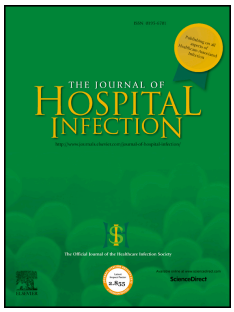
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Multi-centre point prevalence survey of hospital-acquired infections in Ghana

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TITLE PAGE

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ABSTRACT

Background. There is a paucity of data describing hospital acquired infections (HAIs) in Africa.

Objective. To describe the prevalence and distribution of HAIs in acute care hospitals in Ghana.

Methods. Between September and December 2016, point prevalence surveys were conducted in participating hospitals using protocols of the European Centre for Disease Prevention and Control. We reviewed medical records of eligible inpatients at or before 8am on the day of survey to identify HAIs present at the time of survey**.**

Findings. Ten hospitals were surveyed, representing 32.9% of all acute care beds in government hospitals. Of 2107 inpatients surveyed, 184 HAIs were identified among 172 patients, corresponding to an overall prevalence of 8.2%. The prevalence values in hospitals ranged from 3.5 to 14.4% with higher proportion of infections in secondary and tertiary care facilities. The most frequent HAIs were surgical site infections (32.6%), bloodstream infections (19.5%), urinary tract infections (18.5%), and respiratory tract infections (16.3%). Device-associated infections accounted for 7.1% of HAIs. For 12.5% of HAIs, a microorganism was reported; the most isolated microorganism was *Escherichia coli*. Approximately 61% of all patients surveyed were on antibiotics; 89.5% of patients with an HAI received at least one antimicrobial agent on the day of survey. The strongest independent predictors for HAI were the presence of invasive device before onset of infection and duration of hospital stay.

Conclusion. We recorded a low HAI burden compared to findings from other low and middle income countries.

Keywords: hospital-acquired infection, prevalence, Ghana

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INTRODUCTION

Globally, hospital acquired infections (HAIs) are the most frequent adverse event to occur during hospitalization [1,2], and are the cause of extended admissions, increased medical costs and marked morbidity and mortality[3–5]. Continued improvements in patient safety depend on a comprehensive understanding of the local epidemiology of HAIs. Reliable data on HAIs is scarce in low resourced countries and it is likely that existing data underestimate the true burden[6]. Available data describe an HAI prevalence rate of 15.5 per 100 patients in developing countries [6]. In sub-Saharan Africa these infections are suspected to be widespread [1]. High rates of HAIs persist due to lack of national infection prevention and control (IPC) policies, IPC personnel, and poor adherence to existing HAI guidelines [1].

Elimination of HAIs is a priority of the Ministry of Health in Ghana, as has been recently demonstrated by an update of the policy and guideline document IPC[7]. The Ghana Health Service emphasises the importance of IPC through campaigns on water, sanitation and hygiene. Despite these efforts, there is currently no existing surveillance system to provide estimates of the burden of HAIs across acute care patient populations in Ghana. The most recent estimate of a 6.7% HAI prevalence derives from a single-centre study published in 2009[8]. To address this knowledge gap, we conducted a large-scale multicentre HAI point prevalence survey to determine the prevalence and distribution of HAIs in acute care hospitals. The findings provide a global picture of the epidemiological situation in the country and serve as a baseline for the evaluation of future IPC interventions in Ghana.

METHODS

Study design and settings

We conducted a country-wide point-prevalence study at 10 acute care hospitals, surveying all units/departments at each facility. The hospitals were selected from 10 geographically distinct regional health directorates in the country. In Ghana, there are 3 teaching hospitals, 10 regional hospitals, and about 162 district hospitals [9]. The Ghana Health Service reported a bed occupancy rate of 60.4% (n=8,195) for a total of 12806 bed capacity for all government hospitals in 2017[9]. Representative samples of acute care hospitals were drawn across Ghana (Figure 1) by applying a systematic random sampling to the national list of hospitals ranked according to size and hospital type (teaching hospitals, regional hospitals, and district hospitals) as per guidelines of the European Center for Disease Prevention and Control (ECDC)[11]. The ECDC protocol provides a validated and standardized Europe-wide consensus tool that can be implemented in settings with limited network connectivity, and is thus suitable for use in resource-constrained settings. Briefly, the hospital list for each directorate was ranked in ascending order of the number of beds. A sampling interval k was obtained by dividing the total number of hospitals within each category by the number to be sampled. One hospital was surveyed per directorate. A random number i was selected between 1 and k. For each regional health directorate, the i^{th}+k hospital in the ascending order list of hospitals was selected to constitute the survey site for that region. The invitation for hospitals to participate in the survey was sent in July 2016 to hospital directors. Participation was voluntary. The survey was conducted from September 19 to December 2, 2016. The study received approval from the Ethical Review Committees of the Ghana Health Service (GHS-ERC 08/05/2016) and the Institutional Review Board of KBTH (KBTH-STC/IRB/00044/2016). Informed consent was

waived for the conduct of the study. We de-identified patients from study data to ensure anonymity. Arbitrary numbers were allotted to all data assigned to the study.

Patient selection

Inpatients of any age admitted and monitored for more than 24 hours at the included hospitals were eligible for inclusion in the study. Patients attending outpatient areas, accident and emergency departments, those who had been admitted for under 24 hours, and those on rehabilitation units were excluded. The medical records of inpatients at or before 8am on the day of survey at each participating hospital were reviewed by the study team within 12-hours. For hospitals with large bed capacity (> 1000), the total time frame for data collection at all wards of a single hospital did not exceed one week.

Data collection personnel and tools

Study information was collected manually on standardized data forms. Two teams collected data from each hospital: a primary team of research investigators from the HAI Ghana research team and a secondary team of selected group of health professionals (members of the quality assurance or infection control team) from each hospital. The secondary teams were constituted to build capacity of participating hospitals to conduct future HAI prevalence surveys. The primary team reviewed medical records at each hospital and identified and collected information on patients who were receiving antimicrobial agents for the treatment of active infections or for no documented reasons using ECDC surveillance definitions[11]. Data collected from the medical and nursing records and other relevant charts were interpreted with the help of attending physicians to determine whether patients had an HAI. Medical records of patients that did not fulfill case definition for HAIs were reviewed by the secondary team for data extraction. The secondary team received training in conducting a HAI survey. Training sessions were concluded

with a pilot point-prevalence survey at selected hospital wards to allow for remedial action. Standardized training packages were developed and made available for use by participating hospitals for future surveys. Data were collected on hospital characteristics including ward type and size, number of beds and the number of patients admitted in each ward at the time of survey. Patienhat-based variables included age, gender, surgery since admission, presence of indwelling devices, patients' antimicrobial usage, presence of active HAI, results of routine microbiology tests performed, and the McCabe score. The McCabe score categorizes the severity of underlying medical conditions into non-fatal disease (expected survival at least five years); ultimately fatal disease (expected survival between one and five years); rapidly fatal disease (expected death within one year); and unknown[11]. The specialty of the main disease of the patient or of the consulting physician in charge of the patients was captured as consultant specialty.

Case definitions

We defined HAI according ECDC guidelines[11]. An active infection was reported when signs and symptoms were evident on the survey day (with or without laboratory results) and patient was receiving corresponding antibiotic treatment. Patients were considered infected even when signs and symptoms were no longer present but the patient was still receiving treatment for that infection on the date of the survey. In this case, the signs and symptoms present from the start of antibiotic treatment until survey day were checked to verify whether an infection was hospital-acquired. An infection was hospital-acquired when the onset of the signs and symptoms was after 48 hours of the current admission; or became apparent within 48 hours of admission, but the patient had been discharged from an acute care hospital less than 48 hours before the current admission[11]. For surgical site infections, the definition included infections that occurred up to 30 days after surgical intervention and affecting either the incision or deep tissue at the operating

site, or infections related to an implant that occurred within a year. Device-associated HAI was recorded for urinary tract infections (urinary catheter in place within seven days preceding HAI onset), bloodstream infections (vascular catheter in place within 48 hours before HAI onset) and pneumonia (intubation within 48 hours before HAI onset).

Statistical analysis

Data was analysed with the use of ACCESS (Microsoft Office 2016) and Statistical Package for Social Sciences (SPSS, Version 21.0). The point prevalence of HAIs was reported as the percentage of patients with at least one HAI over the total number of patients. For descriptive statistics we calculated the prevalence with 95% confidence interval (95% CI), mean ± standard deviation (SD), or median with interquartile range (IQR) where appropriate. Univariate and multivariate analyses were carried out to identify independent risk factors associated with HAIs. A multivariable logistic regression with linear or restricted cubic splines was used to model the association between the proportion of HAI and duration of hospital stay before survey date.

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RESULTS

Data were collected from 2 teaching hospitals, 3 regional hospitals, and 5 district hospitals. Overall, 4208 acute care beds were included in this study, representing 32.9% of the total bed capacity for government hospitals in Ghana. Patient-based data were collected for a total of 2107 inpatients, representing 50.1% of the total bed capacity of participating hospitals.

Hospital and patient characteristics

Of the hospitals surveyed, 5 were primary, 3 were secondary, 2 were tertiary and none was a specialised facility. The median bed-size of the included hospitals was 304 beds (range 139 to 1533 beds). The overall bed occupancy rate was 59.1%. Only 1 of the participating hospital had an infection control nurse, and none had an infection control doctor. There were no active surveillance programs on HAIs in any of the participating hospitals. The median age of the patients surveyed was 26 years. This varied from 1 day to 90 years (IQR: 2-46 years). Males comprised 43.5% of total patients surveyed. The mean length of stay from admission until the survey date in our study was 17.3 (±7.3) days (range 2.1 to 33.1 days; median 11 days; interquartile range, IQR: 3.4 -20.6 days). The median length of stay of patients with HAI was 6 days (IQR, 4 – 16 days) until onset of infection and 12.5 days (IQR, 7 - 23 days) until the time of survey. The median length of stay until the survey date in patients without HAI was 3 days (IQR, 2 – 9 days).

Prevalence of hospital acquired infections

In total, 184 infections in 172 patients fulfilled the criteria of HAI, corresponding to a point prevalence of 8.2% (n=172/2107; 95%CI, 7.1 to 9.4). Overall, 161 (93.6%) patients had one HAI. The remaining 11 patients had multiple HAIs; 10 had two and 1 had 3 HAIs on the day of the survey. The HAI prevalence differed across hospitals (Figure 1) and within each hospital category (Figure 2). Across tertiary hospitals, the HAI burden was 9.2%, with a median ward

prevalence of 8.9%, and IQR of 5.2–14.3%. A similar distribution was observed in secondary hospitals: HAI prevalence, 9.5%; median ward prevalence, 7.0%; and IQR, 4.7-14.8%. Primary hospitals had a significantly lower HAI prevalence of 5.2%, with a median ward prevalence of 2.1%, and IQR of 1.1–5.4%. The most frequently reported HAI types were surgical site infections (n=60, 32.6%), bloodstream infections (n=36, 19.5%), urinary tract infections (n=34, 18.5%), and respiratory tract infections (n=30, 16.3%) (Table I). The HAI prevalence was highest among patients admitted to surgical departments (Figure 3), where 11.2% (n=58/517) of patients had at least one HAI compared with an average of 7.2% (n=114/1590) for all other specialties combined.

Device-associated HAIs and origin of infection

Hospital acquired urinary tract infections were device-associated in 17.6% (n=6/36) of the cases and pneumonia in 3.2% (n=2/30). 86.1% (n=31/36) and 13.8% (n=5/36) of patients with bloodstream infections respectively had peripheral and central vascular catheters present in the 48 hours preceding infection. The bloodstream infections were secondary to another infection site in 16.7% (n=6/36) of cases [respiratory tract infection (n=4/6); skin and soft tissue infection (n=2/6)]. For 83.3% (n=30/36) of bloodstream infections, the source of infection was unknown. Of the HAIs identified, 159 (86.4%) were related to the current hospital stay and occurred in 147 patients. The HAIs originated from another hospital facility in 25 (13.6%)cases, and were all present at the time of admission. These included 10 (40%) surgical site infections, 6 (24%) urinary tract infections, 3 (12%) respiratory tract infections, 3 (12%) bloodstream infections, 2 (8%) skin and soft tissue infections and 1 (4%) gastrointestinal tract infection.

Causative pathogens and antibiotic use

For 12.5% (n=23/184) of HAIs a microorganism was reported, ranging from 35.3% (n=12/34) in

urinary tract infections, 10.0% (n=6/60) in surgical site infections, and 11.1% (n=4/36) in bloodstream infections, to 1.9% (n=1/54) in all the other HAI types (Table II). The most frequently isolated microorganisms from HAIs was *Escherichia coli* (n=4/23). Meticillin resistance was not reported in any of the *Staphylococcus aureus* isolates with known susceptibility data. 84.6% (n=11/13) of Enterobacteriaceae were resistant to third-generation cephalosporins. Two out of 5 Gram-negative isolates tested were meropenem-resistant. Overall, 61.3% (n=1291/2107) of the patients surveyed were treated with antibiotics, whilst 89.5% (n=154/172) of patient with HAI received at least one antimicrobial agent on the day of survey. Antibiotic use in patients without documented HAIs was 58.8% (n=1137/1934). In primary hospitals, 59.9% (n=402/671) of the surveyed patients were treated with antibiotics, compared to 76.5% (n=317/494) and 60.8% (n=572/941) for secondary and tertiary hospitals respectively. Data on antibiotic prescription patterns and indication for use will be published elsewhere.

Patient Risk factors

The presence of relevant invasive device prior to HAI onset, and length of hospital stay ≥15 days were strongly associated with HAI in the univariate analysis (Supplementary Table I). In the final multivariate model, patients admitted in a primary care hospital were significantly less likely to develop HAIs (Table III). The strongest independent predictors for HAI were observed for the presence of relevant invasive device before onset of infection, and for duration of hospital stay before HAI survey. The relationship between HAI and duration of hospital stay was best described by linear spline functions (Figure 4) incorporating three breakpoints at 6, 10 and 20 days of hospital admission. The adjusted odds ratios can be interpreted as the odds of protection against HAI acquisition decreasing at a rate of 4% from date of admission (day 0) to day 6, followed by increasing HAI levels at varying rates thereafter (here, the odds of HAI acquisition

1 increases by 9% from day 6 to 10, with a further 17% increase from days 10 to 20. The rate of
2 acquiring an HAI nearly doubles after day 20).

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DISCUSSION

This paper represents the first multi-center point prevalence study of HAIs from Ghana, and includes data from patients at various levels of health service delivery in different parts of the country. We found an overall 8.2% prevalence of HAIs, with the highest prevalence among surgical inpatients. The prevalence across the various hospitals ranged from 3.5% to 14.4% with higher proportion of infections found in secondary and tertiary care facilities. Our findings are comparable to findings from other studies conducted in Africa where the overall prevalence of HAIs has been found to be between 2.5% and 14.8% [1,2], and studies from Europe, Brazil and Vietnam with prevalence's of 7.2%, 10.2% and 7.8%, respectively [11–13]. A recent survey in Benin, however, reported HAI prevalence as high as 19.1% [14]. Our study was conducted using ECDC approved methodology, and direct comparison of our results to other studies is hampered by the differences in methodologies applied.

Surgical site, urinary tract and blood stream infections were the most common HAIs from this study. In the only previously reported point prevalence survey of HAIs in Ghana, surgical site infections accounted for 39.3% of all HAIs [8]. In a recent survey of abdominal surgeries from the Tamale Teaching Hospital, 11.25% of all cases developed surgical site infections [15]. Surgical site infections represent a commonly reported HAI worldwide, especially, in low income countries as compared to urinary tract and respiratory tract infections which predominate in high income countries [16]. The higher prevalence of surgical site infections may be due to inadequate pre-, peri-, and post-operative hygienic practices in low-resource settings. In a recent study of the air quality in operating theatres at a tertiary care facility in Ghana, high levels of air contamination were detected and this correlated with high rates of door openings and number of people present during surgery [17]. High rates of surgical site infections may also be ascribed to

these infections being easier to recognize and diagnose in low-resource settings compared to other HAIs [2]. In our study, the reported values for surgical site infections may however be understated since a proportion of surgical site infections may occur post-discharge from hospital and may not have been reported [2,18]. Recognition of surgical site infections arising post discharge would require setting up a surveillance system that includes active follow up. The relatively high rates of surgical site infections reported in our study highlights the need to improve safety in surgical practice across hospitals in Ghana by implementing the new WHO guidelines for the prevention of surgical site infections [19].

Among patients surveyed, 61.3% were actively on antibiotics at the time of the survey, with higher rates of antibiotic use observed in secondary and tertiary hospital facilities than primary hospitals. Antibiotic use among patients who had HAIs (89.5%) was significantly higher compared to patients without documented HAIs (58.8%). We did not collect adequate clinical data to allow evaluation of whether antibiotic use was justified based on clinical indication. However, the high rates of antibiotic use are comparable to findings from countries with similar developmental profiles [13,14], and could be contributing to the high levels of antibiotic resistance recorded in Ghana [20–22]. Among patients with HAIs we found low records of documented associated pathogens. Notably, five of the hospitals that participated in the study did not have infrastructure for microbiological culture and antibiotic susceptibility testing. The data may further represent low utilization of microbiological diagnostics which may be linked with high out of pocket cost associated with performance of these tests. Lack of information of antibiotic susceptibility affects selection of appropriate agents for therapy as well as implementation of IPC precautions. Among sixteen Gram-negative isolates reported, we observed widespread resistance to commonly used beta-lactam, aminoglycoside and quinolone

antibiotics, and 2 of the 5 isolates tested were resistant to meropenem (Table II). Resistance appeared less common in Gram-positive bacteria but the low number of clinically relevant isolates does not allow any firm interpretation of these data. The findings should be interpreted with great caution as results were drawn from local laboratories and isolates were not stored for confirmation by our team. Nevertheless, the findings are alarming and point toward widespread antimicrobial resistance in Ghana as reported elsewhere [21,23,24].

The risk of acquiring HAIs in this study was associated with prolonged stay in hospital. The risk of HAI was however low for patients admitted in primary hospital facilities compared to secondary and tertiary hospital facilities. This could be explained by secondary and tertiary facilities being more likely to provide complex care to critically ill patients; with more frequent use of devices such as central venous catheters and artificial ventilators usually associated with the development of HAIs. None of the hospitals enrolled in our study had an infection prevention and control doctor, only one hospital had a full time infection control nurse, and none had an active infection control team. Several of the hospitals made use of quality assurance teams to perform the role of infection control teams. This state of affairs persists despite the availability of a national infection prevention and control policy document, which stipulates the implementation of all the core components of infection prevention and control [7,25]. Implementation of infection prevention and control activities is important to reduce the burden of HAIs, and should be adapted to the local context [26]. The standard at the surveyed hospitals is far from the goals of the infection prevention guidelines that recommend one full time infection control nurse per 100 beds in acute care centers and per 150-205 beds in long-term care facilities [27] or 250 beds as stipulated by WHO core component guidelines[28]. It is instructive to note that improving the

human resource personnel for infection prevention has been outlined as a global priority area [29].

This study has potential limitations. Although hospitals in our study represent different levels of hospital facilities, they may not be representative for all healthcare facilities in Ghana. Our prevalence figures may be underestimated, since we did not take into account infections that occur post discharge but may have originated from hospitals. Also the low rates may have been affected by the relatively low bed occupancy of 59% and the variable availability of microbiological culture results. Our findings are also based on folder review, which is prone to poorly recorded or incomplete data as well as absent information. A key strength of this study is that data was actively collected using international standardized tools and validated by a set of trained individuals leading to a reduction in the variability in case definition and detection.

Conclusions. In summary, we recorded an 8.2% prevalence of HAIs, this is low compared to findings from other low and middle income countries. Addressing the problem of HAIs in low resource countries may require significant investment and commitment to infection prevention and control, including training and deployment of infection control healthcare professionals as an additional strategy to help implement the numerous guidelines and recommendations.

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Conflicts of interests

None

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Author contributions

MJN, AKL, NON, EO, ABB, SB, GSM, JAO, CEL, APF, ND, SD, CB, CA conceptualized the study; participated in its design, acquisition of data; helped to draft the manuscript and revise it critically for important intellectual content. AKL, NON performed the statistical analysis. All authors have approved the final article. The authors are members of the HAI Ghana project group; with the developmental objective to reduce morbidity, mortality and cost related to HAI. The Ghana HAI project is an international multicentre and interdisciplinary research network that brings together academia (PhD students and Post-Doctoral fellows supervised by Ghanaian and Danish team of experts in the fields of clinical microbiology, interventional studies, cost analysis and ethnographic research), hospitals and policy makers who work in infection prevention and control. The project is hosted by the Department of Medical Microbiology, University of Ghana with institutional partners from the Institute of Statistical, Social and Economic Research, University of Ghana; Institutional Care Division, Ghana Health Service; Department of Public Health, Aarhus University; Department of Clinical Microbiology at Rigshospitalet, Denmark; Department of International Health, Immunology and Microbiology, University of Copenhagen, Denmark. The HAI project is at the present time conducting a

prospective surveillance of neonatal sepsis, surgical site infections and puerperal infections in line with health care priorities of the Ghana Health Service.

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Table I. Prevalence of hospital-acquired infection (HAI) by type among 2107 patients surveyed

HAI		Prevalence among total HAIs	(95% CI)	Prevalence among total surveyed patients	(95% CI)
Type	Number				
Surgical site infections	60	32.6	(26.2-39.7)	2.8	(2.2-3.7)
Bloodstream infections	36	19.5	(14.5-25.9)	1.7	(1.2-2.7)
Urinary tract infections	34	18.5	(13.5-24.7)	1.6	(1.1-2.3)
Respiratory tract infections	30	16.3	(11.6-22.3)	1.4	(1.0-2.0)
[a] Others					
Skin and soft tissue	10	5.4	(3.0-9.7)	0.5	(0.3-0.9)
Gastrointestinal infections	10	5.4	(3.0-9.7)	0.5	(0.3-0.9)
Ear, nose and throat	2	1.1	(0.3-3.9)	0.1	(0.02-0.3)
Central nervous system	1	0.5	(0.09-3.0)	0.1	(0.01-0.3)
Not specified	1	0.5	(0.09-3.0)	0.1	(0.01-0.3)
Total	184				

[a] CI, confidence interval; HAI, hospital acquired infection

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HAI pathogens	[a] UTI (n=34)	SSI (n=60)	BSI (n=36)	Others (n=54)	[b] Reported antibiotic susceptibility*
Gram negatives					
Acinetobacter species (n=1)	0	0	1	0	Mer-S; Cip-S; Cot-R; Cef-R
Citrobacter species (n=1)	1	0	0	0	Amk-S; Cip-R; Cef-R; Amo-clav-R
Klebsiella oxytoca (n=1)	1	0	0	0	Mer-S; Amk-S; Cip-R; Cef-R, Amo-clav-R; Nit-S
Proteus mirabilis (n=1)	1	0	0	0	Amk-S; Gen-S; Cip-R; Cxr-R; Cef-R; Tet-R
Other coliforms (n=2)	0	2	0	0	Cip-S (n=2/2); Lev-S (n=2/2); Gen-R (n=2/2); Amk-S (n=1/1); Chl-R (n=1/1); Pip/Taz-R (n=2/2); Cef-R (n=2/2)
Enterobacter species (n=2)	1	1	0	0	Mer-R (n=1/2); Amk-R (n=1/1); Cip-R (n=1/2); Cxr-R (n=1/1); Cef-R (n=1/1)
Klebsiella species (n=2)	2	0	0	0	Mer-R (n=1/1); Amk-R (n=1/1); Gen-R (n=1/1); Cip-R (n=2/2); Cxr-R (n=1/1); Lev-(n=1/1); Pip/Taz-R (n=1/1); Cot-R (n=1/1); Cef-R (n=2/2)
Pseudomonas aeruginosa (n=2)	0	2	0	0	Amk-s (n=2/2); Gen-R (n=2/2); Cip-R (n=2/2); Lev-R (2/2); Ceft-R (n=1/2)
Escherichia coli (n=4)	3	1	0	0	Amk-R (n=3/4); Gen-S (n=1/4); Cip-R (n=2/2); Lev-R (2/2); Cef-R (n=2/3);Nit-S (n=1/1); Chl-R (n=1/1);Cot-R (n=1/1); Pip/Taz-R (n=1/1)
sub-total (n=16)	9 (26.5)	6 (10.0)	1 (2.8)	0	
Gram positives					
Enterococcus faecalis (n=1)	1	0	0	0	Van-S; Amp-S; Lev-R
Enterococcus species (n=1)	1	0	0	0	Van-S; Cip-R; Lev-R
Staphylococcus aureus (n=1)	1	0	0	0	Ery-S; Gen-S; Chl-S; Tet-S; Cot-S.
Staphylococcus epidermidis (n=2)	0	0	1	1	Cip-S (n=2/2); Gen-R (n=1/1); Chl-S; Tet-S.
Streptococcus viridans (n=2)	0	0	2	0	Pen-S (n=1/2); Cef-S (n=1/1); Ery-R (n=1/2); Lev-R (n=1/2); Van-S (n=1/1)
sub-total (n=7)	3 (8.8)	0	3 (8.3)	1 (1.9)	
Total (n=23)	12 (35.3)	6 (10.0)	4 (11.1)	1 (1.9)	

Table II. Reported causative pathogens, according to type of infection

*The antibiotic susceptibilities may not be generally representative with the very few isolates reported

[a] UTI, urinary tract infection; SSI, surgical site infections; BSI, bloodstream infections; Others, respiratory tract infections, skin and soft tissues infections apart from surgical site infections, Central nervous system infections, gastrointestinal tract infections, and unspecified infections.

[b] -R, resistant; -S, susceptible; n = proportion of tested isolates that are susceptible or resistant to the indicated antibiotic; Mer, meropenem; Amk,amikacin; Gen, gentamicin, Cip, ciprofloxacin; Pip/Taz, piperacillin/Tazobactam; Pen, penicillin; Amp,

ampicillin; Cef, cefotaxime; Cxr, cefuroxime; Lev, levofloxacin; Van, vancomycin; Ery, erythromycin; Chl,chloramphenicol; Nit, nitrofurantoin; Cot, cotrimoxazole; Tet, tetracycline.

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Table III. Multivariable logistics regression analysis of risk factors associated with hospital-acquired infection (HAI) in patients

Patient Characteristics	Level	Adjusted odds ratio	95% confidence interval	P-value
Duration of hospital stay before HAI onset	1 day	2.78	2.08-10.18	<0.001
Surgery since admission	Yes/No	1.79	1.35-2.98)	0.001
Presence of any invasive device	Yes/No	5.03	4.77-13.35	0.001
Urinary catheter in place during hospitalization	Yes/No	1.76	1.13 -3.30	<0.001
Peripheral vascular catheter in place during hospitalization	Yes/No	1.73	1.22-2.57	<0.001
Patient/consultant specialty (Surgery)	Yes/No	1.81	1.26-2.59	0.001
Admission in a primary care hospital	Yes/No	0.37	0.33-0.71	0.010

*The predictive accuracy of the models evaluated by Hosmer and Lemeshow goodness-of-fit test was non-significant with P-value >0.05 suggesting that the model predicted accurately on average. The discriminatory power of the multiple logistic regression analysis as measured by the area under the ROC curve was 0.791. Stepwise modelling was adjusted for univariate variables with P-value <0.1

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FIGURE LEGENDS

Figure 1. Prevalence of hospital-acquired infection (HAI) across study hospitals categorized as primary, secondary and tertiary. (the width of the prevalence circle is proportional to the HAI burden)**.** Number of beds not included in survey (total of all in-patient beds excluded from the survey based on inclusion/exclusion criteria plus all other vacant hospital beds).

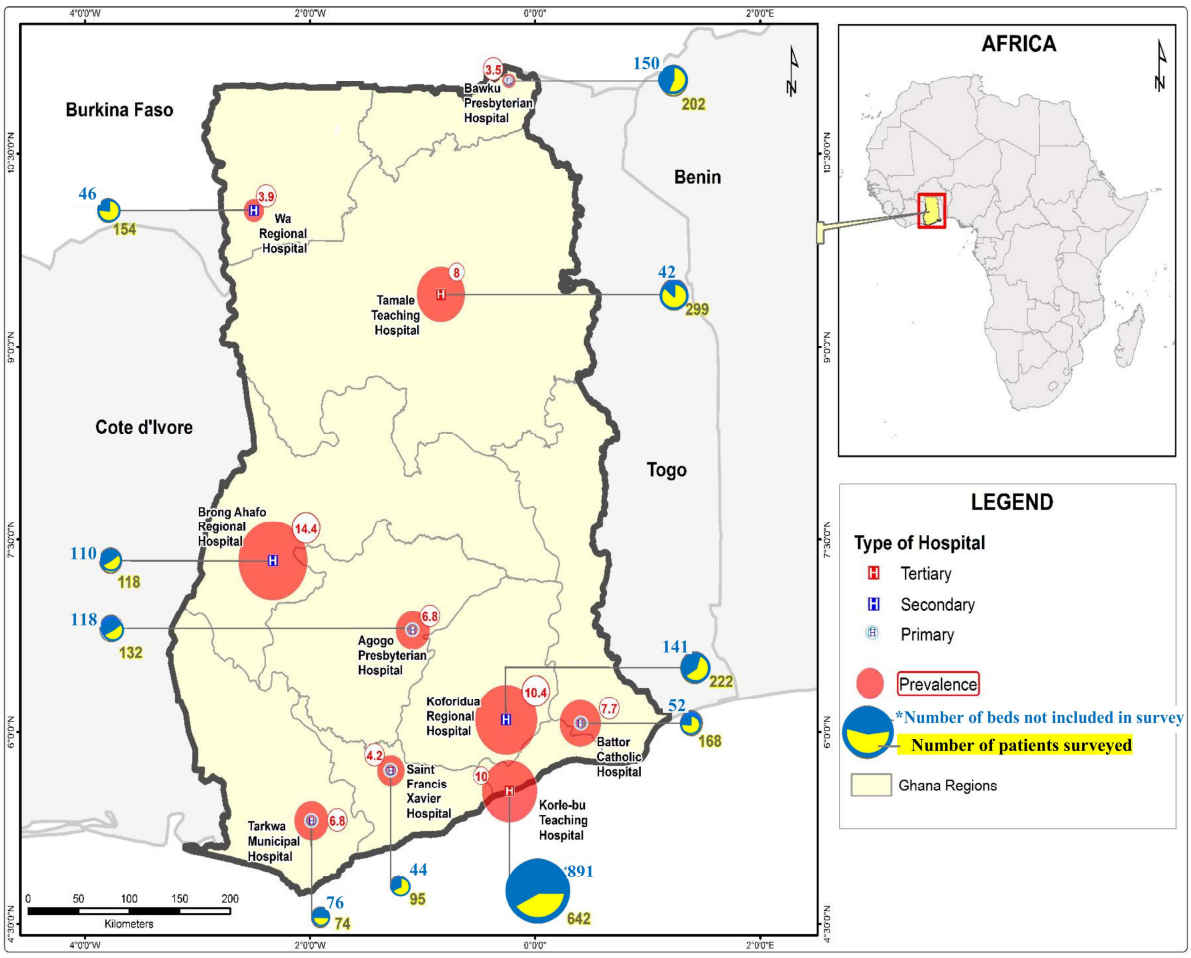
Figure 2. Distribution of hospital-acquired infection (HAI) prevalence by hospital types. The box shows interquartile range; Horizontal line in box shows median of the distribution; X denotes mean of distribution. Lower whisker shows 25 percentile or lower quartile; Upper whisker shows 75 percentile or upper quartile; HAI prevalence: primary hospitals < secondary hospitals = tertiary hospitals (*Marascuilo Post hoc:* Overall chi-square =11.44, P-value=0.003)

Figure 3. Prevalence of hospital-acquired infection (HAI) by type and speciality among 2107 surveyed patients**.** RTI, respiratory tract infections; UTI, urinary tract infections; SSI, surgical site infections; BSI, bloodstream infections; Other infection types: SST, Skin and soft tissue (apart from surgical site infections); GIT, Gastrointestinal Tract; ENT, Ear, Nose and Throat; CNS, Central Nervous System. Other specialities: ophthalmology, urology, nephrology, patients with specialty not indicated. 11 patients had >1 type of HAI: Surgical, 2 patients (all with SSI/RTI); Paediatrics, 3 patients (1 with UTI/SST, 1 with RTI/SST, and 1 with BSI/an unspecified infection); Medicine, 3 patients (1 with RTI/UTI, 1 with RTI/SSI, and 1 with SSI/BSI); Obstetrics and gynaecology, 3 patients (1 with SSI/UTI, 1 with SSI/BSI, and 1 with RTI/SSI/BSI)

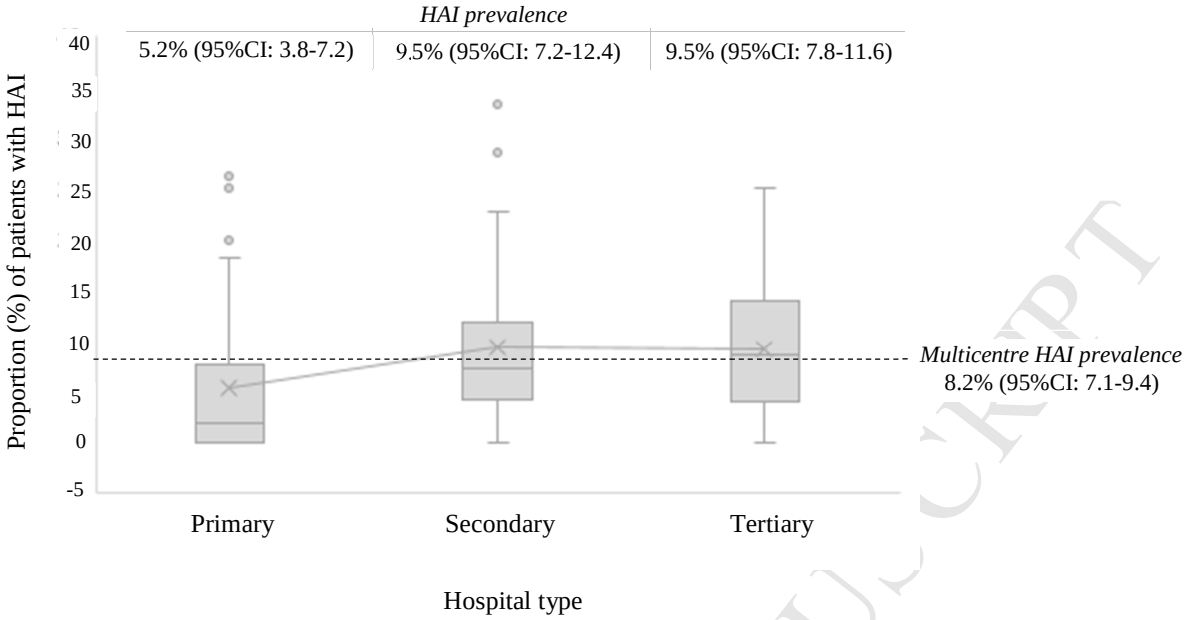
Figure 4. Changes in the odds of hospital-acquired infection (HAI) with length of hospital stay. Model is a linear spline function estimates shown on the logit scale based on the least Akaike's Information Criterion (Supplementary tables II and III).

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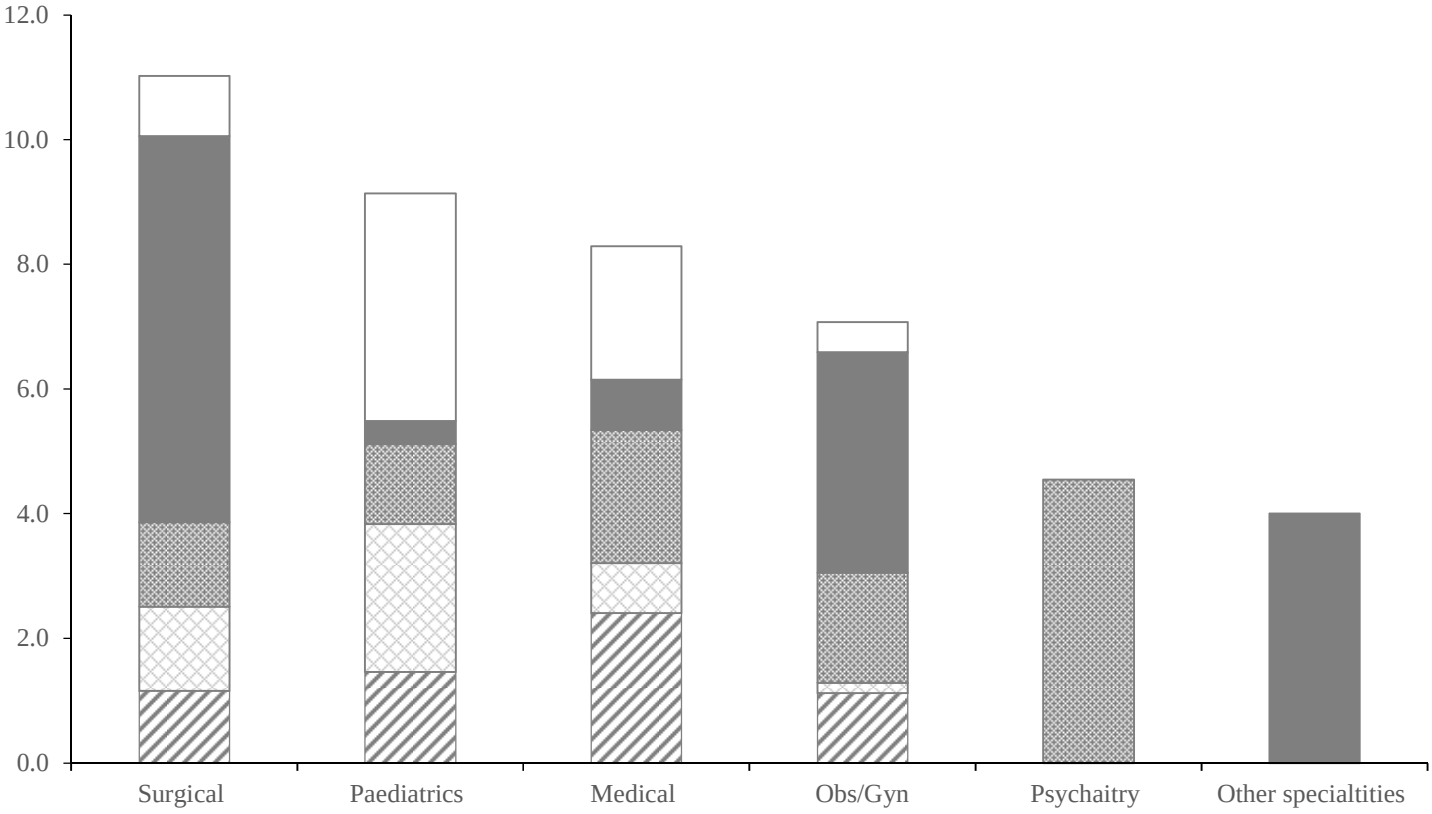


Figure 3

60 HAIs observed among 58 patients	47 HAIs observed among 44 patients	31 HAIs observed among 28 patients	44 HAIs observed among 40 patients	1 HAI observed	1 HAI observed
Surgical (n=517)	Paediatrics (n=547)	Medical (n=374)	Obstetrics and gynaecology (n=622)	Psychiatry (n=22)	Other Specialties (n=25)

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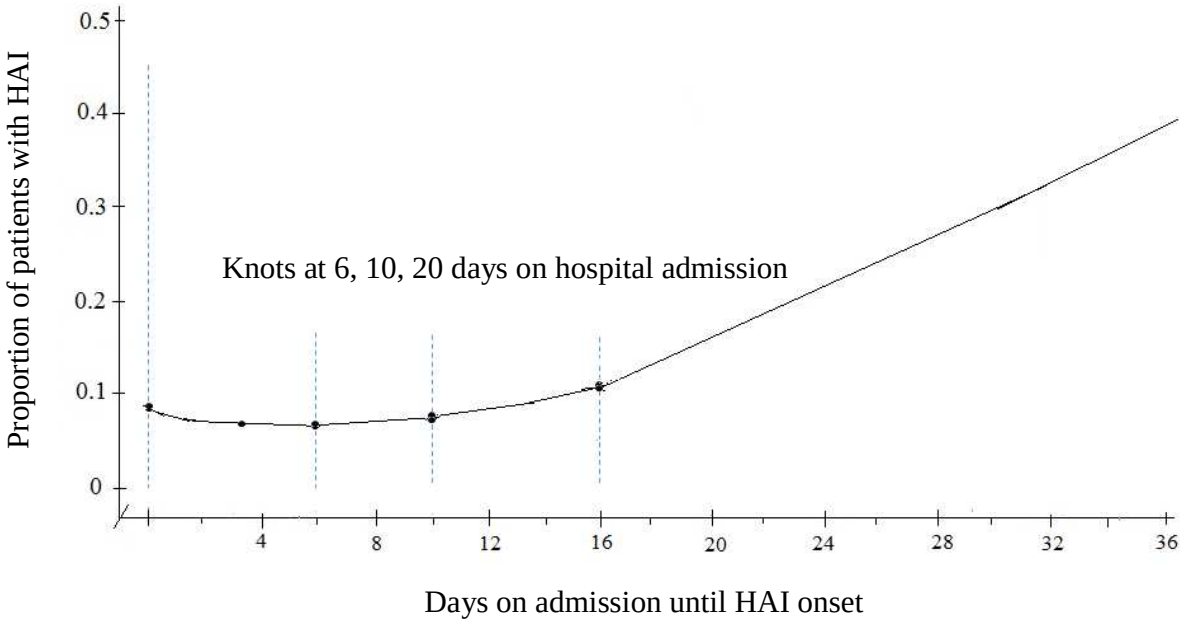


Figure 4

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