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Device-associated Nosocomial Infection in General Hospitals, Kingdom of Saudi Arabia, 2013 – 2016

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Abstract

Background: Healthcare-associated infections (HAIs) are a serious patient safety issue in hospitals worldwide, affecting 5%-10% of hospitalized patients and deadly for patients in intensive care units (ICUs).[1] Device-associated HAI (DA-HAI) surveillance exists in most hospitals. DA-HAIs account for up to 23% of HAIs in ICUs and about 40% of all hospital infections (i.e., central line-associated blood stream infections [CLABSI], ventilator-associated pneumonia [VAP], and catheter-associated urinary tract infections [CAUTI]). This surveillance focuses on DA-HAIs in ICUs and is used for comparison, benchmarking, and detecting areas to focus on for improvement.[2, 3] This study aims to identify DA-HAI rates among a group of selected hospitals in KSA from 2013 – 2016.

Methods: We analyzed secondary data from 12 medical/surgical intensive care units (M/SICUs) and two cardiac care units (CCUs) from 12 Ministry of Health (MoH) hospitals from different regions in the Kingdom of Saudi Arabia (KSA). These data were reported by infection control practitioners to the MoH via the electronic International Nosocomial Infection Control Consortium (INICC) system in each hospital.

Results: Among 6,178 ICU patients with 13,492 DA-HAIs during 2013 – 2016, the average length of stay (LOS) was 10.7 days (range 0 to 379 days). VAP was the most common DA-HAI (57.4%), followed by CAUTI (28.4%), and CLABSI (14.2%). In CCUs there were no CLABSI cases; CAUTI was reported from 1 – 2.6 per 1000 device-days; and VAP did not occur in Hospital B but occurred 8.1 times per 1000 device-days in the CCU in Hospital A. In M/SICUs, variations occurred among time periods, hospitals, and KSA provinces. CLABSI varied between hospitals from 2.2 to 10.5 per 1000 device-days. CAUTI occurred from 2.3 to 4.4 per 1000 device-days, while VAP had the highest rates, from 8.9 – 39.6 per 1000 device-days. Most hospitals had high device-utilization rates (from the 75^{th} – 90^{th} percentile of NHSN's standard and the 50^{th} – 75^{th} percentile of INICC's).

Conclusions: We found higher device-associated infection rates and higher device-utilization ratios in the study's CCUs and M/SICUs than National Healthcare Safety Network (NHSN) benchmarks, except for CLABSI rates, which were lower. To reduce the rates of infection, ongoing monitoring of infection control practices and comprehensive education are required. Further a more sensitive and specific national healthcare safety network is needed in KSA.

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Chapter 1: Introduction

Healthcare-associated infections (HAIs), also called nosocomial infections (NIs), are a serious and growing problem at every level of healthcare and continue to present a challenge to hospital personnel. These infections are acquired during hospital stays or at healthcare facilities; they are not present or incubating before admission.[1]

Targeted device-associated healthcare-associated infection (DA-HAI) surveillance has been implemented in most hospitals in developed and developing countries, as has benchmarking with the National Healthcare Safety Network (NHSN) database.[3] This surveillance, which focuses on DA-HAIs in intensive care units (ICUs), was established by international organizations such as the CDC, the NHSN, the Infectious Diseases Society of America (IDSA), and the Society for Healthcare Epidemiology of America (SHEA).[3] The NHSN surveillance criteria are the most commonly used for hospital comparisons, benchmarking, and detecting areas to focus on for improvements.[2]

To minimize the occurrence of DA-HAIs in ICUs, the NHSN-recommended infection control measures should be implemented and enforced. Evidence-based approaches include daily device assessments, intervention bundles, reducing risk factors, continuing health education for ICU staff, the establishment of infection control committees, and antimicrobial stewardship programs.[4]

ICU patients are more susceptible to NIs because they have more chronic diseases and more severe acute conditions. In addition, ICU patients commonly have extrinsic indwelling catheters or devices that act as a portal of entry for organisms into their bodies; failure to care for and maintain these devices predisposes patients to infection and

colonization. Moreover, these devices might serve as reservoirs for pathogens and be related to transmission of NIs between admitted patients. It is estimated that more than 20% of HAIs in the United States are acquired in the ICU.[4-6] DA-HAIs include central line associated blood stream infections (CLABSIs), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infections (CAUTIs), all common HAIs that are linked to increased burden for healthcare facilities.[6]

Problem Statement

HAIs are a major patient safety concern; they contribute to increased patient mortality, length of stay (LOS) in hospital, antibiotic resistance, and healthcare costs.[3] Prevention and control of HAIs requires the application of multiple approaches, a high standard of infection prevention practices, surveillance, and administrative support.[2] Surveillance is an essential tool in quality improvements and patient safety. It helps determine endemic infection rates, allows for the early detection of epidemics, informs risk assessment for better future planning, and evaluates interventions.[7]

An estimated 100,000 patients die in the world every year due to HAIs, at a cost of $17 billion to $29 billion.[8, 9] U.S. ICU data shows a CAUTI rate of 3.1 - 7.5/1,000 days, a CLABSI rate of 1.6 - 6.8/1,000 days, and a VAP rate of 2.5 - 12.3/1,000 days.[9] In developing countries, although accurate estimates and information about DA-HAI is scant[2, 3], a surveillance study conducted by the International Nosocomial Infection Control Consortium (INICC) of 503 ICU beds in countries in Latin America, Asia, Africa, and Europe from 2007 to 2012 showed that DA-HAI rates were higher than NHSN data in the ICUs of those hospitals. The pooled rate of CLABSIs was nearly 5-fold higher than the reported CLABSI rates from comparable U.S. ICUs. The overall

rates of VAP and CAUTIs were also higher.[10] Although DA-HAI represents a real public health problem [11], it is still an area of critical care research.[4] Also, although previous studies have shown that developing countries have higher DA-HAI rates than the United States and other European countries, the amount of accurate surveillance data remains insufficient. [2, 3, 10]

The Kingdom of Saudi Arabia (KSA), like other developed countries, has limited data regarding DA-HAI rates in general hospitals, and most of the published studies are limited to certain devices. [2] A study conducted by Dr. Tawfique, which was limited to DA-HAI rates for Aramco Hospital in Eastern region, showed that from 2004 to 2011, CAUTI comprised almost half of all DA-HAIs (42.2%), followed by CLABSI (38.5%), and VAP (19.3%). The CLABSI rate was 10 days of infection per 1,000 device-days, the highest, followed by CAUTI at 8.18 days, and VAP at 4.52 days, all significantly higher rates than found in U.S. hospitals.[2,10] Also, a quality improvement project implemented in the medical and surgical ICU in a tertiary hospital in KSA showed that the CLABSI rate was 6.9/1,000 catheter-days, nearly the same as the above mentioned studies' figures.[12]

Purpose of Study

This study identified the DA-HAI rates in general hospitals in KSA from 2013 – 2016. Knowing these is vital to improve patient safety and identify areas or healthcare settings with high infection rates so that health authorities can intervene. With this information, they can take action and initiate immediate improvement plans. Additionally, studies like this are an important addition to the published literature and serve as a resource for further research.

Definitions

DA-HAI definitions are based on the CDC's NHSN surveillance definitions and criteria for all specific types of HAIs published in 2013 (Appendix). [13]

Central line: It is an intravascular catheter that terminates at or close to the heart or in one of the great vessels. It has different uses like infusion, withdrawal of blood, or hemodynamic monitoring. NHSN system specify certain great vessels to be considered in reporting central-line BSI, those are; Aorta, Pulmonary artery, Superior vena cava, Inferior vena cava, Brachiocephalic veins, Internal jugular veins, Subclavian veins, External iliac veins, Common iliac veins and Femoral veins.

Indwelling catheter: The catheters that are inserted into the urinary bladder through the urethra and connected to a drainage bag and left in place. It includes urethral catheters that are used for intermittent or continuous irrigation.

Ventilator: It is an assist device that control respiration includes the weaning period. This device can be through a tracheostomy or by endotracheal intubation.

Central line-associated blood stream infection (CLABSI): a laboratory-confirmed infection when patient has a central line for more than 48 hours. Verified by isolation of the pathogen in his/her blood cultures. This organism is not related to another site and supported by identification of the same organism from the peripheral blood culture. It has to be associated with clinical symptoms of septicemia like fever, chills, high temperature (>38 °C), or hypotension with no other source of infection identified.

If the isolated organism in the blood culture was one of the common skin contaminants including coagulase-negative staphylococci, diphtheroids, *Bacillus spp* , *Aerococcus spp Propionibacterium spp*, viridans group streptococci, and *Micrococcus*

spp, we required to do two or more blood cultures from different site in different time to be taken and required to be positive. Appendix (1).[1, 2, 14]

Ventilator-associated Pneumonia (VAP): a new or progressive infiltrate, consolidation, cavitation, or pleural effusion in the X-ray of patient under mechanical ventilation. VAP diagnosis depends on radiologic, clinical, and laboratory findings. Clinical and laboratory findings should include one or more of the following; new onset of purulent sputum, new sputum character, and isolation of a bacterial microorganism from tracheal aspirate or bronchoalveolar lavage. Appendix (2). [2, 15]

Catheter-associated urinary tract infection (CAUTI): diagnosed if patient has urinary catheter and at least one of the following signs and symptoms: fever of more than 38 °C, supra-pubic tenderness, urgency, and positive urine culture (≥105 CFU/ml) of not more than two kind of bacterial pathogen is isolated. It can be also diagnosed as positive dipstick urine analysis for leukocytes/nitrates with ≥10 white blood cells/mm^3 or ≥3 white blood cells/high-power field (pyuria) of urine (Appendix 3) [2, 16] .

Chapter 2: Literature Review

Healthcare-associated infections (HAIs) are a serious patient safety issue in hospitals worldwide, affecting approximately 5%-10% of hospitalized patients. They can be deadly for patients in intensive care units (ICUs). The HAI burden is greater in health care settings in low-to-middle-income countries. [17]

HAIs was estimated to be 1.7 million with approximately 6% mortality (100,000 deaths per year) in the United States.[9] In developing countries, a report from an International Nosocomial Infection Control Consortium (INICC) surveillance study on 503 ICU beds among several countries in Latin America, Asia, Africa, and Europe in the period between 2007 to 2012, showed that device-associated nosocomial infection rates were higher in the ICUs of those hospitals compared to U.S.[10]

A systematic literature review and meta-analysis of the burden of healthcare-associated infections (HAIs) in Southeast Asia revealed that the pooled prevalence of overall HAIs was 9.0% (95% CI: 7.2%–10.8%).[18] Use of invasive device or procedure is one of the most identified risk factors with length of stay (LOS), diagnosis upon admission, and patient's age as well.[18]

In KSA, there is limited data regarding DA-HAI rates in general hospitals and most of the published studies are limited to a certain device. [2] A study done by Dr. Tawfique which was limited to Aramco Hospital in Eastern region from 2004 to 2011 showed that for DA-HAI rates, CAUTI was the most common (42.2%), followed by CLABSI (38.5%), and VAP (19.3%). The DA-HAI infection rates per 1,000 device-days were 8.18 for CAUTI, 10 for CLABSI, and 4.52 for VAP, which are significantly higher than U.S. hospitals.[2, 10]

Surveillance for DA-HAIs

Active surveillance for healthcare-associated infections acquired during hospital admission is important to measure infection rates, identify the possible etiology of the main infections especially those related to invasive devices, and also to monitor the spread of multi-drug-resistant infections. It is considered a quality criterion of inpatient care.[19] Surveillance should include transparent and real time data collection and monitoring of vital processes as well as evaluation of outcomes. Surveillance is a mainstay in all device associated with infection prevention efforts.[20] Many studies demonstrate that effective implementation of integrated infection control program that focused on DA-HAI surveillance can prevent about two-thirds of HAIs. They reported reduced in DA-HAI as much as 30% with reduction in health care costs.[17, 21]

The KSA MoH implemented INICC multidimensional approach in their DA-HAI surveillance. The INICC is focused on the surveillance and prevention of DA-HAI in adult ICUs, pediatric ICUs, and neonatal intensive care units (NICUs). This INICC multidimensional approach is "an international nonprofit, open, multicenter, collaborative healthcare–associated infection control network with a surveillance system based on that of the CDC's NHSN founded in Argentina in 1998". [21]

Benchmark of surveillance data with NHSN/INICC data: Healthcare facilities are routinely collecting standardized data on DA-HAIs, which are used not only to track the performance internally, but also to compare our local data to national and international benchmarks. The importance of both internal and external benchmarking is to improve health services quality of care by demonstrating strengths and weaknesses, encouraging competitiveness, and assessing the outcomes of interventions planned to reduce HAIs.

Benchmarking of HAI data can be misleading without standardized methodology (outcome indicators and case definitions) besides similar data collection methods and in populations of adequate sizes over a adequate duration. Additionally, the surveillance data should be analyzed and reported using similar risk stratified or risk adjusted metrics (rates, proportions, or ratios) to accurate and fair comparisons. Acknowledged benchmarks for HAI include the NHSN, INICC, European Centre for Disease Prevention and Control (ECDC), and WHO estimates are the best way for benchmark. For accurate benchmark we have to choose right benchmark that should have similar data collection methods and presentation, which is not easy task because of wide variations some times in HAI incidence between benchmark reports using similar methods. For example, fair comparisons of device-associated HAI rates can be affected by several causes in consecutive NHSN reports, include: changes in HAI definitions to reduce the percentage of non-objective diagnoses (e.g., stop counting a clinical sepsis for diagnosis for CALBSI); enrollment of many hospitals with small bed numbers that have lower risk of HAIs (about two-thirds of enrolled hospitals (2010)); and implementation of multiple infection control strategies by many hospitals, that affect the actual HAI incidence rate.

Benchmarking to NHSN reports is preferred because the case definitions and methodologies are similar and differences in HAI rates will likely encourage improvements. However, differences in surveillance environments and NHSN hospitals should be taken into consideration and will be some times not representative to our countries. Furthermore, frequent NHSN changes in case definitions and methodologies and the delays in its implementation could further affect the interpretation. Unlike NHSN that receives locally entered individual data, INICC uses collected data received from 215

enrolled hospitals from 36 countries in South America, Asia, Africa, and Europe. Additionally, data on DA-HAI are collected from all patients who has HAI or not that help in of mortality and length of stay comparisons. INICC Benchmark appears reasonable, it has similar methodologies and challenges, as well as the availability of unique data on mortality and length of stay. However, it does not account for the variability in surveillance that assumed to be between and within participating countries. [22]

General Infection Control Measures

Hand Hygiene. Hands have an important role in infection transmission in healthcare settings. Despite that several studies have indicated that most of the healthcare workers have bad compliance on appropriate hand hygiene. Strict compliance with proper hand hygiene is crucial to patient care especially in ICUs and is extremely cost effective. A descriptive time series study with a multimodal program to promote hand hygiene activities interventions was conducted from October 2006 to December 2011 in a 350-bed community hospital in KSA. It revealed that compliance rate of hand hygiene is lower for physicians than for nurses, with compliance rate of 87% among physicians and 89% among nurses. In addition, DA-HAIs per 1,000 device-days decreased post intervention during the study period. CLA-BSI rates reduced from 8.23 to 4.8 ($P = .04$), VAP rates reduced from 6.12 to 0.78 ($P < .001$), while, CA-UTI rates reduced from 7.08 to 3.5 ($P = .01$).

Enforcement of hand hygiene with continuous monitoring is vital to improve compliance rates and subsequently, reduce the infection rates. Many trials determined that alcohol-based foams or gel are more efficient in reducing bacterial colonization and

the multidrug-resistant pathogens compared to traditional hand washing with only soap and water. In addition, studies showed significant difference in bacterial colonization by using a chlorhexidine-containing antiseptic wash versus alcohol-based foam.[4, 23]

Environmental disinfection. Various pathogenic organisms can be found anywhere in the ICU which can play a role in exposing critically ill patients to increasing the chances of acquiring infections. Environmental disinfection measures will decrease the pathogen burdens and can decrease HAIs rates. Environmental cleaning with UV light and hydrogen peroxide vapor decontamination for reducing colonization still needs more studies and strong evidence.[4, 24]

Isolation Measures. Extended isolation precautions for patients who are infected by antibiotic-resistant organisms was recommended by both the Healthcare Infection Control Practices Advisory Committee and the Society for Healthcare Epidemiology of America guidelines. They encouraged wearing of both gown and glove before entering isolation rooms of patients colonized these resistant pathogens. Recent studies have found that gowns and gloves use by HCWs is effective in minimizing the risk of transmission of MDRO like; MRSA and VRE.[4]

Staff Education. Frequent educational and training programs for ICU staff include infection prevention and control strategies, adherence to and attitudes toward evidence-based guidelines for preventing DA-HAIs which may affect patient safety and the quality of care.[25] Active implementation of educational strategies on the effectiveness of daily checklists and device insertion and removal bundles, daily clinical reminder systems for evaluation and consultations of mechanical ventilator, central line,

and urinary catheter protocols with audit and feedback which can significantly drop the rate of DA-HAIs in Critical care units.[25]

In addition, adequate nurse-to-patient ratio in ICU is necessary for infection prevention and control. Since it is well known that lower nurse-to-patient ratio may increases the risk of nosocomial infection.[4]

Central Line-associated Blood Stream Infection

Central line-associated bloodstream infections (CLABSIs) are severe infections usually causing a increased hospital stay, cost and risk of mortality. Reducing CLABSIs are one of the most important goals in health care settings. Despite, the decrease in CLABSIs, which has occurred in U.S. hospitals from 2008-2013, CLABSI still occur in the ICU each year. [12, 26] Although catheters provide an important benefit as a tool for ICU patients managements, their use puts the patients at a greater risk for infection locally at site of its insertion or systemic. [4]

Definition and Diagnosis. A central line–associated bloodstream infection (CLABSI) is defined as infection of blood stream when happened to patient with central venous catheter for more than 48 hours prior to the development of infection and not related to another infection site. Diagnosis of CLABSI can be made through identification of the organism from the catheter tip by sonication or roll plating, from blood through the catheter, from the site, and it can be from the peripheral blood culture.[20]

Epidemiology of catheter-associated bloodstream infections. CLABSI rates according to US/NHSN reports showed that it is decreased in ICU from ~8-11/1000 catheter (1990) –days to 2/1000 catheter-days (2008). It is also decreased in Europe; HAI

in ICU in German decreased according to the German nosocomial infection surveillance program. However, in middle-income and low-income countries the overall CLABSI rate still high and it is three times higher than in the USA or Europe.[27]

In the United States, blood stream infections were found between 200 000-400 000 BSI, more than 90% were associated with intravascular catheter devices.[28] Systematic review and meta-analysis article which studies the impact of quality improvement interventions on CLABSI in adult ICU showed that the pooled mean of CLABSI occurrence rates was 2.7 CLABSIs per 1000 catheter-days (95% CI, 2.6–2.9).[29]An estimation of CLABSI average attributable costs were from $25,849 to $45,000 per case and it contributes to approximately $670,000,000 to $4,000,000,000 in hospital costs each year with attributable mortality rate ranges from 0% to 17%.[4, 20] Its risk factors include location of the catheter (higher risk with femoral and internal jugular), type of catheter (higher risk in plain catheters than antibiotic impregnated catheters), type of port, securing methods, duration of use, techniques to place and maintain catheters(higher risk with non tunneled than tunneled insertion, and higher in tunneled insertion compared to a completely implantable device), and location and catheter site of care(higher in emergency compared to elective and in unskilled compared to skilled inserter). Host factors also has important role in increasing the susceptibility to the infection for example; age, severity of illness, co-morbidity, immune deficiency). In addition, uses of the catheter can be responsible like transfusions of blood products and total parenteral nutrition.[4, 20]

Microbiology. A review study by Lobdell *et* al. focused on the HAIs that are related to DAIs. It revealed that most CLABSIs are monomicrobial, but can be some times

polymicrobial, and the most organisms associated with this infections are *Staphylococcus epidermidis* , *Enterococci* , *Staphylococcus aureus* , numerous gram-negative bacilli, and *Candida albicans*. Multidrug resistance organisms are growing concern that worries preventive authorities [20] Coagulase negative staphylococcus was the leading pathogen (23.7%) followed by Staphylococcus aureus (11.1%) and Escherichia coli (11.1%). A prospective study was conducted in KSA during the year 2002-2006 in Saudi Aramco Medical Services Organization revealed coagulase negative staphylococcus (23.7%), Staphylococcus aureus (11.1%), and Escherichia coli (11.1%) were the highest recorded microorganisms while, candida caused least infection 5%.[30]

Preventive measures. Comprehensive strategies to improving the rate of CLABSI are a priority for health care institutions and gained considerable attention and resources. Performance improvement protocols include real-time data collection and reporting with monitoring of processes, education and training, appropriate staffing, and use of process checklists and multimodal bundles interventions on proper insertion techniques and management of the central line are fundamental for prevention of CLABSI occurrence.[20] [29] These guidelines are well addressed by the CDC's Healthcare Infection Control Practices Advisory Committee (CDC/HIPAC) Guidelines for the Prevention of Intravascular Catheter-related Infections (2011).[26]

Multimodal bundle intervention programs have been published since approximately 2009, and it is based on initiatives from Michigan bundle proposed by Pronovost *et* al. It includes appropriate hand hygiene, use of CHG-containing products for skin preparation, use of maximal barrier precautions during CVC insertion, subclavian vein placement as the preferred site, and removing unnecessary CVCs.[4, 20]

Maximum sterile barrier precaution during catheter insertion is the fundamental key in Bundle strategy. However, one randomized controlled trial showed that maximum sterile barrier precaution was not effective for prevention of CLABSI and was not statistically significant (2.4/1000 vs. 1.9/1000; RR: 1.2; CI 95% 0.43–3.1; P = 0.78).While Ishikawa *et* al. result and conclusions showed that, we couldn't conclude the same regarding the maximum sterile barrier precaution effectiveness in CLABSI prevention since the study was not performed in the ICU, but in general surgical wards, which make comparisons difficult since central lines outside the ICU are used differently compared to the ICU. In addition, central catheters existed in places above (14 days) and it is well known and evidenced that as long as the catheter stayed, it will be shift the CLABSI risk from catheter insertion to catheter care risk.[12, 27] Also, a meta-analysis of 43 studies, which include 584 ICUs, evidenced that quality improvement interventions lower CLABSI rates in adult ICUs especially by using bundles or checklists with significant reduction in CLABSI risk (*P* = .026) in trials with care bundles or checklists (OR, 0.34 [95% CI, .27–.41]) than in those without them (OR, 0.45 [95% CI, .36–.55]).[29]

Khalid e*t* al. provided evidence through his study on the root cause analysis conducted in 2010 started with extensive education sessions were followed by implementation of strategies in the form of "itemized" bundles derived from practice guidelines, with complete enforcement. CLABSIs were calculated and analyzed in a preintervention (1 year) and postintervention (2 years) and benchmarked against NHSN data.

Significant change was found with improvement on CLABSI rate post intervention CLABSI rate preintervention was 6.9 per 1,000 catheter-days while, in the

post intervention year 1, rate was 1.06/1,000 catheter -days, with incidence-rate ratio (IRR) of 0.15 (95% confidence interval: 0.04-0.44, P < .001) and reduction of 85%. After 2 years CLABSI rates reduced to 0.35/1,000 catheter-days (1/2,860 CDs) with IRR of 0.05 (95% confidence interval: 0.001-0.31, P < .001). Zero CLABSI was recorded for 15 consecutive months post intervention, which is even better than NHSN benchmarks. Additionally, hand hygiene compliance was improved with these central line bundles interventions. [12]

Skin preparation of the insertion site with aseptic technique and use of 2% chlorhexidine, hand hygiene, and maximal sterile barrier are crucial element in multimodal CLABSI bundle prevention. Chlorhexidine (CHG)-containing product, is an antiseptic compound which have been used now a day as a standard of care and one of the bundle strategy of catheter insertion. It has two concentrations; CHG 2% and0.5% CHG in 70% alcohol both of them showed in several studies its effectiveness in CLABSI prevention. Although, recent multimodal interventional studies used 2% and considered that use of high CHG concentration is more effective. In France, one randomized trial evidenced that CLABSI rate decreased from 1.3/1000 catheter-days to 0.4/1000 (hazard ratio, 0.24 (95% CI 0.09–0.65)] after introduction of a CHG-impregnated dressing.[4, 20, 27]

Replacement of CVC administration sets should be developed as a standard operating procedure (usually every 4 to 7 days) and it should be changed within 24 hours of initiation for blood product and/or total parenteral nutrition catheter.[20]

Also, a combination of 7% sodium citrate, 0.15% methylene blue, 0.15% methylparaben, and 0.015% propylparaben(C-MB-P) locked catheter is considered as an

innovative solution for CLABSI prevention. It showed high significance over unfractionated 5000U heparin (0.24 vs. 0.82 per 1000 catheter days; P = 0.005) in reduce central line blood stream infection. While ethanol locks still controversial, two randomized controlled trials illustrated that it has no significant effect in patients with long-term catheters. But, these two trials were used very low ethanol concentrations (50%) in one of them and the other one used high concentration (70%) in very short incubation times although, the use of high concentration of ethanol (70%) has limitation in its use in clinical practice.[4, 20, 27] Two meta-analyses showed that the use of 2-D ultrasound for the placement of central line catheter has been associated with reduced device insertion complications and decreases the number of trials required to cannula insertion successfully. [4] Antimicrobial impregnated central venous catheters are recommended by the Evidence-based Practice in Infection Control (EPIC) guidelines and the Healthcare Infection Control Practices Advisory Committee (HICPAC) for patients who require it in place for 1–3 weeks.[27] Topical antibiotic ointment or creams should be used for dialysis catheters, because of their risk to increase the chance of fungal infection and antimicrobial resistance.[4]

Catheter-associated Urinary Tract Infection (CAUTI)

Urinary tract infections are the fourth most common infection linked to HAI with an estimated 93,300 UTIs in acute care hospitals in 2011 and account for more than 12% of infections reported by acute care hospitals. Instrumentation of the urinary tract by indwelling catheter is nearly causing all healthcare-associated UTIs. CAUTI can lead to such complications as prostatitis, epididymitis, and orchitis in males, Complications associated with Catheter Associated Urinary Tract Infection (CAUTI) includes cystitis,

pyelonephritis, gram-negative bacteremia, and in severe cases can cause endocarditis, and meningitis. These complications cause more extended hospital stays, and more cost and can lead to increase of mortality rate which is estimated at more than 13,000 deaths each year.[31]

Definition and diagnosis. CAUTI is defined as more than 1000 to 10,000 CFU/mL of urine. Diagnosis of CAUTI is one of the biggest challenges in its management particularly in a hospitalized patient with an indwelling urinary catheter because most CAUTIs are asymptomatic.[20] Symptoms of UTI that usually present in cases of non–catheter-associated UTI, such as dysuria and urinary frequency, cannot be assessed in patients on indwelling urinary catheter specially in ICU patients who are most of them unconscious or under sedation. Fever is the only symptom present in CAUTI and unfortunately, it is a non-specific finding in a person with an indwelling urinary catheter and alternative causes of fever are frequently present.[32] Prior to 2013, NHSN CAUTI definition was considering of fever as a symptom for diagnosis of CAUTI if no other source of fever than the urinary tract infection was present. After 2013, the NHSN CAUTI definition was changed to counting of fever as a symptom of CAUTI regardless of whether another fever source is present or not.[32]

Epidemiology of Catheter-associated Urinary Tract Infection. DA-HAIs account for up to 23% of healthcare-associated infections (HAIs) in ICUs and about 40% of all hospital infections. In U.S. hospitals, urinary catheters are used between one in three to four of admitted patients and most of these inserted catheters (more than 60%) are unnecessary. [4] CAUTI is the most common DAI-HAI with an estimation of approximately 450,000cases per year in the United States; 25%-75% is estimated to be

avoidable. Its estimation average attributable costs range from $749 to $832 per case and can contribute to $390,000,000 - $450,000,000 annual hospital costs. In the United States, CAUTI was associated with a three times increased risk of mortality with estimates of more than 50,000 increase in deaths per year.[4] However, more recent studies in United States showed that mortality attributable to CAUTI currently is thought to approach zero. [20, 33]

The risk factors of CAUTI include prolonged catheterization (the risk rises by 5% each day a patient has an indwelling urinary catheter). Almost 26% of patients with urinary catheter for 2 to 10 days duration will develop bacteriuria. Other risk factors include bad adherence to aseptic catheter care, contaminated hands of health care workers in placement or maintenance practices, catheterization after the sixth day of hospitalization or outside operating room, manipulation of the urinary tract and ureteral stents, and reflux of urine from collecting bag. The responsible organisms of CAUTI are commonly originated from the perineal and colonic flora. It can be extraluminal, when the microbes contaminate the urinary tract through external contamination and capillary action. In addition, host factors for CAUTI include age greater than 50 years, female gender, diabetes mellitus, malnutrition and renal insufficiency. Prolonged use of antimicrobial therapy can be a risk for development of MDRO.[4, 20, 33]

Microbiology. The most common CAUTI organisms are *Escherichia coli*, *Enterococci*, *Pseudomonas aeruginosa* , *Klebsiella,* and *Enterobacter* species, and *Candida* species.[20]

Preventive measures. CAUTI prevention is mandated and a cornerstone of health care institutions. Like other devices, performance improvements with best practice

protocols are the fundamental aspects of effective reduction of urinary catheter infection rates. Education and training of the health care workers in order to increase their awareness on; risks, appropriate use of urinary catheters with avoidance and alternatives of it if possible, and removal protocols. In addition, training should be focused on sterile insertion technique and maintenance practices to prevent reflux breaks in the collection system. [20]

Best practice protocols to decrease the risk and incidence of CAUTI are currently implemented in most healthcare facilities. These protocols can reduce the rate of catheter utilization and subsequently reduce the CAUTI rates by at least 50%.[33] In one of the literature review of one study of 600 hospitals revealed that effort in three ICUs, with infection control guidelines for needed catheter placement and a nurse-driven decision (without a physician order) to remove unnecessary catheters. These initiatives reported a decrease in CAUTI rates by 17% to 45% post intervention and CAUTI rates of 8.3 to 11.2 / 1000 catheter-days. However less than 10% of hospitals use these protocols of catheter stop-order and removal reminders. Additionally, it showed that many facilities (75%) do not monitor duration of use for urinary catheters and 56% do not have a monitoring system.[20]

CAUTI prevention initiative developed by the Duke Infection Control Outreach Network consists of three key best practices elements: necessity of indwelling urinary catheter insertion in patients who manifest an inability to void or urinary; all patients with a urinary catheter should be assessed by checklist for the need for continuation of a urinary catheter; and then a treating physician should justify the continued need for the catheter or to order the removal if not needed.[20, 33]

The most effective strategy for CAUTI prevention is limitation or avoidance of insertion of indwelling urinary catheters when possible. To achieve this, through restricting catheterization to appropriate indications is needed.[34] (Table 1)

Table 1. CDC/NHSN recommendation of Appropriate and Inappropriate Indications for Indwelling Urethral Catheter Use.[34]

Appropriate Indications	**Inappropriate Indications**
1- Patient has acute urinary retention or bladder outlet obstruction	1- As a substitute for nursing care of the patient or resident with incontinence
2- Need for accurate measurements of urinary output in critically ill patients	2- As a means of obtaining urine for culture or other diagnostic tests when the patient can voluntarily void
3- Perioperative use for selected surgical procedures: Patients undergoing urologic surgery or other surgery on contiguous structures of the genitourinary tract	3- For prolonged postoperative duration without appropriate indications (e.g., structural repair of urethra or contiguous structures, prolonged effect of epidural anesthesia, etc.)
4- Anticipated prolonged duration of surgery (catheters inserted for this reason should be removed in post-anesthesia care unit)	
5- Patients anticipated to receive large-volume infusions or diuretics during surgery Need for intraoperative monitoring of urinary output	
6- To assist in healing of open sacral or perineal wounds in incontinent patients	
7- Patient requires prolonged immobilization (eg, potentially unstable thoracic or lumbar	

spine, multiple traumatic injuries such as pelvic fractures)	
8- To improve comfort for end-of-life care if needed	

Intermittent catheterization and condom catheter can be suitable alternatives to reduce prolonged duration of indwelling catheter that can reduces the risk of bacteriuria and UTI. A randomized trial revealed a reduction in UTI and death in patients with condom catheters compared with those with indwelling catheter.[4] Avoidance of bladder irrigation and prophylaxis antiseptic agents, which has been shown an increase infection rate and should be not used.[4]

Ventilator Association Pneumonia (VAP)

Healthcare-associated pneumonias are estimated as 157,000 in acute care hospitals in the United States. Patients on mechanical ventilators are at high risk of developing healthcare-associated pneumonia.[35] Intubation increases the risk of pneumonia 6-21 times, and Ventilator Associated Pneumonia (VAP) occurs in 9% to 27% of intubated patients with VAP of 2.1 to 10.7 per 1000 ventilator days and it is the leading cause of mortality from ICU-acquired infections.[4]

Definition and Diagnosis. Ventilator-associated pneumonia (VAP) is defined as a pneumonia that is associated with mechanical ventilation although; the definitions vary amongst databases and clinical investigations so, VAP interpretations from the literature must used carefully with an gratitude of the distinctions of each study's definitions. Diagnosis of VAP commonly uses Gram stain of; tracheal aspirate cultures,

bronchoscopic cultures, protected suction cultures or bronchoalveolar lavage with positive blood culture results may be positive secondary to VAP infection and can accompany the diagnostic evaluation.[20]

In January 2013, CDC/NHSN surveillance of VAP in adult patients receiving mechanical ventilation shifted from VAP to a broader range of complications which is ventilator-associated condition (VAC) and infection-related ventilator-associated complication (IVAC). VAC is as a continuous period of oxygen desaturation following a baseline period of stability or improvement on the ventilator. In this criteria no place for subjective measures such as radiographic interpretations like in diagnosis of VAP before. This shift in pneumonia surveillance from just pneumonia to all ventilator-associated complications will enhance efficiency in identifying patients with potentially poor outcomes, simplify the surveillance process, and minimize the inconsistency that subjective VAP surveillance definitions permit.[36]

Epidemiology. Recently, prospective surveillance study found that VAP was 8% to 28% prevalence rates globally, while in the United States the rate was 13.5%, Europe was 19.4%, and Asia Pacific was 16.0%. VAP infection rate is dying in United Sates in ICUs of less than 4 per 1,000 ventilator days in contrast it is still high internationally which can be explained by the discrepancy of the method of surveillance report. Average attributable cost of VAP was estimated to range from $12,000 to $40,000/case and VAP was also associated with high attributable mortality rate ranging from 24% to 76% and patients with VAP are at high risk to die twice compared with those without VAP. [4, 20] VAP attributable mortality and medical care costs are appearing to be highest for surgical patients and for critically ill patients.[20, 37]

Results of a 6-year epidemiologic surveillance for ventilator-associated pneumonia at a tertiary care intensive care unit in KSA in 2012 revealed that 15.4% of 2,812 ventilated patients, developed VAP. VAP rate/1000 ventilator days was decreased from 19.1 in 2003 to 6.3 in 2009. [38] The most common isolated pathogens were Gram-negative organisms. VAP patients had longer mechanical ventilation duration, ICU and hospital length of stay, but similar ICU and hospital mortality compared with non-VAP patients. It is well known that VAP in ICU is associated with increased hospital lengths of stay and prolonged mechanical ventilation. It is estimated that patients who develop VAP have an increase in ICU stay of 4.3 to 13 extra days and the mean hospital cost with each case of VAP is between $12,000 to $40,000. [4, 39]

Risk factors of VAP include, reintubation, aspiration, tracheostomy, trauma, and burns. Host factors can increase the risk of VAP include older age group more than 60 years, male gender, severity of illness, neurologic impairment, muscular weakness, respiratory distress syndrome and cardiac disease.[20, 37, 38] Safdar and his colleagues revealed that other risk factors can be postsurgical patients, presence of multiple organ failure, supine patient positioning, decreased gastric pH, cardiopulmonary resuscitation, continuous sedation, presence of nasogastric tube.[4]

Microbiology of Ventilator-associated Pneumonia. *Pseudomonas aeruginosa* VAP prevalence is 4.1% which is an aerobic gram-negative bacilli infection globally while in the United States is 3.4, Europe 4.8%, and in Asia 3.2%. All an aerobic gram-negative bacilli account for approximately 60% of VAPs include; *Acinetobacter* species, *Proteus* species, *Escherichia coli*, *Klebsiella* species, and *Haemophilus* influenza. VAP due to *Staphylococcus aureus* infection is increasing, also fungal infection due to

Candida species, which are often isolated in patients with VAP. Viruses usually occur in immunosuppressed patients. Antibiotic resistance is a growing problem including methicillin-resistant *Staphylococcus aureus, P. aeruginosa, Acinetobacter* species), and antibiotic-resistant *Enterobacteriaceae*.[20, 37]

Balkhy *et* al. conducted a retrospective susceptibility study between October 2004 and June 2009 in the adult intensive care unit of King Abdulaziz Medical City in Riyadh, KSA and showed that *Acinetobacter* resistant in VAP was very high; it was more than many countries worldwide. It was 60-89% resistant to all tested antimicrobials followed by Pseudomonas aeruginosa was less 13-31% resistant to all tested antimicrobials.[40, 41]

Preventive measures. The most important goal for ICU cares teams is to reducing VAP for patients on mechanical ventilation. Hand hygiene, VAP bundle, and surveillance are the key factors for VAP prevention. Performance improvement strategies include education about VAP and risk mitigation and training are a foundation for effective practice. VAP bundles are interventional methods to decrease the risk of pneumonia due to inappropriate maintenance, and cleaning of respiratory equipment or due to aspirating secretions with a high bacterial load. It includes elevating the head of bed 30°–45°, avoiding gastric distention, antiseptic oropharyngeal care, use of cuffed endotracheal tubes, in-line suctioning, careful use of gastric acid suppression, daily sedation vacations and spontaneous breathing trials.[20]

Branch-Elliman and colleagues did a cost effective analysis using model inputs from the medical literature and the U.S. Department of Labor to establish the best VAP prevention protocols, they identified that use of subglottic suction endotracheal tubes, and

VAP Prevention Bundle, oral care with chlorhexidine and selective oral decontamination are the least expensive strategies and the strategies with the best cost–benefit ratio.[37]On the other hand, several important limitations were illustrated regarding this cost effective analysis model, including some of the assumptions are from clinical studies that are very old with high possibility of changing of the costs of medical care in this long period, the costs due to the complications VAP prevention interventions not taken in the author consideration (for example emergence of antibiotic resistance due to selective oral decontamination), the overall effect of increasing antibiotic resistance in VAP was not factored into this cost analysis.

It is very likely that increasing rates of VAP attributed to antibiotic-resistant bacteria will result in greater ICU and hospital lengths of stay and greater costs.[37] This literature also illustrated other recent systematic review by Roquilly and colleagues to identify which VAP prevention methods for ICU patients are most effective for minimizing mechanical ventilation duration and decreasing mortality rates. This review of applicable randomized controlled trials of prophylactic digestive methods includes digestive decontamination, antacids, early feeding and microaspiration prevention, also prophylaxis related to the pathway like; closed suctioning systems, tracheostomy as soon as possible, aerosolized antibiotics, continuous drainage of the lung secretions, humidification and silver coated endotracheal tubes. In addition, they reviewed oropharyngeal prophylactic methods which includes oral decontamination, patient's head position, tracheal cuff monitoring and subglottic secretion drainage. They found that selective digestive decontamination was significantly effective in reducing mortality rate while selective digestive decontamination and physiotherapy was the most intervention

reduces mechanical ventilation duration. The only limitation of this analysis was that this analysis didn't examine bundled intervention.

The study summarized that the most cost effective approaches for the prevention of VAP is an economically mandated requirement. In settings with high prevalence of VAP attributed to multidrug-resistant organisms, use of more effective preventive measures should be applied even if they are more expensive and could be justified in order to decrease overall costs and improved outcomes.[37]

In Tawfique *et* al. the study measured the effect of the implementing of the Institute for Healthcare Improvement (IHI) VAP bundle. In the study conducted in adult ICU at Dhahran Health Center in Eastern KSA, they compared the rates of VAP preinterventional and postinterventional. The result showed bundle significant cost effective reduction of the VAP rate, from a mean of 9.3 cases per 1000 ventilator-days in 2006 year to 2.3 cases per 1000 ventilator-days in 2007 and to 2.2 in 2008 year ($P <$ .001). [39]

Other evidence-based preventive measures include: avoiding intubation, reintubation, and early entubation when possible. Use of noninvasive ventilation is an alternative to be used whenever appropriate. Also, the use of oral endotracheal and orogastric tubes is more effective than nasotracheal and nasogastric tubes. Endotracheal tube stents to keep the epiglottis open and continuous suctioning of subglottic secretions to reduce the risk of aspiration should be standard protocol. In addition, the use of a closed suction system is recommended since it can provide a barrier to separate the contaminated catheter from the caregiver, and for the patient, can permit continuous ventilation and reduce respiratory stress.[4]

Other measures too are recommended, like maintaining endotracheal cuff pressure at greater than 20 cm H_2O. The following are all important measures that have been shown to decrease the duration and number of ventilated days and mortality due to VAP: use of a cuff, the semirecumbent positioning of the patients, especially when they are enterally fed, elevating the head 30° to 45°, routine oral decontamination with Chlorhexidine oral rinse, and limiting the use of sedative and neuromuscular blockers. [4]

Chapter 3 – Manuscript

Abstract

Background: Healthcare-associated infections (HAIs) are a serious patient safety issue in hospitals worldwide, affecting 5%-10% of hospitalized patients and deadly for patients in intensive care units (ICUs).[1] Device-associated HAI (DA-HAI) surveillance is implemented in most hospitals. DA-HAIs account for up to 23% of HAIs in ICUs and about 40% of all hospital infections (i.e., central line-associated blood stream infections [CLABSI], ventilator-associated pneumonia [VAP], and catheter-associated urinary tract infections [CAUTI]). This surveillance focuses on DA-HAIs in ICUs and is used for comparison, benchmarking, and detecting areas to focus on for improvement.[2, 3] This study aims to identify DA-HAI rates among a group of selected hospitals in KSA from 2013 – 2016.

Methods: We analyzed secondary data from 12 medical/surgical intensive care units (M/SICUs) and two cardiac care units (CCUs) from 12 Ministry of Health (MoH) hospitals from different regions in the Kingdom of Saudi Arabia (KSA). These data were reported by infection control practitioners to the MoH via the electronic International Nosocomial Infection Control Consortium (INICC) system in each hospital.

Results: Among 6,178 ICU patients with 13,492 DA-HAIs during 2013 – 2016, the average length of stay (LOS) was 10.7 days (range 0 to 379 days). VAP was the most common DA-HAI (57.4%), followed by CAUTI (28.4%), and CLABSI (14.2%). In CCUs there were no CLABSI cases; CAUTI was reported from 1 – 2.6 per 1000 device-days; and VAP did not occur in Hospital B but occurred 8.1 times per 1000 device-days in the CCU in Hospital A. In M/SICUs, variations occurred among time periods, hospitals, and KSA provinces. CLABSI varied between hospitals from 2.2 to 10.5 per 1000 device-days. CAUTI occurred from 2.3 to 4.4 per 1000 device-days, while VAP had the highest rates, from 8.9 – 39.6 per 1000 device-days. Most hospitals had high device-utilization rates (from the 75^{th} – 90^{th} percentile of NHSN's standard and the 50^{th} – 75^{th} percentile of INICC's).

Conclusions: We found higher device-associated infection rates and higher device-utilization ratios in the study's CCUs and M/SICUs than National Healthcare Safety Network (NHSN) benchmarks, except for CLABSI rates, which were lower. To reduce the rates of infection, ongoing monitoring of infection control practices and comprehensive education are required. Further a more sensitive and specific national healthcare safety network is needed in KSA.

Introduction

Healthcare-associated infections (HAIs) are a serious patient safety issue in hospitals worldwide, affecting approximately 5%-10% of hospitalized patients, and can be deadly for patients in intensive care units (ICUs).[1] An estimated 100,000 patients die every year due to HAIs, at a cost of $17 billion to $29 billion.[8, 9] National pooled ICU data shows a CAUTI rate of 3.1 - 7.5/1000 days, a CLABSI rate of 1.6 -6.8/1000 days, and a VAP rate of 2.5 - 12.3/1000 days.[9] In developing countries, although accurate estimation and information about DA-HAI is scant[2, 3], surveillance study conducted by the International Nosocomial Infection Control Consortium (INICC) of 503 ICU beds in countries in Latin America, Asia, Africa, and Europe from 2007 to 2012 showed that DA-HAIs rates were higher in the ICUs of those hospitals. The pooled rate of CLABSI infection is nearly 5-fold higher than the reported CLABSI rates from comparable U.S. ICUs. The overall rates of VAP and CAUTIs were also higher.[10]

Many studies and literature reviews have demonstrated that effective implementation of an integrated infection control program that focuses on DA-HAI surveillance can prevent about two-thirds of HAIs. They reported reductions in DA-HAI of as much as 30% along with a reduction in health care costs.[17, 21]

Surveillance is an essential tool in quality improvements and patient safety that helps to determine the endemic infection rates, which allows for the early detection of epidemics, risk assessment for better future planning, and evaluation of new interventions.[7]

Targeted device-associated healthcare-associated infection (DA-HAI) surveillance has been implemented in most hospitals in developed and developing

countries, as has benchmarking with the National Healthcare Safety Network (NHSN) database.[3] This surveillance, which focuses on DA-HAIs in ICUs, was established by the CDC, NHSN, the Infectious Diseases Society of America (IDSA), and the Society for Healthcare Epidemiology of America (SHEA).[3] The NHSN surveillance criteria are the most commonly used for hospital comparisons, benchmarking, and detecting areas to focus on for improvements.[2]

The INICC system is also used as a benchmark; it consists of DA-HAI data collected from 215 enrolled hospitals from 36 countries, including developing countries. INICC benchmarking appears reasonable and has similar methodologies and challenges over the range of its participating hospitals, as well as the availability of unique data on mortality and length of stay. However, it does not account for the assumed variability in surveillance between and within participating countries. [31]

To minimize the occurrence of DA-HAIs in ICUs, the NHSN-recommended infection control measures should be implemented and enforced. Evidence-based approaches include daily device assessments, intervention bundles, reducing risk factors, continuing health education for ICU staff, the establishment of infection control committees, and antimicrobial stewardship programs.[4]

Although DA-HAI represents a real public health problem [11], it is still an evolving area of critical care research and continued advancements in this field are foreseen.[4] Also, although previous studies have shown that developing countries have higher DA-HAI rates than the United States and other European countries, the amount of accurate surveillance data remains insufficient. [2, 3, 10]

The Kingdom of Saudi Arabia (KSA), like other developing countries, has limited

data regarding DAI rates in general hospitals, and most of the published studies are limited to certain devices. [2] The main aim of this study is to identify DA-HAIs rates in KSA in general hospitals which has different time frame according to the received dataset from different general hospitals but it is had reported from 2013-2016.

Knowing this information is critical and vital for the sake of patient health first as well as for the benefit of health authorities for identifying areas or health care settings with high infection rates. With this information, they can take action accordingly and initiate immediate improvement plans. Additionally, studies like this one are an important addition to the published literature and serve as a resource for further research.

Methodology

This study is a retrospective cohort study using secondary data from 12 medical/surgical Intensive Care Units (M/SICUs) and two Cardiac Care Units (CCUs) from 12 MoH referral hospitals in KSA. The infection control practitioners in every hospital fill out online surveillance data by using special INICC multidimensional approach format collected and sent to the MoH Infection Prevention and Control Department on a monthly basis.

Study setting

The study took place in adult ICUs of 12 MoH hospitals in different provinces of KSA, with two different ICU types (Cardiac and Medical and Surgical ICU) and differing bed capacities. The surveillance data was completed by trained infection control practitioners in every hospital using a special online INICC multidimensional approach format sent to the MoH Infection Control Department on a monthly basis.

Selected general hospitals implemented the INICC multidimensional approach in their DA-HAI surveillance. The INICC system is focused on the surveillance and prevention of DA-HAI in adult ICUs, pediatric ICUs, and neonatal intensive care units (NICUs). The INICC multidimensional approach is based on that of the CDC's NHSN [21]

INICC multidimensional approach

The INICC implements the methodology of the CDC's NSHN but adds the collection of other data essential to increasing infection control personnel's sensitivity to detecting HAIs to avoid underreporting. The INICC method also includes collecting data from all patients, with and without HAI, and the results of cultures, antibiotic therapy, LOS, and mortality.

Outcome and process surveillance are conducted by means of an online platform called the INICC Surveillance Online System (ISOS) that collected by infection control personnel and uploaded daily to calculate DA-HAI rates per 1,000 device days to diagnose CLABSIs, CAUTIs, and VAPs and capture denominator data, patient days, and specific device days in the ICUs. Infection control personnel are trained by the INICC team onsite and also provided with tutorial movies, manuals, and training tools that described in detail how to perform surveillance and upload surveillance data through the ISOS.[21]

Data collection

Data was collected from 12 general governmental hospitals enrolled in the INICC system. The selected hospitals are referral hospitals that are JCI accredited.

Data Source

Data were received from the MoH as a Microsoft Excel™ workbook with personal health identifiers. The source data was de-identified and a unique de-identification key was created in a separate encrypted and locked file for each patient to replace medical record number, date of birth, and bed number. Prior to removing these variables from the initial dataset, age was calculated using the date of birth. Data was received as a separate Excel file for each hospital containing 221 variables, the data entry fields of the INICC form (Appendix A). The separated files were merged together and all variables were aligned with identical data type, length, and format to create a uniform structured dataset. The de-identified dataset was subsetted and times were transposed to create the variables of interest.

The M/S ICUs under study were categorized into five groups according to the time period of surveillance and number of beds. Data from the CCUs was kept separate since we had only two CCUs and a different time frame.

Table 2. List of Participating Hospitals in the current study of the device associated infection rates in Adult ICUs of MoH general hospitals, Kingdom of Saudi Arabia, 2013-2016

Group#	Included Hospitals	Bed size	Time frame
1	Hospital B- Asser Province Hospital C -Jeddah Province Hospital D – Riyadh Province Hospital E - Qassim Province	<15	05/15-02/16
2	Hospital A -Asser Province Hospital F –Taif Province	>15	09/13-03/15
3	Hospital G -Najran Province Hospital H -Tabuk Province	>15	09/13-02/16
4	Hospital I-Taif Province Hospital J -Hail Province Hospital K -Madina Province	>15	09/15-03/16
5	Hospital L- Riyadh Province	>15	01/15-02/16

Study Variables

Given the gradual implementation of the new system, prior to analysis, the datasets were thoroughly examined for inconsistencies, inaccuracies, and invalid entries. During this examination and subsequent data cleaning process, several variables were reclassified or recoded for inaccuracies.

The length of stay was calculated as the difference of the discharge/death day from the admission day. For missing admission or discharge dates, the bed day's variable

that was derived from the system indicating length of stay was used. For X hospitals, length of stay was offset by 1 day from bed days variable.

Device days were calculated as the difference of the device end date from the start date. Incorrect device dates that resulted in a negative number of device days, or device days that exceed the ICU length of stay, or device dates that fell outside the admission and discharge time frame were corrected either by recoding an incorrect date to a more likely accurate date relative to other data points (e.g., admission/discharge dates, antibiotic dates, other device dates, culture dates) or setting the device end date(s) to admission and/or discharge date(s). The infection numbers were calculated for every device as the count of the number of infections per device in every hospital for every time period.

Statistical Analysis

Exploratory analysis of data was done and summary statistics for all independent variables were derived. Continuous variables were summarized with descriptive statistics (N, mean, standard deviation, and ninety-five percent confidence intervals). Categorical variables were summarized with frequency counts, proportions and percentages within each category or between levels of a category as appropriate.

DA-HAI rates per 1,000 device days was calculated using NHSN criteria for every device (Central line, Urinary catheter and Mechanical ventilator) by dividing the device infection number by the number of device days and multiplying the result by 1,000.

The Utilization Ratio was calculated by dividing the number of the device days by the number of bed days. [26, 31, 35]

These calculations were performed separately for different types of ICUs.

For every device rate, we calculated the Standardized Infection Ratio (SIR) to compare the actual number of HAIs reported in our hospitals with the baseline U.S. experience (i.e., NHSN aggregate data are used as the standard population). An SIR greater than 1.0 indicates that more HAIs were observed than predicted and less than 1.0 indicates that fewer HAIs were observed than predicted. Taking in our consideration the adjusting for several risk factors that have been found to be significantly associated with differences in infection incidence (Type of the hospitals, bed size and same duration).[43] The SIR is calculated by dividing the number of observed infections by the number of expected infections. Multiplying the location's number of device days by the NHSN rate and dividing by 1,000 calculate by the expected number of device infection for each location. Then, the expected number of device infection are summed and used as the denominator for the overall SIR across these locations.[43]

Crude device mortality ratio was calculated by dividing number of dead and has device infection by overall number of dead with all devices infection.

We estimated the 95% confidence interval (CI) for each SIR, and device Utilization Ratio; and for each DA-HAI, the CI was calculated as per 1000 device. Finally, we compared our hospital's location-specific rates with NHSN report (2013).[44]

We examined our DA-HAI rates and utilization ration and interpreted it with NHSN /INICC percentile reports to determine if our hospital's rate or ratio is above or below 50^{th} percentile (median).

It is important to remember that DA-HAI and device utilization ratios should be examined together for preventive measures plan to be targeted correctly.

Ethical Considerations

This study did not require IRB review because it did not meet the definition of "human subjects research" or "clinical investigation" as set forth in Emory policies and procedures and federal rules (IRB00087850**)**.

Results

In this study, a total of 6,178 patients were admitted into the ICUs of the 12 selected hospitals from 2013 – 2016. Of these, 70.7% were female. Women were an average of 44.6 years old and men 52 years old. The average length of stay (LOS) was 10.7 days (0 minimum and 379 day maximum stay). Among the patients studied, the overall ICU outcome proportion was 78.7% recovered and 21.3% died.

During the study period of 2013-2016, there were a total of 13,492 DA-HAIs in the 12 MoH hospitals under study. VAP was the most common (57.4%), followed by CAUTI (28.4%), then CLABSI (14.2%). The DA-HAI mortality rates were 41.9% for CLABSI, 40.5% for VAP, and 36.9% for CAUTI. (DA-HAI rates in this study have been standardized with the NHSN rates for accurate comparisons to NHSN data.)

Among ICU patients, the central line had an average of 7.9 device days, the mechanical ventilator had 7.8 days, and the urinary catheter had 7.6 days (Table 3).

The DA-HAI results will be organized by the type of ICU and the group of the hospitals that are gathered by time frame mentioned in the methodology (Table 2).

DA-HAIs in Cardiac Care Units (CCUs) of Two Hospitals

CLABSI. CLABSI rates were zero per 1,000 device-days in both CCUs in Hospital A and Hospital B, although the latter had less than 50 device days that could affect the good estimation of the rate since the denominator is small (Table 4).[44] The CLABSI rates of zero in the MoH CCUs under study was less than the mean for U.S. hospitals (1.1) and are comparable to the NHSN's 10^{th} percentile.

Central line utilization ratio in Hospital A was 0.46 (95% CI 0.38-0.56), at the 50th percentile of NHSN. In Hospital B, the ratio was 0.74 (95% CI 0.5-1.05), which is above the 90th percentile of the NHSN utilization ratio (less than the 75th percentile of INICC ratio). (Table 7)

CAUTI. Hospital A's rate was 1 per 1000 device-days (95% CI 0.21-3.34) while, Hospital B's was 2.6 (95% CI 0.23-11.77) (Table 5). These are at the 50th percentile of NHSN and not far from the mean of U.S. hospitals (2.2). The urinary catheter utilization ratio in both CCUs was above the 90th percentile of the NHSN utilization ratio (and under the 75th percentile of the INICC ratio.

VAP. The VAP rate in Hospital A was very high: 8.1 per 1000 device-days (95% CI: 0.74-37.90) (Table 6). This rate was way above the 90th percentile of NHSN data (but near the 50th percentile of INICC data). In contrast, Hospital B had a rate of zero per 1,000 device-days.

The mechanical ventilator utilization ratio in both CCUs was above the 90th percentile of NHSN's utilization ratio (as well as INICC's). The utilization ratio was 0.53 (95% CI 0.44-0.63) in Hospital A and 0.55 (95% CI 0.43-0.68) in Hospital B.

DA-HAIs in Medical/Surgical ICUs (M/SICUs) of 12 Hospitals

CLABSI. In Group 1 (four hospitals with under 15 beds over a 9 month period) the CLABSI rate ranged from 0 to 6.19/1,000 device-days (Table 4). These rates are comparable with the 50th percentile of NHSN data (Table 7).

In Group 2 (two hospitals with over 15 beds and over a 17 month period), the CLABSI rate ranged from 0 to 4.28/1,000 device-days. The rate of zero is at NHSN's 25th percentile. The upper range (4.28) is comparable to the INICC pooled mean.

In Group 3 (two hospitals with over 15 beds over a 29 month period), the CLABSI rate ranged from 6.68 to 10.68/1,000 device-days. This range is over the 90th percentile of NHSN (and at the 75th percentile of INICC data).

In Group 4 (three hospitals with over 15 beds over a 6 month period), the CLABSI rates ranged from 0 to 22.8/1,000 device-days. Two of the three hospitals fell within the 50th percentile of NHSN data, and the other was an outlier, higher than the 90th percentile of NHSN (and INICC).

In Group 5 (one hospital with over 15 beds over a 14 month period), the CLABSI rate was 10.2 per 1,000 device-days (95 % CI; 0.459-54.25), which is over the 90th percentile of NHSN (and under the 75th percentile of INICC data).

Groups 1, 3 and 4 had high central line utilization ratios compared to the NHSN utilization ratio; they exceeded the 90th percentile. In contrast, Groups 2 and 5 had low central line utilization ratios. Group 2's was 0.33 (95% CI 0.31-0.34) and Group 5's was 0.05 (95% CI; 0.68-0.06), both below the 10th percentile of the NHSN ratio.

CAUTI. As seen in Table 5,The CAUTI rate in Group 1 ranged from 2.3 to 7.19 per 1,000 device-days. Two hospitals were at the 75th percentile of NHSN (and under the 50th percentile of INICC). Two hospitals were higher than the 90th percentile of NHSN (and lower than the 75th percentile and the pooled mean of INICC data). Group 2's range was 0 to 3.9, Group 3's range was 1.9 to 3.5, and Group 4's range was 0 to 5.2. Four hospitals had CAUTI rates under NHSN's 50th percentile and the other three had rates

over NHSN's 75th percentile (but comparable to or less than the INICC pooled mean). Group 5 had a CAUTI rate of 11.75 per 1,000 device-days (95 % CI; 4.46-25.75), which is higher than the 90th percentile of NHSN (and higher than the 75th percentile of INICC).

Urinary catheter utilization ratios in Groups 1, 3, and 4 were higher than other groups. Group 1's was 0.75 (95% CI; 0.73-0.77), Group 3's was 0.79 (95% CI; 0.78-0.81), and Group 4's was 0.85 (95% CI; 0.83-0.88). All of them exceeded the NHSN's 90th percentile for utilization ratio. On the lower end, Group 2's ratio was 0.42 (95% CI; 0.40-0.43) and Group 5's was 0.06 (95% CI; 0.05-0.06), which were less than the 10th percentile of NHSN data.

VAP. VAP rates were found to be high in in all M/SICUs (Table 6). In Group 1, they ranged from 18.1 to 26.6 per 1,000 device days. In Group 2, they ranged from 9.33 to 20.7 per 1,000 device days. In Group 3, they ranged from 0.9 to 16.4 per 1,000 device days, and in Group 4, they ranged from 10.1 to 51.6 (Hospital I was not included in this range because its number of device days was less than 50, which can affect the reliability of the estimate).[44] VAP rates in most of the hospitals were much higher than the NHSN mean (but within the INICC mean). Group 5 had an outlier VAP rate of 186.5 per 1,000 device days (95% CI; 121.44-275.04). All VAP rates in the hospitals under study exceeded the 90th percentile of the NHSN (and were between the 75th and 90th percentile of INICC data) except for one in Group 3.

Mechanical ventilator utilization ratio in Group 1 was 0.54 (95% CI; 0.52-0.56), in Group 3 it was 0.65 (95% CI; 0.64-0.66), and in Group 4 it was 0.94 (95% CI; 0.90-0.98) (Table 8). These were all high utilization ratios that exceeded the 90th percentile of NHSN's utilization ratio (Groups 1 and 3 were at the 75th percentile of INICC's ratio and

Group 4 was at the 90th). Group 2 had a lower mechanical ventilator utilization ratio: 0.31 (95% CI; 0.29-0.32), at the 50th percentile of the NHSN. Group 5 had the lowest device utilization ratio among the groups, 0.05 (95% CI; 0.04-0.06), which was under the 10th percentile of NHSN's ratio (Table 9).

The CLABSI, CAUTI, and VAP rates per 1000 device-days, total number of device-days, device utilization ratios, VAP, from all 12 hospitals different with in M/SICUs and CCU are shown in Tables 4, 5, and 6 (Appendix).

DA-HAI rates and utilization ratio reports of the INICC (2007-2012) and U.S. NHSN (2013) are in Tables 5 and 6.

Discussion

DA-HAI is considered a quality criterion of inpatient care and it includes transparent and real time data collection and monitoring of vital processes as well as evaluation of outcomes. Effective implementation of integrated infection control program that focused on DA-HAIs surveillance can prevent about two-thirds of HAIs. [17, 19, 21] DA-HAIs surveillance is crucial not only to track the performance internally, but also to compare our local data to national and international benchmarks, to improve health services quality of care by demonstrating strengths and weaknesses and assessing the outcomes of interventions planned to reduce HAIs.

In this study we used our DA-HAI surveillance data from some of our main general hospitals gathered through INICC multidimensional approach. It is an online system that adopted the methodology of the CDC's NSHN, and filled by trained infection control preventionest. [21]

The results showed that during the study period from 2013 to 2016, VAP was the most common DA-HAI (57.4%) in the hospitals included in this study, followed by CAUTI (28.4%) then CLABSI (14.2%). This is not consistent with previous studies. Tawfique et al.'s prospective study of DAI rates conducted between 2004 – 2011 in the adult ICUs of the Saudi Aramco Medical Services Organization revealed that CAUTI was the most common DAI (42.2%), followed by CLABSI (38.5%) and VAP (19.3%), with an overall rate of 8.18 for CAUTI, 10 for CLABSI, and 4.52 for VAP (per 1000 device-days). Our study illustrated better CAUTI and CLABSI results than the aforementioned study, although Tawfique et al.'s study was conducted in a single hospital within a different timeframe. [2] A study by El-Saed showed lower VAP rates than our study (but with a lower utilization ratio of 0.57): their VAP rate was 4.8 per 1,000 ventilator days (95% CI, 4.3-5.3). This study was done in National Guard Hospitals, not MoH hospitals at a different time.[45]

In the two CCUs in our study, the CLABSI rates were lower than the NHSN benchmark, with a high central line utilization ratio. CAUTI rates were at the 50th percentile of NHSN and similar to the mean of U.S. hospitals, with a very high urinary catheter utilization ratio. The VAP rate in Hospital A's CCU was 8.1 per 1,000 device days, and zero in Hospital B's CCU. Hospital A's high infection rate only reflects the presence of a single case. Between the two CCUs, the timeframes measured were distinct: Hospital A's surveillance took place over 17 months, and Hospital B's took place over 9 months. Both hospitals had high MV utilization ratios (over the NHSN's 90th percentile); still, Hospital B had zero infections.

In most of the 12 M/S ICUs in our study, we found very good CLABSI rates. These were at the 50th percentile of NHSN benchmarks. Notable CLABSI rates in individual hospitals were as follows: Hospitals A, B, C, E and I had CLABSI rates of zero per 1,000 device-days. Hospital J, in Hail, had the greatest CLABSI rate: 22.8 per 1,000 device-days (95% CI; 12.1-39.47), which was an outlier in the hospitals under study. All but two of the M/S ICUs had high central line utilization ratios (over the NHSN's 75th percentile).

CAUTI rates in three of the 12 hospitals (A, K and I) were less than the NHSN pooled mean, and four (B, C, D, F) had rates lower than the 50th percentile of INICC benchmarks. The urinary catheter utilization ratio in most of these M/S ICUs exceeded the 90th percentile of the NHSN's utilization ratio. [10, 44]

VAP rates in most of the M/S ICUs in the hospitals under study were much higher than the NHSN mean but near the INICC mean and within its confidence interval, with very high mechanical ventilator utilization ratios.

A cohort study conducted from 2008 – 2010 in China demonstrated a nearly similar result: VAP (10.46/1,000 device days) was the predominant DAI followed by CLABSI (7.66/1,000 device days), then CAUTI (1.29/1,000 device days). [3]

The overall DAI rates were much higher than those in the U.S. and even higher than previous studies in the KSA had shown (among various health sectors). The variations in DAI rates among the studies cited could be related to the distinct protocols in place in different health sectors (i.e., MoH, National Guard, ARAMCO, military) and the different application of preventive measures (e.g., bundles) by hospital.

The hospitals in our study met some but not the majority of NHSN benchmarks for DA-HAIs. Most did however fall into the 50th percentile or lower of INICC data, which includes data from different developing countries. In benchmarking to the NHSN data, we should take into consideration the differences in surveillance environments and NHSN hospitals, which may have stricter protocols, continuous monitoring, and immediate interventions, which are still challenges in KSA hospital settings.

Limitations

Our study had a few limitations. First, the accuracy of our surveillance data could have been affected by the lack of compliance of the healthcare workers to the new electronic INICC system versus the old paper-based system. Despite the implementation of INICC training programs, it takes time for new knowledge and skills to translate into accurate reports.[22] For example, we found an inconsistent method of computing the dates in the INICC system that led to incorrect device and bed days that we manually corrected.

Second, calculating the rates of DA-HAIs per 1000 device-days was difficult due to the variable surveillance period durations among the participating hospitals.

Third, some hospital data was not provided. There are more than 12 participating INICC hospitals, but some hospitals didn't send their monthly surveillance data to the MoH.

Chapter 4 – Conclusion and Recommendations

HAIs are a major problem in all health care institutions. Surveillance is a main component for successful HAI prevention efforts. The standard method of surveillance is the training of infection-control professionals to identify and report HAIs on the basis of specific definitions and surveillance approaches adopted through the CDC/NHSN surveillance systems. Surveillance data is valuable and can serve as guidance for the implementation of prevention plans and quality improvement strategies for the reduction of DA-HAI rates specifically. Therefore, ICPs should strive to do things accurately by continuously improving their performance and reliability, especially with the new INICC system.

In our study we found that KSA still faces certain challenges in infection control such as lack of compliance with the electronic surveillance system, a high rate of DA-HAI, and high utilization ratios, especially in the ICUs.

The main finding of our study was a high incidence of DA-HAIs, especially in M/S ICUs, compared to NHSN data. To improve patient care and decrease infection rates in KSA ICUs, we offer the following recommendations.

The MoH Infection Control Department should implement a continuous widespread education program for all healthcare workers, concentrating on reducing device utilization and establishing more effective infection control practices and management of invasive device use in KSA hospitals. [25]

Because online systematic surveillance systems like the INICC multidimensional approach help in achieving increases to strict adherence to infection control surveillance

and guidelines and increase the awareness of healthcare teams to DA-HAI risks in the ICUs [21], healthcare workers should receive further training to use the system properly. Participating hospitals that are not submitting their data to the MoH should be obliged to do so.

Some of the KSA healthcare system still relies on paper-based reporting and should be transitioned to electronic reporting in order to accelerate the process of data collection and surveillance with accurate real-time data and analysis. This will reduce the burden of manual data collection, and staff time can be used for prevention activities, such as improvements in process measures.

The HAI surveillance system should be continuously monitored and audited to identify the hospitals with high HAI rates for improvement plans and immediate interventions. Some of the hospitals in our study had high device infection rates across the board. Information about hospitals with high infection rates should be shared with the highest-level health authorities and these hospitals must be monitored so that their rates are lowered within a set period of time. Hospitals with low infection rates should be announced publicly and rewarded for more encouragement. Other hospitals can learn from their experience in lowering DA-HAIs.

More published studies are needed on HAI rates that can serve as resources and references for future studies and can help so practitioners and researchers can locally benchmark infection rates.

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Appendix

Table 3. Demographic characteristics of patients in Intensive Care Units in 12 adult intensive care units of General MOH hospitals, KSA, 2013-2016.

	Number	Mean	Std Dev	Minimum	Maximum
Patient	6178				
Gender Male	1799	52.4	23.5	0	115
Gender Female	4370	44.6	22.7	0	108
LOS	6178	10.7	19.2	0	376
DEVICE DAYS_CL	1793	7.9	11.8	0	116
DEVICEDAYS_MV	2769	7.6	13.3	0	196
DEVICEDAYS_UC_FOLEY	4267	7.8	15.1	0	254

Table 4. Central Line-Associated Blood Stream Infection rates (CLABSI) in Intensive Care Units in 12 adult intensive care units of General MOH hospitals, KSA, 2013-2016.

Hospitals	ICU	Central line -Device days	BEDDAYS	#BSI	CLABSI (95% CI)	NHSN	INICC
Hospital A-Asser	Cardiac	104	226	0	0	1.1	3.47
Hospital B-Asser		28	38	0	0	1.1	3.47
Group 1(4 hospitals)	Medical/Surgical BED< 15 (05/15-02/16)	CLABSI rates 9 Months ranges from 0-6.19/1000 CL.days				0.9	4.93
Hospital B-Asser		91	97	0	0	0.9	4.93
Hospital C-Jeddah		725	1068	0	0	0.9	4.93
Hospital D-Riyadh		717	1308	4	6.19 (2.07-14.73)	0.9	4.93
Hospital E-Quassim		500	1050	0	0	0.9	4.93
Group 2(2 Hospitals)	Medical/Surgical BED> 15 (09/13-03/15)	CLABSI rates 17 Months ranges from 0 to 4.28/1000 CL.days				0.9	4.93
Hospital A-Asser		468	3070	0	0	0.9	4.93
Hospital F-Ta		1298	2318	5	4.28 (1.62-9.38)	0.9	4.93
Group 3(2 Hospitals)	Medical/Surgical BED> 15 (09/13-02/16)	CLABSI rates 29 Months ranges from 6.68 to 10.89/1000 CL.days				0.9	4.93
Hospital G-Najran		5486	7905	33	6.68 (4.68-9.27)	0.9	4.93
Hospital H=Tabuk		2814	4577	20	7.89 (4.98-11.96)	0.9	4.93
Group 4(3 Hospitals)	Medical/Surgical BED> 15 (09/15-03/16)	CLABSI rates 6 Months ranges from 0 to 22.8/1000 CL.days				0.9	4.93
Hospital I=Taif		62	136	0	0	0.9	4.93
Hospital J-Hail		536	845	11	22.80 (12.1-39.47)	0.9	4.93
Hospital K-Yanbou		776	1156	2	2.86 (0.57-9.18)	0.9	4.93
Group 5 (Hospital L) Riyadh	Medical/Surgical BED> 15 (01/15-02/16)	109	2324	1	10.2 (0.459-54.25)	0.9	4.93

Table 5. Catheter Associated Urinary Tract Infection rate (CAUTI) in Intensive Care Units in 12 adult intensive care units of General MOH hospitals, KSA, 2013-2016.

Hospitals	ICU	Urinary catheter-Device days	Bed days	#UTI	CAUTI (95% CI)	NHSN	INICC
Hospital A-Asser	Cardiac	872	1260	2	1.0 (0.21-3.34)	2.2	5.86
Hospital B-Asser		180	231	1	2.6 (0.23-11.77)	2.2	5.86
Group 1(4 hospitals)	Medical/Surgical BED< 15	CAUTI rates 9 Months ranges from 2.3 to 7.19/1000 UC.days				1.2	5.34
Hospital B-Asser		508	651	2	3.28 (0.65-10.51)	1.2	5.34
Hospital C-Jeddah		1268	1635	7	4.60 (2.051-9.03)	1.2	5.34
Hospital D-Riyadh		1802	2132	6	2.77 (1.15-5.72)	1.2	5.34
Hospital E-Quassim		1158	1924	10	7.19 (3.69-12.77)	1.2	5.34
Group 2(2 Hospitals)		CAUTI rates 17 Months ranges from 0 to 3.97/1000 UC.days				1.6	5.34
Hospital A-Asser	Medical/Surgical BED> 15 (09/13-03/15)	1630	5739	0	0	1.6	5.34
Hospital F-Taif		2204	3452	14	3.97 (2.27-6.48)	1.6	5.34
Group 3(2 Hospitals)		CAUTI rates 29 Months ranges from 1.9 to 3.5/1000 UC.days				1.6	5.34
Hospital G-Najran	Medical/Surgical BED> 15 (09/13-02/16)	10110	12555	57	3.52(2.69-4.53)	1.6	5.34
Hospital H=Tabuk		8189	10494	25	1.91(1.26-2.77)	1.6	5.34
Group 4(3 Hospitals)		CAUTI rates 6 Months ranges from 0 to 5.2/1000 UC.days				1.6	5.34
Hospital I=Taif	Medical/Surgical BED> 15 (09/15-03/16)	33	62	0	0	1.6	5.34
Hospital J-Hail		2627	2984	22	5.23 (3.37-7.78)	1.6	5.34
Hospital K-Yanbou		1124	1389	1	0.56 (0.05-2.59)	1.6	5.34
Group 5 (Hospital L) Riyadh	Medical/Surgical BED> 15 (01/15-02/16)	266	4645	5	11.75(4.46-25.75)	1.6	5.34

Table 6. Ventilator Associated Pneumonia (VAP) rates in Intensive Care Units in 12 adult intensive care units of General MOH hospitals, KSA, 2013-2016.

Hospitals	ICU	Mechanical Ventilator-Device days	Bed days	#Pneu	VAP (95% CI)	NHSN-VAP	INICC
Hospital A-Asser	Cardiac	123	233	1	8.13 (0.74-37.90)	1	11.5
Hospital B-Asser	Medical/Surgical BED< 15	72	132	0	0	1	11.5
Group 1(4 hospitals)		VAP rates 9 Months ranges from 18.1 to 26.6 /1000 MV.days				1.1	16.5
Hospital B-Asser		201	310	4	18.09 6.04-43.01	1.1	16.5
Hospital C-Jeddah		658	1376	17	23.49 14.20-36.76	1.1	16.5
Hospital D-Riyadh		1232	1935	36	26.56 18.91-36.35	1.1	16.5
Hospital E-Quassim		639	1468	16	22.76 13.54-36.09	1.1	16.5
Group 2(2 Hospitals)		VAP rates 17 Months ranges from 9.33 to 20.7 /1000 MV.days				0.9	16.5
Hospital A-Asser	Medical/Surgical BED> 15 (09/13-03/15)	1072	5437	9	9.33 4.61-17.03	0.9	16.5
Hospital F-Taif		1287	2222	24	20.72 13.62-30.31	0.9	16.5
Group 3(2 Hospitals)		VAP rates 29 Months ranges from 0.9 to 16.4 /1000 MV.days				0.9	16.5
Hospital G-Najran	Medical/Surgical BED> 15 (09/13-02/16)	6499	10665	96	16.41 13.37-19.95	0.9	16.5
Hospital H=Tabuk		6173	8925	5	0.89 0.34-1.97	0.9	16.5
Group 4(3 Hospitals)		VAP rates 6 Months ranges from 10.1 to 51.6 /1000 MV.days				0.9	16.5
Hospital I=Taif	Medical/Surgical BED> 15 (09/15-03/16)	7	32	2	317.46 63.31-1017.61	0.9	16.5
Hospital J-Hail		1465	2405	68	51.57 40.38-64.96	0.9	16.5
Hospital K-Yanbou		661	1210	6	10.086 4.19-20.79	0.9	16.5
Group 5 (Hospital L) Riyadh	Medical/Surgical BED> 15 (01/15-02/16)	137	2963	23	186.5 (121.44-275.04)	0.9	16.5

Table 7. Device-associated health care–acquired infection rates reports of the INICC (2007-2012) and U.S. NHSN (2013)

		NHSN						INICC					
CLABSI		Pooled Mean	10%	25%	50%	75%	90%	Pooled Mean	10%	25%	50%	75%	90%
	Cardiac	1.1	0	0	0.8	1.6	2.5	3.47	0	0	1.97	3.97	8.26
	M/S ICU < 15	0.9	0	0	0	1.2	2.6	4.93	0	0.89	3.31	7.9	17.01
	M/S > 15	0.9	0	0	0.7	1.4	2.2	4.93	0	0.89	3.31	7.9	17.01
CAUTI	Cardiac	2.2	0	0.6	1.8	3.4	4.9	5.86	0	0	0.64	3.35	10.96
	M/S ICU < 15	1.2	0	0	0.6	1.8	3.2	5.34	0	1.11	3.08	7.74	14.29
	M/S > 15	1.6	0	0.6	1.3	2.2	3.3	5.34	0	1.11	3.08	7.74	14.29
VAP	Cardiac	1	0	0	0	1.5	3.9	11.5	0	0	7.39	13.68	26.72
	M/S ICU < 15	1.1	0	0	0	1.2	3.6	16.5	0	5.95	12.23	24.94	39.27
	M/S > 15	0.9	0	0	0.4	1.3	2.8	16.5	0	5.95	12.23	24.94	39.27

Table 8. Device utilization ratios in Intensive Care Units in 12 adult intensive care units of General MOH hospitals, KSA, 2013-2016.

HOSPITALs	ICU	Central line device days	Bed days	Central line utilization ratio	Urinary catheter device days	Bed days	Urinary catheter utilization ratio	Mechanical ventilator -Device days	MV-Bed days	Mechanical ventilator-.utilization ratio
ASSIR	Coronary	104	226	0.46 (0.38-0.56)	872	1260	0.69 0.65-0.74	123	233	0.53 0.44-0.63
KMH		28	38	0.74 0.5-1.05	180	231	0.78 0.67-0.89	72	132	0.55 0.43-0.68
Group 1(4 Hospitals)	Medical/Surgical BED< 15	2033	3523	0.58 0.55-0.6	4736	6342	0.75 0.73-0.77	2730	5089	0.54 0.52-0.56
Group 2(2Hospitals)	Medical/Surgical BED> 15 (09/13-03/15)	1766	5388	0.33 0.31-0.34	3834	9191	0.42 0.40-0.43	2359	7659	0.31 0.29-0.32
Group 3(2 Hospitals)	Medical/Surgical BED> 15 (09/13-02/16)	8300	12482	0.66 0.65-0.68	18299	23049	0.79 0.78-0.81	12672	19590	0.65 0.64-0.66
Group 4(3 Hospitals)	Medical/Surgical BED> 15 (09/15-03/16)	1374	2137	0.64 0.61-0.68	3784	4435	0.85 0.83-0.88	2133	2270	0.94 0.90-0.98
Group 5(1 Hospitals)	Medical/Surgical BED> 15 (01/15-02/16)	109	2324	0.05 0.68-0.06	266	4645	0.06 0.05-0.06	137	2963	0.05 0.04-0.06

Table 9. Device-associated health care–acquired infection utilization ratio reports of the INICC (2007-2012) and U.S. NHSN (2013)

DA-HAI	ICU	NHSN pooled mean	NHSN Percentile					INICC pooled mean (95%CI)	INICC. Percentile				
CLABSI			10%	25%	50%	75%	90%		10%	25%	50%	75%	90%
	CARDIAC	0.42	0.18	0.3	0.41	0.56	0.69	0.58 (0.58-0.58)	0.11	0.35	0.55	0.85	1
	MEDICAL/SURGICAL<15	0.35	0.1	0.19	0.33	0.49	0.62	0.54 (0.54-0.54)	0.21	0.42	0.59	0.83	1
	MEDICAL/SURGICAL>15	0.48	0.29	0.4	0.51	0.6	0.69	0.54 (0.54-0.54)	0.21	0.42	0.59	0.83	1
CAUTI													
	CARDIAC	0.50	0.29	0.42	0.54	0.66	0.76	0.56 (0.56-0.56)	0.23	0.44	0.64	0.74	0.96
	MEDICAL/SURGICAL<15	0.53	0.31	0.45	0.6	0.72	0.79	0.62 (0.62-0.62)	0.53	0.54	0.73	0.9	0.99
	MEDICAL/SURGICAL>15	0.64	0.46	0.59	0.7	0.77	0.82	0.62 (0.62-0.62)	0.53	0.54	0.73	0.9	0.99
VAP													
	CARDIAC	0.26	0.09	0.16	0.25	0.33	0.4	0.29 (0.29-0.30)	0.05	0.14	0.32	0.43	0.51
	MEDICAL/SURGICAL<15	0.24	0.05	0.1	0.19	0.32	0.43	0.36 (0.36-0.36)	0.14	0.27	0.45	0.62	0.8
	MEDICAL/SURGICAL>15	0.34	0.19	0.25	0.33	0.41	0.49	0.36 (0.36-0.36)	0.14	0.27	0.45	0.62	0.8