BMJ Open

Emergency department antimicrobial use in a low-resource setting: results from a retrospective observational study at a referral hospital in Liberia

Sojung Yi ,[1] Anu Ramachandran,[1] Lane Epps,[1] Alex Mayah,[1] Taylor W Burkholder ,[2] Michael Senyu Jaung,[3] Ahson Haider,[4] Paul Whesseh,[5] John Shakpeh,[5] Kayla Enriquez ,[1] Corey Bills [6]

To cite: Yi S, Ramachandran A, Epps L, *et al*. Emergency department antimicrobial use in a low-resource setting: results from a retrospective observational study at a referral hospital in Liberia. *BMJ Open* 2022;**12**:e056709. doi:10.1136/bmjopen-2021-056709

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-056709).

SY and AR are joint first authors.

Received 09 September 2021
Accepted 24 March 2022

For numbered affiliations see end of article.

Correspondence to
Dr Sojung Yi;
sojung.yi@ucsf.edu

ABSTRACT

Objective Data on antimicrobial use in low-income and middle-income countries (LMICs) remain limited. In Liberia, the absence of local data impedes surveillance and may lead to suboptimal treatment, injudicious use and resistance against antimicrobials. This study aims to examine antimicrobial prescribing patterns for patients in the emergency department (ED) of a large Liberian public hospital. Secondarily, this prescribing was compared with WHO prescribing indicators.

Design Retrospective observational study.

Setting An adult ED of a large public hospital in Monrovia, Liberia.

Participants A total of 1082 adult patients (>18 years of age) were recorded in the ED, from 1 January to 30 June 2019.

Main outcome measures Number, type and name of antimicrobials ordered per patient were presented as number and percentages, with comparison to known WHO prescribing indicators. Pearson χ^2 tests were used to assess patient variables and trends in medication use.

Results Of the total patients, 44.0% (n=476) were female and the mean age was 40.2 years (SD=17.4). An average of 2.78 (SD=2.02) medicines were prescribed per patient encounter. At least one antimicrobial was ordered for 64.5% encounters (n=713) and two or more antimicrobials for 35.7% (n=386). All antimicrobial orders in our sample used the generic name. Ceftriaxone, metronidazole and ampicillin were the most common and accounted for 61.2% (n=743) of antimicrobial prescriptions. The majority (99.9%, n=1211) of antimicrobials prescribed were from the WHO Essential Drugs List.

Conclusion This study is one of the first on ED-specific antimicrobial use in LMICs. We revealed a high rate of antimicrobial prescription, regardless of patient demographic or diagnosis. While empiric antimicrobial use is justified in certain acute clinical scenarios, the high rate from this setting warrants further investigation. The results of this study underscore the importance of ED surveillance to develop targeted antimicrobial stewardship interventions and improve patient care.

Strengths and limitations of this study

- This is the first study to report on overall antimicrobial use in an emergency department in a low-resource setting in West Africa.
- Rates of antimicrobial use are significant in this context and generally higher than known international standards of rational drug use.
- Lack of patient detail and consistency in patient chart documentation presents significant obstacles for understanding antimicrobial prescription, use and ultimate administration course.
- Local laboratory culture data and antimicrobial resistance limits further generalisability of future recommendations.

INTRODUCTION

It is estimated that over half of all medicines worldwide are prescribed, dispensed or sold inappropriately.[1 2] In addition, approximately half of all patients fail to take their medication as prescribed or dispensed.[3] The systematic misuse and overuse of antimicrobial medications, specifically, is an urgent crisis leading to worldwide antimicrobial resistance. The rise in antimicrobial-resistant infections has led to increased morbidity, mortality and healthcare costs, with the impact arguably greatest on low-income countries, where there are fewer medication choices and higher rates of infectious disease.[4]

In 2015, the WHO renewed its proposal for improving awareness, increasing surveillance and optimising the rational use of antimicrobial medications.[5] Rational use of medications means patients receive the appropriate medicines, in doses that meet their individual requirements, for an adequate period of time and at the lowest cost both to them and the community.[6] The WHO/International Network for the Rational Use of Drugs (INRUD) has outlined indicators for rapid assessment of the facility, prescriber and patient care in prescribing patterns.[7] These include five indicators for prescribing

characteristics related to polypharmacy, antibiotic use, injection use, generic prescribing and adherence to the WHO Essential Medicines List.[8]

However, despite the growing global burden of inappropriate antimicrobial use and these international efforts for standardised assessment tools, few countries monitor medicine use, with data in low-income and middle-income countries (LMICs) being even more scarce.[9] Absence of local epidemiological data often leads to delayed or suboptimal treatment guidelines, contributing to the cycle of injudicious empirical use of antibiotics by prescribers based on anecdotal evidence or experience.[4]

In Liberia, a protracted civil war from 1989 to 2003 severely weakened its national health system, and the Ebola crisis of 2014–2016 exacerbated persistent vulnerabilities. With antibiotics available for purchase without prescription and limited public awareness of proper medicine use, antimicrobial resistance and transmission of infectious diseases, there is high potential for overuse of antimicrobial medications in Liberia. There have been no previous studies measuring antimicrobial use and resistance.

The aim of this study is to examine antimicrobial prescribing patterns among patients presenting to the emergency department (ED) of a large public referral hospital in Liberia. Secondarily, we aim to evaluate prescription patterns as they relate to the WHO/INURD guidelines and to identify areas to improve antimicrobial use in this low-resource setting.

METHODS

We performed a descriptive, observational study, investigating antimicrobial prescription patterns in all adult patients presenting to the ED at Redemption Hospital in Monrovia, the capital of Liberia. As the largest public hospital in Liberia, Redemption Hospital is a secondary level health facility with approximately 400 staff and 206 inpatient beds,[10] with a patient encatchment area estimated at over 400 000 people.[11]

We retrospectively reviewed 6 months of patients based on available ED charts. Charts were originally collected prospectively as part of a larger quality improvement project, from 1 January to 30 June 2019. This study includes adult patients (greater than or equal to 18 years) presenting to and cared for in a single ED. Patients seeking walk-in care are initially evaluated at the hospital triage and then referred based on complaint to an outpatient clinic, the obstetric unit, the paediatric ED or the adult ED. Only patients referred to and treated in the adult ED were included in this study. After patients are referred to the adult ED for evaluation, their charts are retrieved from medical records. The patient is then evaluated in the ED.

Eventual disposition after initial treatment and stabilisation may include either discharge or hospitalisation. Low acuity complaints are dealt with immediately and the patient is discharged from the ED with prescriptions for medication if needed. Most complaints, however, require more resources from the ED often leading to a prolonged ED stay. Among those patients necessitating admission, the lack of inpatient beds and providers leads to further ED length of stay and continued care management by ED providers.

The hospital ledger, intended to record all patient encounters in the ED, was compared with the actual number of patient charts collected during this study period. This comparison showed a discrepancy in the hospital ledger compared with the total patient charts collected; patients who were recorded in the ledger but had no corresponding chart to review were excluded.

For each encounter, patient demographics (age and sex), chief complaint, diagnosis and antimicrobial medications prescribed were collected. Cultures were not obtained given the limited capacity of Liberian clinical laboratories. If antimicrobials were prescribed, the medication class was recorded. Given the inconsistent documentation of medication dose, frequency, route and duration, further details of these medications were not included in this study.

Only antibiotics prescribed by and initiated for use in the ED were included. This study did not attempt to detail or describe inpatient antibiotic use. The patient chart reflected the patient's complete hospital course and not a static entry at one time period, therefore antibiotics could be changed including the addition of, or eventual discontinuation of, specific treatments depending on the patient's clinical course. Some antibiotics were changed during the course of the ED stay and contributed to the number of antibiotics prescribed. Often a patient with a prolonged stay in the ED is often noted to be 'admitted' to the ED, however, with care continually managed by ED staff. This study examines all antibiotic prescribing practices within the ED, whether discharged immediately or a prolonged stay.

Antimicrobial prescriptions were organised by pharmaceutical class, spectrum of activity and primary diagnosis. Due to the lack of consensus definition,[4 5] we defined broad spectrum as any antibiotic that acts against a wide range of disease-causing bacteria. These broad-spectrum antibiotics included combinations of penicillins including beta-lactamase inhibitors, third-generation and fourth-generation cephalosporins, fluoroquinolones and carbapenems. Narrow-spectrum antibiotics were defined as first-generation penicillins, aminoglycosides, metronidazole or macrolides.

There are no standardised treatment guidelines for infections in this hospital. An approved hospital formulary and essential medicines list exists; however, hospital antimicrobial stores are not recorded regularly, so the number of days that a set of key antimicrobials is out of stock is not easily trackable.

Statistical analysis

All data were securely collected and managed via REDCap (University of California San Francisco, San Francisco,

Table 1 WHO/INRUD prescribing indicators

	WHO/INRUD prescribing indicator	WHO reference values	Redemption hospital (Liberia)
1	Average number of medicines per encounter	<2	**2.78**
2	Percentage of medicines prescribed by generic name	100%	100%
3	Percentage of encounters with an antibiotic prescribed	<30%	**64.5%**
4	Percentage of encounters with an injection prescribed	<20%	**34.0%**
5	Percentage of medicines prescribed from an essential medicines list or formulary	100%	**95.4%**

Values in bold are above the WHO reference value.
INRUD, International Network for the Rational Use of Drugs.

California). All statistical analyses were performed using Stata (V.17, StataCorp LLC, College Station, Texas, USA). Baseline demographic and clinical characteristics of patients were presented as numbers and percentages for discrete variables.

We compared rates of medication use, and specifically antibiotic use, in this cohort to known respective reference values proposed by the WHO/INRUD prescribing indicators.[7 12 13] WHO references are not empirically determined, and the WHO recognises prescribing habits may differ widely from the proposed values, as presenting case mix at a facility and availability of resources influence these indicators. However, they represent the best-known standard about which to compare. The five WHO measures include: the average number of medicines per encounter, the percentage of medicines prescribed by generic name, the percentage of encounters with an antibiotic prescribed, the percentage of encounters with an injection prescribed and the percentage of medicines prescribed from an essential medicines list or formulary (table 1).

In the setting of categorical variables, Pearson χ^2 tests were used to assess whether antimicrobial ordering practices differed by patient sex, age and disposition. A p value<0.05 was considered statistically significant. Subsequent multivariable modelling (presented as ORs and 95% CIs) was attempted to explore the association between whether patients received any antibiotic and their demographic and clinical characteristics.

RESULTS

A total of 1082 adult ED patient charts were reviewed during the study period from 1 January to 30 June 2019. During the study period, 1552 patient encounters were recorded in the ED ledger; 1267 had available charts found and 185 were excluded from inclusion for being <18 years old, chart duplicates or containing insufficient information for analysis. Patient demographics and ED disposition are summarised in table 2. Disposition information was available for 898 of the 1082 patients (83.0%), of which 53.1% (n=575) were discharged from the ED and 9.8% (n=106) were admitted to inpatient wards. For patients with an ED disposition of 'discharged', they were discharged directly from the ED after evaluation. Of the patients seen in the ED during this study period, 44.0% were female (n=476) and the mean age was 40.2 years (SD=17.4). The overall rate of ED mortality was 12.3% (n=133) and 8.4% (n=91) after excluding patients who were dead on ED arrival (n=42).

The relationship between ED diagnosis and antimicrobial ordering is summarised in table 3. Several diagnoses were associated with 100% rates of antimicrobial ordering, including pelvic inflammatory disease (n=21), typhoid (n=20), chronic obstructive pulmonary disorder (n=13), HIV (n=11) and renal stone (n=6). Overall, 93% of patients were diagnosed with abdominal infections (n=122), 95.1% of patients were diagnosed with sepsis (n=39) and 92% of patients (n=115) were diagnosed with

Table 2 Patient demographics and antimicrobial ordering practices

	Total n (%)	Antimicrobial ordered n (%)	P value*
Total	1082 (100)	713 (65.9)	
Sex			0.26
Female	476 (44.0)	322 (67.7)	
Male	606 (56.0)	390 (64.4)	
Age (years)			0.29
18–35	571 (47.8)	331 (64.0)	
36–60	383 (35.4)	260 (67.9)	
60+	148 (13.7)	103 (69.6)	
ED disposition†			<0.001‡
Admitted	106 (9.8)	94 (88.7)	
Discharged	575 (53.1)	411 (71.5)	
Transfer	54 (5.0)	35 (64.8)	
Left Against Medical Advice (AMA)	30 (2.8)	24 (80.0)	
Died	133 (12.3)	81 (60.9)	

*P values listed are from Pearson χ^2 tests.
†Disposition data were available for 898 patients, out of the total 1082 indicated above.
‡P value compares admitted versus discharged patients only, and excludes transfers, AMAs and deaths.
ED, emergency department.

Table 3 Top 20 ED diagnoses with antimicrobials ordered

Diagnosis	Diagnosis n=558	Antimicrobials ordered n (%)
Pelvic inflammatory disease	21	21 (100)
Typhoid	20	20 (100)
Chronic obstructive pulmonary disease	13	13 (100)
HIV	11	11 (100)
Nephrolithiasis	6	6 (100)
Ovarian problem	5	5 (100)
Peritonitis	5	5 (100)
Renal failure	5	5 (100)
Ovarian problem	5	5 (100)
Allergic reaction	4	4 (100)
Meningitis	1	1 (100)
Gout	1	1 (100)
Dehydration	23	22 (95.7)
Sepsis	41	39 (95.1)
Urinary retention	19	18 (94.7)
Liver failure	15	14 (93.3)
Abdominal infections*	131	122 (93.1)
Skin and soft tissue infection	14	13 (92.9)
Malaria	125	115 (92.0)
Asthma	12	11 (91.7)
Urinary tract infection	55	49 (89.1)
Respiratory infection	26	23 (88.5)

*Includes diarrheal illnesses (eg, enteritis, colitis) and presumptive acute intra-abdominal infections (eg, presumed cholecystitis, appendicitis or diverticulitis) without peritonitis.
ED, emergency department.

malaria received antimicrobials (which includes antibiotics and antimalarials). Only 100 patients (80.0% of 125 with suspected or laboratory confirmed malaria) received antimalarials (table 4), suggesting that some patients with a diagnosis of malaria received both antimalarial prescriptions and antibiotic prescriptions.

Our study found the following results based on WHO/INRUD Prescribing Indicators (table 1).

Indicator 1: average number of medicines per encounter

The average number of all medicines prescribed per patient encounter was 2.78 (SD=2.02). The mean number of antimicrobials prescribed per all patient encounters was 1.12 (SD=1.01) and 1.17 (SD=1.01) among those who presented to the ED alive (n=1040). Among patient encounters in which antimicrobials were prescribed, the mean number was 1.70 (SD=0.78). Prescribing multiple antimicrobials per encounter was common, with 35.7% of patients (n=386) receiving two or more prescriptions (table 4).

Indicator 2: percentage of medicines prescribed by generic name

All antimicrobial medications were described by the drug's generic name (table 4).

Indicator 3: percentage of encounters with an antibiotic prescribed

Among all ED patient encounters, 65.9% had at least one antimicrobial order (n=713), and of those, 52.2% had the medication recorded as being administered (n=372). After removal of patients confirmed dead on ED arrival, the proportion of individuals receiving at least one antibiotic was 68.6%, as none of these patients received antibiotics.

Antimicrobials were ordered at a similar rate among females (67.7%) and males (64.4%, p=0.26; table 2). Antimicrobial ordering increased with age but was not significantly different between age groups (p=0.29). Antimicrobial ordering was significantly higher among patients admitted to the hospital as compared with those discharged (88.7%, p<0.001), but 71.5% of discharged patients were also prescribed antimicrobials.

Indicator 4: percentage of encounters with an injection prescribed

Ceftriaxone, metronidazole and ampicillin were the most commonly prescribed and accounted for 61.2% (n=743) of all antimicrobial prescriptions. Route of administration (oral, intravenous, etc) was not routinely recorded,

Table 4 Specific antimicrobial prescriptions and categories

	Number of prescriptions, n=1212 (%)
Antimicrobial name	
Ceftriaxone	342 (28.2)
Metronidazole	249 (20.5)
Ampicillin	152 (12.5)
Ciprofloxacin	82 (6.8)
Artemether	78 (6.4)
Amoxicillin	74 (6.1)
Gentamicin	69 (5.7)
Cloxacillin	56 (4.6)
Cotrimoxazole	19 (1.6)
Artemisinin	18 (1.5)
Doxycycline	17 (1.4)
Albendazole	14 (1.2)
Penicillin	13 (1.1)
Erythromycin	8 (0.7)
Ampicillin+cloxacillin	6 (0.5)
Mebendazole	3 (.3)
Quinine	3 (.3)
Fluconazole	2 (.2)
Nystatin	2 (.2)
Other*	5 (4.1)
Antimicrobial category	n=1212 (%)
Antibiotic	1089 (89.9)
Antifungal	6 (0.5)
Anthelmintic	17 (1.4)
Antimalarial	100 (8.3)
Antibiotic class	n=1089 (%)
Broad spectrum	750 (68.9)
Narrow spectrum	339 (31.1)
Antimicrobial prescriptions per patient encounter	n=1082 (%)
0	369 (34.1)
1	327 (30.2)
2	288 (26.6)
3	82 (7.6)
4	16 (1.5)

*One prescription each of nitrofurantoin, chloramphenicol, vancomycin, micafungin and griseofulvin.

but antimicrobials only available in injectable formulation (ceftriaxone, gentamicin, vancomycin and micafungin) accounted for a cumulative 34.0% (n=413) of all ordered antimicrobials. Our study did not review the hospital pharmacy's dispensing records and inconsistent recording of administration or completion of the medications in patient charts made it difficult to assess which medication the patient ultimately received.

Indicator 5: percentage of antibiotics prescribed from WHO Essential Drugs List

The majority (n=1211, 99.9%) of antimicrobials prescribed were from the WHO essential drugs formulary list[14] with micafungin (n=1) being the only exception. Antimicrobial categories prescribed are described in table 4. The majority were antibiotics (n=1089, 89.9% of prescriptions), followed by antimalarials (n=100, 8.3%). Among antibiotics, 68.9% (n=750) were broad spectrum.

Due to the large proportion of patients who received antibiotics and the subsequent lack of significant differences in univariable analysis across multiple characteristics, multivariable regression analysis was not performed.

DISCUSSION

This is the first study of antimicrobial prescribing practices in patients presenting to a large public hospital in Liberia. It describes the prescribing patterns in an acute care setting and reveals areas that could benefit from focused improvement efforts via comparison with WHO/INRUD prescribing indicators.

The WHO standard for average number of drugs prescribed per patient encounter is 2.0.[13] Rates higher than this standard are suggestive of polypharmacy, which can increase the risk of adverse drug interactions, non-adherence and antimicrobial resistance.[1] Our observed value of medicines per encounter (2.78 overall and 1.12 antimicrobials) is higher than the WHO index and falls within the range of similar emergency settings in LMICs reporting an average of 2.7 in Kenya,[15] 3.04 in Nigeria[16] and 4.8 in Ghana.[17] The high rate of prescriptions in this study may correlate to the relatively high ED mortality rate of 12.3% (8.4% when excluding patients dead on arrival). For reference, a meta-analysis of emergency care in 59 LMICs revealed a median mortality of 1.8%,[18] while ED rates of death in the USA are 0.04%.[19] Relatively higher rates of ED mortality in low-resource settings are multifactorial, with cited causes from similar contexts including undernutrition,[20] infectious diseases, injuries,[21] lack of staff training[22] and larger health systems barriers.[23]

In our sample, all medications were prescribed by their generic name. Prescribing generics is recommended to reduce health system and patient costs, to ensure consistency in medication dispensation and to allow for more accurate analysis of local drug resistance and disease prevalence patterns.[8 24] At the time of this study, there were minimal brand-named drug advertisements in Liberia leading to limited influence on prescribers or patient preference for non-generic products.

While our study often included medication administration dose, frequency and duration, it was more difficult to assess where the medications were acquired from and the ultimate course of the medications. Medications can be bought by patient families from local pharmacies outside of the hospital formularies even without a prescription, so whether the antimicrobials are given for their full course

may be limited by what is available in these different locations.

Over 60% of patients seen had at least one antimicrobial order, and a third had two or more antimicrobials ordered, regardless of the diagnosis. This value is much greater than the WHO standard, which recommends antibiotic prescriptions to not exceed 30% of all patient encounters.[13] This value is also higher than estimates from settings in the Eastern Mediterranean (53.2%), the Americas (39.3%) and European (33.5%) regions.[2] Several reasons for higher rates of antimicrobial prescribing have been previously studied, including patients with higher burdens of comorbidities,[8] increased rates of local infections, lack of diagnostics leading to empiric treatment[17] or a shortage of essential medicines prompting prescribers to combine medicines for more clinical effect.[25] All are possible in this context. Appropriate wound care with sterile materials and clean water is also limited, which may lead to increased antimicrobial use.

Antimicrobial ordering was largely unrelated to patient demographics, aside from a trend of increasing use with older age. The trend in increased prescriptions associated with older age may reflect an increasing severity of acute illness, the presence of more comorbidities in older patients or a lower risk tolerance among healthcare providers in treating older adults. Epidemiological data about chronic diseases in this area are limited, but many parts of the surrounding African region have a double burden of both communicable and non-communicable diseases,[26] which when coupled with an increasingly ageing population with significant comorbidities may lead to multiple medications.[27 28]

In this study, the route of administration (oral, intravenous, etc) was limited, but antimicrobials only available in injectable formulation (ceftriaxone, gentamicin, vancomycin and micafungin) accounted for 34.0% of all antimicrobial prescriptions. This value is greater than the WHO reference range of 20%. However, due to incomplete recording of administration and course of medications in the patient charts, as well as lack of hospital pharmacy dispensing records, the medications that patients ultimately received cannot be confirmed. Reasons for a high rate of intravenous medication prescription are multifactorial, but since patients cannot procure and self-administer intravenous medications, the high prescription pattern likely reflects a bias at the prescriber level. Inappropriate use of injectable medications can increase the risk of blood-borne infections and lead to morbidity and mortality.[29]

The majority (99.9%) of antimicrobials prescribed were from the WHO Essential Medicines List. Micafungin was the only medication not on the list. While antimicrobials can be available through the hospital or local formularies, which medications are actually present or affordable to the patient is not monitored with consistency or standardisation.

Global indicators including the WHO prescribing indicators are not contextualised and do not account for patient severity.[8] Antimicrobial use in this setting can be surmised from ultimate diagnoses but not evaluated precisely. While it is beyond the scope of this study, our results taken together suggest that antimicrobials may be overprescribed for non-communicable diseases and diagnoses, including allergic reaction and nephrolithiasis. Additionally, even when prescribed for infectious conditions, broad-spectrum antibiotics were used more often as first-line therapy (68.9% of prescriptions).

Facility and local stakeholder-driven efforts focused on awareness of local medication availability are critical to the development of antimicrobial surveillance. In Zambia, a study from the University Teaching Hospital (UTH) in Lusaka revealed significant differences between guidelines from international publications, the Zambian government and actual clinical practice.[9] Similar to our study context, antimicrobial treatment selection was influenced by a limited formulary in the hospital and public availability of antimicrobials without prescription. UTH proposed developing standardised guidelines for infectious and non-infectious diseases by individual institutions or regions to better respond to the local current needs, to use new information about optimal antimicrobial use, to standardise treatment and ultimately to improve patient outcomes.

The 2014–2016 Ebola virus disease outbreak in Liberia demonstrated critical gaps in the health system and health facility infection prevention and control practices, resulting in viral transmission to both healthcare workers and patients.[30] The Ebola response when coupled with results from this study provides insight into the need for a coordinated government response, in collaboration with local health facility input, in developing future Liberian antibiotic stewardship programmes.

There are several limitations to our study. First, patient charts were inconsistent in recording clinical courses. Even though antimicrobials were recorded as being prescribed, documentation on administration was inconsistent. Medication dose, frequency and route were sometimes included, but the total duration was rarely recorded in patient charts, or perhaps cut short by other causes that were not detailed. Lack of detail and consistency in patient charts not only affect analysis of the data but also patient safety. Given these charting limitations, appropriateness of antimicrobial prescribing for individual patients was not explored in this study. Second, while there is an approved hospital formulary list of essential medicines, availability of antimicrobials in the hospital formulary was not recorded regularly. In addition to inconsistent record-keeping, the stock itself may be variable due to supply chain issues, financing or other challenges that were not examined. Third, this study is a single hospital based setting and does not include antimicrobials prescribed or procured at unlicensed pharmacies prior to the hospital course, post discharge or even perhaps in lieu of professional care. Anecdotally in Liberia and according to published accounts in other LMICs,[31] many pharmacies dispense without a prescription. Our study reveals results

that are consistent with those in previous studies from other LMICs in the region. However, external validity is still limited as our study is from a single site without available published literature from Liberia for comparison. Our results may not be reflective of the antimicrobial ordering practices throughout the country, and more studies are needed to expand the depth and breadth of this understanding.

CONCLUSION

There is an urgent need to improve surveillance of antimicrobial use and resistance and to develop better prescribing practices in Liberia. Baseline data on the use of antimicrobials are the first step in promoting stewardship and quality improvement. Our study results reveal critical steps to improve antimicrobial prescribing which involves standardising clinical practice guidelines especially regarding appropriate antibiotic use, patient charting practices and inventory processes at the hospital formulary. In addition, understanding the role of independent community pharmacies and laboratory capacities will further clarify resources available to patients and providers. Lastly, education about each of these components by local health leaders is key to sustainable change. Greater commitment from local stakeholders and the government may foster optimal utilisation of scarce resources and improve antimicrobial prescribing practices in the region.

Author affiliations
[1]Department of Emergency Medicine, University of California San Francisco, San Francisco, California, USA
[2]Department of Emergency Medicine, University of Southern California, Los Angeles, California, USA
[3]Department of Emergency Medicine, Baylor College of Medicine, Houston, Texas, USA
[4]San Francisco State University, San Francisco, California, USA
[5]Redemption Hospital, Monrovia, Liberia
[6]Emergency Medicine, University of Colorado Denver School of Medicine, Aurora, Colorado, USA

Twitter Sojung Yi @sojung_yi

Contributors LE, AM, PW and JS collected primary data. SY, RA, LE, MSJ, KE and CB synthesised and analysed data. SY, RA, KE and CB wrote the manuscript and revised the manuscript. TWB, MSJ, LE, AH, PW and JS reviewed the manuscript. CB is the guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study was reviewed and deemed exempt by the National Research Ethics Board of the Ministry of Health in Liberia. The study was also reviewed and deemed exempt by the Institutional Review Board (IRB) of the University of California San Francisco (Study #: 18-25346; Reference #: 224880). This research includes program evaluations and quality improvement activities that do not require further IRB oversight. For both committees, the study title is: 'Effective Triage and Stabilization of Adults Presenting to the Triage Unit, Adult Emergency Room and Isolation Unit at Redemption Hospital in Monrovia, Liberia'.

Data availability statement Data are available upon reasonable request.

ORCID iDs
Sojung Yi http://orcid.org/0000-0002-8163-5053
Taylor W Burkholder http://orcid.org/0000-0003-4648-180X
Kayla Enriquez http://orcid.org/0000-0002-4186-0045
Corey Bills http://orcid.org/0000-0002-3456-6008

REFERENCES

1 World Health Organization. Promoting rational use of medicines: core components. who policy perspectives on medicines, 2002. No.5. Available: http://apps.who.int/medicinedocs/pdf/h3011e/h3011e.pdf [Accessed April 21, 2021].
2 Shankar PR. Medicines use in primary care in developing and transitional countries: fact book summarizing results from studies reported between 1990 and 2006. *Bull World Health Organ* 2009;87:804–805.
3 Sabaté E, *eds*, World Health Organization. Adherence to long-term therapies: evidence for action. *World Health Organization* 2003.
4 Laxminarayan R, Duse A, Wattal C, *et al*. Antibiotic resistance-the need for global solutions. *Lancet Infect Dis* 2013;13:1057–98.
5 World Health Organization. Global action plan on AMR. *World Health Organization* 2021 http://www.who.int/antimicrobial-resistance/global-action-plan/en/
6 Holloway K, van Dijk L. The world medicines situation 2011. *Rational Use Of Medicine* 2011;24.
7 Systems SP. How to investigate antimicrobial use in hospitals: selected indicators. published for the U. *S. Agency for International Development by the Strengthening Pharmaceutical Systems Program. Management Sciences for Health* 2012;79.
8 Ofori-Asenso R. A closer look at the world Health organization's prescribing indicators. *J Pharmacol Pharmacother* 2016;7:51–4.
9 Masich AM, Vega AD, Callahan P, *et al*. Antimicrobial usage at a large teaching hospital in Lusaka, Zambia. *PLoS One* 2020;15
10 Jones T, Ho L, Kun KK, *et al*. Rebuilding people-centred maternal health services in post-Ebola Liberia through participatory action research. *Glob Public Health* 2018;13:1650–69.
11 Ministry of health Liberia. Abbreviated resettlement action plan for the construction of the new redemption Hospital by the Ministry of health. *Published online* 2016 https://documents1.worldbank.org/curated/en/332861479984929201/pdf/SFG2673-RP-P152359-Box396334B-PUBLIC-Disclosed-11-23-2016.pdf
12 World Health Organization. Guide to drug financing mechanisms, 1998. Available: https://apps.who.int/iris/handle/10665/42110
13 World Health Organization. Using indicators to measure country pharmaceutical situations. *Fact Book on WHO Level I and Level II monitoring indicators* 2006.
14 World Health Organization. World Health organization model list of essential medicines, 21st list, 2019., 2019. Available: https://www.who.int/publications/i/item/WHOMVPEMPIAU2019.06
15 Mulwa NC, Osanjo GO, Ndwigah SN. Patterns of prescribing practices in Makueni County referral Hospital, Kenya;8.
16 Tamuno I, Fadare JO. Drug prescription pattern in a Nigerian tertiary hospital. *Trop J Pharm Res* 2012;11:146–52.
17 Bosu WK, Ofori-Adjei D. An audit of prescribing practices in health care facilities of the Wassa West district of Ghana. *West Afr J Med* 2000;19:298–303.
18 Obermeyer Z, Abujaber S, Makar M, *et al*. Emergency care in 59 low- and middle-income countries: a systematic review. *Bull World Health Organ* 2015;93:577–86.
19 Tang N, Stein J, Hsia RY, *et al*. Trends and characteristics of US emergency department visits, 1997-2007. *JAMA* 2010;304:664–70.
20 Ahmed T, Hossain M, Sanin KI. Global burden of maternal and child undernutrition and micronutrient deficiencies. *Ann Nutr Metab* 2012;61:8–17.
21 James SL, Castle CD, Dingels ZV, *et al*. Estimating global injuries morbidity and mortality: methods and data used in the global burden of disease 2017 study. *Inj Prev* 2020;26:i125–53.

22 Aluisio AR, Barry MA, Martin KD, *et al*. Impact of emergency medicine training implementation on mortality outcomes in Kigali, Rwanda: an interrupted time-series study. *Afr J Emerg Med* 2019;9:14–20.
23 Baelani I, Jochberger S, Laimer T, *et al*. Availability of critical care resources to treat patients with severe sepsis or septic shock in Africa: a self-reported, continent-wide survey of anaesthesia providers. *Crit Care* 2011;15:R10.
24 Nicolosi E, Gray A. Potential cost savings from generic medicines—protecting the prescribed minimum benefits. *South African Family Practice* 2009;51:59–63.
25 Ball DE, Maidza J, Rusike T, *et al*. Drug use indicators at St Mary's clinic. *Cent Afr J Med* 2000;46:54–5.
26 de-Graft Aikins A, Unwin N, Agyemang C. Tackling Africa's chronic disease burden: from the local to the global. *Global Health* 2010;6.
27 Dagli RJ, Sharma A. Polypharmacy: a global risk factor for elderly people. *J Int Oral Health* 2014;6:i–ii.
28 National Research Council. Aging in sub-Saharan Africa: recommendations for furthering research. *National Academies Press* 2006;11708.
29 Kermode M. Unsafe injections in low-income country health settings: need for injection safety promotion to prevent the spread of blood-borne viruses. *Health Promot Int* 2004;19:95–103.
30 Ridge LJ, Stimpfel AW, Klar RT, *et al*. Infection prevention and control in Liberia 5 years after Ebola: a case study. *Workplace Health Saf* 2021;69:242–51.
31 Barker AK, Brown K, Ahsan M, *et al*. What drives inappropriate antibiotic dispensing? A mixed-methods study of pharmacy employee perspectives in Haryana, India. *BMJ Open* 2017;7