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Exploratory model for estimating occupation-day costs associated to Hospital Related Infections based on data from national prevalence project: IRAS Brasil Project

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RESUMO

Foi estabelecido modelo de custo de ocupação-dia de unidades hospitalares com dados obtidos a partir de estudo de corte transversal, nacional e multicêntrico de prevalência de IRAS em 11 hospitais de grande porte. Para estruturar o modelo foram usados dados do estudo (taxa de ocupação e prevalência de IRAS por categoria) e da literatura (custo de ocupação de leito de UTI e gerais). O modelo utilizou premissas e estimou custos de ocupação-dia total e médio por paciente com IRAS ou sem IRAS. Pode-se concluir que o custo diário do paciente com IRAS foi 55% superior ao de um paciente sem IRAS, com 12,0% dos pacientes com IRAS representando 18,0% do custo total diário de ocupação, fundamentalmente devido ao uso das acomodações hospitalares.

Palavras-chave: *Método de Monte Carlo; Custos Hospitalares; Infecções Relacionadas à Assistência à Saúde.*

ABSTRACT

The study established a model for estimating cost for hospitalization-day by hospital units, based on data obtained from a national transversal surveillance multicenter panel conducted on 11 institutions to establish health-care related infections (HAI) prevalence. The data from the surveillance panel used to compose the model were: percent of hospitalized patients and percent of HAI per category; and data obtained from literature were: hospitalization cost in intensive care units and in general units. The model used scenarios and estimated total hospitalization costs for all patients and mean costs per patient, with and without HAI. It was possible to conclude that the day cost per HAI patient was 55.0% superior compared to patients without HAI, with 12.0% of HAI patients being responsible for 18.0% of daily hospitalization costs, fundamentally due to specific hospital units usage patterns.

Keywords: *Monte Carlo Method; Hospital Costs; Hospital Acquired Infections.*

Healthcare associated infections (HAI) are frequent hospital events associated with greater morbi-mortality and with potential increase of hospital costs.[1,2] The impact of HAIs on costs has been object of researches.[2] However, its mensuration is an arduous task in Brazilian institutions, owing to the high administrative complexity of hospitals and to the lack of consistent cost data.[3,4]

The morbidity associated to HAI may trigger the use of hospital resources of greater complexity or duration, for instance the occupancy of specialized units. This association could have impact on the occupancy costs, owing either to the greater length of stay or to the use of specialized resources.[5] In order to measure this impact, this study established a preliminary and exploratory model for estimating the per day occupancy costs of patients with and without HAI in different hospital units. Source data used in the model were obtained from one national HAI prevalence project[6] and local publications.[1,7]

The model used data obtained from a cross-sectional, multicenter study carried out in 11 high complexity Brazilian hospitals, named "Projeto IRAS Brasil",[6] as follows:

1. Hospital occupancy rate;
2. HAI prevalence;
3. HAI prevalence per type [sepsis, pneumonia, urinary tract infection (UTI) and skin and soft tissue infections (SSTI)];
4. Occupancy cost of bed in Intensive Care Units (ICU), obtained from one publication [1];
5. Occupancy cost of bed in general ward (non-ICU), derived from one publication.[7]

Based on a hypothetical scenario, the hospital locations of the patients with HAI (ICU or general beds) were fixed in the model to avoid instability, in accordance with the following criteria: 100% of sepsis cases, 60% of pneumonia, 30% of SSTI/UTI were considered to be in ICU beds. The hospital locations of the patients without HAI were determined by the prevalence study.[5] Additionally, length of stay was estimated based in the prevalence study data, calculated from admission and discharge dates for patients with and without HAI up until the prevalence visit date.

Simulations were run in Brazilian Reais (R$), but in order to allow for broader comparisons the monetary values are expressed in United States (US$) dollars in this paper, at a theoretical conversion rate of US$ 1.00 to R$ 2.25.

The model was designed to estimate both a mean total occupancy-day cost (i.e. all patients of one category – with or without HAI – within the hospital in one day) and a mean per patient occupancy-day cost (i.e. a single patient of one category – with or without HAI – in one day).

In order to estimate the occupancy-day cost of inpatients with HAI, both total and per patient, the model uses the following equation:

$$\sum[\{(Pi^{1-4} \times Beds) \times Y \times A\} + \{(Pi^{1-4} \times Beds) \times (1-Y) \times B\}]$$

Where:
Pi^{1-4} = Prevalence per HAI type,[6] with *Pi* of 1 to 4 representing respectively the prevalence of: 1 sepsis; 2 pneumonia; 3 UTI; 4 SSTI;
Beds = total available hospital beds, according to occupancy rate determined (276 beds-day);[6]
Y = ICU patient rate for patients with HAI, according to described scenario above;
A = Occupancy cost per day in ICU bed (US$ 1,075.56);[1]
B = Ocuppancy cost per day in non-ICU bed (US$ 233.33).[7]

The total sum of all HAI types delivers the total occupancy-day cost for all HAI patients, i.e. total inpatients with HAI occupancy-day cost. This result divided by the total number of patients with HAI on a single day gives a per inpatient cost, i.e. per inpatient with HAI occupancy-day cost.

In order to estimate the occupancy-day cost of inpatients without HAI, both total and per patient, the model uses the following equation:

$$\{(P \times Beds) \times Y \times A\} + \{(P \times Beds) \times (1-Y) \times B\}$$

Where:
P = Prevalence of cases without HAI (88.0% ± 5.8%);[6]
Beds = total available hospital beds, according to occupancy rate determined (276 beds-day);[6]
Y = ICU inpatient rate for patients without HAI, according to study (21.6% ± 10.9%);[6]
A = Occupancy cost per day in ICU bed (US$ 1,075.56);[1]
B = Ocuppancy cost per day in non-ICU bed (US$ 233.33).[7]

The total occupancy-day cost for all patients without HAI is then determined, i.e. total inpatients without HAI occupancy-day cost. This result divided by the total number of patients without HAI on a single day gives a per inpatient cost, i.e. per inpatient without HAI occupancy-day cost.

Monte Carlo simulation by Markov Chain (MCMC)[8] was performed (Oracle Crystal Ball, Fusion Edition, 2010, EUA) with 5,000 iterations, considering the premises above in order to calculate the mean cost for total occupancy per day and per patients with and without HAI, admitted either to general ward or ICU beds. For each iteration, different random values were substituted in the appropriate equations according to the estimated distribution curve, resulting in 5,000 distinct estimates for each type of patient (with or without HAI) and for each type of bed (general ward or ICU). The model revealed the minimum and maximum projections with certainty degree for each category (with or without HAI, general ward or ICU beds).

Table 1 shows data obtained from the hospitals participating in the prevalence study.[6] These data were used in the model and showed mean of 372.4 beds/hospital and mean occupancy rate of 74.1%, adding up to 276 available beds/day. HAIs were categorized as sepsis, pneumonia, ICU and SSTI during study visits, based on diagnostic criteria widely established [6]. Previously published Brazilian references[1,7] were used as source data for approximate per day occupancy costs. From all admitted patients evaluated, 88.0% (+/-5.8%) did not have HAI at the time of the prevalence visit. Of which, 78.4% (+/-10.9%) occupied regular beds and 21.6% (+/-10.9%) occupied ICU beds. On the other hand, 12.0% (+/- 5.8%) had HAI at the time of the prevalence visit, of which 4.0% (+/-2.8%) were categorized as Sepsis, 3.8% (+/-2.6%) as Pneumonia, 1.0% (+/-0.7%) as UTI, and 3.2% (+/- 1.9%) as SSTI. As explained above, the HAI patients' bed occupation pattern was fixed to avoid instability in the model, with ICU beds occupation for 100% of sepsis, 60% of pneumonia, and 30% of SSTI/UTI patients.

Table 2 shows the Monte Carlo simulation model results, expressed as occupation-day costs for total and per patient in both groups, with and without HAI. The simulation showed that the total estimated occupancy-day cost for patients with HAI was of US$ 25,075.53 (ranging from US$ 11,455.18 to US$ 53,998.43, 90% certainty degree). On the other hand, the estimated occupancy-day cost for total patients without HAI was of US$ 113,147.57 (ranging from US$ 54,698.44 to US$ 214,340.06, 95% certainty degree). The mean occupancy-day cost per patient was estimated based on the total calculated cost for all patients

Table 1 – Data applied in cost model with mean, standard deviations (SDs) and distribution curves.

Data	Mean Prevalence (%)	SD (+/-)	Distribution
Patients without HAI	*88,0%*	*5,8%*	*Normal*
Patients with HAI	*12,0%*	*5,8%*	
Sepsis	*4,0%*	*2,8%*	*Normal*
Pneumonia	*3,8%*	*2,6%*	*Normal*
UTI	*1,0%*	*0,7%*	*Normal*
SSTI	*3,2%*	*1,9%*	*Normal*
Occupation cost in ICU[1]	*U$$ 1075.56*	*US$ 53.78*	*Normal*
Occupation cost in ward[7]	*US$ 233.33*	*US$ 100.00*	*Uniform*

Table 2 – Monte Carlo simulation results expressed as occupation-day costs for: a) Total inpatients with HAI; b) Total inpatients without HAI; c) Cost per inpatient with HAI; d) Cost per inpatient without HAI.

	Mean Cost (U$$)	Confidence Interval	Certainty
a) Total inpatients w/ HAI	*US$ 25,075.53*	*US$ 11,455.18 – US$ 53,998.43*	*90%*
b) Total inpatients w/out HAI	*US$ 113,147.57*	*US$ 54,698.44 – US$ 214,340.06*	*95%*
c) Per inpatient w/ HAI	*US$ 737.13*	*US$ 318.29 – US$ 4,125.97*	*85%*
d) Per inpatient w/out HAI	*US$ 474.35*	*US$ 215.76 – US$ 857.88*	*95%*

divided by the total patients in each group (with or without HAI), derived from the occupancy rates obtained by the study. The mean cost per patient with HAI was US$ 737.13 (ranging from US$ 318.29 to US$ 4,125.97, 85% certainty degree) and the mean cost per patient without HAI was US$ 474.35 (ranging from US$ 215.76 to US$ 857.88, 95% certainty degree). The mean length of stay, as calculated from admission to prevalence visit or discharge, was 8.6 days for patients without HAI and of 89.8 for patients with HAI.

Data on hospital costs are scarce in Brazilian specialized literature, due to the lack of information and to the absence of standardized methods to determine healthcare costs.[1] In the current study, it was chosen to use a cost criteria based on functional similarity,[1] enabling cost classification of occupancy-day for different types of accommodations (ICU and general wards). Although there are other forms of measuring hospital costs, we understand that the proposed standardization is simple and rational, allowing for wider comparisons. Additionally, the present study aimed at establishing a model to estimate the relationship between HAI and its resource use impacting on costs, expressed as type of bed occupied (ICU or general).

The mean costs used for beds-day in the current study were obtained from literature. The authors acknowledge the risk that the costs used may not exactly reflect the reality and may differ in distinct settings. However, we understand that the model would still be valid even if different references for costs were applied, since its aim was to estimate the impact of HAI on costs of specialized resource use, irrespective of the specific monetary values. That is to say, if HAI were associated with a greater use of high-complexity resources in hospitals, the relative impact on costs would still be captured. Thus, a relatively higher resource use was considered more relevant in the present study than the actual monetary value of each occupancy type. Even though, monetary costs are presented (table 2), but should be regarded as estimates useful for comparisons between patients with and without HAI. The source data used in the model most probably reflect a comparative scenario related to higher resource use for HAI patients. Anyhow, if specific costs are available, the model may as well reflect actual values.

MCMC modelling has been applied in many healthcare and economic areas for cost estimation.[8,9] When data about specific phenomena are scarce or unavailable, *in silico* models may help exploring scenarios that are potentially representative of reality. Therefore, the application of Monte Carlo simulation aimed at bringing up the association between HAI and occupancy--day costs using scenarios of bed occupancy (ICU or regular). Naturally, the current modelling does not bear simulations for other cost categories or hospital activities. The HAI prevalence study[6] from which data inputs were obtained was a large and widely representative study in Brazil, with specific data on high complexity hospitals. Based on this, it was possible to observe the relationship between HAI and higher hospital resource usage, as demonstrated by an apparent higher ICU bed occupation and a longer hospital stay (8.6 days for patients without HAI, compared to 89.8 days for HAI patients).

The prevalence study, however, did not aim at investigating possible causes of higher hospital resource use. It is known that HAI is related to higher hospital stays and other resources use.[5, 10] Nevertheless, irrespective of being the root cause for the higher resource use, the present model demonstrated that costs were impacted, probably due to a higher hospital occupation (both ICU bed occupation and longer hospital stay). Of course, the root cause for higher ICU or longer hospital stay may or may not be the actual HAI episodes. In any case, HAI patients cost relatively more to the hospital than non-HAI patients, since the per day cost of a single HAI patient was 55% superior to a non--HAI patient (US$ 737.13 vs US$ 474.35, respectively). It means that 12.0% of patients with HAI detected in the study[6] may have represented 18.0% of the total daily occupation cost within these high complexity hospitals. In a hypothetical scenario, if one considers the longer length of stay (89.8 days) and a daily extra increase of US$ 262.78 in the occupation cost, then an increment of US$ 21,337.73 could be achieved by one single HAI patient.

Despite the limitations of the source data used or of the occupation scenario adopted for HAI patients in the ICU, the present model seems valid as an exploratory tool for determining the impact of HAI on occupation costs in high complexity Brazilian hospitals.

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