International Journal of Infection Control
www.ijic.info ISSN 1996-9783

ORIGINAL ARTICLE

Establishment of a hospital-acquired infection surveillance system in a teaching hospital in Rwanda

Stephanie Lukas[1,3], Unarose Hogan[2,3], Viatory Muhirwa[3], Caroline Davis[3,4], John Nyiligira[3,5], Onyema Ogbuagu [3,6], Rex Wong[3,4]

1. St. Louis College of Pharmacy, USA
2. New York University, USA
3. University Central Hospital of Kigali, Rwanda
4. Global Health Leadership Institute, Yale University, USA
5. University of Rwanda, Rwanda
6. Section of Infectious Diseases, Yale University, USA

doi: 10.3396/IJIC.v12i3.018.16

Abstract

Hospital-acquired infection (HAI) surveillance is a resource and time intensive practice that is challenging to implement in many low to middle income countries (LMIC). A quality improvement project was established to develop a surveillance system to monitor HAIs in the University Teaching Hospital of Kigali. A multi-disciplinary steering committee developed a new surveillance system based on the World Health Organization (WHO) HAI definitions. For the baseline point prevalence survey conducted by a trained surveillance team, HAI rates were reported as percentages of all individuals surveyed in a unit/ward with a HAI. Chi square and logistic regression analyses were performed to determine factors independently associated with the presence of a HAI. Two hundred and seventy-one (271) patients were surveyed comprising 89 males (28.6%) and 130 females (41.8%); gender data was missing for 52 individuals. The average age was 32.3 years. The overall HAI prevalence rate was 15.1%. HAI rates were highest in intensive care unit [ICU] (50.0%), Neonatal ICU (23.1%) and the Orthopaedics/Burn Unit (37.3%). Factors associated with an increased risk of developing HAIs were surgery within the past month (OR = 2.75, 95% CI: 1.40, 5.40), use of a urinary catheter (OR = 2.10, 95% CI: 1.05, 4.25), use of mechanical ventilator (OR = 3.14, 95% CI: 1.01, 9.74), and increased number of risk factors (OR= 1.50, P=0.03, CI =1.05 – 2.15). It is feasible in a low resource setting to establish a sustainable HAI surveillance program. The high rates of HAIs noted are worrying.

Keyword: healthcare associated infections; infection control; surveillance; prevalence; Rwanda

Corresponding Author

Rex Wong
University Central Hospital of Kigali, Rwanda
Email: rexwongyc@gmail.com

Background

Hospital-acquired infections (HAIs) are infections occurring at least 48 hours into a patient's hospital stay that were neither present nor incubating at the time of admission.[1-3] HAIs are critical safety concerns for patients, healthcare professionals and healthcare systems.[1-3] The negative consequences of HAIs are well documented and include increased patient morbidity and/or mortality; risk of disease among healthcare workers; and significant financial burden to patients, their family members and health care facilities.[4-10]

Studies have shown that institution-based infection surveillance can support evidence-based prevention and control programs in order to reduce HAI prevalence.[11-12] However, HAI surveillance is a resource and time-intensive practice that is challenging to implement in many low to middle-income countries (LMICs),[6-8] frequently due to absent or lacking microbiology laboratory infrastructure to support HAI diagnoses.[1] Furthermore, patient records may be incomplete, inconsistent and, therefore, unusable for HAI surveillance. The requirement for prolonged surveillance, specifically for surgical site infections, which can occur up to thirty days post-operatively, may be difficult to conduct. These challenges may lead to non- or under-detection of HAI's with resultant missed opportunities to institute the appropriate medical treatment for the patient with a HAI as well as identify rates and trends that would inform infection prevention and control (IPC) measures to reduce or prevent future cross-transmission between patients and healthcare staff.[6-9]

The prevalence of HAIs in LMICs ranges from 5% to 65% among hospitalized patients, with surgical site infections being the most common.[13-15] Higher HAI rates are typically observed in hospital units where patients require a high intensity of care and undergo more frequent medical procedures and / or are exposed to medical devices such as intensive care units (ICU), neonatal ICU and surgical wards.[16-21]

We observed in our institution that HAI prevalence data were not being accurately collected due to insufficient resources and expertise. Accordingly, a quality improvement project was established to develop a cost-effective and sustainable system to track, monitor and report HAIs. This effort was part of Rwanda's Human Resources for Health (HRH) program, a national initiative sponsored by the United States government and directed by the Rwandan Ministry of Health to expand and develop its hospital management, physician, and nursing workforce.[22] Using a peer-mentoring model, the HRH program partners United States and Rwandese physicians, nurses and hospital managers supported by a mandate that includes developing and implement collaborative projects with the goal of improving healthcare services. This paper describes the process of developing and implementing a HAI surveillance system and reports its results.

Methods

Setting

The HAI surveillance system was established in Rwanda's largest teaching hospital, the University Teaching Hospital of Kigali, which serves as the primary referral hospital for the entire country and receives patients from more than 40 district hospitals. The hospital has 445 beds and an average occupancy rate of 72%. Prior to this quality improvement initiative, a single person – the hospital's appointed IPC coordinator – had been responsible for tracking and reporting all HAIs. The IPC coordinator is a clinical nurse and was assigned to the quality improvement department of the hospital to create and enforce hospital infection control policies, monitor HAIs, and monitor and respond to disease outbreaks. The historically reported HAI rate was not a complete or accurate reflection of the problem.

Overview of approach

A multi-disciplinary HAI steering committee was convened to develop a new HAI surveillance system. The HAI steering committee developed a surveillance system based on WHO definitions and created a tool for data collection.[1] A survey team was formed and trained to conduct surveillance. A point-prevalence survey was conducted on all inpatient units at baseline and continued to monitor changes in infection rates in subsequent monthly assessments planned after the initial baseline surveillance. Surveillance results were reported to department leadership and senior hospital management, and used to prioritize IPC efforts.

The HAI steering committee

The HAI steering committee was formed in August 2013. The committee included the hospital's appointed IPC coordinator, the hospital's IPC Committee chairperson, an HRH IPC nurse, an HRH infectious disease specialty physician, and three HRH health managers. The HAI steering committee set out to develop a system to assess the rate of HAI hospital-wide.

Developing the surveillance tool

At the core of any HAI surveillance system is the need for uncomplicated and accurate diagnosis of HAIs. The United States Centers for Disease Control and Prevention (CDC) offers standardized HAI definitions;[23] however, LMIC often lack appropriate laboratory support to meet definition criteria. Simplified definitions of HAIs, have been offered by the World Health Organization (WHO) for use in resource limited contexts that are primarily based on clinical diagnoses.[1] The team adapted the WHO's simplified criteria for HAI detection in lower-income countries and decided to use a point-prevalence surveillance system.[1,24] Meeting the WHO criteria for HAI diagnosis, requires less technology and less laboratory support than other surveillance criteria.

The primary methodology adopted in many LMIC when initiating HAI surveillance is a cross sectional, point-prevalence surveillance approach.[25] Point-prevalence surveillance methods have advantages over prospective surveillance in terms of less resources and capacity required and can be very useful in determining trends and comparisons in infection prevalence and is also easy for comparison between surveys.[25]

At our institution, prospective surveillance was considered by the HAI steering committee, however, the limited availability of the laboratory resources and human capacity made this a less-preferred approach. A point-prevalence data collection tool was developed for use in all inpatient units. The tool is divided into four sections: basic patient demographics, risk factors for HAIs, clinical features of specific HAIs, and laboratory data. Data sources include medical records, laboratory results, and where necessary, staff interviews to clarify the patients' status.

Infections developed 48 hours or more into a hospital stay were recorded as HAIs.[1-3] The tool was piloted first on the 52-bed orthopaedics/burn unit and adjusted thereafter based on the feedback and lessons learned from the pilot implementation.

HAI survey teams

To obtain point-prevalence data from all inpatient units on a regular and sustainable schedule, a team of surveyors was created and trained with the long-term goal of enhancing infection prevention and control interest and expertise among a diverse group of healthcare staff and acting as champions for IPC systems in the facility. The hospital IPC Committee and hospital senior management team recommended survey team members based on their work experience, performance, and clinical or research interests. The majority of surveyors were nurses, most of whom occupied a managerial position in the facility. The training, conducted by select members of the IPC committee, included the importance of HAI surveillance, the point-prevalence survey process, HAI criteria, the use of the surveillance tool, data reporting process, and patient confidentiality. The training consisted of lecture-style instruction, mock-case studies to familiarise the team with the form and then validation of each team member's results on their first day of surveillance as well as random validation by the hospital's IPC coordinator throughout the baseline collection.

The HAI survey team member role was to collect HAI-related data from patient files, laboratory results and/or medical team; communicate with unit/ward staff regarding the HAI surveillance process; and help disseminate the results/findings to the appropriate unit/ward leadership, staff and other stakeholders. Survey team members were never assigned to their home units/wards to limit conflicts of interest or bias.

Surveillance process

The hospital's IPC coordinator led the surveillance and communicated with all unit/ward staff regarding the HAI surveillance process. Every month, under the IPC coordinator's direction, survey teams spent two days conducting HAI surveillance on their assigned hospital's inpatient units. The teams collected surveillance data from the entire hospital from

September 2013 to March 2014. Data collected were recorded on the standardized surveillance form. The survey team members maintained strict confidentiality of data and results. According to data collected on each inpatient based on the WHO criteria, the survey team made determinations on the presence of HAIs.

Dissemination and utilisation of surveillance results

After each inpatient unit/ward was surveyed, the hospital's IPC coordinator compiled and analysed the data to calculate the types and rates of HAI. Results were communicated to unit/ward leadership, staff, senior management team and other stakeholders. Results were also used to prioritise IPC initiatives, primarily through the work of the hospital's IPC Committee.

Data analysis

Patient demographics were reported as simple frequencies within groups of individuals with or without HAIs. Overall and location-specific HAI rates were reported as percentages of all individuals surveyed in the hospital or unit/ward respectively with any HAI. Chi square tests were performed to determine the association between the presence of a HAI and patient demographic and clinical characteristics. Logistic regression model was also used to determine the association of gender, age group, individual risk factors, and number of risk factors as independent variables to the presence of HAI as the dependent variable. Odds ratio with 95% confidence intervals (CIs) were computed with the 2-sided P-value set at <=0.05 for statistical significance. All analyses were conducted using SPSS software version 20 (SPSS, Inc., Chicago).

Ethical consideration / approval

This study was approved by the hospital ethics committee (ref number EC/ CHUK/ 006/ 16).

Table I. HAI rates by patient demographic information

		HAI		No infection		Total	
		n	%	n	%	n	%
Sample	**N = 271**	41	(15.1%)	230	(84.9%)	271	
Gender[a]	**Male**	9	(41%)	80	(42%)	89	(41%)
	Female	13	(59%)	117	(58%)	130	(59%)
	Total	**22**		**197**		**219**	
Age	**< 1**	3	(8%)	1	(0%)	4	(2%)
Group	**1 – 9**	7	(18%)	22	(10%)	29	(11%)
	10 – 19	3	(8%)	24	(11%)	27	(10%)
	20 - 29	8	(21%)	52	(24%)	60	(23%)
	30 – 39	6	(15%)	31	(14%)	37	(14%)
	40 - 49	6	(15%)	34	(15%)	40	(15%)
	50 - 59	2	(5%)	19	(9%)	21	(8%)
	60+	4	(10%)	28	(13%)	32	(12%)
	Total	**39**		**220**		**259**	

[a]*Missing information*

Results

Patient demographics and HAI epidemiology

Two hundred and seventy-one (271) patients were surveyed during the baseline implementation phase comprising 89 males (28.6%) and 130 females (41.8%); gender data was missing for 52 individuals. The average age was 32.3 years; 36.6 years for males and 29.4 years for females. Of the patients surveyed, 41 met criteria for the presence of a HAI, resulting in an overall HAI prevalence rate of 15.1% (Table I). Highest HAI rates were observed in ICU (50.0%), NICU (23.1%) and the orthopaedics/burn Unit (37.3%) (Tables II and III).

There were similar rates of HAI between males and females, and across different age group strata (Table IV). Factors found to be significantly associated with increased risk of developing HAIs included surgery within the past month (OR = 2.75, 95% CI: 1.40, 5.40), use of a urinary catheter (OR = 2.10, 95% CI: 1.05, 4.25), use of mechanical ventilator (OR = 3.14, 95% CI: 1.01, 9.74), and other miscellaneous risk factors such as use of chest drain, naso-gastric tube, or external fixator (OR=3.93, CI: 1.88 - 8.19). The probability of HAI is higher with the increased number of risk factors (OR= 1.50, P=0.03, CI =1.05 - 2.15) (Table IV).

Discussion

By adopting a point-prevalence HAI surveillance system, the IPC team was able to obtain an accurate hospital-wide HAI rate for the first time. The method was appropriate for a lower-resource setting as it did not rely solely on laboratory testing. The overall HAI rate (15.5%) is comparable to that found in other resource-limited countries.[13-15] The risk factors identified are also consistent with those described in other studies.[16-21] Patients who had surgery within the past one month, used urinary catheters and/or mechanical ventilators experienced a higher risk of HAIs. Patients who had more risk factors experienced a higher risk of HAIs;

As has been reported by other studies, our surveillance results show the hospital's ICU and orthopaedics/burn units to have higher HAI rates. In these high-dependent care units, patients are more likely to be critically ill and receive more invasive procedures and indwelling lines, which may lead to more HAIs. It is plausible that lax or poor adherence to infection control procedures by healthcare staff also promote high HAI rates observed in these settings.

Table II. Baseline HAI rates by department

Ward	N	Number of HAIs	HAI Rate
Neonatal Intensive Care Unit	13	3	23.1%
Intensive Care Unit	4	2	50.0%
Maternity	35	1	2.9%
General Surgery	33	4	12.1%
Internal Medicine	68	5	7.4%
Custodial	6	0	0.0%
Private	2	1	50.0%[a]
Neurology	16	3	18.8%
Ophthalmology	7	1	14.3%
Pediatrics	36	2	5.6%
Orthopedics/Burn	51	19	37.3%
Total	271	41	15.1%

[a] *The sample size for private ward was too small to draw valid conclusion HAI*

Table III. Hospital acquired infection frequency by types of infection

	N	%
Surgical Site Infection	19	(31%)
Non-Surgical Wound Infection (e.g., burns, other skin or soft tissue infections)	17	(27%)
Pressure sore	4	(6%)
Vascular Catheter Infection	2	(3%)
Septicemia	8	(13%)
Urinary infection	6	(10%)
Respiratory infection	2	(3%)
Other infections (eye, umbilical)	4	(6%)
Total	**62**	

The concordance of our baseline HAI surveillance with the HAI rates and patterns reported from other developing countries supports a point-prevalence HAI surveillance system strategy that uses clinical criteria, as being effective in measuring the HAI rates. Though the methodology is relatively simple and less resource-intense compared to other strategies, it does require survey team training and supervision as well as investments of time. For example, the surveillance system requires surveyors to spend two days a month collecting data. Such time commitment can be demanding for individuals who already have heavy workloads.

The data collection process requires surveyors to audit and extract information from patient medical records. This process can be challenging as clinical documentation is often incomplete, resulting in missing information in the surveillance data set. In some instances, surveyors had to seek out other sources of clinical information, such as from physicians and nurses. Unfortunately, these processes are error-prone and thereby impact data accuracy.

Other limitations and challenges of our surveillance approach are worth highlighting. While WHO's simplified criteria is a useful tool in limited-resource settings without ample access to sophisticated diagnostic techniques, it does not take into account microbiological data to support HAI determinations. Also, hospital acquired surgical site infections may be underreported as by definition they can occur up to 30 days post-operatively, but most surgical patients are discharged by that point and were only represented in this sample prior to discharge or if readmitted during the surveillance timeframe. Additionally, repeated point-prevalence surveys are snapshots of various moments in time, and therefore may be influenced by seasonality, patient census (especially in wards with few beds such as this hospital's ICU), lab resources, and/or staff issues such as workload. Depending on the number of surveyors and the schedule of surveillance, the time required to complete a full cycle of hospital surveillance could be very long, making it difficult to repeat the survey frequently. Such an issue may pose a challenge to the system's sustainability or the results' timeliness.

Certainly a key to sustainability, is institutionalising a HAI surveillance process going beyond just the survey team and the HAI steering committee. Buy-in from hospital authorities would determine its long-term success. The widespread dissemination of HAI prevalence results to wards and hospital management provides opportunities to keep attention focused on expanding surveillance for and improving the rates of HAIs and provokes channelling more resources to improving IPC practices hospital-wide. However, in LMIC, this is unlikely to occur due to limited resources for addressing multiple and occasionally overwhelming healthcare challenges. This referral hospital has buy-in for the surveillance system at many levels including

Table IV. Prevalence of HAIs according to patient characteristics and risk factors

		HAI		No HAI		Adjusted Odds Ratio[a]	95% CI	P-value
		n	%	n	%			
Gender	Female	13	(10%)	117	(90%)	1.00	Reference	
	Male	9	(10%)	80	(89.9%)	1.42	(0.46 – 4.40)	0.55
Age group	< 1	3	(23.1%)	10	(76.9%)	1.00	Reference	
	1 – 9	7	(24.1%)	22	(75.9%)	2.58	(0.04-171.51)	0.66
	10 – 19	3	(11.1%)	24	(88.9%)	1.77	(0.03-96.27)	0.78
	20 - 29	8	(13.3%)	52	(86.7%)	1.25	(0.02-76.88)	0.92
	30 – 39	6	(16.2%)	31	(83.8%)	1.04	(0.02-48.73)	0.98
	40 – 49	6	(15.0%)	34	(85.0%)	0.85	(0.01-53.65)	0.94
	50 – 59	2	(9.5%)	19	(90.5%)	0.82	(0.01-50.93)	0.93
	60+	4	(12.5%)	28	(87.5%)	0.80	(0.01-60.36)	0.92
Risk Factor	HIV	2	(5.9%)	34	(15.2%)	0.35	(0.08 – 1.53)	0.145
	Cancer	0	(0%)	38	(15%)	0.85	(0.81 – 0.90)	0.185
	Neonate	3	(21.4%)	37	(14.5%)	1.61	(0.43 – 6.06)	0.474
	Intensive Care Unit	2	(50%)	38	(14.3%)	5.97	(0.82 – 43.69)	0.047
	Elderly (>60)	4	(12.9%)	35	(14.7%)	0.86	(0.28 – 2.61)	0.798
	Surgery within past 1 month	23	(24%)	18	(10.3%)	2.75	(1.40 – 5.40)	0.003
	Urinary catheter	20	(19.6%)	17	(10.4%)	2.11	(1.05 – 4.25)	0.034
	Intravenous catheter	33	(17.2%)	6	(7.8%)	2.46	(0.99 – 6.12)	0.048
	Mechanical ventilator	5	(33.3%)	35	(13.7%)	3.14	(1.01 -9.74)	0.038
	Other[b]	16	(32%)	23	(10.7%)	3.93	(1.88 – 8.19)	<0.001
Number of risk factors						1.50	(1.05-2.15)	0.03

[a]*Adjusted OR for risk factors used negative as reference group within each risk factor*
[b]*Included chest drain, nasogastric tube, external fixator*

the hospital leadership, but it will be the dedication of staff, the time allowed to them and the hospital's capacity to use these results to foster change that will make this system truly sustainable. An early sign of the positive impact of the instituted surveillance project is that the hospital is using the data to focus IPC strategies in departments with higher rates of HAIs. It is in the plan that future surveillance efforts and reports would be routinely conducted on a monthly basis; and the establishment of the routine intends to attract similar levels of interest and support. As we also identified prolonged hospital stays as contributing to higher HAI risks, it will be important to identify and address factors that contribute to prolonged hospitalisations.

Conclusion

Though time intensive, it is feasible in a low-resource setting to establish a successful HAI surveillance. A baseline HAI rate was established for the teaching hospital using a point-prevalence surveillance strategy. Efforts to preventing HAI may be prioritised in units/wards with higher HAI rates and closer attention may be focused on patients with key risk factors. Surveillance should continue in order to assess changes in overall infection rates over time and gauge the effectiveness of HAI interventions.

Acknowledgements

The authors would like to thank all the surveyors who participated the in HAI data collection and the hospital senior management team in supporting this quality improvement project.

Funding

This work was supported by the Human Resources for Health project funded by the US Government. However, the publication of this paper has no funding support.

References

1. Ducel G, Fabry J, Nicolle L. Prevention of hospital acquired infections: a practical guide. WHO 2002 (Ed. 2).
2. Burke JP. Infection control-a problem for patient safety. *New England Journal of Medicine* 2003; **348(7):** 651-656. http://dx.doi.org/10.1056/NEJMhpr020557
3. Bates DW, Larizgoitia I, Prasopa-Plaizier N, Jha AK. Global priorities for patient safety research. *BMJ* 2009; **338(7704):** 1242-1244. http://dx.doi.org/10.1136/bmj.b1775
4. Pittet D, Donaldson L. Clean Care is Safer Care: a worldwide priority. *Lancet* 2005; **366(9493):** 1246-1247. http://dx.doi.org/10.1016/S0140-6736(05)67506-X
5. Martone WJ, Jarvis WR, Culver DH, Haley RW. Incidence and nature of endemic and epidemic nosocomial infections. Hospital Infections. 3rd ed. Boston: Little, Brown and Co. 1992: 577-596.
6. Allegranzi B, Pittet D. Preventing infections acquired during health-care delivery. *The Lancet* 2008; **372(9651):** 1719-1720. http://dx.doi.org/10.1016/S0140-6736(08)61715-8
7. Nyamogoba H, Obala AA. Nosocomial infections in developing countries: cost effective control and prevention. *East African Medical Journal* 2002; **79(8):** 435-441. http://dx.doi.org/10.4314/eamj.v79i8.8831
8. Orrett FA, Brooks PJ, Richardson EG. Nosocomial infections in a rural regional hospital in a developing country: infection rates by site, service, cost, and infection control practices. *Infection Control & Hospital Epidemiology* 1998; **19(02):** 136-140. http://dx.doi.org/10.2307/30142004
9. Rosselló-Urgell J. Nosocomial infection surveillance and control activities in Spain under HELICS and NosoMed programs frame. *Journal of Hospital Infection* 2004; **56:** 55-57. http://dx.doi.org/10.1016/j.jhin.2003.12.036
10. Gastmeier P. Nosocomial infection surveillance and control policies. *Current Opinion in Infectious Diseases* 2004; **17(4):** 295-301. http://dx.doi.org/10.1097/01.qco.0000136929.75543.8a
11. Haley RW, Quade D, Freeman HE, Bennett JV. Study on the efficacy of nosocomial infection control (SENIC Project): summary of study design. *American Journal of Epidemiology* 1980; **111(5):** 472-485.
12. Haley RW, Culver DH, White JW, *et al.* The efficacy oe infection surveillance and control programs in preventing nosocomial infections in us hospitals. *American Journal of Epidemiology* 1985; **121(2):** 182-205.
13. Tesfahunegn Z, Asrat D, Woldeamanuel Y, Estifanos K. Bacteriology of surgical site and catheter related urinary tract infections among patients admitted in Mekelle Hospital, Mekelle, Tigray, Ethiopia. *Ethiopian Medical Journal* 2009; **47(2):** 117-127.
14. Jroundi I, Khoudri I, Azzouzi A, *et al.* Prevalence of hospital-acquired infection in a Moroccan university hospital. *American Journal of Infection Control* 2007; **35(6):** 412-416. http://dx.doi.org/10.1016/j.ajic.2006.06.010
15. Mahjoub M, Bouafia N, Bannour W, *et al.* Healthcare-associated infections in a Tunisian university hospital: from analysis to action. *Pan African Medical Journal* 2015; **20:** 197. http://dx.doi.org/10.11604/pamj.2015.20.197.4062
16. Pittet D, Allegranzi B, Boyce J. The World Health Organization guidelines on hand hygiene in health care and their consensus recommendations. *Infection Control & Hospital Epidemiology* 2009; **30(07):** 611-622. http://dx.doi.org/10.1086/600379
17. Vincent JL, Rello J, Marshall J, *et al.* International study of the prevalence and outcomes of infection in intensive care units. *JAMA* 2009; **302(21):** 2323-2329. http://dx.doi.org/10.1001/jama.2009.1754
18. Centers for Disease Control (CDC). Public health focus: surveillance, prevention, and control of nosocomial infections. *MMWR*. 1992; **41(42):** 783.
19. Lauria FN, Angeletti C. The impact of nosocomial infections on hospital care costs. *Infection* 2003; **31:** 35-43.
20. Astagneau P, Fleury L, Leroy S, *et al.* Cost of antimicrobial treatment for nosocomial infections based on a French prevalence survey. *Journal of Hospital Infection* 1999; **42(4):** 303-312. http://dx.doi.org/10.1053/jhin.1998.0612

21. Kappstein I, Schulgen G, Beyer U, Geiger K, Schumacher M, Daschner FD. Prolongation of hospital stay and extra costs due to ventilator-associated pneumonia in an intensive care unit. *European Journal of Clinical Microbiology and Infectious Diseases* 1992; **11(6):** 504-508. http://dx.doi.org/10.1007/BF01960804
22. Binagwaho A, Kyamanywa P, Farmer PE, *et al*. The human resources for health program in Rwanda—a new partnership. *New England Journal of Medicine* 2013; **369(21):** 2054-2059. http://dx.doi.org/10.1056/NEJMsr1302176
23. CDC. Outline for Healthcare-Associated Infections Surveillance. April 2006. http://www.cdc.gov/nhsn/pdfs/outlineforhaisurveillance.pdf
24. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care–associated infection and criteria for specific types of infections in the acute care setting. *American Journal of Infection Control* 2008; **36(5):** 309-332. http://dx.doi.org/10.1016/j.ajic.2008.03.002
25. Balkhy HH, Cunningham G, Chew FK, *et al.* Hospital-and community-acquired infections: a point prevalence and risk factors survey in a tertiary care center in Saudi Arabia. *International Journal of Infectious Diseases* 2006; **10(4):** 326-333. http://dx.doi.org/10.1016/j.ijid.2005.06.013