symptoms: fever (>38.0 °C), chills, or hypotension. **AND** Organism(s) identified in the blood are not related to an infection at another site. **AND** The same NHSN common commensal is identified by culture from two or more **blood specimens** collected on separate occasions [31].

Common Commensal: Common Commensal organisms include, but are not limited to, *diphtheroids* (*Corynebacterium* spp. not *C. diphtheria*), *Bacillus* spp. (not *B. anthracis*), *Propionibacterium* spp., coagulase-negative *staphylococci* (including *S. epidermidis*), viridans group *streptococci*, *Aerococcus* spp. *Micrococcus* spp. and *Rhodococcus* spp. [31].

2.5. Recorded data

Income group by WB country classifications by income level (low, lower middle, upper middle, high) [28], country name, city name, hospital name, hospital ownership (publicly owned facilities, not-for-profit privately owned facilities, for-profit privately owned facilities, university hospitals) [25], ICU type [29], age, gender, device-days (CL-days, MV-days, UC-days) [29], device-utilization (DU) ratio as a marker of severity of illness of patients (CL-utilization ratio, MV-utilization ratio, UC-utilization ratio) [30], LOS [29], and HAI acquisition according with CDC/NHSN definitions (CLABSI, VAP, CAUTI) [26,27] were recorded as independent variables. The evaluated outcome was **in "ICU all-cause mortality"**.

2.6. Statistical analysis

Multiple logistic regression was used to compare patients who were alive and those who passed away. Independently, statistically significant factors were associated with a higher mortality RF. The Wald test was employed as the test statistic, and a level of statistical significance of 0.05 was established. Adjusted odds ratios (aORs) and the corresponding 95% confidence intervals (CIs) for statistically significant variables were calculated from the outputs of multiple logistic regression. The DU ratio served as a measure of severity of illness. With all the confounders taken into account, we estimated variables that were independently linked with the outcome (mortality).

We estimated variables independently associated with the outcome (mortality), adjusted to the following prospectively collected data: Gender, age, type of hospitalization (medical, surgical), in ICU LOS, CL-days, MV-days, UC-days, CL-utilization ratio as a marker of severity of illness of patients, MV-utilization ratio as a marker of severity of illness of patients, UC-utilization ratio as a marker of severity of illness of patients, type of ICU (medical-surgical, medical, pediatric, surgical, coronary, neuro-surgical, cardio-thoracic, neurologic, trauma, pediatric-oncology, adult-oncology), facility ownership (publicly owned facilities, not-for-profit privately owned facilities, for-profit privately owned facilities, university hospitals) [25], and income-level per country ac-

cording to WB (low, lower-middle, upper-middle, high) [28]. The evaluated outcome was the "in ICU all-cause mortality". All statistical analyses were performed using R software, version 4.1.3.

3. Results

From 08/01/2003 to 02/12/2022, during the course of 19 years, a multinational, multicenter, cohort, prospective, surveillance study was conducted in 236 ICUs of 77 hospitals in 44 cities in 10 countries (Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Palestine, Saudi Arabia, Turkey, United Arab Emirates) from the Middle East [24], currently participating in INICC.

Of all 77 hospitals, 30 (38.96%) were academic, 38 (49.35%) were publicly owned facilities, and 9 (11.69%) were for-profit privately owned facilities. Among all 236 ICUs, 62 (26.27%) were medical-surgical; 50 (21.19%) were medical; 27 (11.44%) were pediatric; 27 (11.44%) were surgical; 19 (8.05%) were coronary; 6 (2.54%) was neurologic; 12 (5.08%) were neuro-surgical; 8 (3.39%) were trauma; 10 (4.24%) were respiratory; 3 (1.27%) was pediatric-oncology . 4 (1.69%) were burn; 5 (2.12%) were cardio-thoracic; 3 (1.27%) were adult-oncology.

This is a cohort study, and the length of participation of hospitals is variable, and ranged from 1.2 to 219.9 months (mean = 43.21, SD = 46.26). More participating hospitals and patients' characteristics are shown in Table 1. Data on 66,440 critical patients were gathered and they were followed from admission to discharge from ICU during 652,167 patient-days, and 13,974 died.

Mortality rates per ICU type are shown in **See** Table 2**.** Mortality rates according to WB country classification by income level (lower-middle income, upper-middle income, and high income) and by facility ownership type (publicly owned facilities, for-profit privately owned facilities, university hospitals, not-for-profit privately owned facilities) are shown in Table 3. We found that resistance of *Acinetobacter baumanii* to carbapenem is 44.71%, of *Klebsiella pneumonia* to carbapenem is 13.47%, and *Pseudomonas aeruginosa* de carbapenem is 28.14%.

Using multiple logistic regression, the following nine variables were identified as RF statistically significantly independently associated with "in ICU all cause-mortality" **(**Table 4**)**: Acquisition of a CLABSI; acquisition of a VAP; older age rising the risk 2% per year; female gender; longer LOS, rising the risk 2% per days of stay; more CL-days, rising the risk 1% per CL-day; higher mechanical ventilator utilization ratio; Publicly owned facilities; medical hospitalization instead of surgical. On the other hand, high income countries showed significantly lower risk of mortality.

Table 1
Setting and patient characteristics.

Period	08-01-2003 to 02-12-2022
Years, n	19
ICUs, n	236
Hospitals, n	77
Cities, n	44
Countries, n	10
Total patients, n	66,440
Total patient-days, n	652,167
Average LOS, mean, SD	mean = 9.82, SD = 13.68
Gender	
Male, n (%)	41,393 (62.3%)
Female, n, (%)	25,047 (37.7%)
Age, mean, SD	Mean = 44.56, SD = 26.80
Hospitalization type	
Number of patients with medical Hospitalization, n (%)	50,012 (75.27%)
Number of patients with surgical Hospitalization, n (%)	16,428 (24.73%)
Survival status	
Alive, n (%)	52,466 (78.97%)
Death, n (%)	13,974 (21.03%)
Device-days and device utilization ratio	
CL-days, n, mean, SD	390,548, mean = 5.88, SD = 12.29
MV-days, n, mean, SD	311,921, mean = 4.69, SD = 10.89
UC-days, n, mean, SD	470,731, mean = 7.09, SD = 12.06
CL-utilization ratio, mean, SD	mean = 0.51, SD = 0.86
MV-utilization ratio, mean, SD	mean = 0.34, SD = 0.58
UC- utilization ratio mean, SD	mean = 0.68, SD = 0.74
Healthcare associated infections	
CLABSI, n (%)	1872 (28.55%)
VAP, n (%)	3424 (52.22%)
CAUTI, n (%)	1261 (19.23%)
Number of countries, stratified per income level according to World Bank	
Lower middle income, n (%)	3 (30%)
Upper middle income, n (%)	3 (30%)
High income, n (%)	4 (40%)
Number of patients admitted per facility ownership	
For-profit privately owned facilities, n (%)	9082 (13.67%)
Publicly owned facilities, n (%)	33,075 (49.78%)
University hospitals, n (%)	24,283 (36.55%)
Number of patients admitted per type of ICU, n (%)	
Cardio-thoracic ICU	2641 (3.98%)
Coronary ICU	4307 (6.48%)
Medical ICU	4893 (7.36%)
Medical-Surgical ICU	40,745 (61.33%)
Neuro-surgical ICU	113 (0.17%)
Neurologic ICU	197 (0.3%)
Adult Oncology ICU	3496 (5.26%)
Pediatric Oncology ICU	1507 (2.27%)
Pediatric ICU	5202 (7.83%)
Respiratory ICU	298 (0.45%)
Surgical ICU	2976 (4.48%)
Trauma ICU	59 (0.089%)
Burn ICU	6 (0.009%)

ICU = intensive care unit; CL = central line; MV = mechanical ventilator; UC = urinary catheter;
LOS = length of stay; CLABSI = central line associated bloodstream infection; VAP = ventilator-associated pneumonia; CAUTI = catheter associated urinary tract infection;
SD = standard deviation.

4. Discussion

According with the literature, although device use in INICC ICUs was similar to that reported in CDC-NHSN ICUs [32], HAI rates were higher in ICUs of the Middle East [11-19].

The present study found an association between CLABSI or VAP and mortality, coinciding with previous findings, such as the study of Ylipalosaari analyzing the impact of HAIs on mortality. They found in multivariate logistic regression analysis that HAIs remained an independent hospital mortality RF after adjustment for APACHE II score and age [33].

Older age was also found to be associated with mortality in our study. We found a 2% rise in mortality per year of age. In an analysis of risk factors and associated mortality in a Turkish university hospital, with logistic regression analyses, age (>60 years) was found to be a significant mortality RF [21].

The present study additionally found an association between the female gender and mortality. Coincidentally, Todorov et al. investigated the effect of gender on the likelihood of receiving intensive care in critically ill cardio- and neurovascular patients in a large nationwide Swiss cohort, and found the same association. They conducted a retrospective study of 450,948 adult patients with neuro-and cardiovascular disease admitted to all Swiss hospitals between 2012 and 2016. Overall, women had a lower likelihood of being admitted to an ICU than men, despite being more severely ill. ICU admission probability was lowest in women aged >65 years. Despite having a more severe illness, women over 45 years of age had the same ICU admission probability as men in the same age group. The odds of dying were significantly higher in

Table 2
Mortality rate stratified per ICU type.

ICU type	Number of patients, n	Number of patients dead, n (%), 95% CI
Respiratory ICU	298	122 (40.94%); 95% CI: 34.00–48.88
Adult-oncology ICU	3496	1093 (31.26%); 95% CI: 29.44 to 33.17
Neuro-surgical ICU	113	33 (29.2%); 95% CI: 20.10–41.01
Medical ICU	4893	1350 (27.59%); 95% CI: 26.14–29.10
Neurologic ICU	197	50 (25.38%); 95% CI: 18.84–33.46
Medical-surgical ICU	40,745	9504 (23.33%); 95% CI: 22.86–23.80
Surgical ICU	2976	609 (20.46%); 95% CI: 18.87–22.16
Cardio-thoracic ICU	2641	462 (17.49%); 95% CI: 15.93–19.16
Burn ICU	6	1 (16.67%); 95% CI: 0.042–92.86
Pediatric ICU	5202	488 (9.38%); 95% CI: 8.57–10.25
Trauma ICU	59	5 (8.48%); 95% CI: 2.75–19.77
Pediatric-oncology ICU	1507	72 (4.78%); 95% CI: 3.74–6.02
Coronary ICU	4307	185 (4.30%); 95% CI: 3.70–4.96

ICU = intensive care unit; CI = confidence interval.

Table 3
Mortality rate stratified per World Bank country classifications by income level and per Facility ownership type.

	Number of patients, n	Number of patients dead, n (%), 95% CI
Lower-middle income		
Pooled	9356	1967 (21.02%); 95% CI: 20.11–21.97
Publicly owned facilities	205	42 (20.49%); 95% CI: 14.77–27.69
For-profit privately owned facilities	1306	222 (17%); 95% CI: 14.84–19.39
University hospitals	7845	1703 (21.71%); 95% CI: 20.69–22.76
Upper-middle income		
Pooled	21,851	5654 (25.88%); 95% CI: 25.21–26.56
Publicly owned facilities	332	71 (21.39%); 95% CI: 16.70–26.97
For-profit privately owned facilities	5081	1180 (23.22%); 95% CI: 21.92–24.59
University hospitals	16,438	4403 (26.79%); 95% CI: 26.00–27.59
High income		
Pooled	35,233	6353 (18.03%); 95% CI: 17.59–18.48
Publicly owned facilities	32,538	5961 (18.32%); 95% CI: 17.86–18.79
For-profit privately owned facilities	2695	392 (14.55%); 95% CI: 13.14–16.06

CI = confidence interval.

women than in men per unit increase in Simplified Acute Physiology Score (SAPS) II. In the care of the critically ill, this study suggests that women are less likely to receive ICU treatment regardless of disease severity [22].

Moreover, an association was found between prolonged LOS and mortality, rising mortality risk by 2% per day of hospitalization. Consistent with a previous study analyzing mortality RF in ICU patients, prolonged LOS was observed as independent RF in a multivariate analysis [34].

Furthermore, this study found an association between MV-utilization ratio and mortality. Similarly, in several researches of RF for predicting mortality in ICU, applying multivariate logistic regression analysis, identified MV, as a mortality RF [20,21,23].

This study further observed an association between CL-days and mortality. We found a 1% increased mortality per day of use of CL.

Table 4
Multiple Logistic regression analysis of risk factors associated with death.

	aOR	95% CI	*P* value
Age	1.02	1.01–1.02	<0.0001
Gender, female	1.14	1.09–1.19	<0.0001
Medical Hospitalization	1.64	1.54–1.75	<0.0001
Length of stay	1.02	1.01–1.02	<0.0001
MV-days	0.97	0.97–0.98	<0.0001
CL-days	1.01	1.01–1.02	<0.0001
UC-days	1.00	1.00–1.01	0.10
MV-utilization ratio	14.51	13.46–15.64	<0.0001
CL-utilization ratio	1.07	1.03–1.11	<0.0001
UC-utilization ratio	0.62	0.57–0.66	<0.0001
CLABSI	1.49	1.33–1.66	<0.0001
VAP	1.50	1.38–1.63	<0.0001
CAUTI	1.13	0.99–1.30	0.07
Publicly owned facilities	1.31	1.17–1.47	<0.0001
University hospital	1.62	1.40–1.88	0.23
Upper Middle Income level according with World Bank	0.63	0.58–0.69	<0.0001
High Income level according with World Bank	0.59	0.51–0.70	<0.0001
Cardio-thoracic ICU	0.56	0.06–5.05	0.60
Coronary ICU	0.11	0.01–0.98	0.05
Medical ICU	0.55	0.06–5.05	0.60
Medical-surgical ICU	0.42	0.05–3.81	0.44
Neuro-surgical ICU	0.53	0.06–5.08	0.59
Neurologic ICU	0.64	0.07–5.95	0.69
Adult Oncology ICU	1.39	0.15–12.69	0.77
Pediatric Oncology ICU	0.46	0.05–4.27	0.50
Pediatric ICU	0.37	0.04–3.34	0.37
Respiratory ICU	0.30	0.03–2.78	0.29
Surgical ICU	0.49	0.05–4.41	0.52
Trauma ICU	0.16	0.01–1.72	0.13

ICU = intensive care unit; CL = central line; MV = mechanical ventilator; UC = urinary catheter;
LOS = length of stay; CLABSI = central line associated bloodstream infection; VAP = ventilator-associated pneumonia; CAUTI = catheter associated urinary tract infection;
aOR = adjusted odds ratio; CI = confidence interval.

Showing a similar association in a study analyzing mortality RFs in a Turkish university hospital, with logistic regression analyses, CL were found to be a significant mortality RF [21].

Additionally, the present study found that high-income countries have a significantly lower risk of mortality. This finding could be explained by the probably inadequate health care quality programs in those LMICs participating in this study.

The current study also observed that publicly owned facilities have a significantly higher risk of mortality. Analyzing this same association, Devereaux conducted a systematic review and meta-analysis of studies that compared mortality rates in private for-profit and private non-profit hospitals. In studies of the adult population, private for-profit hospitals were associated with an increased risk of death [35].

In addition, this study found that medical hospitalization has a significantly higher risk of mortality than surgical hospitalization. This could be explained by the fact that, on the one hand, patients admitted for planned surgical procedures have a less severe condition than those admitted for medical reasons, and thus, most of them are stable. But, on the other hand, when a medical patient is admitted to the ICU, they are rarely stable [36].

Finally, the present study did not find a difference in the risk of death comparing different kinds of ICUs. To our knowledge, this variable has not been analyzed by other researchers.

Some of the mortality RFs identified in our study are unlikely to change, such as the income level of the country, facility ownership, hospitalization type, age, and gender. However, some of the mortality RFs we identified can be modified; for example, LOS, CL-days, MV-utilization ratio, CLABSI acquisition, and VAP acquisition. As HAI rates

in the Middle East are significantly higher than in the US, there is room for improvement [11-19]. Based on our findings, it is suggested that we focus on strategies to reduce LOS, CL-days, MV-utilization ratio, and implement an evidence-based set of HAI prevention recommendations, such as those recently published by IDSA/SHEA/APIC [37,38]. Also, the high rate of HAIs prevalent in the Middle East [11-19] can be reduced by utilizing a strategy of monitoring compliance with recommendations and providing performance feedback to healthcare personnel, as demonstrated in several ICUs of the Middle East [11,39,40].

Our research has some limitations. First, this study is not representative of all hospitals in the Middle East since it is a surveillance system in which hospitals voluntarily join and free of charge. Second, it is likely that the hospitals that participate in our surveillance system are the ones that have a better-quality HAI surveillance and prevention program, and for this reason, the mortality rates in our study are likely to be lower than the rates found in other hospitals not participating in our study. Finally, participating hospitals have not collected data on disease severity scores and underlying diseases, but instead we collected DU-utilization ratio as a marker of the severity of illness of the patients [30].

5. Conclusions

The key conclusion of our research is that in order to achieve a reduction in patient mortality in intensive care units in Middle Eastern countries, it is essential to reduce LOS, reduce use of CL-days and MV-utilization ratio, and apply effective interventions to prevent acquisition of CLABSI and VAP, due to that by reducing this rates of CLABSI and VAP, this will generate a reduction in patient mortality.

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Author contributions

Rosenthal, V.D. was responsible for conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing original draft; review & editing; design; software development; technical support; drafting tutorials for surveillance process; training of data collectors; provision of study patients; data validation; data assembly; data interpretation; epidemiological analysis; drafting of the manuscript.

Zhilin Jin and Ruijie Yin contributed equally to data curation; formal analysis; methodology; validation; writing original draft; review & editing; building machine learning models; conducting statistical analysis; critical revision for important intellectual content; and final approval of the manuscript.

Remaining authors were involved in the provision of study patients.

All authors were involved in critical revision of the manuscript for important intellectual content, and final approval of the manuscript.

Declaration of Competing Interest

All authors report no conflicts of interest related to this article. The Institutional Review Board of each hospital agreed to the study protocol, and patient confidentiality was protected by codifying the recorded information, making it only identifiable to the infection control team.

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