TITLE PAGE

Title:

Prevalence of antibiotic resistance in East African Hospitals

Authors:

Ann N. Wekesa, MD*

Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, Netherlands

email: annwek@gmail.com

Marc J.M. Bonten, PhD

Department of Medical Microbiology and Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, Netherlands

email: mbonten@umcutrecht.nl

Patricia C.J. Bruijning-Verhagen, PhD

Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, Netherlands

email: p.bruijning@umcutrecht.nl

Keywords:

- antibiotic resistance

- hospital

- East Africa

Running title:

Prevalence of antibiotic resistance in East African Hospitals

Corresponding author:

Ann N. Wekesa

University Medical Center Utrecht

Heidelberglaan 100

3584 CK Utrecht

The Netherlands

email: annwek@gmail.com

T +31 (0) 628 32 66 99

Summary:

Antibiotic resistance is high in major hospital in four East African countries.

Category: Systematic review

Abstract

Introduction: Antibiotic resistance is a global burden, besides it is worse in low and middle income countries where infectious diseases are still on the rise. This is occasioned by misuse of antibiotics.

Methods: We did a systematic literature review to assess the prevalence of antibiotic resistance in major hospitals within the East African region.

Results: 20 articles were included in this review; they were published between 1997 and 2013. Of the 20 articles, 9 (45%) from Tanzania, 6 (30%) were from Kenya, 4 (20%), 1 (5%) from Uganda and Rwanda respectively. Overall resistance rates varied in different studies. Prevalence for MRSA ranged from 0.4% to 84.1% as shown in table 1 while that of ESBL ranged from 9.9% to 81.9%

Conclusion: Antimicrobial resistance is high in most major hospitals in East Africa

INTRODUCTION

Antibiotic resistance continues to be a global setback in management of many bacterial infectious diseases.[1],[2],[3] The burden is more pronounced in developing countries where infectious diseases are rampant[4]. It is estimated that globally 26% of deaths are due to infectious diseases of which 98% occur in low and middle-income countries. East Africa and Africa in general consist of low-income countries thus bear the highest encumbrance of impact of infectious diseases.

In East African countries, like many developing countries, there is uncontrolled use of antibiotics mainly because, due to limited resources, most physicians opt for syndromic treatment of infections hence minimal microbiological samples are taken for culture and sensitivity analysis before initiating patients on treatment. In addition there is extensive over the counter treatment with widespread self-medication. These are well known factors that lead to development of antibiotic resistance [1,5,6] [7,8], [9].

With convenience of travel across the world, this does not only remain an east African problem but rather a worldwide drawback particularly because these countries are frequently visited by citizens from high-income countries for reasons such as tourism, business and diplomatic reasons, thus, they can easily acquire resistant microbial carriage back to their countries' of origin[10].

In this paper, we review the current available knowledge on the prevalence and extent of antibiotic resistance in East African major hospitals other than *Mycobacteria* species, current gaps and propose possible feasible solutions on the management of antibiotic resistance.

MATERIALS AND METHODS

Definition of the region

We defined the region east Africa as comprising Kenya, Tanzania, Uganda, Rwanda and Burundi which form the East African Community and are part of the Eastern Africa as described by the UN scheme of geographic regions.

Search strategy and selection criteria

We did our systematic review in accordance with the PRISMA guidelines. To ensure that we caught all relevant studies we searched Medline, Embase, and Cochrane databases without any restriction on date of publication, language and type of study design. The search terms were 'bacterial resistance', 'antimicrobial resistant', 'antimicrobial resistance', "antibiotic resistant", 'antibiotic resistance', 'bacterial surveillance', 'antibiotic use', 'methicillin-resistant staphylococcal aureus', meticillin-resistant staphylococcal aureus, 'MRSA', 'beta lactamase', 'extended beta lactamase', 'ESBL', 'vancomycin-resistant enterobacteriaceae','VRE', 'highly-

resistant enterobacteriaceae',‘HRE'. These were combined with different countries and with ‘East Africa'.

We included all studies that involved quantification of antibiotic resistance performed in the major hospitals in the region. These were either the national referral hospitals, or the teaching hospitals in the above-mentioned countries.

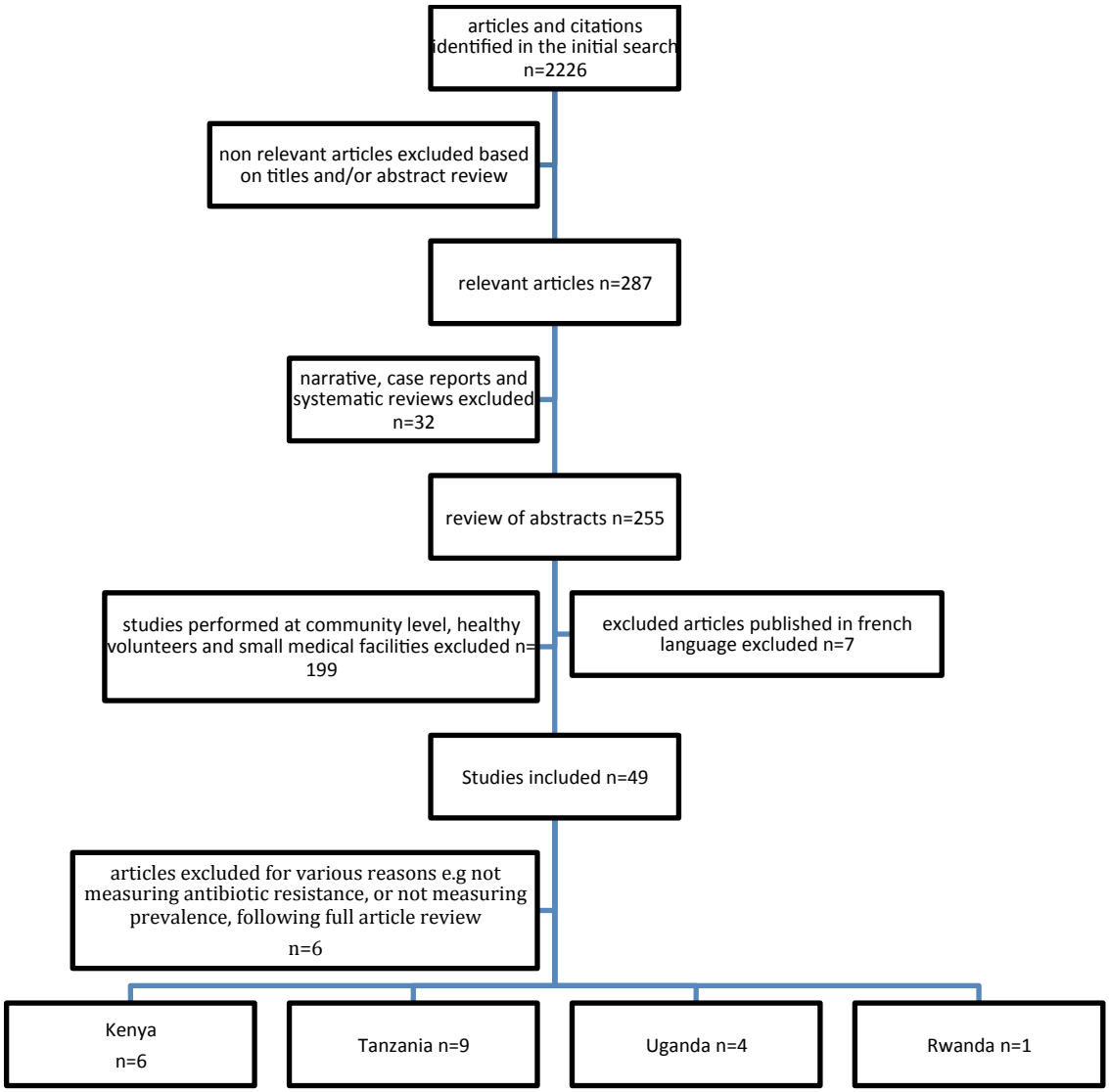
The initial selection of relevant articles (n=287) was based on screening titles; this was followed by review of the abstracts for further selection. We excluded studies exclusively focusing on *Mycobacterium tuberculosis, leprae and Mycobacterium lepromatosis because* this has been widely studied and our main focus was on resistant bacteria other than the *Mycobacteria* species. We also excluded all studies that were performed at community level or on healthy volunteers and case reports. Likewise, we excluded studies published in French, as our level of the French language is basic and not sufficient to understand a scientific paper. Following full text review, we additionally excluded 28 more studies as they were not measuring antibiotic resistance and/or they were not measuring prevalence of antibiotic resistant organisms. (Figure 1.)

Data extraction

We appraised the quality of included studies using the Newcastle-Ottawa quality assessment scale. We extracted a wide selection of data from each study into an excel spreadsheet. These included, the author, year of publication, the title of the article, country, study design, number of participants, department in which the participants were drawn from, number of isolates, group of organisms under study, the specific species, resistance to antibiotic group, number of resistant isolates, and any other relevant comments.

Of special interest, we checked all the articles if they assessed organisms that were, *methicillin-resistant Staphylococcus aureus (MRSA), Extended-Spectrum Beta Lactamases (ESBL), vancomycin-resistant enterococci (VRE) and* highly resistant *Enterobacteriaceae (HRE).*

Figure 1. Study selection



We defined prevalence as follows; for MRSA we identified the number of S. aureus in the study and further identified the proportion that was MRSA. For multidrug resistant gram-negative bacteria (MDRGNB), we identified the number of enterobacteriaceae species (mainly *E.coli,* and *Klebsiella spp)* followed by the proportion which was either ESBL positive or HRE. In addition, we looked at what microbiologal tests were used to confirm the presence of MRSA, ESBL and HRE.

FUNDING

This study was not funded by any agency. The authors had full responsibility for accessing all the data used in the study and final accountability for the decision to submit for publication.

RESULTS

In overall, 20 articles were included in this review. They were published between 1997 and 2013. Of the 20 articles, 9 (45%) from Tanzania, 6 (30%) were from Kenya, 4 (20%), 1 (5%) from Uganda and Rwanda respectively. There was no study from Burundi that was included in the final review.

Overview of study design and study setting

All the articles retrieved were observational studies, with most researchers performing cross-sectional studies 13 (55%). The participants in the studies were drawn from different departments, both in patient departments and out patient departments. Only one study exclusively drew their participants from intensive care unit (ICU)[11]. 2 studies exclusively focused on pediatric populations[12,13]. The number of participants varied widely, ranging from 63 participants to 1092; the median number of participants was 222. In some of the studies, only the number of isolates used was mentioned[14,15],[16], (table 1). The group of bacterial organisms being studied varied widely, including but not limited to pathogens that lead to surgical site infections, blood stream infections, neonatal sepsis, sexually transmitted infections, respiratory infections, meningitis and skin and soft tissue infections. Only 2 studies reported screening their participants for HIV status [17],[18]. Most studies looked at multiple bacterial species. 14 studies documented having assessed the prevalence of MRSA (table 1) while 9 studies reported the prevalence of ESBL (table 2).

Microbiological methods

Different microbiological methods were used for identification of MRSA and ESBL isolates. In most of the studies, disk diffusion method according to Clinical and Laboratory Standards Institute (CLSI) was used for screening for either MRSA or ESBL followed by a confirmatory test (table 3 and 4).

Table 1. MRSA prevalence among S. aureus isolates from different studies in four African countries

Author	Year	Country	Study design	Domain	Patients included (n=)	Number of S. aureus isolates	Number of MRSA (% of S. aureus))
Maina EK et al [19]	2013	Kenya	Prospective study	Patients with active SSTI in all hospital departments	100	82	69 (84.1)
Mshangila et al [20]	2013	Uganda	Cross- sectional	Pre-operative patients scheduled for cataract surgery screened with ocular swabs without signs of infection	131	29	8 (27.6)
Dinda et al [21]	2013	Kenya	Prospective cohort	Patients with surgical site infection in general surgical units	268	10	1 (10)
Seni et al [22]	2013	Uganda	Cross- sectional	Patients with clinical surgical site infection in surgical units (Obstetrics & gynecology, general surgery and orthopedic wards)	314	64	24(37.5)
Moremi et al [14]	2012	Tanzania	Cross- sectional	Clinical swabs (wound pus and nasal swabs) from all hospital patients (In-patients and outpatients departments)	-	160	24(15)
Mawalla et al [18]	2011	Tanzania	Cross- sectional	Patients with surgical site infection in surgical unit	250	16	3 (18.8)
Kayange et al [12]	2010	Tanzania	Cross- sectional	Neonates with clinical sepsis in the Neonatal unit	300	32	9 (28)
Kohli et al [17]	2010	Kenya	Retrospective cohort	Patients with BSI (blood cultures) in all hospital departments (In-patients and outpatients)	1092	364	76 (20.9)
Moyo et al [15]	2010	Tanzania	Retrospective cohort	Blood culture specimens from all hospital patients	-	245	57(23.3)
Ojulong et al [23]	2009	Uganda	Cross- sectional	Patients in surgical wards (Obstetrics & gynecology and general surgery wards)	188	54	17(31.5)
Anguzu et al [24]	2007	Uganda	Cross-sectional	Patients with post-operative septic wounds in surgical units (Obstetrics & gynecology and general surgery wards)	94	32	8 (25)
Andhoga et al[25]	2002	Kenya	Cross- sectional	Post-operative patients in surgical units (Obstetrics & gynecology and general surgery wards)	63	46	37 (80.4)
Urassa et al[26]	1999	Tanzania	Cross- sectional	Patients with suspected localized infection or septicemia in all hospital departments (In-patients and outpatients)	260	260	1 (0.4)
Malonza et al[16]	1997	Kenya	Cross- sectional	Clinical swabs (wound pus and nasal swabs) from patients attending general out-patient units	-	421	249 (59.1)

SSTI: skin and soft tissue infection not limited to infected surgical incision

- only number of isolates mentioned in the study and not the number of patients

Table 2. ESBL prevalence among enterobacteriaceae isolates from different studies in four African countries

Author	Year	Country	Study design	Domain	Patients included (n=)	Number of Enterobacteriaceae isolates	Number of ESBL (% of Enterobacteriaceae)
Seni et al [22]	2013	Uganda	Cross- sectional	Patients with clinical surgical site infection in surgical units (Obstetrics & gynecology, general surgery and orthopedic wards)	314	145	118 (81.9)
Muvunyi et al [27]	2011	Rwanda	Prospective cohort	Patients with UTIs in all hospital departments (In-patients and outpatients)	196	184	42 (22.8)
Mawalla et al [18]	2011	Tanzania	Cross- sectional	Patients with surgical site infection in surgical unit	250	24	17 (70.8)
Kayange et al[12]	2010	Tanzania	Cross- sectional	Neonates with clinical sepsis in the Neonatal unit	300	72	35 (48.6)
Moyo et al [28]	2010	Tanzania	Cross- sectional	Urine samples from patients in all hospital departments (In-patients and outpatients)	270	270	122 (45.2)
Kohli et al [17]	2010	Kenya	Retrospective cohort	Patients with BSI (blood cultures) in all hospital departments (In-patients and outpatients)	1092	152	15(9.9)
Mshanaet al [29]	2009	Tanzania	Cross-sectional	All hospital patients (in patient and outpatient departments)	800	292	103(35.3)
Ndugulile et al[11]	2005	Tanzania	Prospective cohort	Patients suspected to have nosocomial infection in ICU	206	33	11 (33.3)
Blomberg et al [30]	2005	Tanzania	Prospective cohort	Pediatric patients with clinical signs of septicemia in In-patient pediatric unit	113	88	18 (20.5)

Overall resistance rates varied in different studies. Due to heterogeneity, we could not pool the results for an overall resistance rate. However, most isolates were resistant to most locally available antibiotics. Prevalence for MRSA ranged from 0.4% to 84.1% as shown in table 1 while that of ESBL ranged from 9.9% to 81.9% as shown in table 2. We computed prevalence of MRSA and ESBL per patient population is as shown in table 5.

One study Pitout et al [31], studied prevalence of carbapenem resistance in *P. aeruginosa.* The findings are as follows; 57/419 (13.7%) was resistant to carbapenems. The majority of CR isolates were from ICU 33/57. No colistin resistance was detected. Vitek 2 determined antimicrobial susceptibility, and confirmation of MBL was by use of both EDTA screen test and MBL Etest (AB BioDisk)

MRSA identification and confirmation

Author	Screening for Antibiotic sensitivity method	Confirmatory tests	Confirmations in case of discrepancy	Control organisms
Maina EK et al [19]	Disk diffusion method	– Oxacillin resistance screening agar, muellar-Hinton agar – Cefoxitin disk diffusion test – PBP2a	PCR for *mecA*	S.aureus ATCC 29213 S.aureus ATCC 43300
Mshangila et al [20]	Standard disk diffusion method (DST)	Phoenix automated instrument (Becton-Dickson, Sparks Maryland)		S.aureus ATCC 25923 S.aureus ATCC 43300
Dinda et al [21]	Disk diffusion according to CLSI 2009 guidelines			S.aureus ATCC 25923
Seni et al [22]	DST	1. Phoenix automated instrument (Becton-Dickson, Sparks Maryland) Cefoxitin disk		S.aureus ATCC 25923
Moremi et al [14]	Standard disk diffusion method (DST) according to CLSI	Automated VITEK 2 system (BioMerieux, Marcy-L'Etoile, France)	PCR for *mecA*	
Mawalla et al [18]	disk diffusion method (DST) according to CLSI			
Kayange et al [12]	disk diffusion method (DST) according to CLSI			
Kohli et al [17]	Disk diffusion using the modified Kirby-Bauer technique			
Moyo et al [15]	Disk diffusion method			
Ojulong et al [23]	Disc diffusion on Mueller-Hinton agar	Confirmed by agar screen method using an agar plate containing 6µg/ml of oxacillin and Mueller-Hinton agar supplemented with NaCl (4% w/v; 0.68 mol/L).		ATCC 25923
Anguzu et al [24]	Kirby-Bauer technique			
Andhoga et al[25]	Commercial antibiotic disks by Himedia laboratories Ltd			
Urassa et al[26]	Disk diffusion method	E-test strips (AB Biodisk, Solna, Sweden)	PCR for *mecA*	
Malonza et al[16]	Disk diffusion method			

ESBL identification and confirmation

Author	Screening for Antibiotic sensitivity method	Confirmatory tests	Control organisms
Seni et al [22]	Double disk method		E. coli ATCC 25922 P. aeroginosa ATCC 27853
Muvunyi et al [27]	Disk diffusion method according to CLSI	Double disk synergy test on Muller-Hinton agar	
Mawalla et al [18]	Disk diffusion method (DST) according to CLSI		
Kayange et al[12]	Disk diffusion method (DST) according to CLSI	Disk approximation method (using ceftazidime, cefotaxime and amoxicillin/clavunate	
Moyo et al [28]	Disk diffusion method	Phenotypic identification through reduced susceptibility to cefotaxime and/or ceftazidime ESBL E-test strips (Biomerieux, Solna, Sweden)	E. coli ATCC 25922 K. pneumoniae ATCC 700603
Kohli et al [17]	Disk diffusion using the modified Kirby-Bauer technique		E. coli ATCC 25922
Mshanaet al [29]	Disk diffusion method	Phenotypic identification through reduced susceptibility to cefotaxime Disk approximation method (using ceftazidime, cefotaxime and amoxicillin/clavunate)	E. coli ATCC 25922
Ndugulile et al[11]	Agar diffusion method using paper disks	Three ESBL Etest strips (AB Biodisk, Solna, Sweden)	
Blomberg et al [30]	Phenotypic identification through reduced susceptibility to cefotaxime and/or Ceftazidime	Disk approximation method (using ceftazidime, cefotaxime and amoxicillin/clavunate) Three ESBL Etest strips (AB Biodisk, Solna, Sweden	

DISCUSSION

In these review performed in East African hospitals, there was a clear trend in increase in the antimicrobial resistance overall, even though all the studies that were retrieved were observational studies mainly cross-section type. Being developing countries, most studies focused on resistance to locally available antibiotics.

14 of the studies looked at the prevalence of MRSA that varied from 1997 to 2013 varied widely ranging from 0.4% to 80.4%. Nevertheless, there seem to be a constant trend in the MRSA prevalence (Figure 2). However, the trend of ESBL prevalence seems to be on the rise ranging from 15% to about 90% from 2005 to 2013 as shown in Figure 3. Most of the studies on MRSA were performed on participants drawn from surgical wards while those on ESBL, the participants were drawn from various departments including, Newborn units, outpatient departments, surgery and two studies participants were from ICU.

6 studies mentioned having tested for vancomycin resistance, two of the studies published in 2009 and 2010 reported no or rare resistance[17],[23], one study published in 2013 reported having observed 4.4% vancomycin resistance in the isolates examined[22]. The other three it was not mentioned in the results. The absence of VRE, could be because they are not screened in most of the studies and not that the prevalence is necessarily low.

One study identified carbapenem resistant organisms, MBL producing *Pseudomonas aeruginosa*.[31] This report indicates that carbapenem resistant organisms are emerging in the region and should raise a big public heath concern.

Most of the hospitals are taking in more patients than they were originally intended for, thus, outbreaks and spread of these antimicrobial resistant organisms is an impending occurrence. There are limited options for treating infections caused by these organisms especially the carbapenem resistance; in addition, the cost of these drugs is quite high and thus not feasible in most developing countries such as the east Africa countries. It is therefore prudent to work on containing the rise of antimicrobial organisms in this region. Several control measures have proved to work in different regions that if applied consistently in this region, they could prove useful. They include; hygienic hand-wash of the healthcare workers, isolation precautions, removal of fecal patina, environmental control and antimicrobial stewardship.

In addition, performing prospective studies to assess the actual extent of antibiotic resistance in east African hospital is crucial, especially with a focus on ICU departments (critically ill patients) who are at a greater risk of being colonized due to the fact that most of them stay in hospital for long, are highly dependent on others for support and use of invasive devices. There have been very minimal studies focusing on this group of patients. The results of such studies could give us a clear indication of the actual prevalence of antibiotic resistance within

the major hospitals in east Africa. The implementation of sustainable cost effective proven solutions for control spread of resistant microbes is also crucial.

CONCLUSION

Antimicrobial resistance is high in most major hospitals in East Africa (both MRSA, MDRGNB). This is irrespective of the specific units within the hospital.

Reference

1. Gould, I. M. The epidemiology of antibiotic resistance. *Int J Antimicrob Agents* **32 Suppl 1,** S2–9 (2008).

2. McGowan, J. E. J. & Carlet, J. Antimicrobial resistance: a worldwide problem for health care institutions. *Am J Infect Control* **26,** 541–543 (1998).

3. Kombe, G. C. & Darrow, D. M. Revisiting emerging infectious diseases: the unfinished agenda. *J Community Heal*. **26,** 113–122 (2001).

4. Fauci, A. S. Infectious diseases: considerations for the 21st century. *Clin Infect Dis* **32,** 675–685 (2001).

5. Okeke, I. N. *et al*. Antimicrobial resistance in developing countries. Part II: strategies for containment. *Lancet Infect Dis* **5,** 568–580 (2005).

6. Hart, C. A. & Kariuki, S. Antimicrobial resistance in developing countries. *BMJ* **317,** 647–650 (1998).

7. Kunin, C. M. Use of antimicrobial drugs in developing countries. *Int J Antimicrob Agents* **5,** 107–113 (1995).

8. Levy, S. B. Antibiotic resistance: consequences of inaction. *Clin Infect Dis* **33 Suppl 3,** S124–9 (2001).

9. Okeke, I. N., Lamikanra, A. & Edelman, R. Socioeconomic and behavioral factors leading to acquired bacterial resistance to antibiotics in developing countries. *Emerg Infect Dis* **5,** 18–27 (1999).

10. Memish, Z. A., Venkatesh, S. & Shibl, A. M. Impact of travel on international spread of antimicrobial resistance. *Int J Antimicrob Agents* **21,** 135–142 (2003).

11. Ndugulile, F., Jureen, R., Harthug, S., Urassa, W. & Langeland, N. Extended spectrum beta-lactamases among Gram-negative bacteria of nosocomial origin from an intensive care unit of a tertiary health facility in Tanzania. *BMC Infect Dis* **5,** 86 (2005).

12. Kayange, N., Kamugisha, E., Mwizamholya, D. L., Jeremiah, S. & Mshana, S. E. Predictors of positive blood culture and deaths among neonates with suspected neonatal sepsis in a tertiary hospital, Mwanza-Tanzania. *BMC Pediatr* **10,** 39 (2010).

13. Blomberg, B. *et al*. Surveillance of antimicrobial resistance at a tertiary hospital in Tanzania. *BMC Public Health* **4,** (2004).

14. Moremi, N. *et al*. Predominance of methicillin resistant Staphylococcus aureus -ST88 and new ST1797 causing wound infection and abscesses. *J Infect Dev Ctries* **6,** 620–625 (2012).

15. Moyo, S., Aboud, S., Kasubi, M. & Maselle, S. Y. Bacteria isolated from bloodstream infections at a tertiary hospital in Dar es Salaam, Tanzania--antimicrobial resistance of isolates. *S Afr Med J* **100,** 835–838 (2010).

16. Malonza, I. M. *et al*. Community acquired bacterial infections and their antimicrobial susceptibility in Nairobi, Kenya. *East Afr Med J* **74,** 166–170 (1997).

17. Kohli, R., Omuse, G. & Revathi, G. Antibacterial susceptibility patterns of blood stream isolates in patients investigated at the Aga Khan University Hospital, Nairobi. *East Afr. Med. J.* **87,** 74–80 (2010).

18. Mawalla, B., Mshana, S. E., Chalya, P. L., Imirzalioglu, C. & Mahalu, W. Predictors of surgical site infections among patients undergoing major surgery at Bugando Medical Centre in Northwestern Tanzania. *BMC Surg* **11,** 21 (2011).

19. Maina, E. K. . E. K., Kiiyukia, C. . C., Wamae, C. N. . c N., Waiyaki, P. G. P. G. . & Kariuki, S. . Characterization of methicillin-resistant Staphylococcus aureus from skin and soft tissue infections in patients in Nairobi, Kenya. *Int. J. Infect. Dis.* **17,** e115–e119 (2013).

20. Mshangila, B. *et al*. External ocular surface bacterial isolates and their antimicrobial susceptibility patterns among pre-operative cataract patients at Mulago National Hospital in Kampala, Uganda. *BMC Ophthalmol* **13,** 71 (2013).

21. Dinda, V. *et al*. Pattern of pathogens and their sensitivity isolated from surgical site infections at the Aga Khan University Hospital, Nairobi, Kenya. *Ethiop J Heal. Sci* **23,** 141–149 (2013).

22. Seni, J. *et al*. Antimicrobial resistance in hospitalized surgical patients: a silently emerging public health concern in Uganda. *BMC Res. Notes* **6,** 298 (2013).

23. Ojulong, J. *et al*. Prevalence of methicillin resistant staphylococcus aureus (MRSA) among isolates from surgical site infections in Mulago hospital-Kampala, Uganda. *Internet J. Infect. Dis.* **7,** 11 (2010).

24. Anguzu, J. R. & Olila, D. Drug sensitivity patterns of bacterial isolates from septic post-operative wounds in a regional referral hospital in Uganda. *Afr. Health Sci.* **7,** 148–154 (2007).

25. Andhoga, J. . *et al*. Aerobic pathogenic bacteria in post-operative wounds at Moi Teaching and Referral Hospital. *East Afr. Med. J.* **79,** 640–644 (2002).

26. Urassa, W. K., Haule, E. A., Kagoma, C. & Langeland, N. Antimicrobial susceptibillty of Staphylococcus aureus strains at Muhimbili Medical Centre, Tanzania. *East Afr. Med. J.* **76,** 693–695 (1999).

27. Muvunyi, C. M. *et al*. Decreased susceptibility to commonly used antimicrobial agents in bacterial pathogens isolated from urinary tract infections in Rwanda: need for new antimicrobial guidelines. *Am J Trop Med Hyg* **84,** 923–928 (2011).

28. Moyo, S. J., Aboud, S., Kasubi, M., Lyamuya, E. F. & Maselle, S. Y. Antimicrobial resistance among producers and non-producers of extended spectrum beta-lactamases in urinary isolates at a tertiary Hospital in Tanzania. *BMC Res Notes* **3,** 348 (2010).

29. Mshana, S. E., Kamugisha, E., Mirambo, M., Chakraborty, T. & Lyamuya, E. F. Prevalence of multiresistant gram-negative organisms in a tertiary hospital in Mwanza, Tanzania. *BMC Res Notes* **2,** 49 (2009).

30. Blomberg, B. *et al*. High rate of fatal cases of pediatric septicemia caused by gram-negative bacteria with extended-spectrum beta-lactamases in Dar es Salaam, Tanzania. *J Clin Microbiol* **43,** 745–749 (2005).

31. Pitout, J. D. D. *et al*. Metallo-beta-lactamase-producing Pseudomonas aeruginosa isolated from a large tertiary centre in Kenya. *Clin Microbiol Infect* **14,** 755–759 (2008).