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Major Article

Risk factors for health care–associated infections: From better knowledge to better prevention

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Background: Health care–associated infections (HCAIs) are preventable with adoption of recognized preventive measures. The first step is to identify patients at higher risk of HCAI. This study aimed to identify patient risk factors (RFs) present on admission and acquired during inpatient stay which could be associated with higher risk of acquiring HCAI.
Methods: A case-control study was conducted in adult patients admitted during 2011 who were hospitalized for >48 hours. Cases were patients with HCAIs. Controls were selected in a ratio of 3:1, case matched by the admission date. The likelihood of increased HCAI was determined through binary logistic regression.
Results: RFs identified as being the more relevant for HCAI were being a man (odds ratio [OR], 2.4; 95% confidence interval [CI], 1.2-4.7), being aged >50 years (OR, 2.9; 95% CI, 1.3-6.9), and having an insertion of a central venous line during hospital stay (OR, 12.4; 95% CI, 5.0-30.5).
Conclusions: RFs that showed statistical significance on admission were the patient's intrinsic factors, and RFs acquired during hospitalization were extrinsic RFs. When a set of RFs were present, the presence of a central venous line proved to be the more relevant one.

BACKGROUND

Health care–associated infections (HCAIs) are a major patient safety problem with significant morbidity, mortality, prolonged hospitalization, and increased costs.[1,2]

There are general HCAI predisposing factors. These factors are associated with characteristics of the patient, such as age, underlying disease, comorbidities, and reduced host defenses.[3] Since the publication of the SENIC (Study on the Efficacy of Nosocomial Infection Control) study,[4] it is known that at least a third of these infections could be prevented by the adoption of recognized preventive measures. More recent studies have increasingly established that a much higher number of HCAIs could be preventable,[5] namely infections related to certain medical devices, such as central venous lines, for which a zero rate is even possible.[6]

Despite significant scientific advances and sophistication of medical equipment and devices, patient care still contributes to acquisition of HCAIs. Numerous studies have shown the need for multimodal interventions[7,8] to obtain significant reductions of HCAI, more specifically bundled care in which a small number of elements of care considered to be essential for prevention are adopted in an all or none approach.[9]

To make the best use of resources, the first and essential step for prevention of HCAIs is to determine which patients are at higher risk of acquiring infection to direct resources to adopt the required preventive care.

Various attempts have been already made to identify the major patient risk factors involved, including definition of risk checklists or scales. However, most of these are directed to specific infections or specific microorganisms.[10-12]

In 1978, Freeman and McGowan attempted to devise a predictive model for HCAI risk.[13] They concluded that comorbidities, invasive procedures, individual characteristics (age, sex, and race), and emergency admission were statistically significant for acquiring an infection. Webster and Bowell developed a risk assessment tool addressing global and local factors, invasive devices, medications, and underlying diseases.[14] More recently, Chang et al[15] proposed a scoring system based on a small number of aspects. They grouped risk factors into 4 categories: demographics, health status, procedures, and medications.

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This study aimed to investigate the patient factors present on admission and acquired during inpatient stay which could be associated with a higher risk of acquiring HCAI, in a private hospital in Lisbon, Portugal.

MATERIALS AND METHODS

Setting

The study hospital is a 124-bed private hospital. The hospital has 7 operating theaters, accident and emergency departments (adult, pediatric, obstetrics, and gynecology), an oncology day care, and nuclear medicine, assisted medical procreation, radiology, physiotherapy, and rehabilitation departments. The hospital core business is surgical patients.

Study population

Inclusion criteria

Inclusion criteria included patients aged ≥18 years, admitted to the hospital during the year of 2011, and hospitalized for >48 hours (medical, surgical, and intensive care unit). Excluded patients included those from obstetrics, psychiatry, and pediatrics and those with a diagnosis of osteomyelitis at admission.

Case definition

The definition of a case was patients with infections acquired in the study hospital because of the health care delivered, during the year 2011, and who met the defined inclusion criteria. All cases of infection had been previously confirmed by the hospital infection prevention team medical consultant lead (infectious disease consultant) in accordance with the Centers for Disease Control and Prevention criteria.[16]

Control definition

The definition of a control was patients who meet inclusion criteria and who did not acquire an HCAI related to care delivered in the study hospital. They were selected by simple random sampling in a ratio of 3:1 cases from hospitalized patients. The matching of cases to controls was made based on the time reference of the day of admission (within 1 week of the date of admission).

Sources of information

The sources of information included clinical records, patient care pathways (medical and nursing records, specialty consultations, outpatient clinic, emergency visits, laboratory results and imaging, and all relevant clinical information for the study), data from the HCAI hospital surveillance system, and the 2011 hospital data (hospital activity) provided by the business office department.

Data collection

All variables were defined prior to data collection. A structured form was used for data collection (intrinsic and extrinsic risk factors, on admission, and during hospital stay). Routinely collected data (demographic and clinical data and laboratory and radiologic findings) were transferred directly from the HCAI hospital surveillance system.

The preoperative American Society of Anesthesiologists (ASA) score was used by the anesthetist to assess the patient's preoperative physical condition according to the ASA classification of physical status.

If a patient required a reoperation within 72 hours of the first operation because of an early complication, such as bleeding, the ASA score was reassessed in case it had changed.

The definition of immunosuppression used was in accordance with the Portuguese National Protocol for bloodstream infections surveillance: an absolute neutrophil count <500/mm^3, or primary or secondary immunologic disease, bone or organ transplant, or immunosuppression therapy (chemotherapy, radiotherapy, and steroid therapy in the 15 days prior to the HCAI).

Skin and soft tissue lesions included acute wounds, such as surgical wounds dehiscence, burns, abrasions, and wounds from open fractures. Chronic wounds included lesions such as pressure ulcers, leg ulcers, and diabetic foot ulcers.

Respiratory problems included cough, sneezing, presence of sputum, and bleeding. Gastric problems referred to vomiting, diarrhea, and bleeding.

Data were systematized in a spreadsheet using Excel for Windows (Microsoft 2007, Redmond, WA). Data from admissions that led to infection were recorded. Information related to HCAI acquired in a previous admission to the study hospital was collected from the inpatient stay that gave rise to the infection.

The data collection form (information at admission time and during the period of hospitalization) for cases and controls was completed by the researchers, including data related to intrinsic and extrinsic risk factors, admission diagnosis, and procedures performed during inpatient stay.

All the HCAIs identified in the hospital surveillance program were included in the study. The surgical patients were followed through readmission to the wards and through the outpatient department in the follow-up appointment with the consultants. Our surveillance program is based on following all patients with an antibiotic prescription, microbiology study request, or invasive device. Infections are reported by link nurses and validated by the infection control doctor. Additionally, link nurses report suspected infections which they identify in the wards.

Statistical analysis

Statistical analysis was performed using SPSS version PASW Statistics 19.

The likelihood of increased HCAI (odds ratio [OR]) was estimated based on the admission and inpatient stay risk factors through binary logistic regression, using the forward likelihood ratio method. A level of significance of 5% was set for all statistical tests.

The association between each risk factor individually with HCAI was quantified, and the joint effects of the most significant risk factors were obtained through multivariate analysis. Additionally, the joint effects of variables identified by Chang et al[15] were also estimated, because they were relevant to validate our results (given our small sample size) and allow a better comparison between both studies.

RESULTS

The study population included a total of 66 cases and 198 controls. The predominant medical specialties in the case group were internal medicine (31.8%), general surgery (25.7%), and orthopedics (18.1%). In the control group, the predominant clinical specialties were also general surgery (16.1%), orthopedics (31.1%), and gynecology (14.6%).

HCAI was detected after discharge in 16% of patients, requiring readmission to treat the infection. Among the patients, 4.5% (n = 3) developed a secondary bloodstream infection (one after an intra-abdominal infection and 2 after urinary tract infections).

In 9% of cases (n = 6), the patient acquired a second infection (2 urinary tract infections, 2 respiratory infections, and 2 bloodstream infections). Two of these patients (3%) acquired a third HCAI (1 infection of the urinary tract and 1 bloodstream infection).

Table 1 presents all the intrinsic and the extrinsic risk factors presented at admission and acquired during the hospital stay.

In the case group, 15.1% of the patients died during the hospital stay, and in the control group the death rate was 0.5%.

Table 1
Risk factor distribution at admission and during hospital stay

Risk factors		Case group (n = 66)	Control group (n = 198)
Risk factors present at admission			
Intrinsic risk factors at admission	Female	(23) 34.8	(102) 51.5
	Male	(43) 65.2	(96) 48.5
	Average age, y	67	55
	Paraplegia/tetraplegia	(4) 6.0	(4) 2.0
	Diabetes	(9) 13.6	(20) 10.1
	Immunosuppression	(16) 24.2	(30) 15.1
	Tumour	(16) 24.2	(30) 15.1
	Previous infection or colonization with MDRO	(5) 7.5	(0) 0.0
	Obesity*	(8) 12.1	(28) 14
	Chronic wound	(9) 13.6	(5) 2.5
	Skin and soft tissue lesions	(6) 9.0	(1) 0.5
	Infection on admission	(15) 22.7	(13) 6.5
	Respiratory problems on admission	(7) 10.6	(3) 1.5
	Gastric problems at admission	(1) 1.5	(1) 0.5
	Temperature at admission (>38°C)	(3) 4.5	(9) 4.5
Extrinsic risk factors at admission	Central venous line at admission	(4) 6.0	(4) 2
	Indwelling urinary catheterization at admission	(11) 16.6	(3) 1.5
	Tracheal intubation at admission	(3) 4.5	(0) 0
	Chemotherapy in previous 3 wk	(3) 4.5	(3) 1.5
	Steroids in previous 3 wk	(1) 1.5	(1) 0.5
	Antimicrobials in the previous 3 wk	(13) 19.6	(14) 7.0
Other risk factors	Transferred from another hospital	(13) 19.6	(2) 1.0
	Readmission	(4) 6.0	(2) 1.0
	Several admissions in the last year	(11) 16.6	(13) 6.5
	Homecare	(3) 4.5	(7) 3.5
	Bedridden	(5) 7.5	(0) 0.0
	Trauma	(3) 4.5	(1) 0.5
Risk factors acquired during the hospital stay			
Extrinsic risk factors acquired inpatient	Central venous line	(28) 42.4	(12) 6.0
	Nasogastric tube	(26) 39.3	(11) 5.0
	Indwelling urinary catheterization	(41) 62.1	(68) 34.3
	Tracheal intubation	(44) 66.7	(148) 74.7
	Surgery	(50) 75.8	(170) 85.8

NOTE. Values are (no. of events) event frequency in percent or as otherwise indicated.
MDRO, multidrug-resistant organism.
*In 37% of patients, it was not possible to obtain the information related to the body mass index.

The average length of stay was 22 days in cases and 5 days in controls.

The extrinsic risk factors related to the surgical procedure and identified during hospitalization, and the antimicrobial prophylaxis risk factors are shown in Table 2.

Table 3 presents the risk factors existent on admission and those acquired during hospital stay, which had a significant association on HCAI acquisition. The other risk factors analyzed, in which a significant association was not observed, were sex, obesity, digestive disorders, presence of tumor, the patient living in home care, bedridden patients, having paraplegia or tetraplegia, trauma patients, infection or colonization with an alert organism, diabetes, immunosuppression, fever, presence of the central venous line device, tracheal intubation, chemotherapy, and treatment with steroids.

The surgical risk factors acquired during hospitalization without association to the HCAI in this study were surgery, having indication for antimicrobial prophylaxis, having an implant, having a peripheral line, and tracheal intubation during hospitalization.

Analysis of the combined effect of the individually identified risk factors on the likelihood of having HCAI was also undertaken. The risk factors tested in combination were transferred from another hospital, the presence of skin and soft tissue lesions on admission,

Table 2
Surgery risk factor distribution and antimicrobial prophylaxis risk factor distribution

Surgery risk factors		Case group (n = 50)	Controls group (n = 170)
ASA score distribution	ASA 2	(27) 56	(105) 62
	ASA 3	(13) 27	(19) 11
	ASA 4	(2) 4	(2) 1
Wound classification distribution	Clean	(22) 44	(104) 61
	Clean-contaminated	(24) 48	(54) 34
	Contaminated	(0) 0	(3) 2
	Dirty-infected	(4) 8	(6) 3
Type of surgery	Elective surgery	(43) 86	(163) 96
	Emergency surgery	(7) 14	(7) 4
Antimicrobial prophylaxis	Having antimicrobial prophylaxis	(38) 76	(149) 88
	With indication for antimicrobial prophylaxis	(36) 72	(97) 57
Surgery with indication for antimicrobial prophylaxis	Antibiotic choice: compliant	(21) 58	(88) 91

NOTE. Values are (no. of events) event frequency in percent.
ASA, American Society of Anesthesiologists.

Table 3
Risk factors on admission and acquired during inpatient stay with a significant association with health care–associated infection

Risk factors		*P* value	Odds ratio	95% confidence interval
Risk factors on admission	Transferred from another hospital	≤.001	24.0	5.3-109.8
	Skin and soft tissue lesions	.006	19.7	2.3-166.9
	Indwelling urinary catheterization	≤.001	13.0	3.5-48.2
	Respiratory problems	.004	7.7	1.9-30.8
	Readmission	.036	6.3	1.1-35.4
	Chronic wounds (presser ulcer, diabetic foot ulcer)	.02	6.1	1.9-18.9
	Age, >50 y vs <50 y	≤.001	4.5	2.0-10.0
	Infection at admission	≤.001	4.2	1.9-9.3
	Antibiotic in the last 3 wk	.003	3.5	1.5-7.9
	Several admissions in the last year	.017	2.8	1.2-6.7
	Central venous line	≤.001	11.4	5.3-24.4
Risk factors acquired during inpatient stay	Nasogastric tube	≤.001	11.1	5.0-24.2
	Indwelling urinary catheterization	≤.001	3.1	1.8-5.6
	Compliance with antimicrobial prophylaxis protocol	≤.001	0.1	1.1-6.5
	ASA score of 3 vs ASA score of 1	.004	5.0	1.7-15.2
	Type of surgery: emergency or elective	.016	3.9	1.3-11.7
	Wound classification as clean-contaminated vs clean	.042	2.0	1.1-3.9
	Antimicrobial prophylaxis	.046	0.4	0.2-0.9

ASA, American Society of Anesthesiologists.

Table 4
Risk factors with statistical significance described by Chang et al[15]

Risk factors		*P* value	Odds ratio	95% confidence interval
Test with the risk factors described by Chang et al[15]	Age, >50 y vs <50 y	.013	2.9	1.3-6.9
	Sex, male vs female	.012	2.4	1.2-4.7
	Insertion of central venous line during stay	≤.001	10.8	4.6-25.7
Test with all the relevant factors described in the present study	Insertion of central venous line during stay	≤.001	12.4	5.0-30.5

the presence of indwelling urinary catheterization during admission, nasogastric tube during hospitalization, and the presence of a central venous line. In the simultaneous presence of all these risk factors, the presence of a central venous line proved to be the most important factor for the acquisition of HCAI (Table 4).

Additionally, we performed an analysis of the combined effect of the risk factors described in the study by Chang et al,[15] which were addressed in the present study (Table 4). Of the factors studied, the following did not show statistical significance: indwelling urinary catheterization during hospitalization, chemotherapy up to 3 weeks before admission, treatment with steroids up to 3 weeks before admission, tracheal intubation, and gastric intubation. Only age, sex, and a central venous line showed statistical significance in the analysis of the combined effect of the group of risk factors described in the study by Chang et al.[15]

DISCUSSION

This study aimed to identify the individual risk factors (intrinsic and extrinsic) for infection through the estimation of the association between these risk factors and the presence of infection to devise a framework for a future HCAI global risk assessment tool.

The risk factors present on admission observed as being the most significant for the acquisition of infection were the following: transfer from another hospital (OR, 24.0; $P \leq .001$), skin problems (OR, 19.7; $P = .006$), urinary catheter present on admission (OR, 13.0; $P \leq .001$), respiratory problems (OR, 7.7; $P = .004$), readmission (OR, 6.3; $P = .036$), chronic wounds (OR, 6.1; $P = .02$), age (OR, 4.5; $P \leq .001$), having an infection on admission (OR, 4.2; $P \leq .001$), taking antibiotics in the last 3 weeks (OR, 3.5; $P = .003$), several admissions (OR, 2.8; $P = .017$), and having a central venous line (OR, 11.4; $P \leq .001$).

Patients transferred to this hospital are patients with specific characteristics: multiple trauma patients, patients sometimes with open fractures or other skin and soft tissue lesions, risk factors that are well documented.[3] The severity of the conditions on admission may also contribute to the increased risk and could be a confounding result. Patients included in this group are patients transferred from an oncology hospital (critical patients requiring ventilation in the intensive care unit). Transfer between health institutions is a well-documented risk factor,[17] particularly patients who at admission are (1) mainly complicated postsurgical situations,[18,19] (2) under chemotherapy,[3] and (3) with respiratory failure. These patients present important extrinsic risk factors for infection, such as (1) indwelling urinary catheterization, which is an important entry port of microorganisms from exogenous flora via health care workers or the patient's own endogenous flora[13,17]; (2) tracheal intubation, also described as an important risk factor for acquiring HCAI[20]; and (3) central venous device, related with infections of the bloodstream, which are typically associated with high levels of morbidity and mortality and increased length of stay.[13,15,19]

Regarding diabetes and obesity, other studies have confirmed that these 2 risk factors show no statistical significance for the acquisition of infection.[18] However, in some studies, diabetes has been associated with specific infections, such as fungal infections associated with cardiac devices.[19]

The statistical significance of the presence of infection at admission and having received antimicrobials in the last 3 weeks was also described previously by Tanner et al.[10]

One of the risk factors acquired during hospitalization with statistical significance for the acquisition of infection was insertion of a central venous line during hospitalization (OR, 11.4; $P \leq .001$), as previously described by others.[11,13,15,17,19]

Having an ASA score of 3 also showed statistical significance (OR, 5.0; $P = .004$). An ASA score of 3 (a patient with a severe systemic disease but not disabling) indicates a level of gravity that, as mentioned by others, is an important risk factor.[18] Having an emergency surgery (OR, 3.9; $P = .016$), also mentioned by Freeman and McGowan,[13] and an indwelling urinary catheterization in hospital

(OR, 3.1; $P \leq .001$) were shown to have statistical significance, as was also observed by other authors.[13-15]

In the analysis of the combined effect of the risk factors, the factor with the greatest significance was having a central venous line during hospitalization (OR, 12.4; $P \leq .001$), as occurred in several other studies.[11,13,15-17]

An analysis of binary logistic regression to test the combined effect of the risk factors was described by Chang et al.[15] In this analysis, the factors that were found to be statistically significant were age, as described by other authors,[3,10,14] and sex. This may be related to the gradual loss of immunity with increasing age.[21,22] Changes in the inflammatory and immune response associated with aging may be associated with an increased risk of infection.[23] In the presence of concomitant chronic diseases and functional limitations, these changes are more pronounced and may also contribute to the increased risk of infection.[24]

In this study, probability increased in patients aged >50 years (OR, 2.9; $P = .013$). The average age in the case group was 67 years, and in the control group it was 55 years. These mean ages may be related to the fact that the hospital has a very strong connection with the insurance systems for road accidents and occupational accidents (construction), which can justify the mean ages close to the active working age.

Regarding sex, we found that men are more likely to acquire infection (OR, 2.4; $P = .012$); this may be related to the type of population receiving care in this hospital because many of the injuries are caused by occupational accidents in construction works, where men are the predominant workers. In a study to identify predictors of bloodstream infection in elderly patients,[11] men were also associated with a greater likelihood of infection.

The main limitation of our study is that these results cannot be extrapolated to other health institutions, given the specificity of the case mix in the study hospital. There were other limitations to the study that should be noted, namely, sample size and inability to fully assess obesity because of missing data for calculating body mass index for all patients. It is necessary to develop more studies in the area of HCAI risk assessment and extend these studies to other hospitals with a different case mix.

CONCLUSIONS

The risk factors that showed statistical significance on admission were the factors related to the patient's intrinsic factors. Risk factors acquired during hospitalization, which showed the most statistical significance, were extrinsic risk factors related to medical procedures. When a set of risk factors are present, the presence of a central venous line proved to be the determinant extrinsic risk factor for infection. This is probably related to the severity of illness. Age and sex were the only intrinsic risk factors identified with statistical significance.

This points to the need to give special attention to all patients >50 years of age. Additionally, patients with a central venous line would need to be more closely followed, with daily assessments and adoption of specific prevention measures as indicated according to individual patient needs.

The development of more studies in this field will allow us to move toward a global infection risk assessment tool to be applied at admission and periodically, to identify patients at risk and to take specific actions to prevent, control, or even eliminate some HCAIs.

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