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ORIGINAL ARTICLE

Effect of Infection Prevention and Control Measures on the Length of Hospital Stay of Patients at Lebanese Hospitals

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Abstract

Background: Infection Prevention and Control (IPC) measures are related to medical practices that prevent or minimize spreading of infectious diseases. The purpose of this study was to evaluate the effect of IPC measures on the length of hospital stay (LOS) of patients in infectious diseases service at Lebanese hospitals.

Methods: This was a prospective cohort study in two Lebanese hospitals between January 2017 and July 2017. Hospital 1 was a governmental university hospital located in Beirut with a total number of 544 beds, with Composite Index of Activities for the Control of Nosocomial Infections - 2 (CIACNI-2) and Composite Indicator of Control of Multi-Resistant Bacteria (CIC-MRB) scores of 76/100 and 69/100, respectively. Hospital 2 was a non-university private hospital located in Mount Lebanon with a total number of 110 beds, CIACNI-2 and CIC-MRB scores of 95/100 and 70/100, respectively. Adult patients of both genders aged over 18 years, admitted to the intensive care, internal medicine or surgical wards, with positive bacteria cultures and treated with antibiotics were eligible to be enrolled in the study. The primary outcome was to assess the effect of IPC measures of each hospital on the total LOS. Bivariate and multivariable analyses were used to identify the statistical associations.

Results: A total of 369 patients were enrolled in the study. Private hospital had higher scores of IPC measures. Patients at the hospital with lower IPC measures had an additional LOS of 2 ± 2.73 days when compared to the hospital with higher IPC measures ($p = 0.106$). Multi linear regression showed that the hospital with higher IPC measures was associated with significant shorter LOS ($p < 0.001$).

Conclusion: Applying high standards of IPC measures can decrease the total length of hospital stay in Lebanese hospitals.

Keywords

Length of hospital stay, Infection prevention and control (IPC) measures, Hospital acquired infection, Lebanese hospitals

Abbreviations

APACHE II: Acute Physiology and Chronic Health Evaluation; CAUTI: Catheter-Associated Urinary Tract Infection; CDC: Centers for Disease Control and Prevention's National Healthcare Safety Network; CI: Confidence Interval; CIACNI - 2: Composite Index of Activities for the Control of Nosocomial Infections - 2; CICMRB: Composite Indicator of Control of Multi-Resistant Bacteria; CNS: Central Nervous System; COPD: Chronic Obstructive Pulmonary Disease;

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CVC: Central Venous Catheter; DA-HAI: Device-Associated Infections; DoH: Declaration of Helsinki; GSC: Glasgow Coma; HAI: Hospital Acquired Infection; ICU: Intensive Care Unit; IDSA: Infectious Diseases Society of America; IPC: Infection Prevention and Control; IRB: Institutional Review Board; *K. pneumoniae: Klebsiella pneumonia;* LOS: Length of Hospital Stay; MDR: Multi-Drug Resistant; OR: Odds Ratio; *P. aeruginosa: Pseudomonas aeruginosa; S. aureus: Staphylococcus aureus; S. maltophilia: Stenotrophomonas maltophilia;* SD: Standard Deviation; SOFA: Sequential Organ Failure Assessment; WHO: World Health Organization; XDR: Extensively Drug-Resistant

Introduction

According to the World Health Organization (WHO), "Hygiene refers to conditions and practices that help to maintain health and prevent the spread of diseases" [1]. Nosocomial infection, also called "hospital acquired infection (HAI)", can be defined as an infection acquired in hospital by a patient who was admitted for a reason other than that infection [2]. These infections are caused mainly by multi-resistant bacteria and can lead to prolonged length of hospital stay (LOS), treatment failure and high rates of morbidity and mortality [3]. Infection Prevention and Control (IPC) measures include policies and regulations, set by an infection control committee, about hand hygiene, personal protective equipment, safe injection practices, safe handling of potentially contaminated equipment or surfaces in patient's environment, medical equipment cleaning, environmental hygiene, contact precautions, airborne infection isolation precautions, sterilization and disinfection, vaccination, education and surveillance. The goal of these measures is to maintain the safest possible hospital environment for patients, visitors and employees [4-11].

Reed and Kemmerly have analyzed the effect of HAIs and presented strategies to reduce the rates of infections; they concluded that infection prevention and control will be a major focus on hospital score [12]. A prospective active surveillance study was conducted by Leblebicioglu, et al. about the impact of a multidimensional infection control approach on catheter-associated urinary tract infection (CAUTI) rates in adult intensive care units in Turkey. These authors concluded that a multidimensional approach was associated with significant reduction in the rates of CAUTI [13]. Another open label, prospective cohort, active surveillance study done by Kanj, et al. in a Lebanese university hospital showed that Device-Associated Infections' (DA-HAI) rates, bacterial resistance, LOS and mortality were moderately high. Additionally, they concluded that infection control programs including surveillance and antibiotic policies are essential to be a priority in Lebanon [14].

To our knowledge, the relationship between LOS and IPC measures remains little studied in Lebanon. We conducted this study to know about the situation of IPC measures at different hospitals and their effects on the health outcomes in Lebanon. The aim of the study was to evaluate the effect of IPC measures on the LOS and the time to develop nosocomial infections in patients at Lebanese hospitals.

Methods

Study design and procedure

This was a prospective cohort study conducted between January 2017 and July 2017 in two Lebanese hospitals in central Beirut and Mount Lebanon areas after providing their Institutional Review Board (IRB) approval. An infectious disease specialist from each hospital has supervised the study's procedure.

Study population

Adult patients of both genders, 18 years of age and older, who were admitted to the intensive care, internal medicine or surgical wards, with a positive bacteria cultures as confirmatory test for infection and treated with antibiotics were eligible to be enrolled in the study.

All principles of the Declaration of Helsinki (DoH) were followed regarding human experimentation. Ethical consideration and patient consent use of routinely collected anonymous patient data was in accordance with the DoH principles and thus no further approval or patients consent were deemed required [15].

Data collection

Data collection started just after the approval from the IRB of each hospital. Medical numbers that matched the inclusion criteria were requested from the Information Technology department (for electronic charts) or the archive department (for paper charts). A systematic random sampling method was followed to select the medical numbers for analysis. Data were collected through three standardized questionnaires.

The first questionnaire was filled out by the primary investigator from medical charts. It included patient demographics such as gender, age, smoking and alcohol statutes, admission ward, previous hospital admission, status upon discharge, LOS and medical history. Infection's risk factors such as device catheterization, mechanical ventilation, surgical intervention and prior antimicrobial therapy were retrieved. The infection variables were also recorded, such as date of infection, type of infection whether community or nosocomial, site of the infection, antibiotic treatment and antibiogram. An infection was defined when at least one positive culture was obtained; it was defined nosocomial (healthcare associated) when it appeared after 48 hours of hospitalization, otherwise it was considered as community acquired infection [16]. Variables of inflammation and the severity of infection were used in the calculation of the Acute Physiology and Chronic Health Evaluation II (APACHE II) [17], Glasgow Coma and the Sequential Organ Failure Assessment (SOFA) scores [18].

The second questionnaire was filled out by the des-

ignated personnel of each department in each hospital (chief infectious disease specialist, chief pharmacist, head of the infection control committee, infectious prevention nurse specialist and microbiologist). The questionnaire was composed of two validated scores and it was used to identify the relationship between hospital's IPC measures and LOS. The first score was the Composite Index of Activities for the Control of Nosocomial Infections 2 ''CIACNI 2'' [19] to assess IPC measures' status of fundamental elements that prevent transmission of infectious agents in healthcare settings. The index requested about the presence or absence of policies and procedures, operational hygiene team, surveillance for hospital acquired infections (HAIs), education of healthcare workers, hand hygiene, personal protective equipment for healthcare personnel (gloves, gowns, masks, goggles, face shields, …), respiratory protection, catheter associated prevention, safe work practices to prevent health-care workers exposure to blood-borne pathogens, environmental measures, patient care equipment, instruments/devices, textiles and laundry. The second score was the Composite Indicator of Control of Multi-Resistant Bacteria ''CICMRB'' [20] to assess the criteria for the control of multi-drug resistant (MDR) bacteria transmission and the actions implemented by the hospital. The indicator requested about the presence or absence of policies and procedures including infection control program and committee, proper use of antibiotic program, surveillance, antibiotic stewardship program, referral to infectious disease physician, pharmacist and nurse, annual assessment of bacterial resistance, annual report on the use of antibiotics, written protocol about multi-resistant bacteria priority, and procedures between the biology laboratory and the operational hygiene team.

The third questionnaire was filled out by the head of human resources (HR) department. It was used to identify the hospital characteristics in terms of accreditation, university or non-university, governmental or non-governmental, total number of beds, number of infectious disease specialists, number of infection prevention nurse specialist, number of pharmacists, and microbiologists.

To confirm the establishment of the requested policies and procedures, the primary investigator asked for a sample copy of each policy and procedure as a proof from each hospital.

Study outcomes

Primary outcome was to assess the effect of IPC measures of each hospital (CIACNI.2 and CICMRB scores) on the total LOS. The CIACNI.2 score was calculated from three chapters that included: Organization (O: 20 points) + Means (M: 30 points) + the Actions of prevention and evaluation (A: 50 points) for a total of 100 points. The results were rendered in the form of a performance class from A (the best results) to E (the worst results) by categories health centers according to the missions, the activities and the size of the institutions [19]. CICMRB score was calculated from three chapters that included: Organization (O: 32 points) + Means (M: 28 points) + Actions (A: 40 points) weighted for a total of 100 points. The results were reported by health facility categories in the form of a performance class of A (most advanced and highest level of commitment) to E (least advanced and delayed for optimization) [20].

Secondary outcomes was the time to develop nosocomial infection.

Bacterial resistance was classified as multi-drug resistant (MDR) and extensively drug-resistant (XDR) based on an international expert proposal for interim standard definitions for acquired resistance [21].

Site of infections' classification was based on the Centers for Disease Control and Prevention's National Healthcare Safety Network surveillance definitions for specific types of infections [22].

The primary investigator assessed the appropriateness of treatment in terms of duration, dose, coverage and indication according to the Infectious Diseases Society of America (IDSA) guidelines of all encountered types of infection [23].

Statistical analysis

Data was entered and analyzed on SPSS (Statistical Package for Social Sciences), version 23. A P value < 0.05 was considered statistically significant for bi-variate analysis. Pearson chi-square test was used to compare categorical variables when the number (n) in the cells was > 5; when cell counts of less than 5 equaled 25% or more of tables records, Fisher's exact test was used.

For quantitative variables with normal distribution and homogeneous variances, independent student t-test was used. Bivariate correlations were used to compare 2 continuous variables, hence Pearson correlation coefficients were used in normal distribution and Spearman correlation coefficients for non-normal distribution.

In the multi-variable analysis, multiple linear regression stepwise forward likelihood method was used. The dependent variable was the total LOS (in days). The independent variables were the variables whose P-value < 0.2 in the bivariate analysis after checking their adequacy for the model (ANOVA test of the last step was significant $p < 0.001$).

Results

Hospital characteristics

Two hospitals were included in the study. Hospital 1 was a university governmental hospital whereas hospital 2 was a non-university private hospital. The patient capacity of the governmental hospital was approximately five times greater than that of the private

Table 1: Hospital characteristics.

Characteristic	Hospital 1	Hospital 2
University Hospital	Yes	No
Governmental (public) Hospital	Yes	No
Region	Beirut	Mount Lebanon
Accredited by the Lebanese Ministry of Public Health	Yes	Yes
Number of infectious disease specialists	4	2
Number of pharmacists	9	1
Number of microbiologists	2	1
Number of infection prevention nurse specialist	0	1
Total number of beds	544	110
Hospital hygiene measures		
- CIACNI-2 score (class)	76/100 (C)	95/100 (A)
- CICMRB score (class)	69/100 (D)	70/100 (C)

CIACNI-2: Composite Index of Activities for the Control of Nosocomial Infections 2; CICMRB: The Composite Indicator of Control of Multi-Resistant Bacteria.

hospital. IPC measures of the private hospital ranked better scores and classes than the public hospital as shown in Table 1. Concerning IPC measures' differences, the hospital with lower IPC measures scores didn't have the procedures for reporting infections, monitoring of hydro-alcoholic solution or gel consumption and evaluating the practices related to prevention of urinary infections on urinary catheter. Additionally, it didn't have a team to implement measures for proper antibiotic use, a system for prior authorization by a physician or pharmacist in prescribing antibiotic as last option. On the other hand, the hospital with higher IPC measures didn't have the procedure for verifying hepatitis B, measles, pertussis and varicella immunization. Both hospitals didn't have protocols for recommendation on the first intention of main infection, annual assessment of bacterial resistance, evaluation of the indication for all prescriptions of antibiotics, evaluation of conformity of antibiotic treatment with the local recommendations,

Table 2: Patient characteristics at each hospital.

Characteristic	Public Hospital	Private Hospital	Total	P Value
Number of patients: no. (%)	180 (48.8)	189 (51.2)	369 (100)	
Age: Mean ± SD year	62.73 ± 19.55	68.17 ± 18.68	65.52 ± 19.2	0.007
Gender: no. (%)				
Male	92 (51.6)	111 (59)	203 (55)	0.14
Smoking: no. (%)	53 (29)	36 (9.7)	89 (24.1)	0.001
Alcohol use: no. (%)	5 (2.75)	16 (8.48)	21 (5.7)	0.018
Source of admission: no. (%)				
Home	172 (94.6)	166 (88)	338 (91.6)	
Other hospital	6 (3.3)	22 (11.7)	28 (7.6)	0.006
Rehabilitation center	2 (1.1)	1 (1.89)	3 (0.8)	
Previous hospital admission*: no. (%)	77 (42.4)	24 (12.72)	101 (27.4)	< 0.001
ICU patients: no. (%)	59 (32.5)	76 (40.28)	135 (36.5)	0.161
• **SOFA score:** Mean ± (SD) point	6.9 ± 3.7	3.3 ± 3.1	5.2 ± 3.9	< 0.001
• **GSC score:** Mean ± (SD) point	9.7 ± 3.0	12.7 ± 3.7	11.1 ± 3.7	0.001
• **APACHE II score:** Mean ± (SD) point	18.8 ± 6.9	14.0 ± 7.5	16.5 ± 7.5	0.014
Co-morbid diseases: no. (%)				
Hypertension	70 (38.5)	91 (48.23)	161 (43.6)	0.075
Coronary artery diseases	59 (32.5)	71 (37.63)	130 (35.2)	0.336
Hyperlipidemia	15 (8.25)	30 (16)	45 (12.2)	0.027
Chronic heart failure	21 (11.55)	9 (4.77)	30 (8.1)	0.015
Atrial fibrillation	16 (8.8)	4 (2.12)	20 (5.4)	0.004
Peripheral vascular disease	7 (3.85)	0 (0)	7 (1.9)	0.006
Diabetes	73 (40.2)	62 (32.9)	135 (36.6)	0.122
Hemodialysis	8 (4.4)	11 (5.8)	19 (5.1)	0.55
Chronic renal failure	27 (14.85)	37 (19.61)	64 (17.3)	0.246
Chronic liver failure	3 (1.65)	8 (4.24)	11 (3)	0.147
Cancer	31 (17)	26 (13.8)	57 (15.4)	0.357
COPD	21 (11.5)	15 (8)	36 (9.8)	0.306
Bedsores	13 (7.15)	11 (5.83)	24 (6.5)	0.585
Cerebrovascular accident	12 (6.6)	4 (2.12)	16 (4.3)	0.032
Anemia	6 (3.3)	6 (3.3)	12 (3.3)	0.932
Hypothyroidism	5 (2.7)	4 (2.12)	9 (2.4)	0.681

*Previous hospital admission: Within 90 days. P value between hospital 1 (public) and 2 (private), Pearson chi-square test was used to compare (2 qualitative variables) and student t-test was used to compare (1 quantitative variable and 1 qualitative variable), Fisher's Exact Test was used when cell counts of less than 5 comprise 25% or more.

SD: Standard Deviation; ICU: Intensive Care Unit; GSC: Glasgow Coma; SOFA: Sequential Organ Failure Assessment; APACHE II: Acute Physiology and Chronic Health Evaluation; COPD: Chronic Obstructive Pulmonary Disease.

written protocol with MDR priority and screening policy in search for MDR.

Patient characteristics

A total of 369 patients admitted between January 2017 and July 2017, fulfilled the inclusion criteria and were enrolled in the study. One eighty patients (48.8%) were collected from the public hospital and 189 patients (51.2%) from the private hospital. Patients at the private hospital had significant higher mean of age (68.17 ± 15.96 vs. 62.73 ± 19.5 years), Glasgow coma score (12.7 ± 3.7 vs. 9.7 ± 3.0 points), alcohol consumption and hyperlipidemia percentages. On the other hand, patients of the governmental hospital had significant higher percentages of smoking, previous hospital admission, cardiac diseases, cerebrovascular accident, SOFA (6.9 ± 3.7 vs. 3.3 ± 3.1 points) and APACHE II scores (18.8 ± 6.9 vs. 14.0 ± 7.5 points). Hypertension was the most common reported comorbidity among all patients, followed by coronary artery diseases and hyperlipidemia as displayed in Table 2.

Treatments, interventions and infections' characteristics

Patients at the public hospital had significant ($p < 0.05$) higher percentages of intubation and urinary (foley) catheter insertion. The most common reasons for inappropriate treatment were uncovering the microorganism according to antibiogram results (12.73%) and wrong duration of treatment (11.38%) as reported in Table 3.

Patients at the private hospital had significant ($p < 0.001$) higher percentages of central venous catheter insertion.

Sepsis was encountered significantly at higher percentages at the hospital with lower IPC measures. Urinary tract infections were the most common reported site of infection at both hospitals (47.1%), followed by pneumonia (18.9%) and skin soft tissue infection (15.1%). Both surgical site and soft tissue infections were found significantly higher in the public hospital as shown in Table 3.

Different types of bacteria were reported in both hospitals (Table 4). *Staphylococcus aureus* (11.6%) was found to be the most common reported Gram positive bacteria, and *Escherichia coli* (51.7%) that of Gram negative bacteria.

Primary outcomes

Effect of IPC measures on the total length of hospi-

Table 3: Treatments, interventions and infections' characteristics.

Characteristic	Public Hospital	Private Hospital	Total	P value
Site of infection				
• Urinary tract: no. (%)	82 (45.1)	92 (48.76)	174 (47.1)	0.548
• Pneumonia: no. (%)	22 (12.1)	48 (25.44)	70 (18.9)	0.001
• Skin soft tissue: no. (%)	43 (23.65)	13 (6.89)	56 (15.1)	< 0.001
• Blood stream: no. (%)	27 (14.85)	18 (9.54)	45 (12.1)	0.108
• Surgical site: no. (%)	30 (16.5)	8 (4.24)	38 (10.2)	< 0.001
• Gastrointestinal: no. (%)	18 (9.9)	18 (9.54)	36 (9.8)	0.878
• Ventilator associated: no. (%)	16 (18.7)	8 (4.24)	24 (6.5)	0.07
• Lower respiratory: no. (%)	7 (3.85)	7 (3.71)	14 (3.8)	0.926
• Bone/Joint: no. (%)	4 (2.2)	0 (0)	4 (1.1)	0.039
• CNS: no. (%)	3 (1.65)	0 (0)	3 (0.8)	0.075
Sepsis: no. (%)	93 (51.15)	34 (18.02)	127 (34.4)	< 0.001
Total number of microbes				
• Monomicrobial: no. (%)	116 (63.8)	173 (91.69)	289 (78.2)	< 0.001
• Bimicrobial: no. (%)	31 (17.05)	10 (5.3)	41 (11.1)	
• Trimicrobial: no. (%)	16 (8.8)	2 (1.06)	18 (4.8)	
• Quadrimicrobial: no. (%)	10 (5.5)	3 (1.59)	13 (3.5)	
• Pentamicrobial: no. (%)	7 (3.85)	0 (0)	7 (1.9)	
Intubated patient: no. (%)	57 (31.66)	42 (22.22)	99 (26.8)	0.041
Foley catheter: no. (%)	103 (57.22)	44 (23.28)	147 (39.8)	< 0.001
Central venous catheter: no. (%)	25 (13.88)	70 (37.03)	95 (25.7)	< 0.001
Surgical intervention: no. (%)	60 (33.33)	49 (25.92)	109 (29.4)	0.12
Inappropriate treatment: no. (%)	46 (25.55)	(33.86)	110 (29.81)	0.22
• **Reason:**		64		
o Organism not covered according to antibiogram results: no. (%)	26 (14.44)	21 (11.11)	47 (12.73)	
o Wrong duration: no. (%)	17 (9.44)	25 (13.22)	42 (11.38)	
o Broader spectrum: no. (%)	2 (1.11)	16 (8.46)	18 (4.87)	
o Wrong dose: no. (%)	1 (0.55)	2 (1.05)	3 (0.81)	

P value between hospital 1 and 2, Pearson chi-square test was used to compare (2 qualitative variables) and student t-test was used to compare (1 quantitative variable and 1 qualitative variable), Fisher's Exact Test was used when cell counts of less than 5 comprise 25% or more of a table.

CNS: Central Nervous System.

Table 4: Bacteria characteristics.

Characteristic	Public Hospital	Private Hospital	Total	P value
Gram Positive Bacteria				
• *Staphylococcus aureus*: no. (%)	24 (13.2)	19 (10.07)	43 (11.6)	0.326
• *Streptococcus pneumoniae*: no. (%)	6 (3.3)	9 (4.77)	15 (4)	0.487
• *Enterococcus faecalis*: no. (%)	27 (14.85)	1 (0.53)	28 (7.6)	< 0.001
Gram Negative Bacteria				
• *Escherichia coli*: no. (%)	87 (47.85)	104 (55.12)	191 (51.7)	0.198
• *Pseudomonas aeruginosa*: no. (%)	23 (12.65)	31 (16.43)	54 (14.6)	0.325
• *Acinetobacter baumannii*: no. (%)	39 (21.45)	8 (4.24)	47 (12.7)	< 0.001
• *Klebsiella pneumoniae*: no. (%)	22 (33.55)	11 (5.83)	33 (8.9)	0.031
• *Proteus mirabilis*: no. (%)	17 (9.35)	8 (4.24)	25 (6.7)	0.046
• *Enterobacter cloacae*: no. (%)	14 (7.7)	5 (2.65)	19 (5.1)	0.026
• *Citrobacter freundii*: no. (%)	7 (3.85)	2 (1.06)	9 (2.4)	0.098
• *Morganella morganii*: no. (%)	5 (2.75)	1 (0.53)	6 (1.6)	0.114
• *Serratia marcesens*: no. (%)	3 (1.65)	3 (1.59)	6 (1.6)	1
• *Stenotrophomonas maltophilia*: no. (%)	3 (1.65)	2 (1.06)	5 (1.3)	0.678
• *Providencia stuartii*: no. (%)	3 (1.65)	0 (0)	3 (0.8)	0.115

P value between hospital 1 and 2, Pearson chi-square test was used to compare (2 qualitative variables), Fisher's Exact Test was used when cell counts of less than 5 comprise 25% or more of a table.

tal stay:

Bivariate association between each predictor variable and total length of hospital stay: Age affected LOS positively, hence for every increase in one year of age the LOS was also increased by 0.116 days (p = 0.025).

Several interventions had also increased LOS significantly such as, ICU admission by 9 ± 1.23 days, central line insertion by 8.81 ± 1.59 days, intubation by 8.53 ± 1.69 days, foley catheter insertion by 4.59 ± 1.32 days, surgical intervention by 3.79 ± 1.34 days. Atrial fibrillation and coronary artery disease have increased LOS by 7 ± 2.71 and 3.07 ± 1.25 days, respectively.

Several sites of infection increased the LOS significantly like, ventilator associated pneumonia by 7.49 ± 2.48 days, surgical site infection by 6.10 ± 2.2 days, blood stream infection by 5.74 ± 2.52 days and pneumonia by 4.96 ± 2.03 days. Infections that potentially increased LOS were poly-microbial infections by 10.76 ± 1.9 days, development of nosocomial infection by 9.86 ± 1.19 days, and sepsis by 4.92 ± 1.27 days.

Some bacteria such as *Klebsiella pneumonia* MDR, *Stenotrophomonas maltophilia*, *Morganella morganii*, *Staphylococcus aureus* MDR and *Acinetobacter baumannii* XDR increased LOS by 13.20 ± 5.40, 12.59 ± 5.31, 10.42 ± 4.86, 9.56 ± 3.15 and 9.12 ± 2.76 days respectively; whereas multi-sensitive *Escherichia coli* decreased the LOS by 3.02 ± 1.44 days.

The patients at the hospital with lower IPC measures scores had additional 2 ± 1.23 days of LOS when compared to the hospital with higher IPC measures scores, but this association was not statistically significant (p = 0.106) as shown in Table 5.

Multiple linear regression between each selected predictor variable and total length of hospital stay: Twelve models were proceeded, so 11 independent variables were kept in the final model with exclusion of the variable of interest (IPC measures). Therefore, the variable of interest was forced back along with the 11 independent variables, selected by the previous model, using the enter method. The final model of the 12 independent variables was not perfect as it didn't show normality and homoscedasticity on the histogram and dispersion diagram, so a logarithmic calculation of the total LOS was performed and replaced as the dependent variable of the model. Accordingly, the normality and homoscedasticity was shown on the histogram, normal P-P plot and dispersion graph (as presented in the Supplementary Figure 1, Supplementary Figure 2 and Supplementary Figure 3). Adjusted R square was > 0.1 (0.354), global test (ANOVA) of the model was significant (p < 0.001), and all variance inflation factors (VIF) were < 10, so no collinearity was found.

There was a significant positive association (P < 0.05) between LOS and the central venous catheter insertion (0.205) > nosocomial infection (0.182) > poly-microbial infection (0.163) > ICU admission (0.153) > *S. aureus* MDR (0.111) > *K. pneumoniae* MDR (0.107) > pneumonia infection (0.104).

There was significant negative association (P < 0.05) between LOS and the hospital with higher IPC measures, the latter was associated with a decreased LOS as shown in Table 6.

The total length of hospital stay could be estimated by using the equation of the model:

Ln total length of hospital stay (in days) = (-0.125 × private hospital) + (0.266 × ICU admission) + (0.103 × sepsis) + (0.393 × central venous catheter insertion) + (0.305 × nosocomial infection) + (0.332 × poly-microbial

Table 5: Bivariate association between each predictor variable and total length of stay (369 observations).

Independent variable	Mean difference of total LOS ± SD Days [95% CI: lower; upper]; Correlation rho	P value
Age	Spearman's rho: 0.116 day for every one year	0.025
Male	0.75 ± 1.24 days [-1.68; 3.2]	0.54
Public Hospital	2 ± 1.23 days [-0.42; 4.40]	0.106
ICU admission	9 ± 1.35 days [6.64; 11.35]	< 0.001
Sepsis	4.92 ± 1.27 days [2.4; 7.43]	< 0.001
Intubation	8.53 ± 1.69 days [5.19; 11.88]	< 0.001
Foley catheter insertion	4.59 ± 1.32 days [1.97; 7.21]	< 0.001
Central venous catheter insertion	8.81 ± 1.59 days [11.97; 5.65]	< 0.001
Surgical intervention	3.79 ± 1.34 days [1.15; 6.44]	0.005
Co-morbidities		
Coronary artery diseases	3.07 ± 1.25 days [0.53; 5.60]	0.018
Atrial fibrillation	7 ± 2.71 days [1.66; 12.33]	0.01
Site of infection		
• Pneumonia	4.96 ± 2.03 days [0.85; 8.95]	0.018
• Blood stream	5.74 ± 2.52 days [0.67; 10.8]	0.027
• Surgical site	6.10 ± 2.2 days [1.65; 10.54]	0.008
• Ventilator associated	7.49 ± 2.48 days [2.60; 12.37]	0.003
Multi sensitive Bacteria		
• *Escherichia coli*	-3.02 ± 1.44 days [-5.86; -0.019]	0.036
• *Morganella morganii*	10.42 ± 4.86 days [0.848; 19.99]	0.033
• *Stenotrophomonas maltophilia*	12.59 ± 5.31 days [2.13; 23.05]	0.018
MDR Bacteria		
• *Staphylococcus aureus*	9.56 ± 3.15 days [3.13; 15.99]	0.005
• *Klebsiella pneumoniae*	13.20 ± 5.40 days [1.53; 24.88]	0.029
XDR Bacteria		
- *Acinetobacter baumannii*	9.12 ± 2.76 days [3.53; 14.71]	0.002
- *Pseudomonas aeruginosa*	23.29 ± 13.18 days [-10.54; 57.14]	0.137
- *Escherichia coli*	13.19 ± 6.86 days [-0.30; 26.69]	0.055
Polymicrobial infection*	10.76 ± 1.9 days [6.98; 14.53]	< 0.001
Developed nosocomial infection	9.86 ± 1.19 days [7.51; 12.22]	< 0.001

*Polymicrobial infection: Involvement of ≥ 2 bacteria. Pearson chi-square test (to compare 2 qualitative variables), Pearson correlation coefficients in normal distribution and Spearman correlation coefficients for non-normal distribution (to compare 2 quantitative variables) and student t-test to compare (1 quantitative variable and 1 qualitative variable), Fisher's Exact Test was used when cell counts of less than 5 comprise 25% or more of a table.

Mean difference for gender was calculated by subtracting the mean LOS of male - mean LOS of female; mean difference for hospital was calculated by subtracting the mean LOS of hospital 1 (public) - mean LOS of hospital 2 (private). Mean differences of other variables (interventions, diseases, conditions, bacteria) were calculated by subtracting mean LOS of yes - mean LOS of no.

LOS: Length of Hospital Stay; ICU: Intensive Care Unit; MDR: Multi-Drug Resistant; XDR: Extensively-Drug Resistant.

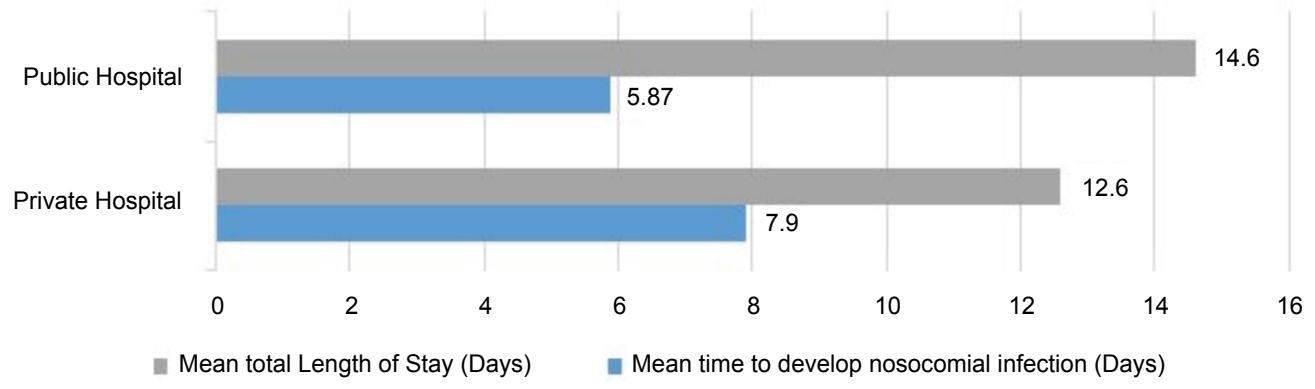

Figure 1: Mean time to develop nosocomial infection at both hospitals in Lebanon.

Student t-test was used to compare the mean time to develop nosocomial infection between public and private hospitals ($p < 0.001$); (X-axis = Days).

infection) + (0.137 × Cerebrovascular accident) + (0.220 × pneumonia infection) + (0.338 × *Staphylococcus aureus* MDR) + (0.123 × *Pseudomonas aeruginosa* MDR) + (0.467 × *Klebsiella pneumoniae* MDR) + (-0.037 × *Stenotropamonas maltophilia*) + 1.631.

Table 6: Multilinear regression between selected predictor variable and total length of hospital stay.

	Unstandardized Beta	Standardized Beta	P value	95.0% CI for Beta	
				Lower	Upper
(Constant)	1.631		< 0.001	1.288	1.974
Private Hospital	-0.125	-0.149	0.006	-0.213	-0.036
ICU admission	0.266	0.153	0.01	0.065	0.468
Sepsis	0.103	0.058	0.238	-0.068	0.273
Central venous catheter	0.393	0.205	0.001	0.167	0.619
Nosocomial infection	0.305	0.182	< 0.001	0.143	0.468
Poly-microbial infection*	0.332	0.163	0.001	0.134	0.531
Cerebrovascular accident	0.137	0.034	0.435	-0.208	0.483
Pneumonia infection	0.22	0.104	0.018	0.038	0.403
S. aureus MDR	0.338	0.111	0.014	0.068	0.608
P. aeruginosa MDR	0.123	0.028	0.523	-0.255	0.5
K. pneumoniae MDR	0.467	0.107	0.015	0.091	0.842
S. maltophilia	-0.037	-0.005	0.909	-0.664	0.59

*Polymicrobial infection: Involvement of ≥ 2 bacteria.

Standardized Beta was used to compare the effect of variable on the length of hospital stay; Unstandardized Beta was used in the estimation of the length of hospital stay through the model's formula. Hospital 1 (public) was coded as 1; and hospital 2 (private) was coded as 2 on the SPSS.

CI: confidence Interval; ICU: Intensive Care Unit; MDR: Multi-Drug Resistant; *S. aureus: Staphylococcus aureus; P. aeruginosa: Pseudomonas aeruginosa; K. pneumoniae: Klebsiella pneumoniae; S. maltophilia: Stenotrophomonas maltophilia.*

Secondary outcome

Time to develop nosocomial infection: Patients at the private hospital needed longer period of time to develop nosocomial infection as the mean difference between both hospitals was 2 ± 1.87 days (p 0.09) as shown in Figure 1.

Discussion

One of the major complications seen in hospitalized patients is hospital acquired infections that leads to increase in morbidity, mortality, and LOS [24].

In Europe, Izquierdo, et al. conducted a quasi-experimental interventional study comparing a pre-intervention cohort and a post-intervention cohort to assess the effectiveness of a better intervention program designed to reduce the high incidence of hospital acquired infections observed at a university hospital in Barcelona, Spain. The authors concluded that implementation of a better intervention program was associated with an 82% reduction in HAIs incidence [25].

In this study, the multilinear regression model showed an association between hospital IPC measures and the LOS. Higher scores and classes of IPC measures were associated with shorter LOS.

Patients with complicated and critical infectious conditions were candidate for ICU admission, this could explain their increased hospital stay in our study; likewise an 11-year retrospective, case-control study of all admissions into the ICU with emphasis on prolonged stay was conducted by Tobi, et al. and found that ICU exerts great physical, material, psychological, and social toll on the patients, that lead to prolonged stay in the ICU [26].

Sepsis increased the LOS significantly in our study, similarly Page, et al. found in their study that sepsis was associated with higher median LOS [27].

Patients with central venous catheter (CVC) developed nosocomial blood stream infections that required additional antimicrobial treatment and thus had higher mean of LOS; a study conducted by Leistner, et al. concluded that CVC blood stream infection was associated with prolonged hospital stay and recommended hospital management to implement control measurements to keep the incidence of CVC blood stream infection as low as possible [28].

In this study we found that nosocomial infection, involvement of more than one type of bacteria and bacterial resistance have increased the mean of hospital stay. Correspondingly, in a 5-year retrospective descriptive study, Cornejo-Juárez, et al. found that emergence of MDR bacteria have exposed the patients at major risk of a bacterial MDR-HAI that impacted adversely on LOS and mortality [29]. Another study done by Wanis, et al. showed that antibiotic resistance was directly proportional to hospital LOS (% of patients with multidrug resistant bacteria increased from 6% [LOS 0-7 days] to 44% [LOS > 28 days]; p < 0.05) [30].

In our study, we found that implementation of better IPC measures was associated with improvement in the primary outcome. Similarly, Alp, et al. evaluated the application of infection surveillance and prevention program at a Turkish university teaching hospital and found that it was associated with a significant reduction in HAI rate and LOS [31].

In Lebanon, a prospective before-after active surveillance study was conducted by Kanj, et al. found that infection control programs including surveillance and antibiotic policies were associated with a significant reduction in HAI rates, bacterial resistance, LOS and mortality [32]. Another study done by Azab, et al. found that implementation of multifaceted infection control pro-

gram resulted in reduction of VAP rate and LOS in the hospital [33].

To our knowledge, this is the first study to assess the impact of IPC measures on the LOS at different hospitals in Lebanon. A variety of population's characteristics was found in this study due to the fact of two different regions in Lebanon. Since data were collected prospectively from medical records at both hospitals, there were minimal recall, measurement and classification biases. The study objective aimed to improve the medical practice in all hospitals by providing evidence about the importance of applying high quality IPC measures on the health outcomes. In this study we performed multi variable analyses to eliminate all the confounding variables that could influence both the dependent variable and independent variables causing a spurious association.

Limitations

This study presents many limitations, the first one being the fact that these data may not be generalized to all medical centers in Lebanon since it was conducted in two Lebanese hospitals due to several hospital IRB refusals and the short duration to collect the needed data.

Collected IPC measures policies and procedures as a proof of their establishment in each hospital was not enough to assess clinician compliance; therefore an audit personnel or team that inspect and follow-up the application of these measures can assure staff's adherence to the given policies and procedures.

The clinical severity of the patients was higher in public compared to private hospital, so longer hospital stay in public hospital was valid. To compare two different hospital was difficult because the clinical practice and individual patients were different. Additionally, difference in the results that we observed could be due to several factors such as, different treatment approaches, available medications at each hospital, regions, different IPC measures and hospital characteristics (private versus public); this could lead to selection bias. To overcome this possible bias, future studies are recommended to compare between hospitals of similar characteristics in order to evaluate the primary outcome before and after improving the IPC measures of each hospital.

Multi-variate analysis on characteristics of only two hospitals suffers from a lack of power. A detailed descriptive analysis can be of more value for further research and later inclusion of this outcomes.

Moreover, the interpretation of culture specimens and sensitivity was performed at each hospital's laboratory rather than at a central laboratory, this could lead to misclassification of individuals and increase the risk of classification bias. So, it would be recommended to perform the culture and the sensitivity of the bacteria at one central laboratory.

Conclusion

According to our study, implementation of high standards of IPC measures was associated with significant decrease in length of hospital stay, which could improve patient care and prevent spreading of infections leading to a better healthcare outcomes in Lebanon.

Moreover, shorter duration to develop hospital acquired infections were found in hospital with higher scores and classes of IPC measures.

The study's results cannot be generalized to all Lebanese hospitals since it was conducted at two hospital sites; therefore, future prospective interventional multi-center large sample size with close follow-up and over long period of time studies are warranted to investigate precisely the influence of IPC measures on hospital stay in a variety of hospitals and patients to come up with a final conclusion.

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None.

Statement of Equal Authors' Contribution

PS made substantial contributions to conception and design of the study. AD, KI, RM and MJ contributed in acquisition of data. PS, AD and RM contributed in the analysis and interpretation of data. PAH supervised the study's procedure in each hospital. AD, PS, NL participated in drafting and revising the article critically for important intellectual content. All authors gave their final approval of the version to be submitted for publication.

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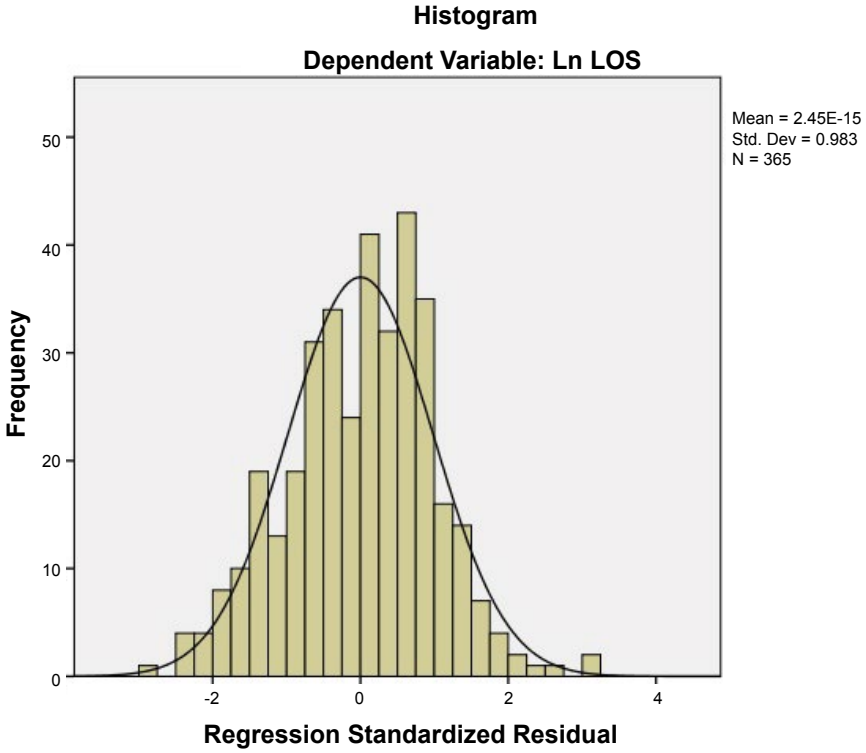
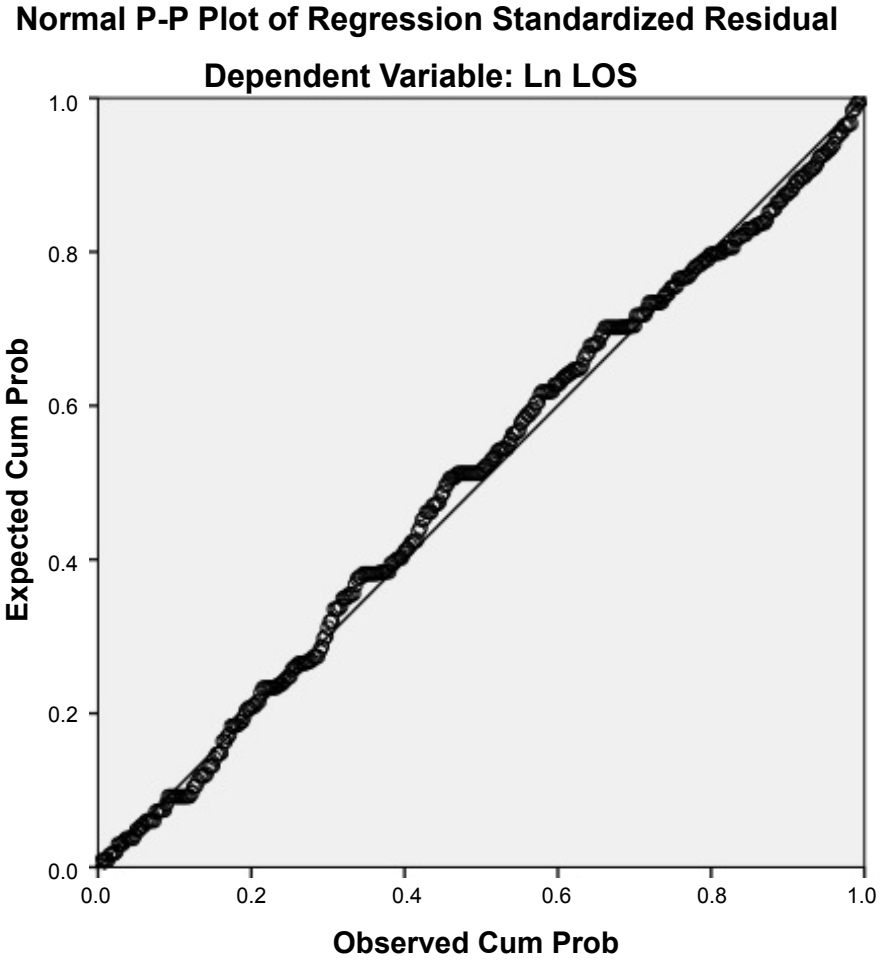
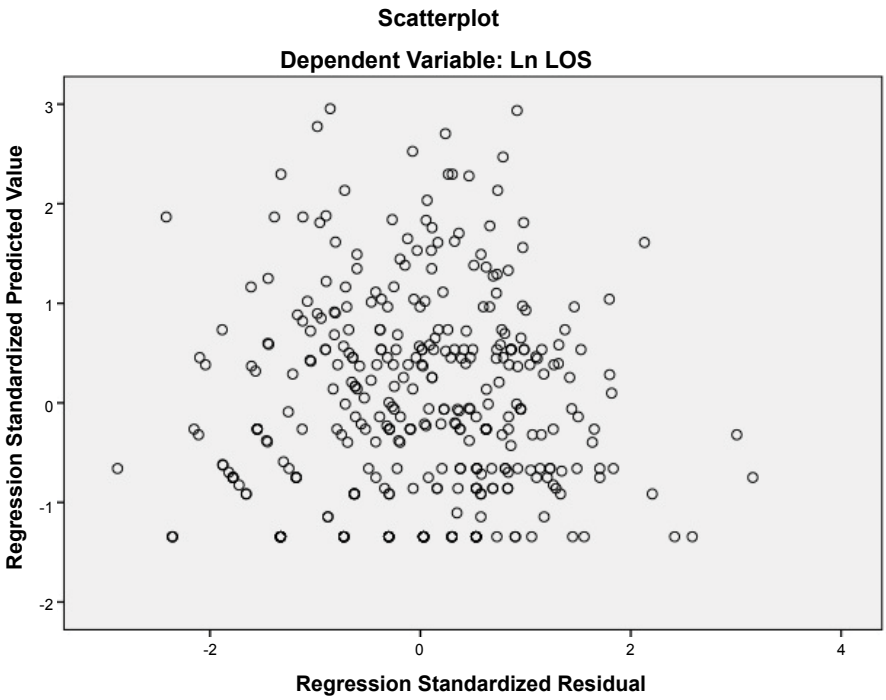


Supplementary Figure 1: Model Histogram - Normal Distribution.



Supplementary Figure 2: Model Normal P-P Plot.



Supplementary Figure 3: Model Scatterplot.