Determining the Effect of Social Deprivation on the Prevalence of Healthcare Associated Infections in Acute Hospitals: a multivariable analysis of a linked data set

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Running title

Deprivation and nosocomial Infections

Key words

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Summary

Background

Healthcare associated infections (HAI) endanger safety by increasing morbidity, mortality, and hospital stay. Studies identifying risk factors for HAI rarely address the wider determinants of health. However a well characterised association exists between increasing social deprivation and poor health outcomes. Therefore it was important to determine whether HAI were associated with social deprivation.

Aim

To determine the association between social deprivation and the prevalence of HAI, in all inpatients in an acute hospital in Scotland on a single day across September and October 2011.

Methods

This study linked Scottish data from the 2011 European Point Prevalence Survey of HAI and Antimicrobial Prescribing to the Scottish Morbidity Record one, a national dataset with Scottish Index of Multiple Deprivation (SIMD) included. Multivariable logistic regression was used to model HAI prevalence against SIMD quintile.

Findings

No overall association was found between SIMD quintile and prevalence of HAI in all inpatients. A significant difference was found between HAI prevalence across SIMD quintile in patients undergoing surgical procedures; with higher prevalence observed with increasing deprivation ($p=0.0071$). Variables associated with HAI prevalence were: intensive care specialty, psychiatric and medical specialities, minimum invasive surgery and all categories of length of stay.

Conclusion

This study found a significant difference in HAI prevalence across SIMD quintile in patients undergoing surgery. To our knowledge this was the first study to examine the overall association between HAI and SIMD. The findings highlight the broad and comprehensive nature of social deprivation in determining health outcomes.

Introduction

Healthcare associated infections (HAI) occur during medical or surgical treatment in a healthcare facility.[1] The European wide prevalence of HAI in acute hospitals during 2011 was 5.7% (95% CI: 4.5 to 7.4), this translates to an estimated 3.2 million (95% CI: 1.9 to 5.2 million) infections occurring in European hospitals each year.[2] HAI threaten patient safety and represent a preventable cause of morbidity and mortality. In Europe during 2008 HAI caused 37000 attributable deaths and indirectly contributed to a further 110,000.[3] HAI place a large burden upon healthcare systems worldwide. In Europe (EU) during 2008 HAI were responsible for an additional 16 million days spent in hospital. This has substantial economic implications, with the direct cost of HAI for EU 27 countries being estimated at €7 Billion per year.[3] HAI are widely studied and multiple different risk factors have been identified. However the majority of studies focus on hospital based factors and broader public health determinants, such as social deprivation, are less frequently investigated.

A well-established association exists between increased levels of social deprivation and poor health.[4,5] It was found that people living in the most deprived areas were twice as likely to suffer serious illness or premature death as those living in the least deprived. This highlights a social gradient for health, with outcomes worsening as you move down the gradient.[5] There is still limited information regarding the link between infectious diseases and social deprivation, especially in a hospital setting in Scotland. One study found a graded relationship between postoperative meticillin-resistant *Staphylococcus aureus* (MRSA) infection and social deprivation; with rates increasing for more deprived persons.[6] However this study was conducted in a single centre and only looked at one infection type. Therefore it was important to clarify whether an association exists between social deprivation and HAI prevalence in all inpatients, using a large and well defined sample.

The second Scottish point prevalence survey (PPS) of Healthcare Associated Infection and Antimicrobial Use was carried out during 2011.[7] This formed part of a larger European wide PPS, co-ordinated by the European Centre for Disease Prevention and Control (ECDC). The survey aimed to collect data from all patients admitted to each of the 42 acute hospitals in Scotland. The survey reported a national HAI prevalence of 4.9% (95% CI: 4.4 to 5.4%). This study aimed to: determine the association between social deprivation and the prevalence of healthcare associated infections, in all inpatients in an acute hospital in Scotland on a single day across September or October 2011.

Methods

This study used record linkage to examine the association between social deprivation and the prevalence of HAI in all inpatients. The data used were primarily derived from the second Scottish PPS. The PPS used an adapted version of the ECDC protocol and a rolling point prevalence survey design; with each ward being surveyed in one day. Data were extracted from multiple sources and training was provided for all data collectors. Personnel undertook two gold standard inter-rater reliability tests and sensitivity, specificity, and agreement were all found to be good (kappa = 0.87 and 0.86). Full details of Scottish PPS methods have been described previously.[7-9] In order to introduce new variables, such as the Scottish Index of Multiple Deprivation (SIMD), PPS data were linked to the Scottish Morbidity Record (SMR) via a patients' community health index (CHI) number. SIMD is an area deprivation score, which incorporates seven aspects of deprivation into a single index and is held within the SMR. This provides a population weighted geographical score related to a patient's address area.[10] SIMD was assigned by matching the survey date in PPS to the relevant date of admission and discharge in SMR data. PPS records without an associated SMR entry were assigned a score using the most recent hospital discharge. Charlson index, a weighted score calculated for each patient depending upon the number and type of co-morbidities present, was calculated using ICD-10 codes held in SMR. Data files were merged 1:1 in SPSS and data recoded and labelled according to the study needs. Length of stay was calculated using the difference in days between PPS survey date and admission date recorded on SMR.

Missing variables were maintained throughout the descriptive and univariable analysis. Missing values were removed from the multivariable analysis in order to avoid complete separation due to small category numbers.[11] Descriptive analysis was performed using SPSS version 21**™**. Variable frequencies by HAI were used to calculate prevalence for each exposure category. Corresponding 95% confidence intervals were calculated using exact binomial methods for small samples and Wilson's method.[7]

Univariable and multivariable analyses were performed using R version 3.0.0. Univariable logistic regression, using the Logit function, was used to model HAI against candidate variables. Odds ratios (OR) were calculated and corresponding 95% confidence intervals. Data was fitted using a complex survey design, which accounted for hospital and ward level clustering. Two approaches were used to build the model: manual and stepwise selection. Variables contribution to the model was assessed using chi squared test, analysis of deviance tables, and changes in Akaike Information Criterion (AIC). Important variables were identified in univariable analysis and were prioritised in the following steps. Variables were sequentially added to the model, a compromise was sought between fit (low AIC), parsimony (fewest variables), and explanatory power (reduction in deviance). Interactions between covariates were determined by sequential addition of 1:1 product terms for explanatory variables into the model. In order to protect against multiple testing a 1% (p=<0.01) threshold was used to determine significance.[12] The final model used was:

$$\begin{aligned} hai \sim\ & SIMD + Speciality + Surgery\ Since\ Admission + Length\ of\ Stay \\ & + SIMD{:}SurgerySinceAdmission \end{aligned}$$

This model was used to calculate OR and corresponding 95% confidence intervals.

Results

The number of patients surveyed was 11604; this represents 94.2% of the total eligible population on the day of survey. The median age of the included patients was 70 years old, this ranged from new born on day of survey to 103 years. The interquartile range was 51 to 81 years. The majority of the patients were female (56.6%), see figure 1. There was an uneven distribution of patients in the PPS sample across social deprivation category, with patients in socially deprived quintiles being over represented in the prevalent hospital population. The first quintile, least deprived, had the fewest number of patients (n=1357) and the 5th quintile, most deprived, the largest (n=2937). Length of stay ranged from 0 to 23012 days.

The unadjusted prevalence varied across multiple strata. Prevalence of HAI across deprivation quintile was largely uniform, with estimates being approximately 4 or 5%. This was reflected in the univariable analysis where no association was reported between SIMD quintiles 1-5 and HAI prevalence. However a positive association was found between patients with SIMD quintile recorded as missing and HAI prevalence (OR=1.50, 95% CI: 1.11 to 2.03), see table I. Other variables found to be associated with higher HAI prevalence were: male sex, age group 50-64 and 65-79, surgical and intensive care specialities, surgery and minimal invasive surgery since admission, life limiting prognosis, end of life prognosis, and all categories of length of stay. In contrast obstetrics and gynaecology, paediatrics, and psychiatry, and age <1 month were found to be associated with lower HAI prevalence. Finally no association was found for Charlson score and location, see table I.

In the multivariable analysis SIMD quintile was not associated with HAI prevalence. Variables found to be associated with higher HAI prevalence were: ICU speciality (OR=3.15, 95% CI:1.99-5.01), , minimally invasive surgery since admission (OR=2.49, 95% CI:1.07-5.76), and all length of stay categories. Finally psychiatric (OR=0.12, 95% CI:0.05-0.29) and medical (OR=0.50, 95% CI:0.36-0.70) specialties were found to be associated with decreased prevalence. However age <1 month, surgery since admission, life limiting prognosis, surgical, paediatric, and obstetrics and gynecological specialties were found to be no longer associated with HAI prevalence, see table II.

Analysis of model interactions found patients undergoing surgery showed a higher HAI prevalence with increasing deprivation quintile. A U-shaped distribution was observed for patients undergoing minimally invasive surgery, with a high HAI prevalence in the least and most deprived quintiles. In contrast limited variation in HAI prevalence was observed in patients not undergoing surgery, see figure 2. Upon testing a significant difference was found between these interaction categories, p=0.0072, see table III.

Discussion

This study aimed to investigate the association between social deprivation and the prevalence of HAI. This was determined using a sample of all patients admitted to acute hospitals in Scotland on one day between September and October 2011. To our knowledge this was the first study to investigate the relationship between social deprivation and all HAI types. The main finding was a higher HAI prevalence with increasing deprivation in patients undergoing surgery. Multiple other factors were also identified as associated with higher HAI prevalence whilst controlling for social deprivation. This paper identified only one other relevant study, which found a positive association between MRSA surgical site infections and deprivation .[6] This study, as in the previous study, found patients from the most deprived social strata, who underwent surgery, experienced higher levels of infection.

The interaction between SIMD quintile and HAI prevalence in surgical patients is interesting and has important implications. A possible explanation centres around the epidemiology of *S.aureus*, which frequently causes surgical site infections and was the most prevalent microorganism identified during the PPS.[7] *S.aureus c*olonisation is an important risk factor for subsequent infection.[13] Although colonisation is associated with multiple interlinked factors, a large number of these are related to contact with healthcare and co-morbidities. [14] These factors tie in with the strong association between deprived persons and subsequent worse health status, which could lead to higher *S.aureus* colonisation and infection prevalence. This is probably more apparent in patients who have undergone surgery as colonisation represents a major risk factor for infection. Therefore this study identifies a potential risk group for which a targeted intervention, such as pre-emptive decolonisation, could be developed. This intervention could reduce morbidity and mortality associated with HAI and consequently could help narrow the widening gap in health inequalities.

Social deprivation and health are intimately linked; studies have found that social deprivation is associated with higher number of admissions and longer length of hospital stay.[15-17] This is reflected in the current PPS sample, which contained a disproportionate number of deprived patients (2937 patients SIMD 5 Vs 1374 SIMD 1). This difference is likely to result from poor health status due to differences in environmental influences, such as: smoking, diet, and health seeking behaviour. Worse health status and related hospital admissions can lead to greater exposure to HAI. To support this we found the absolute number of HAI were more than double in the most deprived (160) compared to the least deprived (72) quintiles. The provision of universal free health care could reduce health inequalities caused by social deprivation in a hospital setting. The multivariable results, which found no overall association, suggest that once patients were admitted to hospital the effect of deprivation was negligible. This was expected as patients admitted to the same ward or specialities, during the PPS, receive the same standard of care independent of their deprivation status. In contrast the community environment is highly variable and greatly influences a person's health status. It would be interesting to look further at the relationship between HAI and SIMD in a country where free healthcare is not provided.

The strengths of this study lie in its large and representative sample size. 11604 persons were included from all acute hospitals in Scotland; the response rate was also high at 94.2%. The methodology was rigorous and standardised. This ensured consistent data collection across all sites. The main limitation of this study was the point prevalence design, which does not allow explanation in terms of risk or causality. Certain biases were also attached to this methodology; first length of stay was included in the model however patients with length of stay missing were found to be positively associated with higher HAI. Upon further investigation length of stay was differentially missing for <1 month age group and females aged 16-49 years. This is due to linkage to SMR-01 only. Data on paediatrics and maternity patients is located on separate databases. Collapsed lower age categories will in part limit the effect of missing data. It was found in the univariable analysis that patients with missing SIMD classification were positively associated with HAI prevalence. This finding indicates a bias in the classification of SIMD in the SMR data set. This could affect the association between HAI and social deprivation, because influential patients were potentially not included in the analysis. Two likely explanations for missing SIMD were: patients have not been discharged from hospital or patients could not provide a postcode. The latter group was likely to be from the most socially deprived quintile. The multivariate model, which included missing data, found SIMD missing classification was not significantly associated with HAI prevalence. Missing values were a concern and could be suppressing an overall association between HAI and social deprivation. It is important to highlight that SIMD is a population based measure therefore subject to the ecological fallacy. To our knowledge no previous HAI PPS has used urban rural location in their analysis. However hospital location and the amount and differential nature of missing data could be obscuring a potential association. Further study in a large more complete data set is required.

In conclusion the findings presented by this study support the growing body of evidence that social deprivation is a powerful upstream driver for health outcomes. This observed difference is even more striking as it occurs within the standardised hospital environment. Further work is required to characterise this difference and develop interventions to reduce the gap in inequality.

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Conflicts of interest

None

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Tables

Table I - Prevalence of HAI and univariate analysis for association between HAI prevalence: demographic factors, surgery, prognosis, Charlson Score, SIMD and location of patient address * reference category

Category	Variables	HAI No	HAI Yes	Prevalence (95% CI)	Odds ratio (95% CI)	p-value
HAI	HAI	10966	559	4.82 (4.44-5.22)	1.00	NA
Sex	Male	4681	274	5.53 (4.93-6.20)	1.26 (1.07-1.47)	0.0195
	Female*	6243	283	4.34 (3.87-4.86)	1.00	
	Missing	42	2	4.55 (1.26-15.13)	1.36 (0.33-3.77)	
Age group	80+ years	3136	148	4.5 (3.8 - 5.3)	1.00	<0.001
	65-79 years	3375	200	5.6 (4.90 - 6.40)	1.26 (1.01 - 1.56)	
	50-64 years	1773	118	6.2 (5.20 - 7.40)	1.41 (1.10 - 1.81)	
	30-49 years	1452	59	3.9 (3.00 - 5.00)	0.86 (0.63 - 1.17)	
	16-29 years	649	21	3.1 (2.10 - 4.70)	0.69 (0.42 - 1.07)	
	2-15 years	105	2	1.9 (0.50 - 6.60)	0.40 (0.07 - 1.29)	
	1 - 23 months	46	2	4.2 (1.20 - 14.00)	0.92 (0.15 - 3.02)	
	< 1 month	428	9	2.1 (1.10 - 3.90)	0.45 (0.21 - 0.83)	
	Missing	2	0	0.0 (0.00 - 65.80)	NA	
Speciality	Geriatric medicine*	4268	223	4.97 (4.37-5.64)	1.00	<0.001
	Medicine	1834	80	4.18 (3.37-5.17)	0.77(0.60-1.00)	
	Surgery	2944	196	6.24 (5.45-7.14)	1.36(1.13-1.64)	
	Intensive care	116	22	15.94 (10.77-22.96)	3.26(1.98-5.14)	
	Obstetrics and Gynaecology	564	11	1.91 (1.07-3.39)	0.40(0.21-0.67)	
	Paediatrics	548	11	1.97 (1.10-3.49)	0.60(0.36-0.93)	
	Psychiatry	484	6	1.22 (0.56-2.65)	0.25(0.11-0.49)	
	Other	132	8	5.71 (2.92-10.87)	1.04(0.46-2.01)	
	Missing	76	2	2.56 (0.71-8.88)	1.13(0.39-2.55)	
Surgery	No Surgery*	8574	339	3.80 (3.43-4.22)	1.00	<0.001
	Surgery	1764	160	8.32 (7.16-9.63)	2.33(1.94-2.80)	
	MIS	527	47	8.19 (6.21-10.72)	2.14(1.55-2.88)	
	Missing	101	13	11.40 (6.79-18.54)	5.35(3.32-8.30)	
Prognosis	Non Fatal*	7212	308	4.10 (3.67-4.57)	1.00	<0.001
	Life limiting	2613	160	5.77 (4.96-6.70)	1.46(1.21-1.74)	
	End of Life	980	82	7.72 (6.26-9.48)	2.00(1.53-2.48)	
	Missing	161	9	5.29 (2.81-9.75)	3.96(2.60-5.90)	
Charlson	0 *	6251	318	4.84 (4.35-5.39)	1.00	0.295
	1-2	3500	171	4.66 (4.02-5.39)	0.84(0.7-1.0)	
	3-4	742	41	5.24 (3.88-7.03)	0.94(0.67-1.29)	
	5+	473	29	5.78 (4.05-8.17)	1.00(0.66- 1.44)	
	Missing	0	0	-	NA	
SIMD	1st quintile (Least deprived)*	1296	72	5.29 (4.20-6.58)	1.00	0.0992
	2nd quintile	1536	74	4.60 (3.68-5.73)	0.87 (0.62-1.21)	
	3rd quintile	1883	81	4.12 (3.33-5.10)	0.77 (0.56-1.07)	
	4th quintile	2269	98	4.14 (3.41-5.02)	0.78 (0.57-1.06)	
	5th quintile (Most deprived)	2769	160	5.46 (4.70-6.35)	1.04 (0.78-1.39)	
	Missing	1213	74	5.75 (4.60-7.16)	1.50 (1.11-2.03)	

Location	Large Urban Area	3869	181	4.47 (3.87-5.15)	0.92 (0.74-1.15)	0.0649
	Other Urban area *	2742	137	4.76 (4.04-5.60)	1.00	
	Accessible small towns	710	27	3.66 (2.53-5.28)	0.76 (0.49-1.12)	
	Remote small towns	180	14	7.22 (4.35-11.75)	1.44 (0.78-2.46)	
	Very remote small towns	142	12	7.79 (4.51-13.13)	1.57 (0.81-2.77)	
	Accessible rural	790	35	4.24 (3.07-5.84)	1.01(0.70-1.42)	
	Remote rural	218	13	5.63 (3.32-9.39)	1.10 (0.59-1.91)	
	Very remote rural	247	21	7.84 (5.18-11.68)	1.58 (0.95-2.48)	
	Missing	2068	119	5.44 (4.57-6.47)	1.49 (1.18-1.87)	
Length of Stay	0-2 days	2331	16	0.7 (0.40 -1.10)	1.00	<0.001
	3-5 days	1654	33	2.0 (1.40 - 2.70)	2.91 (1.62-5.43)	
	6-10 days	1501	83	5.2 (4.20 - 6.40)	8.06 (4.83-14.31)	
	11-23 days	1592	156	8.9 (7.70 - 10.40)	14.28 (8.78-24.93)	
	24+ days	1843	212	10.3 (9.10 -11.70)	16.76 (10.39 -29.1)	
	Missing	2045	59	2.80 (2.20 - 3.60)	4.20 (2.47-7.57)	

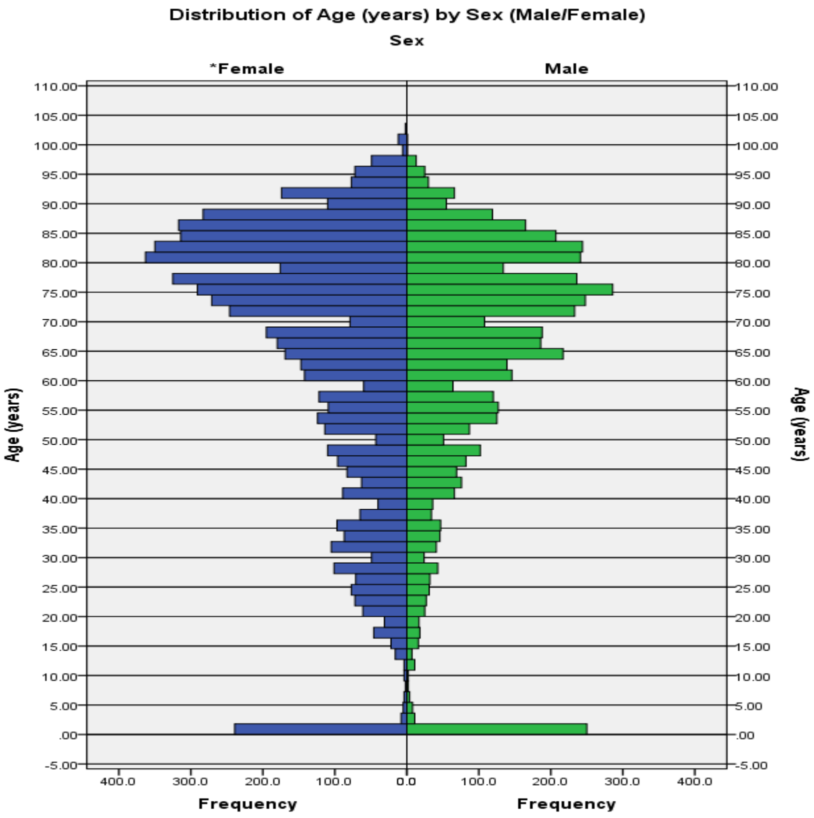
Table II - Results of the multivariate analysis for association between HAI prevalence and SIMD, sex, age, speciality, location, surgery, and prognosis. * Reference category, NA = couldn't calculate due to complete separation

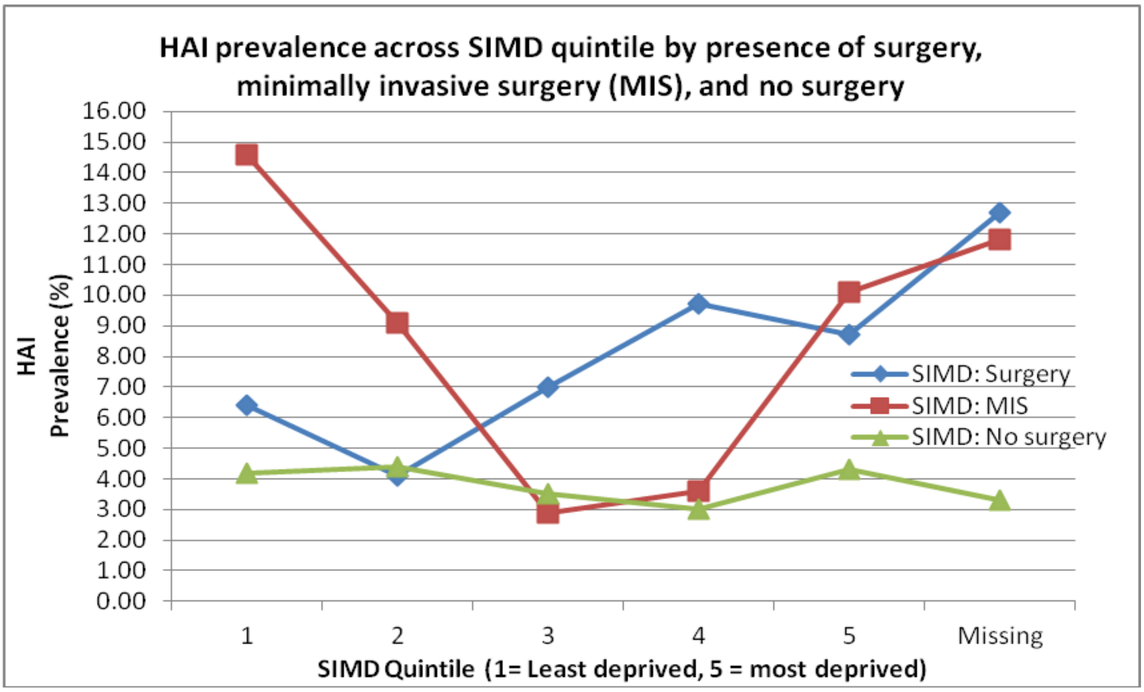
Category	Variable	Adjusted Odds Ratio (95% CI)	P-value
SIMD	1st quintile (Least deprived)*	1.00	0.18
	2nd quintile	1.23(0.79-1.91)	
	3rd quintile	0.96(0.62-1.50)	
	4th quintile	0.80(0.53-1.22)	
	5th quintile (Most deprived)	1.16(0.78-1.72)	
	SIMD missing	1.01(0.59-1.74)	
Speciality	Geriatric medicine *	1.00	<0.0001
	Medicine	0.50(0.36-0.70)	
	Surgery	1.03(0.76-1.41)	
	ICU	3.15(1.99-5.01)	
	Obstetrics and Gynaecology	1.3(0.39-4.30)	
	Paediatric	NA	
	Psychiatry	0.12(0.05-0.29)	
	Other	0.58(0.33-1.03)	
Surgery since admission	No Surgery *	1.00	<0.0001
	Surgery	1.35(0.70-2.59)	
	Minimum invasive surgery	2.49(1.07-5.76)	
Length of Stay	0-2 Days*	1.00	<0.0001
	3-5 Days	2.80(1.53-5.14)	
	6-10 Days	8.07(4.70-13.84)	
	11-23 Days	15.13(8.94-25.6)	
	24+ Days	22.37(13.11-38.18)	

Table III –The prevalence estimates associated with the interaction terms within the model. Minimally invasive surgery ,(MIS).

Category	Variable	Total	HAI= Yes	Prevalence	95% CI	P-value
SIMD	1st quintile: surgery	251	16	6.40	4.00-10.10	0.0071
	2nd quintile: surgery	265	11	4.10	2.30-7.30	
	3rd quintile: surgery	326	23	7.00	4.70-10.40	
	4th quintile: surgery	373	36	9.70	7.10-13.10	
	5th quintile: surgery	481	42	8.70	6.50-11.60	
	Missing SIMD: surgery	251	32	12.70	9.20-17.40	
	1st quintile: MIS	82	12	14.60	8.06-23.90	
	2nd quintile: MIS	88	8	9.10	4.70-16.90	
	3rd quintile: MIS	105	3	2.90	1.00-8.10	
	4th quintile: MIS	112	4	3.60	1.40-8.80	
	5th quintile: MIS	139	14	10.10	6.10-16.20	
	Missing SIMD: MIS	51	6	11.80	5.50-23.40	
	1st quintile: No surgery	1033	43	4.20	3.10-5.60	
	2nd quintile: No surgery	1249	55	4.40	3.40-5.70	
	3rd quintile: No surgery	1527	53	3.50	2.70-4.50	
	4th quintile: No surgery	1873	57	3.00	2.40-3.90	
	5th quintile: No surgery	2293	99	4.30	3.60-5.20	
	Missing SIMD: No surgery	980	32	3.30	2.30-4.60	

Figures





Legends

Figure 1 - Back to Back histogram showing the age distribution of patients stratified by sex n=11559

Figure 2 –HAI prevalence and SIMD quintile. HAI prevalence increases with deprivation quintile in patients undergoing surgery. A U-shaped distribution, with high prevalence in lowest and highest quintile, is seen for patients undergoing minimally invasive surgery (MIS). This is compared to a baseline of patients who do not undergo surgery, no fluctuation in HAI prevalence is observed.