Hospital-acquired infections: a cost estimation for BSI in Portugal

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Abstract

Hospital-acquired infections (HAIs) are defined as a localized or systemic condition resulting from an adverse reaction to the presence of an infectious agent(s) or its toxin(s) that was not present on admission to the acute care facility. We provide an estimation of most direct costs (those associated to longer hospitalization), length of stay and mortality rate due to the onset of a particular HAI, the bloodstream infection (BSI) in a 322-bed Portuguese hospital between 2009 and 2012.

Main drivers of extra resource use are identified, then a matching estimator is implemented in order to estimate the average treatment effect (ATE) for infected patients. ATE was estimated by using two different matching criteria accounting both for personal characteristics and health status of the patients. Results for the additional costs of hospital-acquired infections are significant and in line with literature: BSIs result in average extra costs per patient between 7,930.84€ and 11,230.42€; an extra average length of stay between 20 and 25 days; and expected difference of mortality rate between 8.58% and 18.18%. Findings - confirming expectation of higher costs associated due to these infections - have important policy implications such as decision of investing in prevention campaigns. Indeed, BSIs are considered highly preventable infections such that there is great potential of reducing their incidence.

Key words: Hospital-acquired bloodstream infections; matching estimator

1. Introduction

Nosocomial infections -or hospital-acquired infections (HAIs) - are defined as a localized or systemic condition resulting from an adverse reaction to the presence of an infectious agent(s) or its toxin(s) that was not present on admission to the acute care facility (see *Appendix 1* for details regarding the data collection criteria).[1]

The onset of nosocomial infection "*complicates the delivery of patient care, contributes to patient deaths and disability, promotes resistance to antibiotics, and generates additional expenditure to that already incurred by the patient's underlying disease*."[2]As such, both direct and indirect costs of infection occur: the former referring to longer hospitalization time and more intensive use of resources; while the latter refers to increased potential of patient death, possible reduction in quality of life, and further opportunity costs of working time and relatives' opportunity cost of visiting and assisting (*Table 1).* Here, only laboratory-confirmed infections will be considered.

Table 1: Direct and indirect costs associated to HAIs

Direct Costs	Indirect Costs
a. Longer hospitalization time b. More intensive use of resources b.1 Drugs b.2 Health Professional time	c. Increased potential of death d. Possible reduction of patient's quality of life e. Extra opportunity-cost of patient working f. Relatives' opportunity-cost of visiting and assisting

Source: Sloan and Hsieh (2012)

[1] CDC (2014)
[2] WHO (2005)

This work aims at verifying whether there is a significant difference in outputs attributable to laboratory-confirmed bloodstream infections (BSI) in the Portuguese public Hospital considered which is São Francisco Xavier Hospital (SFXH).

Bloodstream infection is a sub-group of nosocomial infections; this is of particular interest because is considered the most avoidable among hospital-acquired infections.[3] Medical researchers claim that a target of zero cases is realistic for this specific type of nosocomial infections.[4] The analysis uses data of Diagnostic Related Group (DRG) records; information made available by the Hospital Committee of infection Control and Hospital Accounting Department. It aims at identifying the costs related to BSI using a tridimensional approach analyzing three outcomes: the difference in costs of care; length of stay (LOS) and mortality rate between infected and not infected patients will be estimated. The analysis is limited by studying only the most relevant part of the direct costs associated to longer hospitalization time (point *a* in *Table 1*) within a Portuguese health center; however findings are significant and align with the expectation of higher costs associated due to these infections.

In SFXH, the estimated direct costs of BSIs range between 714,851.4€ and 1,000,424€ per year (2.6%-3.7% of total hospital costs); extra average length of stay between 20 and 25 days; and expected difference of mortality rate is between 8.6% and 18.2%.

Recent literature confirms the extra costs associated to the presence of nosocomial infections; however results vary significantly between studies. Defez (2010) estimates cost differentials between €574 and €2,421 (depending on the group of infection) in a 1,198-bed hospital in Nimes, while Orsi et al. (2004) estimate an average difference of €15,413 in a 2,000-bed

[3] In particular the central-line associated bloodstream infections. See Umsheid et al. (2005)
[4] Harnge (2007)

hospital in Rome. Peng et al. (2006) associate a 10% mortality increase to infected patients in the Intensive Care Unit of 177 Pennsylvania hospitals, while Rosenthal et al. (2003) estimate that fatality is 24.6% higher among bloodstream-infected patients in Surgical Intensive Care Units of three hospitals of Buenos Aires. Finally, the extra length of stay associated to blood-stream infections ranges from 9.9 days (Vrijens, 2009) to 19.1 days (Orsi et al., 2002).

The European Center for Disease Prevention and Control (ECDC) released data from a 2011-2012 study,[5] where the average incidence of all HAIs in Europe 27 is estimated as 5.7% (only data from eight[6] countries were not considered representative), ranging from 2.3% in Latvia to 10.8% in Portugal. In 2011 the United States Center for Disease Prevention and Control (CDC) reported[7] that in USA the percentage was lower at approximately 5%. Point prevalence of BSI in Portugal was recorded as 8%[8] of HAIs, being the 5th most common nosocomial infection in the country.

While first literature in USA dates back to 1980 with Haley and al.(1980) work "*The SENIC Project. Study on the efficacy of nosocomial infection control. Summary of study design*", European literature is more recent. The interest in this topic peaked in Europe in response to the rise of patient safety concerns and the recent economic crisis. In particular, in 2004 a patient safety program was promoted by the World Health Organization – The World

[5] ECDC (2013)
[6] Austria ; Croatia , Czech Republic, Estonia , Norway , Romania, Denmark and Sweden
[7] Dudeck et al. (2013)
[8] ECDC (2013)

Alliance for Patient Safety – with the purpose to "*coordinate, facilitate and accelerate patient safety improvement around the world*". [9]

Additionally, European public health care provision is currently under extraordinary pressure due to both the general decrease in financing, as a consequence of public spending reductions, and to increasing costs whose main driver is the introduction and adoption of new technologies. Subsequently, a greater concern is arising with regards to the efficiency of public financing and production. [10] It is in this context that this analysis examines HAIs in Portugal.

The work is organized as follows. In section 2 the database used is presented; methodology of estimation is described in section 3; results are resumed in section 4, then discussion (section 5) and finally the conclusions (section 6).

2. Data

The study is based on data collected by the SFXH, part of the Lisbon Occidental Hospital Center (CHLO)[11] in Portugal, a 322-bed teaching hospital.[12] Seven wards of discharge with 165 beds in total have been included in this analysis, and comprise surgery, orthopedics, hematology, Intensive Unity Care (UCIP), Surgery Intensive Unity Care (UCIC), medicine III, and medicine IV (See *Appendix* 2 for detailed hospital characteristics). These are the wards with higher BSI in the Hospital.

[9] WHO news release (2011). In particular the Global Patient Safety Challenge "Clean Care is Safer Care".
[10] Glied and Smith (2011) Chapter 38
[11] Hospital Egas Moniz, Hospital Santa Cruz and Hospital São Francisco Xavier form the CHLO
[12] 356 in 2009, 317 in 2010 and 359 in 2011

The health center collects information of all hospitalizations, diagnostics, treatments and some individual characteristics of the patients according to the national standards of Diagnostic Related Groups (DRG) records.[13]

The Committee of Infection Control provided the access to data related to patients with BSI infected since 2009, with data regarding other HAI's available only for 2012. The accounting department provided all hospital center costs and balance sheets per ward.

The time frame for this study is the 2009-2012 period, although there is no access to information regarding the onset of other HAIs but BSIs from 2009 to 2011. The sample includes 16,200 observations; among which 194 caught BSI.[14]

It can be noticed that SFXH has higher prevalence rate (1.74%)[15] of BSI than the average national prevalence according to ECDC point prevalence estimation (0.08%).[16] Nevertheless, the density of incidence[17] in 2010 and 2011, respectively 1.3 and 1.1, is in line with the national statistics (DGS 2013) of 1.2.

Each observation in the sample has associated two main codes: the episode number, which is a unique identification; and the procedure number which is associated to each patient, and thus repeats when this patient returns to the hospital.

The only personal characteristics available are age and gender; there is complete data regarding the date of admission and discharge; time of permanence, whether patients had been transferred to or from another health center; admission type (scheduled or not); wards

[13] International Statistical Classification of Diseases and related Health Problem ICD-09
[14] 281 BSI episodes were recorded in the hospital, but only 194 were discharged in the seven wards considered.
[15] Considering the 281 cases of BSI on the 16,200 patient discharged
[16] ECDC (2013)
[17] The incidence density is the number of infection episodes on the number of hospitalization days (here 1,000 days).

admitted to by the patient, including ward of discharge, and the correspondent time of entry and exit from each; primary and secondary diagnosis; medical procedures performed; DRG codification and the length of stay in each ward.

It was possible to count the number of times a patient returned to the Hospital in the last four years (*N_separations*). The number of separations for patients detects those returning to this same hospital and being dismissed in one of the seven wards under consideration in this study.

With more than 1,000 different main diagnostics, a simplification procedure was implemented based on the coding structure of the diagnostics. More general diagnostic classifications were considered using the first two digits of the hierarchical structure. This generalization has some evident limitations. For instance, the classifications of endocrines diseases is such that all belong to the same group at the two digit level, and thus anemia is comparable to lymphadenitis in this methodology, which may contradict standard medical knowledge. Similarly, the *DRGsimple* had been generated by eliminating the last digit of the DRG total code: last digit captures either the disease grade of complexity or the presence of complications. Since nosocomial infections are always coded as complication, it is impossible to establish whether the attribution of complication would have occurred without the onset of HAIs or not. Therefore, the shortened code should not differentiate between two individuals with equal morbidity whose difference is only the onset of the HAI. The database was then enriched with the information of the Committee of Infection Control: infected patients were identified directly from this information.

Only patients admitted for at least two days have been considered since -by definition- hospital-acquired infections may appear at least after two days of stay. Inbound or outbound

patients transferred from other health facilities are excluded since information relative to care received before or after is not available, and an accurate estimation of outputs was not possible. Treatment costs of under-18 patients are expected to significantly differ from the others patients and none of them caught a BSI, therefore 88 observations were dropped because of age criteria.

A further 96 patients were excluded since they spent the majority of their stay either in wards not relevant for this study (Gynecology, Obstetrics; Plastic Surgery and Oncology) or without a correspondent specialty ward in HSFX (Endocrinology; Infection diseases; Otorhinolaryngology; Pneumology and neck and head ward) were left out. By applying all these restrictions, 3,053 observations were excluded from the database (see *Appendix 3* for details). The finalized database accounts for 13,147 individuals- 190 with BSI.

Data regarding costs were made available by the SFXH accounting department.

The accounting of the hospital is organized by specialty wards – which may correspond to one or more operational wards. Surgical intervention costs were not attributable to wards due to the accounting organization. Costs of all patients who undertook a surgical intervention were underestimated. When implementing the estimation method, this limitation loses its relevance. In fact, operated patients with infections will be matched, therefore compared, only with operated patients without infection.

The Hospital has an independent accounting with respect to the other hospitals part of CHLO, nevertheless patients' transfers among the hospitals of CHLO are here considered as within the same care center. In the database are recorded also wards belonging to the CHLO but not part of São Francisco Xavier Hospital, whose costs are unknown. In order to include them in the cost estimation, SFXH costs per ward were considered as proxy of the correspondent wards costs. In other words, the cost of hospitalization in a cardiology ward of any Hospital part of CHLO is assumed equal to the

cardiology ward in SFXH and so on for each specialty. When there was not a specific ward to refer to, the average daily cost of the rest of the stay was applied to the missing values. This approximation was needed for 200 patients (6.3% of total patients), but results did not vary significantly when approximating them to zero.

Both variable costs and fixed costs have been proportionally attributed among the wards by the Hospital Accounting Department.

For each ward considered, total costs have been divided by the number of patients and the number of days they spent in the ward in order to compute an average unitary cost by ward. Unitary cost has been combined with information regarding the length of stay in each ward; finally an approximation of each patient financial burden has been obtained. Yearly costs from 2009-2012 are inflation adjusted according to National Statistics Institute statistics.[18]

The results regarding costs differential must be interpreted keeping in mind the method used for allocating costs, in particular the choice of fixed costs allocations. Further discussion is presented later.

3. Methodology

Population has been divided in two groups: not infected – control group- and infected by BSI- treated group. This grouping allows the analysis of bloodstream infections with respect to the uninfected population.

The following *Table* summarizes the population characteristics for both these groups:

[18] The yearly changes in the general level of prices of goods and services bought by private households.

Table 2: Population Characteristics

		All population	Not Infected	Infected by BSI
Proportion		100%	98.57%	1.43%
Age		67.4	67.34	69.9
	Min	18	18	22
	Max	107	107	100
Women		57.0%	57.2%	43.5%
N. separations				
	One or two	88.97%	88.48%	81.05%
	Three or four	6.09%	6.05%	8.42%
	Five or more	5.54%	5.47%	10.53%
N. of days pre-operation		3.66	3.16	13.05
	Min	1	1	1
	Max	142	108	142
N. of procedures		8.1	8.01	15.22
	Min	1	1	1
	Max	20	20	20
Admission type				
	Scheduled	25.1%	25.3%	9.4%
	Not Scheduled	74.9%	74.7%	90.6%
N. of diagnosis		6.6	6.5	9.95
	Min	1	1	1
	Max	20	20	20
LOS		12.3	11.7	49.2
	Min	2	2	2
	Max	303	298	303

Source: own construction

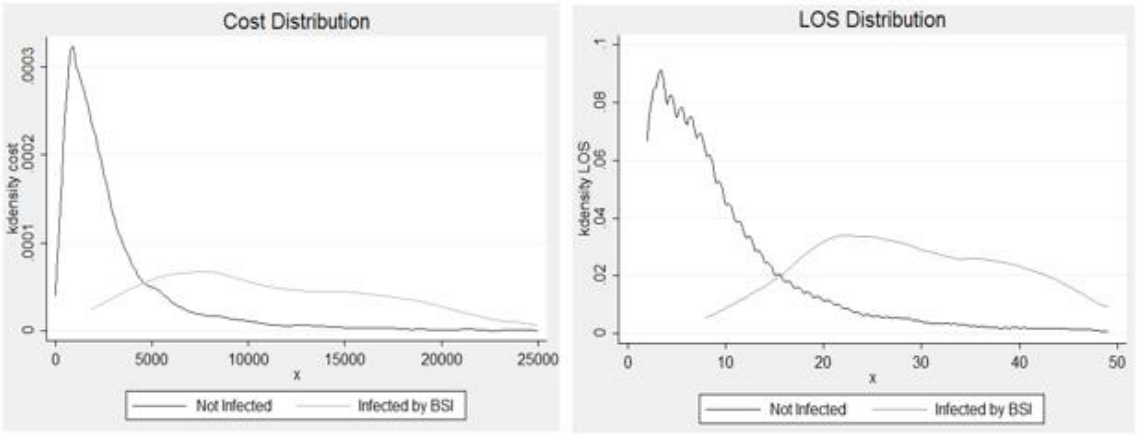
This section will proceed in two estimation phases. In first place, relevant explanatory variables of the outputs considered will be identified: this phase is important for the choice of matching criteria. In second place, the motivation of implementing a matching estimator and matching criteria selected are presented.

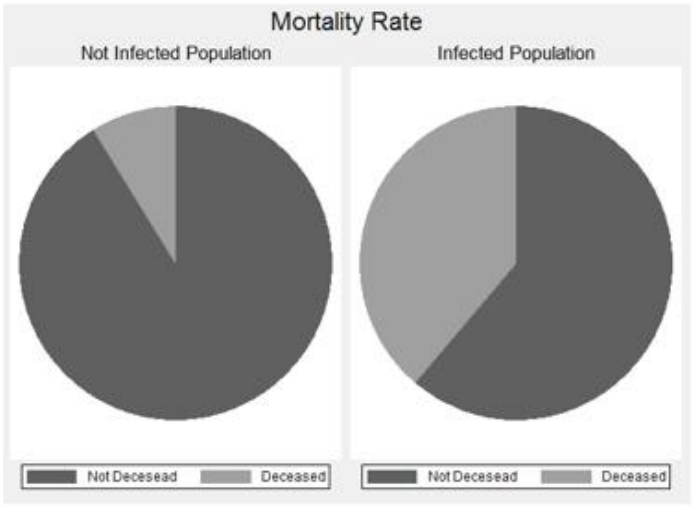
3.1 First Phase: identification of relevant variables

Preliminary analysis begins by testing the difference in outputs among the treatment and control groups, in order to validate the meaningfulness of the research question.

Of the three outputs considered- mortality rate, length of stay (LOS), and cost of care- the following figures show clear differences in output for patients with BSI (the treated group). This is consistent with the literature where patients with BSI are characterized by higher costs, LOS, and mortality rates.

Graph 1, 2, and 3: Output distribution of control and treated group before matching





Statistical inferences are conducted in the form of a t-test, Chi-Square test, Ranksum, and median test. Results confirm the graphical intuition (*Graph 1 and 2)* with the null hypothesis of equality rejected. The distribution of outputs and *Table 4*, which summarizes population characteristics, show the differences between infected and non-infected groups. Both groups have comparable minimum and maximum output values, and the similar range allows for meaningful comparisons among groups.

The regression confounders are examined for the three outputs – LOS, probability of death, and costs.[19] These outputs are regressed on variables that may reflect the complexity of the episode. Dependent variables were regressed on age, gender, ward, type of admission (scheduled or not scheduled), number of separations in the last four years, number of diagnostics and the presence of BSI.

The number of separations, variable *N_separations*, is expected to reflect the risk level of the patients, because returning several times for care may result from a weaker health status.

Among independent variables is included the type of admission, which serves as a proxy for whether a patient was admitted with urgency (non-scheduled). Non-scheduled hospital admissions are expected to have relatively worse outputs compared to patients admitted for scheduled appointments. Since the treatment of BSI does not determine the use of surgery, an indicator variable for the presence of surgical intervention is also included as an independent variable.

The number of diagnostics informs on the complexity of the episode and is considered a determinant of outputs. Although diagnostics are expected to be significant, they are too

[19]From here on, when referring to costs, it is meant approximated and adjusted for inflation costs

numerous to be used outright as an explanatory variable since it is discrete non-ordinal variable that takes over 1,000 values or -at minimum- 97 if simplified. In order to account for the different classes of diseases by proxy, the ward where the patient spent the majority of his/her stay is used. Operative wards were categorized in five groups: surgical; orthopedics; general medicine; intensive care units and hematology (see *Appendix 4* for the specification of wards assigned to each category). Within each group, it is expected that patients have comparable diseases and diagnostics.

The time spent in a hospital is the major determinant of costs, nevertheless it is not used as explanatory variable since it is endogenous given the methodology we used to compute them. Further, the variable number of procedures performed during hospitalization is excluded since it is correlated to BSI variable: infected patients are expected to receive more intensive care than others therefore including both regressors would arise endogeneity concerns.

When regressing on LOS variable and costs, only non-deceased population is included: this is because HAIs may lead to a premature death, and the inclusion of deceased individuals may lead to inconsistent results.[20]

Three types of regressions are used for each of the variables of interest. When regressing on cost an OLS approach is used, on mortality rate a logistic model is used, and for LOS (count variable) a negative-binomial regression model is employed. In the case of LOS, an over-dispersion problem has been detected (see *Appendix 5*), and a negative-binomial model is preferred to a Poisson regression model.[21]

[20] Laupland et al. (2006) and Orsi et al. (2002)
[21] Cameron and Trivedi (2005)

Table 5: Regression of outputs

	Costs	LOS	Pr. of death
	(OLS)	(NBD)	(Logistic)
Age	30.08***	0.0006***	0.0421***
Female	363.3*	-0.0456***	-0.257***
BSI	18265.8***	1.177***	1.434***
N. separations	-0.134**		217.3***
N. diagnostics	1.229***	.	
Not Scheduled admission	2425.1***	0.691***	1.522***
Medicine	613.4*	-0349***	0.596***
Orthopedics	72.91	-0.012	-0.325*
Intensive Care Unit	12899.4***	0.373***	6.257***
Hematology	18370.4***	0.216***	1.401***
Surgical Interventions	2434.2***	6.086***	
Constant	-2777.8***	-5.756***	-7.692***
N	11934	11934	13147
Adj. R-sq	0.19		
Pseudo R-sq		0.056	0.343

*** P-value≤0.01 **p-value≤0.05 *p-value≤0.1
Note: Surgery ward is the baseline ward in the regression

The regressors presented above where selected among the variables present in the database in order to obtain the highest goodness of fit with the information available.

As expected, the presence of BSI is a statistically significant determinant factor for all outputs, and outputs are worse for infected patients. Furthermore, in all regressions age is highly significant and positive with older individuals having higher costs of care. Females on average have higher costs, but shorter length of stay and reduced probability of death relative to males.

The negative relation of *n_separations* in the regression on cost is counterintuitive, but according to the hospital health professionals this may be justified by economies of experience – some tests may not be repeated and more information may be available since the patients' recovery in the same hospital during their stay. When regressing on costs and LOS the ward where the patient spent the most amount of time is more significant than the ward of discharge, while when regressing on mortality rate the opposite was found.

3.2 Second Phase: implementation of matching estimator

Following the results of the preliminary analysis, matching estimators were chosen as the means to proceed. Regressions results in *Table 5* show that there are several determinants for the outputs of interest while *Table 4* and the distributions in *Graph 1* and *2* signal different risk profiles among infected and non-infected groups. It is expected that infected patients have lower outputs both due to their weaker health status and nosocomial infections.

Matching estimators is expected to reduce the heterogeneity bias due to differences across the population, therefore the costs attributable to BSI only may be estimated.

The second phase of the analysis begins with the choice of matching criteria.

In order to account for the severity of illness, both diagnostic grouping and the ward where the LOS is the longest. These are considered as strong requirements as the matching of the simplified DRG classification. These criteria were summed to the explanatory variables in regression resumed in *Table 5*. The deceased population was excluded when matching costs and LOS, for the same reason they were excluded from the regressions. Since surgical intervention was selected as matching criterion, the problem of under-estimation of costs for operated patients will be removed since operated individuals will be compared only with other operated individuals. Surgical intervention is not imputable to the onset of BSI (but it

may be the case for other nosocomial infections), hence the inclusion of this matching criterion should not affect the estimation results.

A single match is preferred to multiple matching, and the sample is large enough to expect a reasonable loss in precision.[22] The estimation also allows for heteroskedasticity and will be bias-corrected for age, number of separations, and number of diagnostics. Matching criteria are listed as follows:

Table 6: Matching criteria

Cost (1)	Cost (2)	LOS (3)	LOS (4)	Mortality rate (5)	Mortality rate (6)
Age	Age	Age	Age	Age	Age
Sex	Sex	Sex	Sex	Sex	Sex
Surgical intervention	Surgical intervention	Surgical intervention	Surgical intervention	Type of admission	Type of admission
Type of admission	Type of admission	Type of admission	Type of admission	N. of separations	N. of separations
N. of separations	N. of separations	N. of separations	N. of separations	N. of diagnostics	N. of diagnostics
Main diagnostic group	Simplified DRG	N. of diagnostics	N. of diagnostics	Ward of discharge	Simplified DRG
Max. stay ward		Main diagnostic group	Simplified DRG	Main diagnostic group	
		Max. stay ward			
Exclusion of deceased population					
Controlling for other nosocomial infections					

In order to verify the validity of the estimation, the matched population must be comparable. Matching estimators aim at eliminating the effect of the other factors influencing the difference in outputs between the control and the treated group. T-test, Chi-square test, Ranksum and median test have been performed on the characteristics of the matched population used as matching criteria and validity of the estimation was confirmed given that

[22] Imbens and Woolridge (2009)

all the matching criteria were never significantly different among the control and the treatment group.

4. Results

Table 7 highlights the estimation results. The figure illustrates two estimation procedures with odd rows (1, 3 and 5) using main diagnostic grouping and ward of longest stay (or dismissal) while even rows (2, 4 and 6) used simplified DRG code for the matching.

When matching for estimating average treatment effect (ATE) of LOS and costs, the observation of patients hospitalized for the majority of time in Orthopedics (3354 patients) were excluded. This is because when regressing this ward on the two outputs its coefficient was found not significant (see *Table 5*).

Table 7: ATE matching results

	ATE	P-value	Lower-limit (95%C.I.)	Upper-limit (95%C.I.)	N. Observations	N. BSI	Perfect Matches
Cost (1)	7,930.84€	0	3,615.73€	12,245.96€	9793	108	48.44%
Cost (2)	11,230.42€	0.001	4,333.86€	18,126.98€	9793	108	46.78%
LOS (3)	19.74	0	10.27	29.21	9793	108	38.18%
LOS (4)	24.60	0	14.31	34.90	9793	108	33.57%
Mortality rate (5)	8.58%	0.051	0.0%	17.2%	13147	190	44.59%
Mortality rate (6)	18.18%	0.006	5.25%	31.11%	13147	190	35.60%

The results appear to be consistent and the differences between both methods non-significant since the average treatment effect of even rows is always included in the 95% Confidence Interval of odd rows.

Last column shows the percentage of treated patients that find a perfect matches: it can be seen that between 32% and 45% infected patients have been perfectly matched, therefore concerns regarding "*selection bias*" are moderate.

Bloodstream nosocomial infections result in average extra costs between 7,930.84€ and 11,230.42€ per infected patient; an extra average length of stay between 20 and 25 days; and expected difference of mortality rate between 8.58% and 18.18%.

When computing the Average Treatment Effect on the Treated (ATTE) the average costs estimated are included in the average costs interval found using ATE method, while the difference in mortality rate and LOS is estimated as higher and results have greater variance (see Appendix 7 for the table with ATTE results).

5. Discussion

Results are significant and in line with literature (briefly presented earlier), nevertheless the confidence interval is quite large. Several factors may be the cause of the variance in results. In first place, it has not always been possible to control for other nosocomial infections different from BSI because only data of 2012 were made available: hence it may be that a patient infected by BSI is matched with a patient infected by another HAI. These result in an under-estimation of the negative outputs due to the morbidity. Secondly, a patients characteristics may be correlated with outputs, such as civil and employment status, and this information was not available. Finally, some medical risk-factors were not recorded: for instance, the insertion of catheter and for critically ill patients or admission classifications scores (such as APACHE or SAPS score).[23] This may be a relevant indicator of health status

[23] Warren (2006)

at the admission time when the probability of being infected are equal for all patients and would have been included as a matching criteria of ICUs.[24]

A limitation of this study is that the cost differential identified cannot be interpreted as an immediate monetary benefit for the payer in case of complete eradication of bloodstream nosocomial infections. Fixed resources may find a different more efficient use whether freed, but it may also be the case that the payer expenses increase if the investment in prevention was equal to the estimated cost differential since only the variable costs due to the BSI would be eliminated or reduced. [25]

Therefore, possible further studies may focus on the marginal costs of such infections: average treatment effect of costs may consider only laboratory expenses; extra drugs expenses; extra administrative costs; value of higher risk of mortality, costs of lower quality of life, extra opportunity cost of working and relatives' time for visiting and assisting. Here, marginal costs may be directly compared with the costs of implementing infection control campaign.

6. Conclusions

It was estimated that in SFXH bloodstream nosocomial infections result in average unitary extra costs attributed to longer LOS between 7,930.84€ and 11,230.42€; an extra average length of stay between 20 and 25 days; and expected difference of mortality rate between 8.58% and 18.18%. The average cost, LOS and mortality rate in the sample are, respectively: 4679.37€; 12 days and 9.3% (see *Appendix 5* and *6* for details). In SFXH the total extra

[24] Laupland et al. (2006)

[25] This is possible, but uncertain, because not all costs- as presented in *Table I*- were considered

financial burden ranges between 2,859,405€ and 4,001,696€,[26] because costs are applied to 1.7% of patients (according to the prevalence rate of BSI of the SFXH).

The results have great relevance: they show that there is the possibility of consistent savings by reducing nosocomial infections.

Nevertheless average treatment effect may not be interpreted as a direct saving in case of zero-infections since both fixed and variable direct costs are accounted for. The actual short-term saving would result in the reduction of only the variable costs, while fixed costs may be recovered only in the medium-long term. Still non-recoverable costs may find a more efficient use meaning further immediate saving to be summed to the marginal cost reduction. This inefficiently used resources are even larger since this study did not account for all costs attributable to the morbidity (in particular none of the indirect costs). The public insurer should consider these resources as a potential gain in efficiency of provision. In order to achieve a higher level of production, respecting the current financial constraints, different approaches are possible: positive (negative) trends may be prized (punished); or prevention campaigns financed. A new remuneration system may take into account the progress in the preventable HAIs' control, incentivizing the progressive reduction of this morbidity or penalizing the increase of the same. By financing prevention campaigns, the insurer would enhance the implementation of good practices for preventing the onset of BSIs or other nosocomial infections. If this is the intention, a cost-effectiveness analysis of the program must be available, in order to evaluate whether its implementation would be an efficiency gain: it may occur that a positive rate of infection is economically efficient.[27]

[26] Between 714,851.4€ and 1,000,424€ per year
[27] Graves et al. (2009)

This study attempts to create new information regarding the costs of BSIs in Portugal in order to better inform decision makers, nevertheless it must be supported by further research. [28]

[28] Graves and McGowan (2008)

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Appendix

1. Definition of BSI

Nosocomial bloodstream infections are registered in the Commission of Infections Control only if one of the following three criteria is applicable:

1) One or more hemoculture positive results for a determined microorganism without relation to any other infection source.

2) The patient presents:

• Either fever, shivers or hypotension and

• Signals and symptoms and laboratory confirmed proofs not related to any other infection source

• In at least two hemocultures whose sample was collected in different points in time is identified the same usual skin contaminant (ex: difteróides -Corynebacterium spp-, Bacillus spp, Propionibacterium spp, Staphylococcus coagulase negative -including S. epidermidis-, Streptococcus group viridians, Aerococcus spp or Micrococcus spp);

3) The patient with age inferior or equal to 1 year:

• Presents at least two of the following symptoms: fever (>38ºC rectal), hypothermia (<37ºC rectal), apnoea or bradycardia

• Signals and symptoms and laboratory confirmed proofs not related to any other infection source

• In at least two hemocultures whose sample was collected in different points in time is identified the same usual skin contaminant (ex: difteróides -Corynebacterium spp-, Bacillus spp,Propionibacterium spp, Staphylococcus coagulase negative -including S. epidermidis-, Streptococcus group viridians, Aerococcus spp or Micrococcus spp);

2. Hospital characteristics

Ward	N. of Beds	Daily costs per patient			
		2009	2010	2011	2012
Surgery Intermediate Care Unit Surgery	42	225.4338	243.8328	226.8879	195.1717
Orthopedics Intermediate Care Unit Orthopedics	33	246.2927	287.6434	354.8872	307.2037
Medicine III	25	287.4892	309.8867	322.7008	197.7955
Medicine IV	36	218.1261	227.6094	263.9933	185.8002
Hematology	13	460.343	400.9913	760.9247	386.3838
ICU Polyvalent	8	784.9433	865.0998	956.8535	743.9505
ICU Surgery	8	864.8287	893.7355	854.2299	618.5171

3. Database exclusions resumed

	Total	Percentage	Motivation/Observation
Observation in original database	16,200	100%	
Patients with LOS≤48 hours	1,731	10.69%	HAIs definition: after at least 2 days of hospitalization
Patients transferred in/out	1,136	7.01%	Incomplete information: unknown LOS; total costs
Patients spending most of their stay in a ward not relevant for this study*	98	0.6%	Gynecology, Obstetrics; Plastic Surgery and Oncology
Patients aged <18	88	0.54%	Incomparable outputs due to different treatments related to age
Database used	13,147	81.15%	
With BSI	190	1.17%	
With other HAIs but BSI	76	0.47%	Only available for 2012
With cost approximation	180	1.11%	Because patients passed through wards whose cost information was unavailable

4. Specification of Attribution of ward to each general ward

	Ward	**Ward code**
Surgery	General Surgery	34001
	Intermediate Surgery Care	34002
	General Surgery other Hospital	36002; 36003; 38004
	Neurosurgery other Hospital	36014
	Vascular Surgery	36030
	Intermediate Surgery Care other Hospital	36036; 36039
	Cardiotorax Surgery other Hospital	36032; 38003
Medicine	Medicine III	34020
	Medicine IV	34006; 34021
	Medicine Intermediate Care Unit	36011;36012;36012;36013
	Medicine/Orthopedics	34024;34025
	Vascular Celebral Accident Unit	34028; 34007
	Cardiology	34028
	Medicine of other hospitals	36011; 36012;36013;36031;34008; 36037
	Cardiology of other hospital	36001; 38001

Orthopedics	Orthopedics	34022
	Orthopedics Intermediate Care Unit	34023
	Orthopedics of other hospital	34097
ICU	Surgery Intensive Care Unit	34003
	Polyvalent Intensive Care Unit	34008
	Intensive Care Unit of other Hospital	36027
	Polyvalent Intensive Care Unit of other Hospital	38007
Hematology	Hematology	34019
Not Included	Neurology	36015
	Neurotraumatology	36016
	Ophthalmology	36017
	Otorhinolary	36019
	Urology	36025
	Rheumatology	36021
	Pulmonology	36020
	Dermatology	36005
	Endocrinology	36006
	Gastroenterology	36007
	Infectiology	34009
	Psychiatry	35001;35002;35003;35004;35005

5. Variable LOS details

TOTDIAS

	Percentiles	Smallest		
1%	2	2		
5%	2	2		
10%	2	2	Obs	13223
25%	4	2	Sum of Wgt.	13223
50%	8		Mean	12.34054
		Largest	Std. Dev.	15.87558
75%	14	235		
90%	26	290	Variance	252.0342
95%	38	298	Skewness	5.629949
99%	76	303	Kurtosis	58.5893

6. Variable Mortality and Cost details

Mortality

	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	13223
25%	0	0	Sum of Wgt.	13223
50%	0		Mean	.0930197
		Largest	Std. Dev.	.2904711
75%	0	1		
90%	0	1	Variance	.0843734
95%	1	1	Skewness	2.802314
99%	1	1	Kurtosis	8.852966

costapproxadj

	Percentiles	Smallest		
1%	395.5	0		
5%	487.3618	371.6		
10%	660.7078	371.6	Obs	13223
25%	1166.215	371.6	Sum of Wgt.	13223
50%	2122.012		Mean	4741.698
		Largest	Std. Dev.	14525.94
75%	3980.875	297522.1		
90%	8418.82	302829.9	Variance	2.11e+08
95%	13776.37	322537.4	Skewness	16.53474
99%	48715.84	661107.6	Kurtosis	459.8853

7. ATTE matching results

	ATTE	P-value	Lower- limit (95%C.I.)	Upper-limit (95%C.I.)	N. Obs.	N. BSI	Perfect Matches
Cost (1)	10,135.55	0.013	2,164.16	1,8106.94	9793	108	93,64%
Cost (2)	8,396.3	0.052	-75,98	16,868	9793	108	96,86%
LOS (3)	27.61	0	19.06	36.15	9793	108	91,93%
LOS (4)	27.58	0	18.93	36.21	9793	108	96,80%
Mortality rate (5)	9.37%	0.008	2.4%	16.31%	13147	190	94,58%
Mortality rate (6)	21.88%	0	13.95%	29.81%	13147	190	100%