Knowledge and perceptions of antimicrobial resistance and antimicrobial stewardship among staff at a national cancer referral center in Uganda

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Abstract

Objectives: As access to cancer care has improved throughout sub-Saharan Africa, treatment-associated infections have increased. Assessing healthcare worker knowledge of antimicrobial stewardship and identifying the barriers to infection management will inform the development of contextually appropriate antimicrobial stewardship programs, improving cancer outcomes in sub-Saharan Africa.

Design: Cross-sectional survey.

Setting: The Uganda Cancer Institute (UCI), a national cancer referral center in Kampala, Uganda.

Participants: We surveyed 61 UCI staff: 29 nurses, 7 pharmacists, and 25 physicians.

Methods: The survey contained 25 questions and 1 ranking exercise. We examined differences in responses by staff role.

Results: All 60 respondents who answered the question had heard the term “antimicrobial resistance.” Only 44 (73%) had heard the term “antimicrobial stewardship.” Nurses were less likely than pharmacists or physicians to be familiar with either term. Also, 41 respondents (68%) felt that loss of antibiotic susceptibility is a major issue at UCI. Regarding barriers to diagnosing infections, 54 (93%) of 58 thought that it was difficult to obtain blood cultures and 48 (86%) of 56 thought that it was difficult to regularly measure temperatures.

Conclusions: Although most recognized the term “antimicrobial resistance,” fewer were familiar with the term “antimicrobial stewardship.” Inappropriate antibiotic use was recognized as a contributor to antimicrobial resistance, but hand hygiene was underrecognized as a contributing factor. We identified numerous barriers to diagnosing infections, including the ability to obtain blood cultures and consistently monitor temperatures. Educating staff regarding antimicrobial selection, allocating resources for blood cultures, and implementing strategies to enhance fever detection will improve infection management.

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By 2030, 1.28 million new cancer cases and 970,000 cancer-related deaths are anticipated in sub-Saharan Africa annually.1 Over the past 20 years, access to cancer diagnosis and treatment has expanded; however, improved access to treatment has resulted in increased treatment-related infections.2,4 In sub-Saharan Africa, the growing prevalence of multidrug-resistant (MDR) bacterial infections has emerged as a public health emergency.5,6 Those with cancer are at increased risk of developing MDR bacterial infections due to frequent healthcare exposure and high rates of antibiotic use. This is particularly concerning because MDR bacterial bloodstream infections are associated with high mortality among those with cancer.7 In sub-Saharan Africa, limited access to microbiology laboratories and the high cost of blood cultures make it difficult to identify patients with MDR bacterial infections.8 When identified, these patients often require treatment with second-line antibiotics that are expensive and may not be readily available. Because there are relatively few trained infectious diseases specialists in sub-Saharan Africa,9 it is important to ensure that all members of the clinical oncology team understand the high prevalence of MDR bacterial infections and are well versed in evidence-based antimicrobial management practices.

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Antimicrobial stewardship is a coordinated group of interventions designed to improve appropriate antimicrobial use by optimizing treatment regimens. The World Health Organization developed a practical tool kit to guide the design and implementation of antimicrobial stewardship programs (ASPs) in low-resource settings. However, patients with cancer are a vulnerable population with unique diagnostic and antimicrobial management needs. Many are immunosuppressed due to their underlying disease or cancer treatment regimens. In sub-Saharan Africa, up to 35% of those with cancer also have human immunodeficiency virus (HIV), which is associated with increased rates of antimicrobial resistance. Although ASPs have been developed for patients receiving cancer treatment in high-resource settings, they have not been adapted to account for the high prevalence of MDR bacteria, resource limitations, and local healthcare infrastructure in lower- and middle-income countries (LMICs). Because patients receiving cancer treatment in sub-Saharan Africa have high rates of infection-related mortality, implementing locally adapted ASPs could significantly improve patient outcomes. To develop these programs, it is critical to assess healthcare workers’ baseline knowledge of antimicrobial resistance and antimicrobial stewardship and to explore the unique challenges faced when diagnosing and treating infections in a low-resource setting.

We evaluated the knowledge and attitudes regarding antimicrobial resistance and antimicrobial stewardship among physicians, nurses, and pharmacists at the Uganda Cancer Institute (UCI), a national cancer referral hospital in sub-Saharan Africa. We also assessed sources of antibiotic education and to understand the perceived barriers to infection diagnosis and treatment.

Methods

Study design, period, and setting

In April and May of 2021, we conducted a cross-sectional survey of UCI inpatient staff. The UCI is a national cancer referral center in Kampala, Uganda, and the East African Center of Excellence in Oncology. More than 5,000 adult and pediatric patients are treated annually in the 100-bed hospital and >20 ambulatory clinics. Patient care is provided by >169 staff, including 112 nurses, 9 pharmacists, and 48 physicians. Over the past 7 years, our group has collaborated on several infection management initiatives, and we have established a multidisciplinary antimicrobial stewardship team of microbiologists, infectious diseases physicians, pharmacists, oncologists, and nurses. Initiatives include adapting international neutropenic fever guidelines to the local context and initiating an infectious diseases consultation service.

Survey development

We designed a self-administered survey (1) to assess the knowledge, attitudes, and perceptions of antimicrobial resistance and antimicrobial stewardship, (2) to characterize current sources of antibiotic education, and (3) to identify perceived barriers to infection diagnosis and treatment (Supplementary File 1). The survey contained 26 questions and 1 ranking exercise. To create the survey, we used our knowledge of UCI clinical management practices and adapted questions from surveys designed to assess the unique challenges faced when diagnosing and treating infections in LMICs. We pilot-tested the survey on 10 US and Ugandan healthcare providers to optimize clarity and readability.

Survey distribution

We compiled a list of staff who work on the UCI inpatient wards. We then used face-to-face conversations, phone calls, and text messages to invite them to participate. Participants could choose to complete the survey on paper or online. For the paper survey, we gave the participants a copy, which they completed and returned to a designated study team member. For the online survey, we texted or e-mailed the participants a direct link to the REDCap survey. The completed surveys were entered into a REDCap database. The study team manually entered paper survey responses, while online survey responses were automatically uploaded.

Data analysis

We tabulated survey responses, presented as frequencies and percentages. For each question, we excluded missing responses from analysis. We compared survey responses using nonparametric tests. To test for differences in binary variables for educational formats by staff role, we used the Fisher exact test for overall differences, followed by Fisher exact pairwise comparisons using the Holm method to adjust for multiple comparisons. To determine whether there were differences among any of the ordinal variables for knowledge regarding antimicrobial resistance and antimicrobial stewardship by staff role, we used the Kruskal-Wallis test. If significant, we used the Dunn test for pairwise comparisons between groups with the Holm adjustment for multiple comparisons to determine which variables differed significantly. We compared relative differences in responses across all Likert-type or ranking questions using the Friedman test. If significant, we performed pairwise comparisons using the exact test with the Holm adjustment to account for multiple comparisons to determine which questions differed significantly. We analyzed survey responses using R Studio software (R Foundation for Statistical Computing, Vienna, Austria) and Stata version 16.1 software (StataCorp, College Station, TX). We considered P < .05 statistically significant.

Ethical considerations

The Fred Hutchinson Cancer Research Center Institutional Review Board, the Uganda Cancer Institute Research and Ethics Committee, and the Uganda National Council on Science and Technology approved the study. We used a standardize script to obtain verbal consent and an anonymous study number to document consent.

Results

Understanding of antimicrobial resistance

Among the 75 staff who we identified as providing inpatient care, we were able to contact 65 (86%). Of these, 61 (94%) completed the survey (Table 1). Although all respondents had heard of the term “antimicrobial resistance” (Table 2), the survey revealed significant differences in degrees of knowledge based on staff role (P < .001). Nurses were less familiar with the term than pharmacists (P = .03) or physicians (P < .001).

Most respondents agreed that loss of antibiotic susceptibility is a major problem at UCI (Table 2). We detected a significant difference in the degree to which various factors were felt to contribute to antimicrobial resistance (P < .001) (Fig. 1). Poor patient adherence to antibiotics, patient request for antibiotics (ie, insistence that
antibiotics be prescribed), and the use of too many antibiotics were the most commonly identified contributing factors. Provider hand hygiene and attendant hand hygiene were the contributing factors least often identified. Overall, 56 (93%) of 60 respondents knew that giving antibiotics to a patient who does not have an infection can cause loss of antibiotic susceptibility. In addition, 39 respondents (65%) strongly agreed and 17 respondents (28%) agreed that restricting some antibiotics could prevent loss of antibiotic susceptibility.

**Antimicrobial stewardship**

Although 44 (73%) of 60 respondents had heard of the term “antimicrobial stewardship,” 12 (27%) of these 44 did not know what it meant (Table 2). We detected a significant difference in knowledge of the term “antimicrobial stewardship” by staff role ($P < .001$). Nurses were less familiar with the term than pharmacists ($P < .001$) or physicians ($P < .001$).

All but 1 respondent strongly agreed (52 of 60, 87%) or agreed (7 of 60, 12%) that it would be good to have more guidance on antibiotic selection. We detected significant differences in the importance assigned to various factors when choosing antibiotics ($P < .001$). Patient white blood cell count, severity of illness, and recent blood culture results were considered significantly more important than either the patient’s HIV status or CD4 count (ie, T-cell test) (Fig. 2).

**Sources of antibiotic information and continuing antibiotic education**

Of 61 respondents, 52 (85%) thought that knowledge about antibiotics was “very important” to their clinical profession. Almost two-thirds received training about antibiotics within the past year (Supplementary Table 1). Antibiotic training was less common among nurses than among pharmacists or physicians, although these differences were not statistically significant ($P = .09$). The most common training formats were teaching on patient rounds and in-person courses outside UCI (Supplementary Table 1).

Among the 60 respondents, 39 reported using at least 1 source of information daily to answer antibiotic questions (Fig. 3a). We detected significant differences in the frequency with which respondents used these sources ($P < .001$); Internet searches were used significantly more frequently than any other source except for discussions with colleagues. Of 59 respondents, 56 (95%) agreed or strongly agreed that they would like to receive more training in antibiotic use. Figure 3b shows the formats that respondents felt would be most helpful for future antibiotic training.

**Diagnostic limitations**

When asked about factors that limit infection diagnosis, inability to obtain blood cultures, inability to regularly measure patient temperatures, and delayed laboratory test results were most frequently identified (Fig. 4). Other factors identified included delays in seeing a physician, drug stockouts, and patient load. Respondents felt that cost, culture supply availability, and delayed culture results limited the ability to obtain and use blood cultures (Fig. 4).

**Antibiotic limitations**

Of 61 respondents, 45 (75%) thought it was easy to know which antibiotics are available in the UCI pharmacy. Only 10 (16%) thought it was easy to find the appropriate antibiotics in the evenings, and only 22 (36%) thought it was easy to find the appropriate antibiotics on weekends. When asked to rank the interventions that could most improve infection management, disseminating educational materials, developing educational programs, and creating updated UCI-specific infection management guidelines were considered most important. (Fig. 5). Of 61 respondents, 40 (65%) suggested additional ways to improve infection diagnosis and management (Supplementary Table 2). Suggestions included improving early infection identification, providing blood cultures for all patients with suspected infections, creating a dedicated infection management team, and educating patients about proper antibiotic use.

**Discussion**

In our cross-sectional survey, we evaluated the knowledge and attitudes regarding antimicrobial resistance and antimicrobial stewardship among nurses, pharmacists, and physicians working at a national cancer center in sub-Saharan Africa. Most respondents considered antibiotic knowledge very important to their clinical job and desired additional training in antibiotic use. We found that nurses were less familiar with the terms “antimicrobial resistance” and “antimicrobial stewardship” than pharmacists or physicians. Finally, we identified numerous barriers to diagnosing infections, including the ability to regularly monitor patient temperatures and to obtain blood cultures. These findings will inform our ongoing efforts to develop ASPs that account for the unique barriers encountered at UCI and in other cancer treatment programs throughout sub-Saharan Africa.

A primary goal of antimicrobial stewardship is to decrease the emergence, selection, and spread of antimicrobial resistance by optimizing antimicrobial use.$^{10,15}$ To this end, it is important to educate clinicians about the causes of antimicrobial resistance.$^{16}$ More than 80% of our survey respondents recognized antimicrobial resistance as a significant problem at UCI, which was higher than in previous surveys of healthcare workers from sub-Saharan Africa.$^{17,18}$ This finding may reflect our ongoing efforts to educate staff about the high prevalence of MDR gram-negative bacterial infections at UCI.$^{2,19}$ Among the UCI staff, there was general recognition that inappropriate antibiotic use contributes to antimicrobial resistance. Hand hygiene was not as well recognized as a contributing factor and represents an opportunity for improved education. Similar surveys from sub-Saharan Africa show that hand hygiene is an underrecognized contributor to resistance.$^{17,18,20}$ Yet, good hand hygiene reduces transmission of resistant bacteria within
the healthcare setting. For example, in a recent study from Mulago National Referral Hospital in Kampala, resistant gram-negative bacteria primarily spread through direct contact between patients and healthcare providers or nonmedical caretakers. It is also important to address environmental limitations that occur in low-resource settings (eg, lack of alcohol-based hand gel, inadequate handwashing facilities), which remain an ongoing challenge at UCI.

The appropriate use of microbiologic diagnostics to guide therapeutic decisions, or diagnostic stewardship, is another important aspect of antimicrobial stewardship. Diagnostic stewardship includes the ability to rapidly identify patients with suspected infections and to obtain the appropriate microbiologic laboratory tests. The ability to consistently monitor temperatures was seen as a key limitation to identifying patients with infections at UCI. In high-resource settings, temperatures are routinely measured 3–4 times daily and are, therefore, not included as a core component of diagnostic stewardship. However, in sub-Saharan Africa, 1 nurse may care for 30–70 patients, making it challenging to consistently measure vital signs. Developing strategies that account for staffing limitations could improve fever detection, facilitate blood culture collection, and decrease time to antibiotics. We are currently collaborating with UCI nurses to train patient family members to measure temperatures and alert nurses when a fever occurs. Since time from fever onset to the administration of guideline-recommended antibiotics is associated with outcomes, improved fever detection could decrease mortality for patients receiving cancer treatment in sub-Saharan Africa.

Obtaining blood cultures for patients with suspected infections is also an important component of diagnostic stewardship. Blood cultures decrease the use of unnecessary broad-spectrum antibiotics by allowing clinicians to tailor a patient’s antibiotic therapy to the causative organisms. They are also critical for developing a hospital antibiogram, in which the antimicrobial susceptibilities of organisms isolated at that hospital are aggregated into easily referenced tables. The antibiogram allows clinicians to track changes in antibiotic susceptibility and adapt evidence-based institutional treatment guidelines accordingly. In our study, patient cost was the most frequently identified barrier to obtaining blood cultures, which is consistent with findings from previous studies in sub-Saharan Africa. In Uganda, blood cultures cost up to $10.00 USD (ie, 4–5 days’ average wages), which is prohibitively expensive. Since blood cultures are essential for diagnosing and treating infections in patients with cancer, policy makers should consider these a core component of cancer care and factor these into the cost of cancer treatment.

To improve rational antibiotic decision making, it is necessary to understand provider prescribing practices. Among UCI clinicians, patient white blood cell count was most frequently considered to be “very important” when choosing antibiotics. This is fitting because patients with neutropenic fever are at high risk of infection-related complications. Fewer respondents identified HIV status or CD4 count as important. However, there is evidence that patients with HIV are at higher risk of developing treatment-related infections than their HIV negative counterparts. Of the 61 respondents, 60 (98%) answered the questions regarding antimicrobial resistance and antimicrobial stewardship. One physician did not answer question 1 and 2 and 1 nurse did not answer question 3.

### Table 2. Participant Responses to Questions Regarding the Antimicrobial Resistance and Antimicrobial Stewardship By Staff Role

| Survey Questions | All, No. (%) | Nurses, No. (%) | Pharmacists, No. (%) | Physicians, No. (%) |
|------------------|--------------|-----------------|----------------------|---------------------|
| 1. Have you heard of the term “antimicrobial resistance”? | 60* (100) | 28 (47) | 7 (12) | 25 (42) |
| I have not heard the term | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| I have heard the term, but do not know what it means | 2 (3) | 2 (7) | 0 (0) | 0 (0) |
| I have heard the term, and know a little about what it means | 22 (37) | 17 (59) | 1 (14) | 4 (17) |
| I have heard the term and know a lot about what it means | 36 (60) | 10 (34) | 6 (86) | 20 (83) |
| 2. Loss of antimicrobial sensitivity (development of antimicrobial resistance) is a major problem for patients at UCI. | | | | |
| Strongly disagree | 2 (3) | 1 (3) | 0 (0) | 1 (4) |
| Somewhat disagree | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Neither agree nor disagree | 1 (2) | 1 (3) | 0 (0) | 0 (0) |
| Somewhat agree | 17 (28) | 11 (38) | 1 (14) | 5 (21) |
| Strongly agree | 34 (57) | 13 (45) | 6 (86) | 15 (62) |
| Don’t know | 6 (10) | 3 (10) | 0 (0) | 3 (12) |
| 3. Have you heard of the term “antimicrobial stewardship”? | | | | |
| I have not heard the term | 16 (27) | 12 (43) | 0 (0) | 4 (16) |
| I have heard the term, but do not know what it means | 12 (20) | 9 (32) | 0 (0) | 3 (12) |
| I have heard the term, and know a little about what it means | 17 (28) | 6 (21) | 2 (29) | 9 (36) |
| I have heard the term and know a lot about what it means | 15 (25) | 1 (3.6) | 5 (71) | 9 (36) |

*Of the 61 respondents, 60 (98%) answered the questions regarding antimicrobial resistance and antimicrobial stewardship. One physician did not answer question 1 and 2 and 1 nurse did not answer question 3.
with HIV have high rates of antibiotic exposure and are at increased risk of developing infections with resistant bacteria. The microbiology of febrile illness also varies by HIV status. For example, in sub-Saharan Africa tuberculosis is a leading cause of sepsis among those with HIV. Because one-third of patients with cancer in sub-Saharan Africa also have HIV, understanding the relationship between HIV status and treatment-related infections will inform locally relevant guidelines for cancer-related infections.

Educational interventions improve healthcare workers’ ability to prescribe the appropriate antibiotics. Almost two-thirds of our respondents received antibiotic teaching within the past year. Most received teaching during clinical care activities and used Internet searches and discussions with colleagues to answer antibiotic questions, indicating that just-in-time learning was a primary educational strategy. Respondents also considered readily accessible materials such as smartphone applications, teaching on ward rounds, and informational handouts to be “very helpful” learning formats. Although continuing medical education is traditionally delivered through didactic lectures, active learning strategies (eg, audit and feedback, case-based learning) and multimodal interventions increase knowledge retention and translation into clinical practice. The COVID-19 pandemic highlights the importance of using multimodal strategies, particularly for those living in low-resource settings. Online learning platforms are expensive and challenging to use when there is inconsistent Internet access. On-demand mobile tools (eg, smartphone apps) increase access to critical information during routine patient care and improve knowledge sharing across educational sites. Incorporating these tools into our ASP could improve evidence-based infectious disease management at our center.

Overall, in our study, nurses were less familiar with the terms “antimicrobial resistance” and “antimicrobial stewardship” than physicians or pharmacists. At UCI and in other hospitals in low-resource settings, nurses are often responsible for identifying patients with infections and initiating antibiotics. Thus, it is critical for oncology nurses to understand how to select the appropriate

![Perceived Contributions to Antimicrobial Resistance](image-url)

**Fig. 1.** Factors that physicians, pharmacists, and nurses working at the Uganda Cancer Institute (UCI) perceive as contributing to antimicrobial resistance at the UCI. Percentages shown next to bars represent the combined total percentage of respondents reporting that the factor does not or usually does not contribute (left of bars, main chart), occasionally or frequently contributes (right of bars, main chart), or neither contributes nor does not contribute (right of neutral chart).
Most stewardship interventions target physicians and pharmacists; thus, nurses are underutilized members of the stewardship team. In high-resource settings, nurse-driven protocols have been developed to facilitate blood culture collection and antibiotic initiation for patients with neutropenic fever. In sub-Saharan Africa, similar protocols have been developed to manage bacterial meningitis. These protocols improve guideline adherence, decrease time-to-antibiotics, and improve patient outcomes. Developing nurse-led protocols and training nurses in the principles of antimicrobial stewardship are ways to adapt ASPs for patients receiving cancer treatment in low-resource settings.

Our study had several limitations. This survey was completed at a single cancer center in sub-Saharan Africa, and the results may not be representative of other cancer centers. Given the numerous infectious diseases initiatives underway at UCI, knowledge of antimicrobial resistance and antimicrobial stewardship may be higher at UCI than in other cancer treatment programs. Those who responded may also have more training or inherent interest in the topic. In addition, some respondents did not answer every question, which influenced our ability to compare answers across questions. Because the survey took place during the COVID-19 pandemic, the frequency of education, concerns about supply availability, and issues with antibiotic shortages may not be typical. However, studies completed in low-resource settings before the COVID-19 pandemic had similar findings regarding antimicrobial education and antibiotic supply availability.

In this survey, we evaluated the knowledge and perceptions of antimicrobial resistance and stewardship among physicians, nurses, and pharmacists working at a single cancer hospital in sub-Saharan Africa. UCI staff were knowledgeable about the term antimicrobial resistance and antimicrobial stewardship may be higher at UCI than in other cancer treatment programs. Those who responded may also have more training or inherent interest in the topic. In addition, some respondents did not answer every question, which influenced our ability to compare answers across questions. Because the survey took place during the COVID-19 pandemic, the frequency of education, concerns about supply availability, and issues with antibiotic shortages may not be typical. However, studies completed in low-resource settings before the COVID-19 pandemic had similar findings regarding antimicrobial education and antibiotic supply availability.

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Fig. 3. Sources of antibiotic information for physicians, nurses, and pharmacists working at the Uganda Cancer Institute. Figure 3A shows the current sources of information used when answering specific antibiotic questions. Figure 3B shows the educational formats felt to be useful for future antibiotic training. Results are arranged by median category for frequency of use (3A) or degree of usefulness (3B).
Fig. 4. Factors that physicians, pharmacists, and nurses working at the Uganda Cancer Institute perceive as limiting the ability to diagnose infections and obtain blood cultures.

- Inability to obtain blood cultures: 93%
- Inability to regularly measure patient temperatures: 86%
- Delay in receiving lab results: 79%
- Inability to obtain other infectious testing: 76%
- Inability to obtain imaging: 59%

Limitations in Blood Culture Availability:

- Patient cost: 91%
- Culture supplies unavailable: 90%
- Delays in obtaining culture results: 89%
- Inability to transport culture bottles to lab: 53%
- Staff availability to draw cultures: 50%

Fig. 5. Interventions that nurses, pharmacists, and physicians perceive to be the most important to improving infection management at the Uganda Cancer Institute. Respondents ranked each intervention based on order of importance, with 1 being the most important and 6 the least important. Respondents who ranked all interventions were included (n = 30).

- Formal educational programs
- Establishing consistent microbiology diagnostics
- UCI–specific guidelines
- Distribution of educational materials
- Having dedicated pharmacists trained in antibiotics
- Establishing infectious diseases consult service

Median Rank
resources for blood cultures, implementing strategies to improve fever detection, and incorporating nurses as key members of the antimicrobial stewardship team. Our findings will inform the development of ASPs for cancer treatment programs in low-resource settings.

**Supplementary material.** For supplementary material accompanying this paper visit https://doi.org/10.1017/ash.2022.28

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**References**

1. Ferlay J, Shin HR, Bray F, Forman D, Mathers C, Parkin DM. Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. *Int J Cancer* 2010;127:2893–2917.
2. Lubwama M, Phipps W, Najjuka CF, et al. Bacteremia in febrile cancer patients in Uganda. *BMC Res Notes* 2019;12:464.
3. Mohammed HB, Yismaw MB, Fentie AM, Tadesse TA. Febrile neutropenia management in pediatric cancer patients at Ethiopian tertiary-care teaching hospital. *BMC Res Notes* 2019;12:528.
4. Ticku-Ward B. Prevalence and outcome of febrile neutropenia in paediatric cancer patients at Korle Bu teaching hospital, Accra, Ghana. *Pediatr Blood Cancer* 2016;63:586.
5. Saravanan M, Ramachandran B, Barabadi H. The prevalence and drug resistance pattern of extended spectrum β-lactamases (ESBLs) producing Enterobacteriaceae in Africa. *Microb Pathogen* 2018;114:180–192.
6. Sangare S, Maiga A, Guindo I, et al. Prevalence of extended-spectrum beta-lactamase–producing Enterobacteriaceae isolated from blood cultures in Africa. *Medecine et maladies infectieuses* 2015;45:374–382.
7. Scheis T, Weber S, Reinheimer C, et al. Bloodstream infections with gram-negative organisms and the impact of multidrug resistance in patients with hematological malignancies. *Ann Hematol* 2018;97:2225–2234.
8. Petti CA, Polage CR, Quinn TC, Ronald AR, Sande MA. Laboratory medicine in Africa: a barrier to effective health care. *Clin Infect Dis* 2006; 42:377–382.
9. Cooke FJ, Choubina P, Holmes AH. Postgraduate training in infectious diseases: investigating the current status in the international community. *Lancet Infect Dis* 2005;5:440–449.
10. Antimicrobial stewardship programmes in health-care facilities in low- and middle-income countries: a WHO practical toolkit. World Health Organization website. https://www.who.int/publications-detail-redirect/9789241515481. Published 2019. Accessed February 25, 2022.
11. Firefold AG, Bow EJ, Sepkowitz KA, et al. Clinical practice guideline for the use of antimicrobial agents in neutropenic patients with cancer: 2010 update by the Infectious Diseases Society of America. *Clin Infect Dis* 2011; 52:e56–e91.
12. Tverdek FP, Rolston KV, Chemaly RF. Antimicrobial stewardship in patients with cancer. *Pharmacotherapy* 2012;32:722–734.
13. Gulleen EA, Adams SV, Chang B, et al. Factors and outcomes related to the use of guideline-recommended antibiotics in patients with neutropenic fever at the Uganda Cancer Institute. *Open Forum Infect Dis*; 2021;8:1–9. doi: 10.1093/ofid/ofab307.
14. García C, Llomocca LP, García K, et al. Knowledge, attitudes and practice survey about antimicrobial resistance and prescribing among physicians in a hospital setting in Lima, Peru. *BMC Clin Pharmacol* 2011;11:1–8.
15. Fishman N, America SHEoA, America IDSo. Policy statement on antimicrobial stewardship by the Society for Healthcare Epidemiology of America (SHEA), the Infectious Diseases Society of America (IDSA), and the Pediatric Infectious Diseases Society (PIDS). *Infect Control Hosp Epidemiol* 2012;33:322–327.
16. Mendelson M, Matsoso MP. The World Health Organization global action plan for antimicrobial resistance. *S Afr Med J* 2015;105:325.
17. Abahamy A. Antibiotic stewardship: factors influencing the choice and outcomes of antimicrobial therapy in a resource-limited, rural, public hospital in mUmbhanyakde District, KwaZulu-Natal, South Africa: pre-intervention phase. *SA Pharm J* 2016;83:33–44.
18. Gebrehiwot Z, Tadiwos Y. Knowledge and beliefs of healthcare professionals towards antimicrobial resistance in hiwot fana specialized university hospital, in Harar, Ethiopia. *Infect Drug Resist* 2020;13:2027–2035.
19. Lubwama M, Adams S, Muwonge C, et al. Multidrug-resistant bacteria are common cause of neutropenic fever and increase mortality among patients with hematologic malignancies in Uganda. *Open Forum Infect Dis* 2019;6 suppl 2:S108–S109.
20. Kheder SI. Physicians’ knowledge and perception of antimicrobial resistance: a survey in Khartoum state hospital settings. *J Pharmaceut Res Int* 2013;347–362.
21. WHO Guidelines on Hand Hygiene in Health Care. Geneva: WHO; 2009:270.
22. Mboowa G, Serwadda I, Bulafu D, et al. Transmission dynamics of antimicrobial resistance at a national referral hospital in Uganda. *Am J Trop Med Hygiene* 2021;105:498–506.
23. Diagnostic stewardship: a guide to implementation in antimicrobial resistance surveillance sites: World Health Organization website. https://apps.who.int/iris/bitstream/handle/10665/251553/WHO-DGO-AMR-2016-3-eng.pdf. Published 2016. Accessed February 25, 2022.
24. Mula CT, Middleton L, Muula A, Solomon V, Varga C. Nurses’ role in antibiotic stewardship at medical wards of a referral hospital in Malawi: understanding reality and identifying barriers. *Int J Africa Nurs Sci* 2021;15:100311.
25. Koenig C, Schneider C, Morgan JE, Ammann RA, Sung L, Phillips B. Association of time to antibiotics and clinical outcomes in patients with fever and neutropenia during chemotherapy for cancer: a systematic review. *Support Care Cancer* 2020;28:1369–1383.
26. Jacobs J, Hardy L, Semret M, et al. Diagnostic bacteriology in district hospitals in sub-Saharan Africa: at the front-line of containment of antimicrobial resistance. *Front Med* 2019;9:205.
27. Pollack LA, Srinivasan A. Core elements of hospital antibiotic stewardship programs from the Centers for Disease Control and Prevention. *Clin Infect Dis* 2014;59:597–5100.
28. Cox JA, Vliege E, Mendelson M, et al. Antibiotic stewardship in low-and middle-income countries: the same but different? *Clin Microbiol Infect* 2017;23:812–818.
29. GDP Per capita (current US$)–Uganda. World Bank website. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=UG. Published 2016. Accessed February 25, 2022.
30. Park J, Kini TM, Hwang J-H, et al. Risk factors for febrile neutropenia during chemotherapy for HIV-related lymphoma. *J Korean Med Sci* 2012; 27:1468–1471.
31. Nwosu FC, Avershina E, Wilson R, Rudi K. Gut microbiota in HIV infection: implication for disease progression and management. *Gastroent Res Pract* 2014;2014:803185.
32. Gaskell KM, Feasey NA, Heyderman RS. Management of severe non-TB bacterial infection in HIV-infected adults. *Expert review of anti-infective therapy* 2015;13:183–195.
33. Mulu W, Yizengaw E, Alemu M, et al. Pharyngeal colonization and drug resistance profiles of Moraxella catarrhalis, Streptococcus pneumoniae, Staphylococcus aureus, and Haemophilus influenzae among HIV infected children attending ART Clinic of Felegehiwot Referral Hospital, Ethiopia. *PloS One* 2018;13:1–15.
34. Moore CC, Jacob ST, Banura P, et al. Etiology of sepsis in Uganda using a quantitative polymerase chain reaction-based TaqMan array card. *Clin Infect Dis* 2019;68:266–272.
35. Bender Ignacio R, Ghadrshenas M, Low D, Orem J, Casper C, Phipps W. HIV status and associated clinical characteristics among adult patients with cancer at the Uganda Cancer Institute. *J Global Oncol* 2017;4:1–10.

36. Sullivan T. ACCME annual report data 2011. *Reconstructive Review* 2012;2:88–93. doi: 10.15438/rr.v2i2.20.

37. Lall P, Rees R, Law GCY, Dunleavy G, Cotić Ž, Car J. Influences on the implementation of mobile learning for medical and nursing education: qualitative systematic review by the digital health education collaboration. *J Med Internet Res* 2019;21:e12895.

38. Salter C. Clinical pathways in the emergency department: successful implementation of ‘adult patients who are febrile following chemotherapy’ pathway. *Australasian Emerg Nurs J* 2005;8:27–34.

39. Wall EC, Mukaka M, Denis B, et al. Goal directed therapy for suspected acute bacterial meningitis in adults and adolescents in sub-Saharan Africa. *PLoS One* 2017;12:e0186687.

40. Knowles R, Sharland M, Hsia Y, et al. Measuring antibiotic availability and use in 20 low- and middle-income countries. *Bull W H O* 2020;98:177–187C.