J Antimicrob Chemother 2014; **69**: 2337–2353
doi:10.1093/jac/dku176 Advance Access publication 30 May 2014

Journal of Antimicrobial Chemotherapy

Antimicrobial drug resistance among clinically relevant bacterial isolates in sub-Saharan Africa: a systematic review

Stije J. Leopold[1], Frank van Leth[1], Hayalnesh Tarekegn[1] and Constance Schultsz[1,2]*

[1]*Department of Global Health, Amsterdam Institute for Global Health and Development, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands;* [2]*Department of Medical Microbiology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands*

*Corresponding author. Tel: +31-20-5667800; Fax: +31-20-5669557; E-mail: schultsz@gmail.com

Received 5 November 2013; returned 17 January 2014; revised 25 March 2014; accepted 28 April 2014

Background: Little is known about the prevalence of antimicrobial resistance (AMR) amongst bacterial pathogens in sub-Saharan Africa (sSA), despite calls for continent-wide surveillance to inform empirical treatment guidelines.

Methods: We searched PubMed and additional databases for susceptibility data of key pathogens for surveillance, published between 1990 and 2013. Extracted data were standardized to a prevalence of resistance in populations of isolates and reported by clinical syndrome, microorganism, relevant antimicrobial drugs and region.

Results: We identified 2005 publications, of which 190 were analysed. Studies predominantly originated from east sSA (61%), were hospital based (60%), were from an urban setting (73%) and reported on isolates from patients with a febrile illness (42%). Quality procedures for susceptibility testing were described in <50% of studies. Median prevalence (MP) of resistance to chloramphenicol in Enterobacteriaceae, isolated from patients with a febrile illness, ranged between 31.0% and 94.2%, whilst MP of resistance to third-generation cephalosporins ranged between 0.0% and 46.5%. MP of resistance to nalidixic acid in *Salmonella enterica* Typhi ranged between 15.4% and 43.2%. The limited number of studies providing prevalence data on AMR in Gram-positive pathogens or in pathogens isolated from patients with a respiratory tract infection, meningitis, urinary tract infection or hospital-acquired infection suggested high prevalence of resistance to chloramphenicol, trimethoprim/sulfamethoxazole and tetracycline and low prevalence to third-generation cephalosporins and fluoroquinolones.

Conclusions: Our results indicate high prevalence of AMR in clinical bacterial isolates to antimicrobial drugs commonly used in sSA. Enhanced approaches for AMR surveillance are needed to support empirical therapy in sSA.

Keywords: antimicrobial resistance, antimicrobial susceptibility testing, surveillance, empirical treatment, bacterial infections

Introduction

Effective empirical therapy of bacterial diseases requires knowledge of local antimicrobial resistance (AMR) patterns, acquired through up-to-date surveillance. Recently, alarming reports on the prevalence of (multi)drug-resistant bacteria in low- and middle-income countries in Asia, particularly the Indian subcontinent, have been published.[1]

Very little is known about current resistance patterns of common pathogenic bacteria in sub-Saharan Africa (sSA) where surveillance capacity is minimal.[2] In sSA, the relative burden of infectious diseases is high.[3] Recent studies show that the consumption of antimicrobials is rising in sSA;[4] however, often only a small repertoire of (poor-quality) antimicrobials is available, which may be sold over the counter without proper diagnostic guidance.[5] Inadequate hygiene and infection control in hospitals may increase the spread of (multi)drug-resistant pathogens.[6] In the absence of continent-wide surveillance of drug resistance in sSA, as recommended by the WHO,[7] and while awaiting further implementation of effective surveillance programmes in sSA, few analyses and reviews have been done describing increasing AMR in the region.[8,9] Other review studies have either focused on a certain subregion,[10] specific age group,[11] class of antibiotics[12] or clinical syndrome.[13,14]

This review aims to give a broader and updated overview of AMR in sSA (excluding South Africa) between 1990 and 2013. Common bacterial pathogens for this region were included, classified by the WHO as key pathogens for surveillance, causing community- as well as hospital-acquired infections.

Methods

Search strategy

We searched PubMed for articles published in English, French, German or Dutch between 1990 and 2013 using a dedicated search string

© *The Author 2014. Published by Oxford University Press on behalf of the British Society for Antimicrobial Chemotherapy. All rights reserved. For Permissions, please e-mail: journals.permissions@oup.com*

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

(see the Supplementary methods, available as Supplementary data at *JAC* Online). Additional searches were performed in the online database of the Cochrane Database of Systematic Reviews and in African Journals Online using the search terms 'antimicrobial drug resistance', 'antimicrobial susceptibility' and 'Africa'. Reference lists of relevant articles were scanned for additional titles (see the Supplementary methods).

Study selection criteria

Studies were included in this systematic review if they were published between January 1990 and January 2013 and reported *in vitro* resistance levels to relevant antibiotics in key pathogens for surveillance, determined for at least 10 unique isolates which were cultured from patients with corresponding clinical syndromes, in sSA. We included studies reporting on samples from both sterile as well as non-sterile sites taken from patients of all age groups.

The selection of clinical syndromes, pathogens and antibiotics was based on the WHO recommendations published in the 2002 Surveillance Standards for Antimicrobial Resistance[7] (Table 1). In addition to the list recommended by WHO, the following pathogens were added based on their clinical relevance: non-typhoidal *Salmonella* species,[15] *Shigella flexneri* and *Shigella sonnei* (designated *Shigella* non-*dysenteriae*), *Vibrio cholerae*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Staphylococcus aureus* (Table 1). For patients with a febrile illness, key pathogens isolated from any clinical sample were included. The selection of relevant antibiotics was broadened based on expert opinion and included narrow-spectrum and extended-spectrum β-lactams (with or without β-lactamase inhibitor), aminoglycosides, macrolides, (fluoro)quinolones, chloramphenicol, tetracyclines, trimethoprim/sulfamethoxazole (co-trimoxazole) and nitrofurantoin (Table S1, available as Supplementary data at *JAC* Online).

The selection of countries in sSA was based on the composition of the geographical region of sSA as defined by the United Nations Statistics Division[16] (2011; Figure 1). The Republic of South Africa was excluded based on the premise that a disproportionate amount of data would be available in comparison to the other included countries.[13] Distinction was made between hospital-acquired and community-acquired infections, with the former being defined as new clinical infections in patients who had been admitted for ≥48 h in a hospital setting.

Selection procedure

The titles and abstracts of all search results were listed per country and were reviewed by at least two investigators (S. J. L., H. T., C. S. and F. v. L.) to identify papers for full-text review. Abstract-based selection was done using predefined inclusion and exclusion criteria. When selection of articles on the basis of abstracts remained inconclusive, full texts were retrieved. Disagreement about selection of abstracts was resolved by the independent review of a third investigator. Names of authors from articles in the search results were not blinded before or during abstract and full-text review. When papers were selected for full-text review after abstract review, retrieval of the full-text version was attempted through PubMed, institutional web sites, the medical library of the University of Amsterdam, the Royal Tropical Institute (Amsterdam), HINARI (Geneva) or by personal communication with study authors. Full-text review was performed by two investigators (S. J. L. and H. T.) using a pre-specified checklist.

Studies were required to fulfil all selection criteria and none of the exclusion criteria. None of the papers selected for full-text review was excluded based on *a priori* set quality criteria given the absence of such criteria for AMR surveys or laboratory-based studies (see the Supplementary methods).

Discrepancies between the two reviewers on inclusion or exclusion of an article for analysis were independently resolved by a third investigator. Reports on specific subgroups such as patients infected with HIV/AIDS; or reports on isolates which were analysed in a laboratory outside the region but obtained from patients in one of the predefined countries, were included.

Data extraction

A database was created in which the study period and the year of publication, study location, clinical syndrome and pathogen(s) tested were recorded. In addition, we recorded the age group, study and laboratory setting, sample type, culture methods, susceptibility testing methods,

Table 1. Predefined list of clinical syndromes, pathogens and included publications

Clinical syndrome	Syndromes included	Pathogen	References
Acute diarrhoea	dysentery, gastrointestinal tract infection, diarrhoea, enteritis	*Shigella dysenteriae*, *Shigella* non-*dysenteriae*, non-typhoidal *Salmonella*, *Vibrio cholerae*, *Escherichia coli*	28–70
Acute respiratory infection	acute otitis media, upper respiratory tract infection, lower respiratory tract infection, pneumonia	*Streptococcus pneumoniae*, *Haemophilus influenzae*, *Staphylococcus aureus*	71–80
Febrile illness/ septicaemia	febrile illness, typhoid fever, bacteraemia, septicaemia, invasive pneumococcal disease, neonatal infection	*S. pneumoniae*, *H. influenzae*, *S. aureus*, *Neisseria meningitidis*, *Salmonella enterica* Typhi, non-typhoidal *Salmonella*, *E. coli*, *Shigella* non-*dysenteriae*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*	54,78,81–154
Hospital-acquired infection	hospital acquired: UTI, acute diarrhoea, septicaemia, bacteraemia, surgical wound infection, acute respiratory infection	*S. aureus*, *E. coli*, *P. aeruginosa*, *K. pneumoniae*	107,155–159
Meningitis	pyogenic meningitis, meningitis	*N. meningitidis*, *S. pneumoniae*, *H. influenzae*, *S. aureus*	160–172,146,173–175
UTI	urethritis, cystitis, pyelonephritis	*E. coli*, *K. pneumoniae*, *P. aeruginosa*, *S. aureus*	159,176–193
Urethral/vaginal discharge	gonorrhoea, urethral discharge, vaginal discharge, sexually transmitted infection	*Neisseria gonorrhoeae*	194–214
Wound infection	burn wound, wound infection, skin infection	*S. aureus*, *P. aeruginosa*	215–217

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

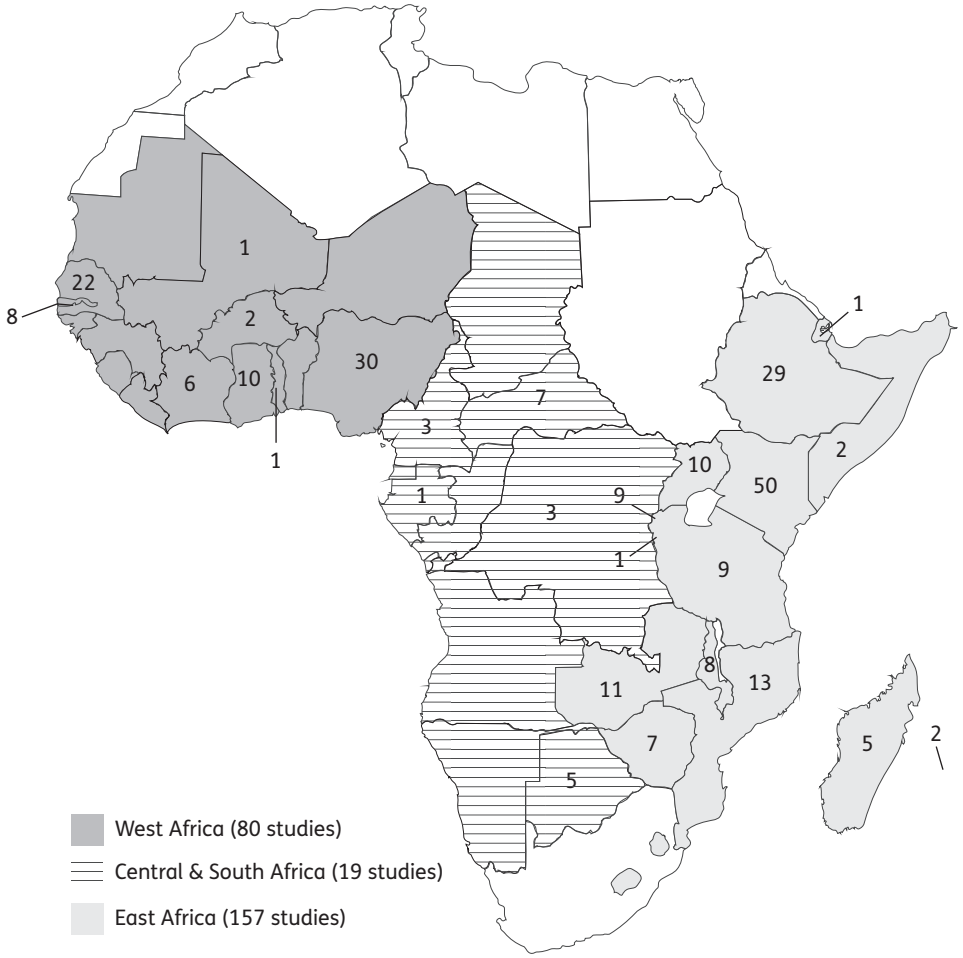


Figure 1. Composition of geographical subregions of Africa. The selection of countries in Africa was based on the composition of geographical regions as defined by the United Nations Statistics Division. We included all countries in the western, central, eastern and southern regions of the African continent except for the Republic of South Africa. Data from Central and South Africa were combined for analysis. The entire region of northern Africa (Algeria, Egypt, Libya, Morocco, South Sudan, Sudan, Tunisia and Western Sahara) was not included. Numbers in countries indicate the number of studies included in the analysis for the country in which the number appears. The total number of studies (256) exceeds the number of publications (190) because publications could include multiple studies (see the Methods section).

type of guideline used for susceptibility testing and whether quality control was done and breakpoints were reported. Quantitative data included the population size, sample size, number of isolates tested and the number of resistant strains per pathogen. Susceptibility data were recorded for each pathogen individually for a range of pre-specified antibiotics. The investigators recorded resistance data by extracting the percentages or numbers of susceptible, intermediate and resistant strains when available, based on the interpretation used in the original articles.

Analysis approach

The extracted data were standardized to a prevalence of resistance, defined as the percentage of isolates being resistant out of the total number of isolates tested for the specific drug. Intermediate susceptible strains were categorized as resistant. Susceptibility data obtained by determination of the MIC were only included if prevalence of resistance could be determined and were combined with resistance estimates obtained using disc diffusion for a given pathogen. We report the prevalence of resistance as the median with the corresponding IQR by clinical syndrome, microorganism and most relevant antimicrobial drugs.

For publications that reported on a single clinical syndrome but for separate independent periods of data collection or from different independent study populations, e.g. community-acquired and hospital-acquired infections, we considered each independent dataset as a separate study. A single study could report on multiple syndromes, resulting in the number of syndromes reported being larger than the number of studies included, which in turn is larger than the number of publications extracted.

We did not pursue a meta-analysis of AMR to antimicrobial drugs of particular interest, after initial meta-regression showed an unacceptably large heterogeneity between the studies at the level of geographical region. A meta-analysis within each of the geographical regions was considered but rejected on the basis of having too few studies for most of the pathogen–antimicrobial drug combinations per region. For selected clinical syndromes and microorganisms, we show individual study data of resistance estimates to give insight into the spread and precision of individual studies. In addition, attempts were made to analyse time trends of resistance to relevant antimicrobial drugs for these microorganisms. CIs were based on the binomial distribution with an Agresti adjustment if needed.[17] All analyses were performed using STATA version 12 (STATA, College Station, TX, USA).

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

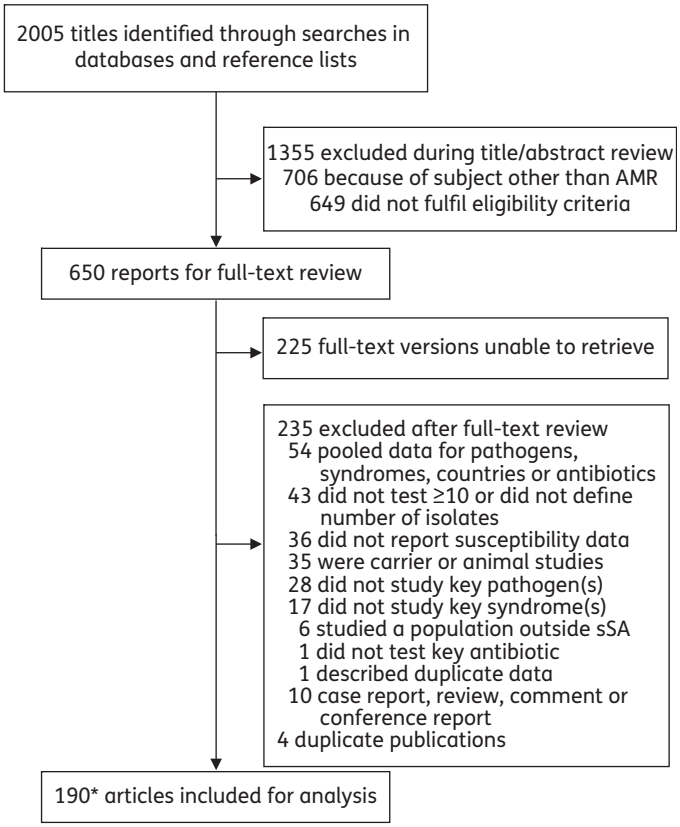


Figure 2. Flow chart of article selection procedure. *The total number of studies (256) exceeds the number of publications (190) because publications could include multiple studies (see the Methods section).

Results

Characteristics of studies included in the analysis

Our search generated 2005 articles. During abstract review, 1355 articles were excluded because they did not meet the inclusion criteria. Six hundred and fifty articles were identified for full-text review, of which 190 were included in the final analysis (Figure 2), yielding a total of 256 studies. Eighty studies originated from west sSA (WA), 19 from central or southern sSA (CSA) and 157 from east sSA (EA). Two out of 8 (25%) countries in WA (Nigeria and Senegal) accounted for 65% of studies from this region, whilst 2 of 14 (14%) countries (Ethiopia and Kenya) accounted for 50% of studies from EA (Figure 1).

A total of 256 studies were included in the analysis, of which a majority of 154 (60%) reported on data obtained in hospital-based clinical studies. Seventy-three percent of the studies were derived from an urban setting. The laboratories where antimicrobial susceptibility data were generated were based in clinical hospitals in 190 (74%) studies. The use of guidelines for antimicrobial susceptibility testing (AST) was reported in 197 (77%) studies. However, only 116 (45%) studies reported which breakpoints were used to define susceptibility and resistance of the isolates tested, while 120 (47%) studies reported on the application of quality controls when performing AST.

The 256 studies provided 259 estimates for the included clinical syndromes. Four publications reported on both community-acquired and hospital-acquired infections. The number of studies per clinical syndrome varied widely, with a low number of studies including bacterial meningitis (20; 8%) and urinary tract infection (UTI) (24; 9%) isolates, compared with studies including isolates associated with diarrhoea (54; 21%) and febrile illness (109; 42%).

The study period in which data were collected was not reported in the majority of the studies, precluding analysis of time trends.

Pathogens isolated from patients with a community-acquired febrile illness

The median prevalence of resistance to ampicillin and co-trimoxazole for the Enterobacteriaceae, isolated from patients with febrile illness, ranged between 55.6% and 96.7% and between 51.0% and 86.7%, respectively. The median prevalence of resistance to chloramphenicol, including for *Salmonella enterica* Typhi, ranged between 31.6% and 94.2% for WA and between 31.0% and 70.2% for EA, whilst a study from CSA showed a prevalence of 41.3% in *Salmonella* Typhi. The median prevalence of resistance to third-generation cephalosporins ranged between 0.0% and 46.5% in WA, between 6.0% and 15.4% in CSA and between 0.0% and 22.0% in EA (Table S2, available as Supplementary data at *JAC* Online). Fluoroquinolone resistance prevalence was generally low. However, the median prevalence of resistance to nalidixic acid in *Salmonella* Typhi, indicative of reduced susceptibility to fluoroquinolones, ranged between 34.8% in EA, 15.4% in CSA and 43.2% in WA. Data on azithromycin resistance in any of the Enterobacteriaceae was only found in one study on *Salmonella* Typhi from CSA reporting a 1% resistance prevalence.[154] Individual study data of chloramphenicol, third-generation cephalosporins and fluoroquinolone resistance prevalence in *Escherichia coli* and *Salmonella* Typhi, combining all sSA regions, are presented in Figure 3. The median prevalence of gentamicin resistance ranged between 16.0% and 35.0% for *E. coli* and 28.6% and 47.0% for *K. pneumoniae* (Table S2).

Data for *Streptococcus pneumoniae* isolated from patients with a febrile illness indicated high levels of resistance to co-trimoxazole and tetracycline (Table S3, available as Supplementary data at *JAC* Online). Resistance to erythromycin showed a consistently low prevalence whilst the median prevalence of resistance to amoxicillin was 3.6% in WA and 15.8% in EA. There was an equally striking difference in the median prevalence of resistance reported to third-generation cephalosporins of 0% in WA and 22.1% in EA, in the absence of data from CSA (Table S3). In contrast, the median prevalence of resistance to chloramphenicol was similar in both regions with 8.0% in WA and 7.1% in EA.

The median prevalence of resistance to oxacillin in *S. aureus* isolated from patients with a febrile illness was 13.4% for WA and 8.0% for EA, in the absence of data from CSA. The median prevalence of resistance to tetracycline, erythromycin, chloramphenicol and co-trimoxazole in *S. aureus* ranged from 21.4% for erythromycin to up to 80.0% for co-trimoxazole (Table S3).

Pathogens isolated from patients with community-acquired acute diarrhoea or UTI

The median prevalence of resistance to ciprofloxacin and third-generation cephalosporins in Enterobacteriaceae isolated from patients with diarrhoea was low (Table S4, available as Supplementary data at *JAC* Online). Data on resistance to third-

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

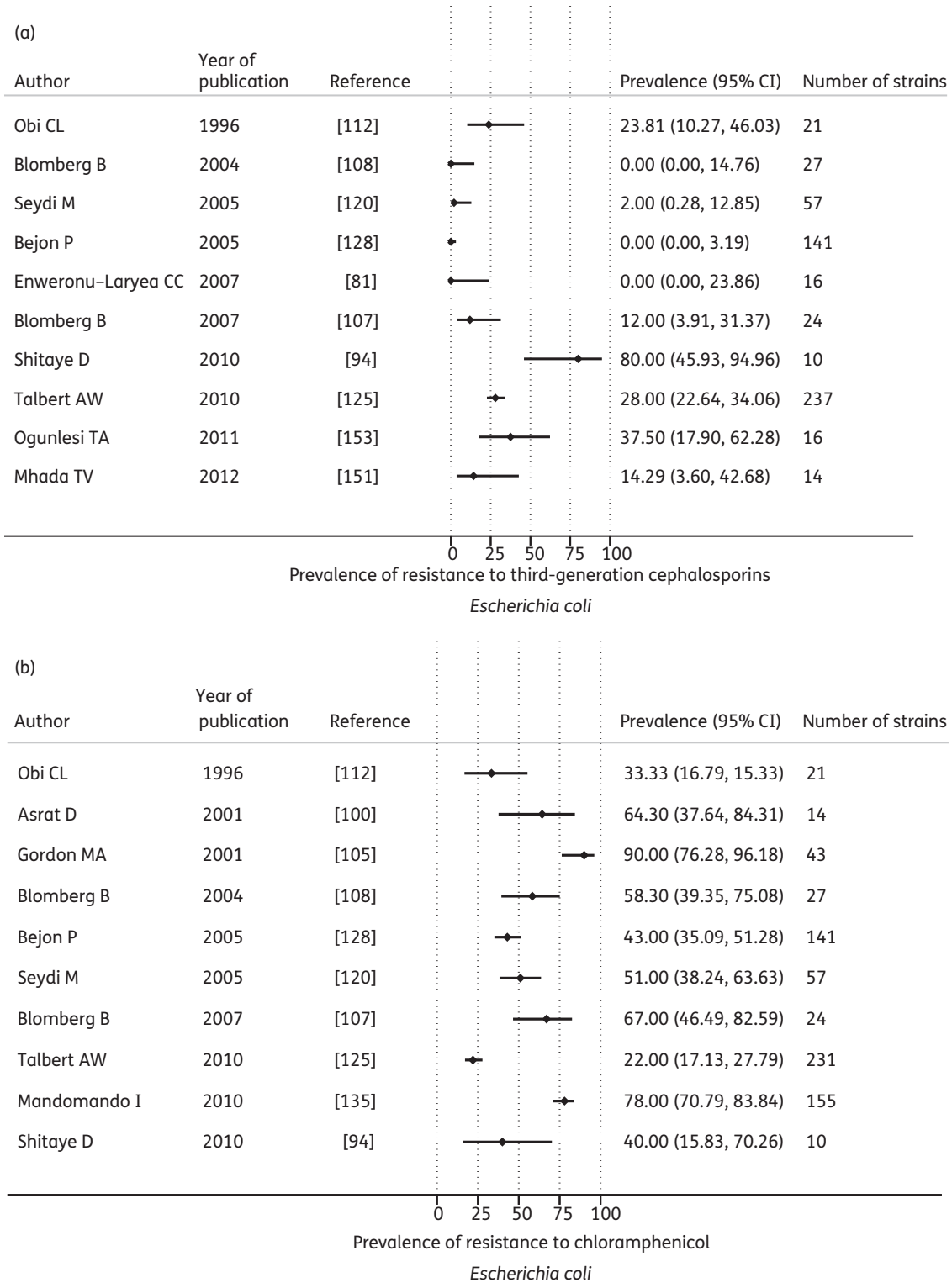
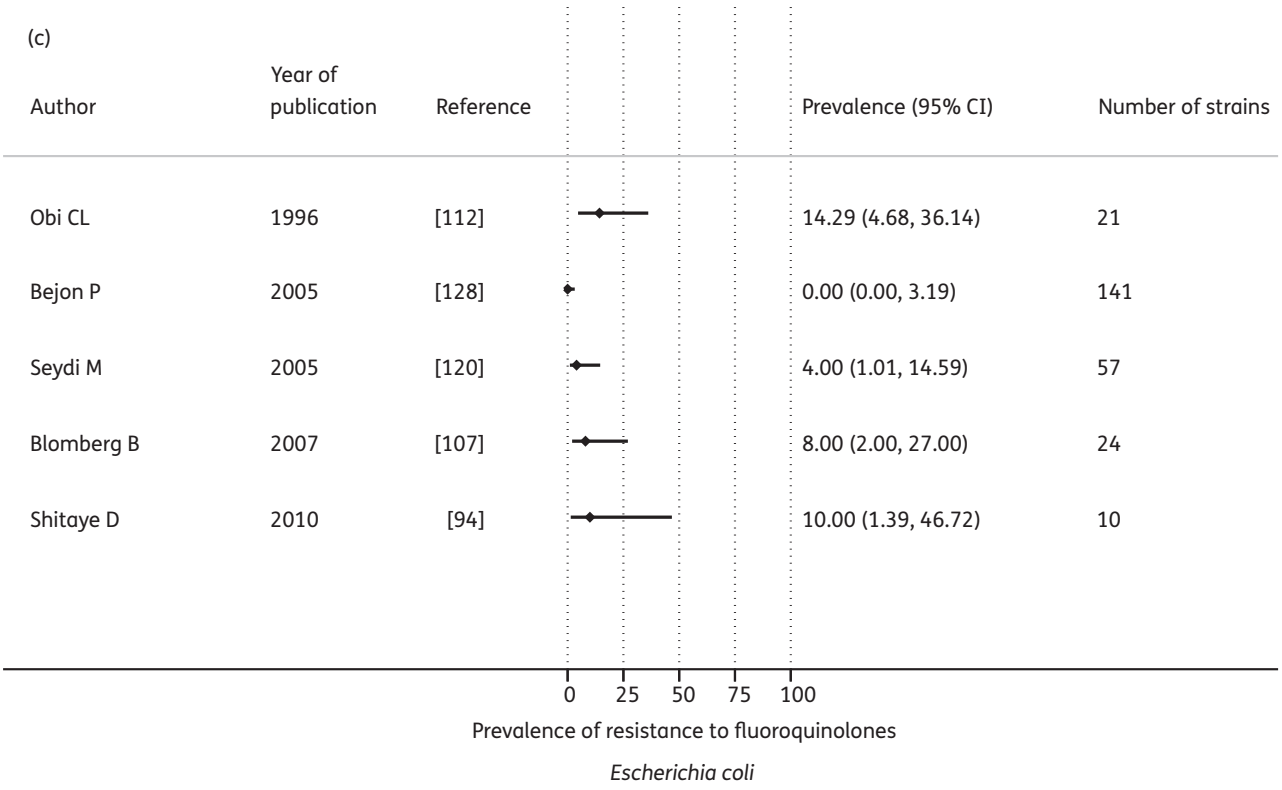


Figure 3. Point prevalence estimates of resistance in *E. coli* and *Salmonella* Typhi isolated from patients with a community-acquired febrile illness. Summary chart of point prevalence estimates of individual studies presenting prevalence data on resistance to third-generation cephalosporins (a and d), chloramphenicol (b and e) and fluoroquinolones (c and f) of *E. coli* (a–c) and *Salmonella* Typhi (d–f) isolated from patients with a community-acquired febrile illness, combining all sub-Saharan African regions. A publication that appears with multiple entries reported on separate independent periods of data collection or on different independent study populations, each of which was considered a separate study.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

(c)



(d)

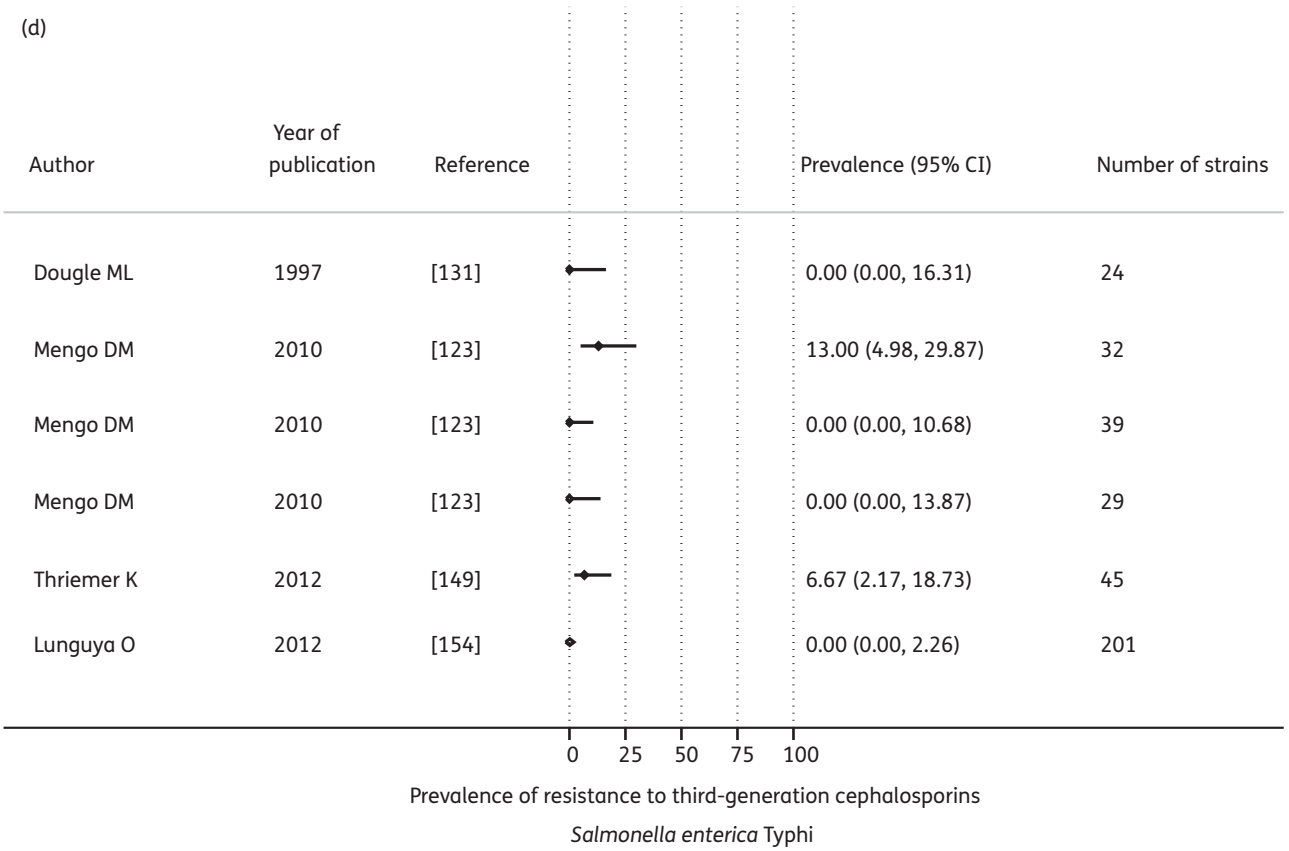
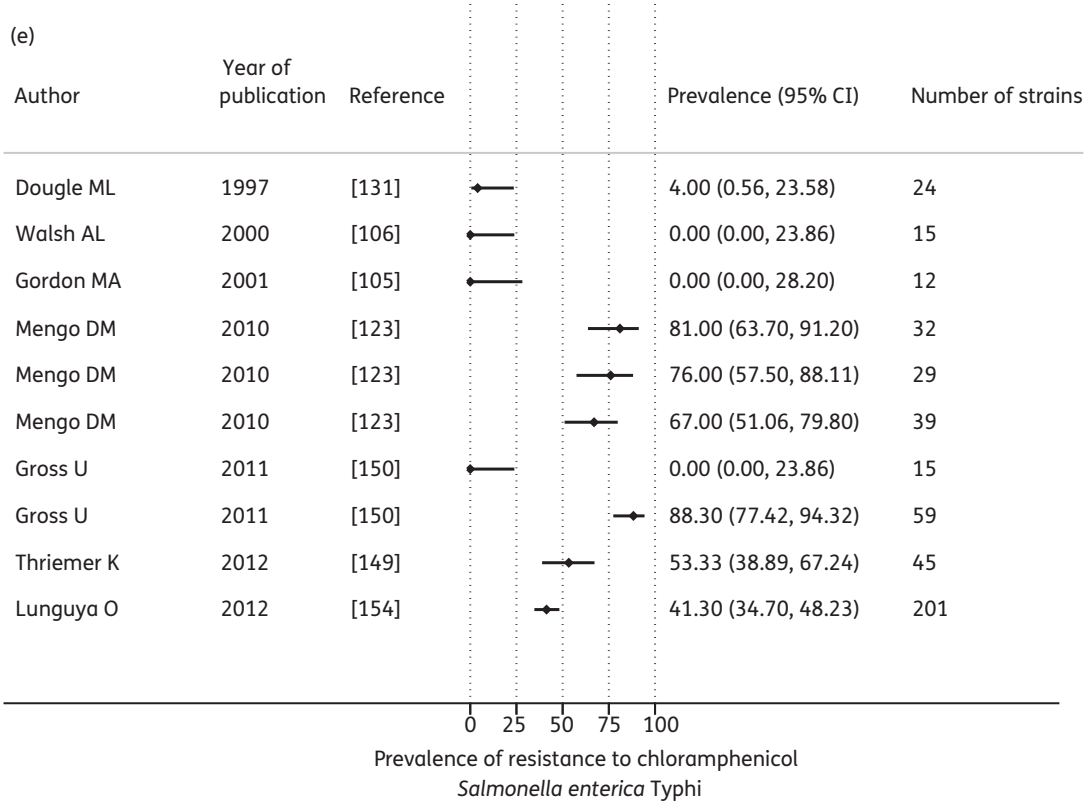


Figure 3. *Continued*

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024



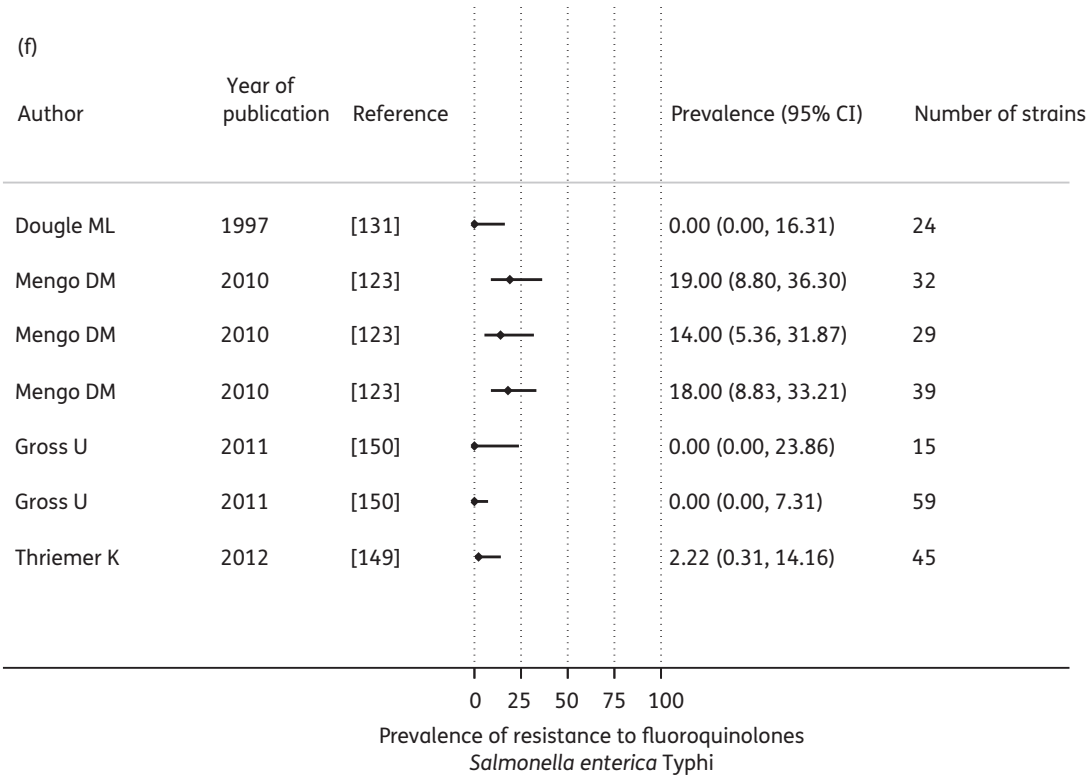


Figure 3. *Continued*

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

generation cephalosporins of *E. coli* and *K. pneumoniae* isolated from patients with UTIs were only available for WA and indicated a median prevalence of resistance of 5.0% and 4.3%, respectively (Table S5, available as Supplementary data at *JAC* Online). Data on resistance in Enterobacteriaceae isolated from urinary culture indicated high levels of resistance to co-trimoxazole and ampicillin, similar to isolates from patients with diarrhoea (Tables S4 and S5), leaving nitrofurantoin and ciprofloxacin for oral therapy (Table S5). Individual study data of co-trimoxazole, fluoroquinolone and nitrofurantoin resistance rates of *E. coli* and *K. pneumoniae*, isolated from patients with a community-acquired UTI combining all sSA regions, are presented in Figure 4.

Pathogens isolated from patients with community-acquired acute respiratory tract infection

A limited number of studies reported on resistance in respiratory isolates of *S. pneumoniae* and *Haemophilus influenzae* (Table S6, available as Supplementary data at *JAC* Online). The median prevalence of resistance to erythromycin was consistently low for *S. pneumoniae* and ranged between 0% and 5.9%. The median prevalence of resistance to tetracycline was high for both *S. pneumoniae* (42.7%) and *H. influenzae* (100%) in WA, but much lower in EA (13% and 0%, respectively). Similarly, the median prevalence of resistance to co-trimoxazole appeared much higher in WA than in EA for both pathogens.

Pathogens isolated from patients with other clinical syndromes

The number of studies reporting on isolates of *S. pneumoniae*, *H. influenzae* and *Neisseria meningitidis* from patients with meningitis (not related to outbreaks) for which resistance data were reported was small. However, data indicated a high median prevalence of resistance to chloramphenicol and ampicillin for *H. influenzae* isolates (Table S7, available as Supplementary data at *JAC* Online). Very few studies reported data on resistance to third-generation cephalosporins in these pathogens. The median prevalence of resistance reported was 0% for *S. pneumoniae*, between 0% and 6.0% for *H. influenzae* and 6.5% for *N. meningitidis* (Table S7).

Neisseria gonorrhoea, isolated from patients with urethral or vaginal discharge, showed a high median prevalence of resistance to penicillin and tetracycline. The median prevalence of resistance to ciprofloxacin and ceftriaxone was 0%, except for ceftriaxone resistance in CSA for which a median of 11.6% was reported (Table S8, available as Supplementary data at *JAC* Online).

We found very few studies on hospital-acquired infections in sSA and the available studies reported on small numbers of isolates. Data from EA suggested that methicillin-resistant *S. aureus* is prevalent in hospitals. Data on isolates obtained from wound infections provided similar limited information (Tables S9, S10, S11 and S12, all available as Supplementary data at *JAC* Online).

Discussion

AMR is rapidly increasing across the globe. Given the importance of bacterial infections in the aetiology of febrile illness and other clinical syndromes in sSA, empirical treatment of these clinical syndromes should include antimicrobial therapy guided by the local epidemiology of AMR.[14,18,19] Unfortunately, as our results show, data on the prevalence of resistance to commonly used antimicrobial drugs in major bacterial pathogens based on systematic prospective surveillance of AMR in sSA are still limited or absent.

Our results indicate that the majority of the available data for sSA included in the analysis come from a limited number of countries and settings. There is a paucity of data from CSA countries. In addition to the introduction of bias, this geographical distribution of included studies indicates a virtual absence of recent information on AMR in clinical pathogens, outside of outbreak settings, in the majority of sSA countries. The median prevalence of resistance reported to chloramphenicol, which is inexpensive and therefore commonly used, was high across the different clinical syndromes and throughout sSA and chloramphenicol should not be recommended for use without availability of susceptibility test results. The median prevalence of resistance to third-generation cephalosporins in *E. coli* and *K. pneumoniae*, presumably largely due to the production of extended-spectrum β-lactamases, and the median prevalence of resistance to gentamicin, the main representative of the aminoglycosides reported, were also considerable. Taken together, these data present a worrisome picture of AMR in Enterobacteriaceae in sSA, currently leaving third-generation cephalosporins and the fluoroquinolones as the main drugs of choice for empirical treatment of febrile illness and the carbapenems as an alternative (Table S13, available as Supplementary data at *JAC* Online).

Strikingly few studies reported on resistance rates in Enterobacteriaceae isolated from patients with UTI. This observation is surprising as bacterial culture of urine is relatively easy, in contrast to culture of faeces, blood or CSF, and AST results can provide clues into the prevalence of AMR in the community. In addition, empirical treatment of UTIs is likely to contribute heavily to community-based antimicrobial drug usage, thus contributing to AMR. A high median prevalence of resistance to co-trimoxazole, ampicillin and amoxicillin/clavulanic acid in *E. coli* and *K. pneumoniae* was reported. The main remaining options for oral therapy are nitrofurantoin and fluoroquinolones. However, nitrofurantoin may not be available in all countries in sSA.

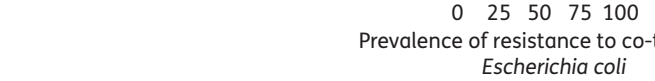
As was also reported by other investigators,[13] there is a staggering lack of data on resistance in pathogens causing bacterial meningitis, outside of outbreak settings. The development of rapid diagnostic tests (RDTs) to improve diagnostic capacity for bacterial meningitis is extremely valuable for diagnostic practice, but enhanced efforts in clinical bacteriology will be needed to provide data on penicillin resistance in isolates of *S. pneumoniae* and *N. meningitidis* which RDTs currently do not provide.[20,21] The latter notion also applies to *N. gonorrhoea* and resistance to fluoroquinolones and third-generation cephalosporins. Data on AMR in nosocomial infections are equally lacking and there is an urgent need for better insight into AMR prevalence in hospitals, particularly in intensive care settings.[20]

There are a number of methodological considerations related to the studies included in our review. The majority of studies were urban hospital-laboratory based and therefore reflected AMR prevalence in a biased study population with potentially higher resistance prevalence than population-based studies or studies from rural areas would have yielded. In addition, reporting of technical performance of susceptibility testing suggests that quality

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

(a)

Author	Year of publication	Reference	Prevalence (%) (95% CI)	Number of strains
Adeyemo AA	1994	[178]	0.00 (0.00, 20.67)	18
Obi CL	1996	[187]	99.00 (96.09, 99.75)	192
Wolday D	1997	[184]	75.00 (68.54, 80.51)	201
Moges F	2002	[183]	60.30 (49.11, 70.51)	78
Dromigny JA	2002	[191]	59.00 (52.58, 65.12)	234
Dromigny JA	2002	[191]	61.60 (55.48, 67.37)	255
Musa–Aisien AS	2003	[177]	60.00 (34.81, 80.82)	15
Dromigny JA	2003	[190]	60.90 (54.49, 66.96)	233
Hima–Lerible H	2003	[180]	85.00 (78.88, 89.58)	174
Brown BJ	2003	[176]	0.00 (0.00, 21.63)	24
Adjei O	2004	[179]	13.33 (3.36, 40.54)	15
Dromigny JA	2005	[189]	67.80 (60.44, 74.37)	171
Dromigny JA	2005	[189]	71.10 (62.14, 78.67)	114
Dromigny JA	2005	[189]	64.60 (55.38, 72.85)	113
Tessema B	2007	[182]	76.50 (69.45, 82.33)	166
Randrianirina F	2007	[186]	73.10 (69.43, 76.48)	607
Sire JM	2007	[188]	58.50 (52.73, 64.04)	289
Sire JM	2007	[188]	71.90 (66.75, 76.53)	323
Sire JM	2007	[188]	72.10 (65.61, 77.78)	207
Assefa A	2008	[181]	13.60 (4.45, 34.72)	22
Aboderin OA	2009	[192]	95.00 (82.10, 98.75)	41
Muvunyi CM	2011	[159]	80.60 (69.86, 88.16)	72



Prevalence of resistance to co-trimoxazole
Escherichia coli

(b)

Author	Year of publication	Reference	Prevalence (%) (95% CI)	Number of strains
Adeyemo AA	1994	[178]	0.00 (0.00, 20.67)	18
Obi CL	1996	[187]	0.00 (0.00, 2.36)	192
Moges F	2002	[183]	0.00 (0.00, 2.72)	78
Hima–Lerible H	2003	[180]	10.00 (6.31, 15.49)	174
Tessema B	2007	[182]	12.70 (8.43, 18.69)	166
Randrianirina F	2007	[186]	16.40 (13.67, 19.56)	607
Sire JM	2007	[188]	9.70 (6.78, 13.69)	289
Sire JM	2007	[188]	15.40 (11.87, 19.75)	323
Sire JM	2007	[188]	22.10 (16.97, 28.25)	207
Aboderin OA	2009	[192]	80.50 (65.60, 89.94)	41
Muvunyi CM	2011	[159]	30.95 (21.35, 42.53)	72

Prevalence of resistance to fluoroquinolones
Escherichia coli

Figure 4. Point prevalence estimates of resistance in *E. coli* and *K. pneumoniae* isolated from patients with a community-acquired UTI. Summary chart of point prevalence estimates of individual studies presenting prevalence data on resistance to trimethoprim/sulfamethoxazole (co-trimoxazole) (a and d), fluoroquinolones (b and e) and nitrofurantoin (c) of *E. coli* (a–c) and *K. pneumoniae* (d and e) isolated from patients with a community-acquired UTI, combining all sub-Saharan African regions. A publication that appears with multiple entries reported on separate independent periods of data collection or on different independent study populations, each of which was considered a separate study.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

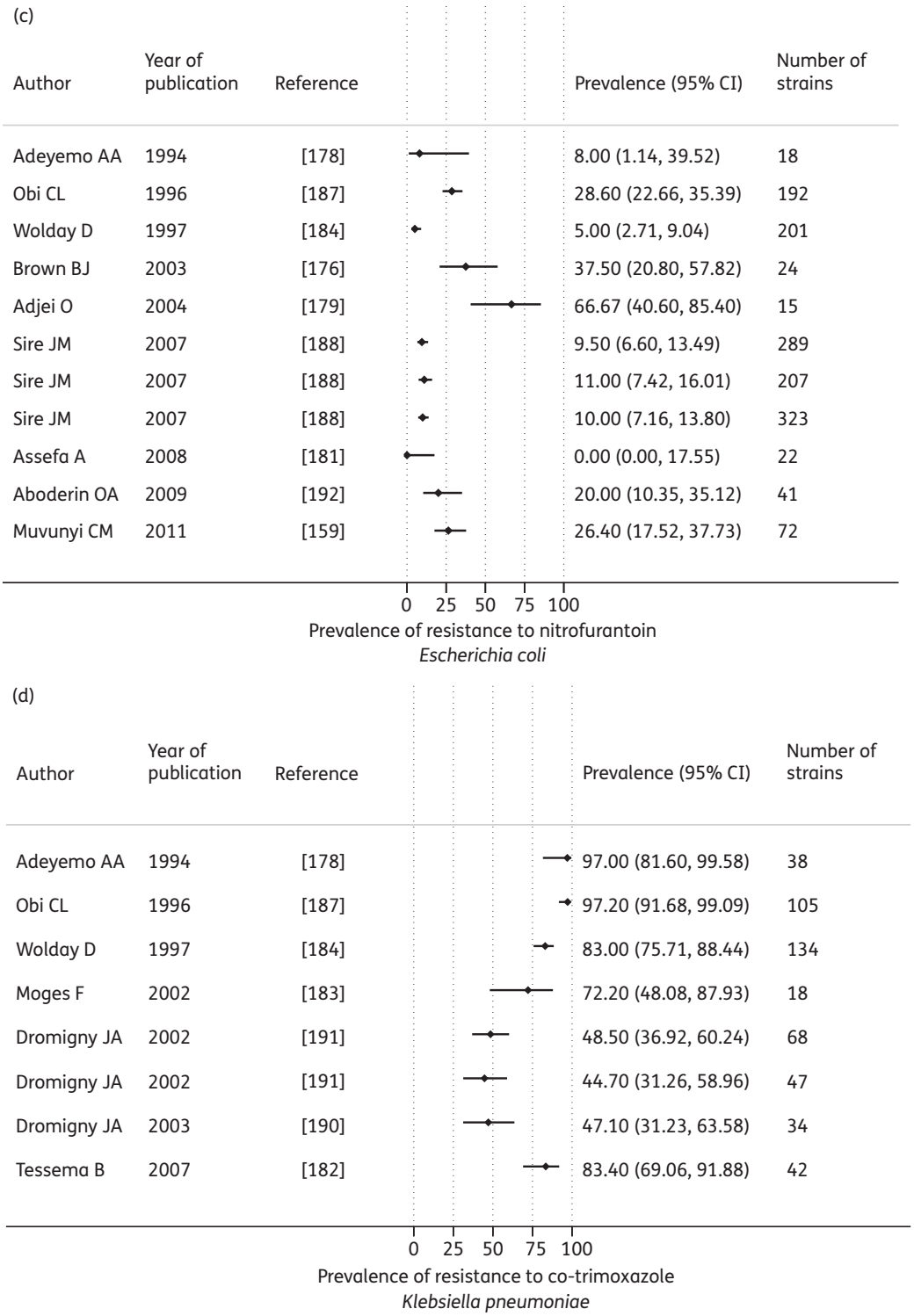


Figure 4. *Continued*

control and quality assurance procedures were in place in only a limited number of laboratories. The poor reporting of breakpoints used to assign strains to a susceptible, intermediate resistance (where applicable) or resistance category suggests that a heterogeneous set of cut-offs may have been used, which may have changed over time. However, in a sensitivity analysis we observed a similar median prevalence of resistance to the most commonly reported antimicrobial drugs in *E. coli*, *S. aureus* and

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

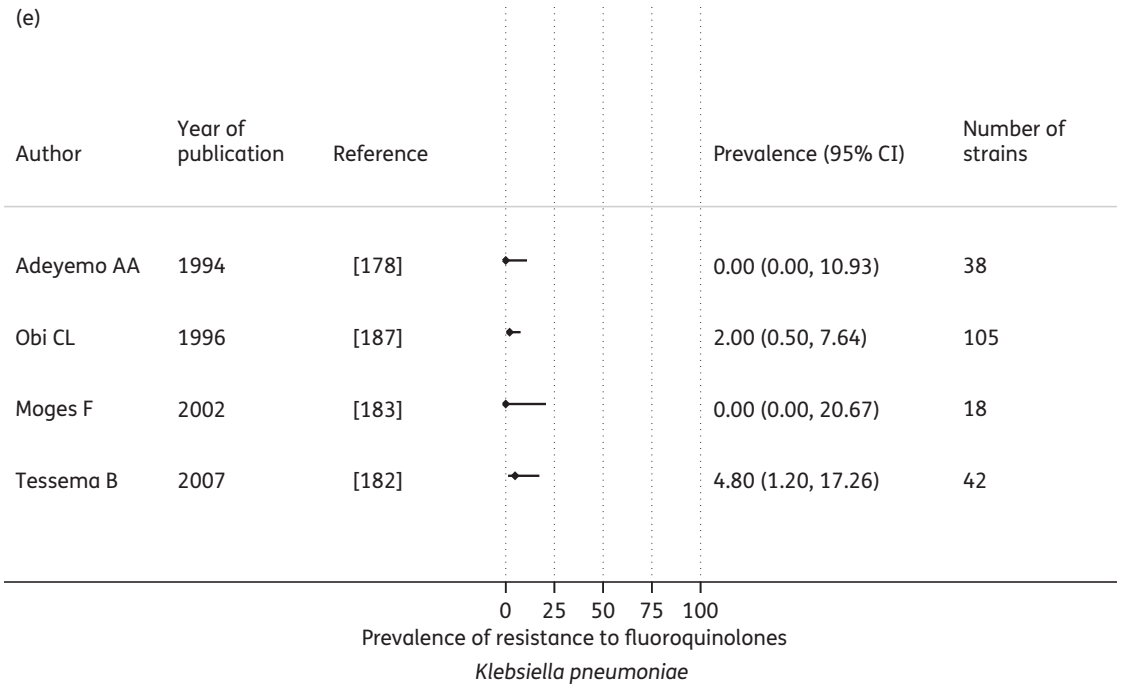


Figure 4. *Continued*

Salmonella Typhi, stratified by region (EA and WA), in studies reporting breakpoints compared with studies not reporting breakpoints (data not shown). Previous reviews on bacterial AMR in sSA, which were limited to certain regions[10] or antibiotic class,[12] reported similar issues. Clearly, there is a need for not only standardized performance of laboratory procedures but also for standardized reporting of the results obtained in the international literature.

A considerable proportion of publications identified for full-text review could not be retrieved despite our access to major online databases and medical libraries through multiple research institutes. Publications in highly accessed journals were therefore more likely to be retrieved for analysis. We only included studies reporting AMR data that could be related to a relevant clinical syndrome. With this approach we minimized case-mix and allowed ourselves to describe AMR data with relevance to a clinical setting and empirical treatment strategies. We therefore excluded articles that did not describe any clinical syndrome, in which a clinical syndrome or patient population could not be linked to the pathogens studied or in which a combined resistance was reported for pathogens isolated from different clinical syndromes. Due to these selection criteria, certain potentially highly relevant resistance data may have been excluded from the analysis, including e.g. data on non-typhoidal *Salmonella* species and data reported in carrier studies. Information on the year of isolation of the reported pathogens was often missing and therefore it was impossible to analyse trends of AMR over time. Despite these drawbacks, our results suggest high prevalence of AMR in clinical bacterial isolates to antimicrobial drugs that are commonly used in sSA. This finding warrants adjustment of empirical treatment guidelines towards recommendations including antimicrobial drugs for which resistance prevalence appears low to moderate, including, for example, nitrofurantoin for uncomplicated UTI and vancomycin for treatment of methicillin-resistant *S. aureus* infections. Unfortunately, such drugs are often not available in local hospitals or pharmacies.

The WHO recommends continent-wide surveillance of AMR as a health systems approach for containment,[22] of which the relevance has been underlined by others.[23,24] The implementation of surveillance programmes in low- and middle-income countries was shown to be challenging because human and financial resources and microbiology expertise are insufficient,[25,26] particularly if adequate sample sizes are to be reached. Clearly, novel approaches to AMR surveillance are needed, which may depend on smaller sample sizes and can provide locally relevant knowledge of AMR patterns, allowing for appropriate empirical antimicrobial therapy.[27]

Funding

The study was carried out as part of our routine work.

Transparency declarations

None to declare.

Author contributions

C. S. conceived the study. C. S., F. v. L. and S. J. L. designed the study. S. J. L. and H. T. searched published work, reviewed published papers and made the primary selection of eligible papers. C. S. and F. v. L. resolved disagreements regarding the eligibility of papers. S. J. L., H. T. and F. v. L. compiled the data. F. v. L. and C. S. analysed the data. All authors contributed to the writing of the report and have seen and approved the final version.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

Supplementary data

Supplementary methods and Tables S1 to S13 are available as Supplementary data at *JAC* Online (http://jac.oxfordjournals.org/).

References

1 Kumarasamy KK, Toleman MA, Walsh TR *et al*. Emergence of a new antibiotic resistance mechanism in India, Pakistan, and the UK: a molecular, biological, and epidemiological study. *Lancet Infect Dis* 2010; **10**: 597–602.

2 Okeke IN, Aboderin OA, Byarugaba DK *et al*. Growing problem of multidrug-resistant enteric pathogens in Africa. *Emerg Infect Dis* 2007; **13**: 1640–6.

3 Murray CJ, Ezzati M, Flaxman AD *et al*. GBD 2010: a multi-investigator collaboration for global comparative descriptive epidemiology. *Lancet* 2012; **380**: 2055–8.

4 Laxminarayan R, Bhutta Z, Duse A *et al*. Drug resistance. In: Jamison DT, Breman JG, Measham AR *et al*., eds. *Disease Control Priorities in Developing Countries*. 2nd edn. Washington, DC: World Bank, 2006.

5 Morgan DJ, Okeke IN, Laxminarayan R *et al*. Non-prescription antimicrobial use worldwide: a systematic review. *Lancet Infect Dis* 2011; **11**: 692–701.

6 Okeke IN, Lamikanra A, Edelman R. Socioeconomic and behavioral factors leading to acquired bacterial resistance to antibiotics in developing countries. *Emerg Infect Dis* 1999; **5**: 18–27.

7 WHO. *Surveillance Standards for Antimicrobial Resistance*. 2002. http://www.who.int/csr/resources/publications/drugresist/whocdscsrdrs20015.pdf (23 March, date last accessed).

8 Okeke IN, Laxminarayan R, Bhutta Z *et al*. Antimicrobial resistance in developing countries. Part I: recent trends and current status. *Lancet Infect Dis* 2005; **5**: 481–93.

9 Hart C, Kariuki S. Antimicrobial resistance in developing countries. *BMJ* 1998; **128**: 2462–6.

10 Vlieghe E, Phoba MF, Tamfun JJM *et al*. Antibiotic resistance among bacterial pathogens in Central Africa: a review of the published literature between 1955 and 2008. *Int J Antimicrob Agents* 2009; **34**: 295–303.

11 Lubell Y, Ashley E, Turner C *et al*. Susceptibility of community-acquired pathogens to antibiotics in Africa and Asia in neonates—an alarmingly short review. *Trop Med Int Health* 2011; **16**: 145–51.

12 Lubell Y, Turner P, Ashley E *et al*. Susceptibility of bacterial isolates from community-acquired infections in sub-Saharan Africa and Asia to macrolide antibiotics. *Trop Med Int Health* 2011; **16**: 1–14.

13 Ashley E, Lubell Y, White NJ *et al*. Antimicrobial susceptibility of bacterial isolates from community acquired infections in sub-Saharan Africa and Asian low and middle income countries. *Trop Med Int Health* 2011; **16**: 1167–79.

14 Reddy E, Shaw AV, Crump J. Community-acquired bloodstream infections in Africa: a systematic review and meta-analysis. *Lancet Infect Dis* 2010; **10**: 417–32.

15 Feasey NA, Dougan G, Kingsley RA *et al*. Invasive non-typhoidal *Salmonella* disease: an emerging and neglected tropical disease in Africa. *Lancet* 2012; **379**: 2489–99.

16 United Nations Statistics Division. *Composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings*. 2011. http://unstats.un.org/unsd/methods/m49/m49regin.htm (23 March 2014, date last accessed).

17 Agresti A, Coull BA. Approximate is better than 'exact' for interval estimation of binomial proportions. *Am Stat* 1998; **52**: 119–26.

18 Berkley JA, Lowe BS, Mwangi I *et al*. Bacteremia among children admitted to a rural hospital in Kenya. *N Engl J Med* 2005; **352**: 39–47.

19 Brent AJ, Ahmed I, Ndiritu M *et al*. Incidence of clinically significant bacteraemia in children who present to hospital in Kenya: community-based observational study. *Lancet* 2006; **367**: 482–8.

20 Yansouni CP, Bottieau E, Lutumba P *et al*. Rapid diagnostic tests for neurological infections in central Africa. *Lancet Infect Dis* 2013; **13**: 546–58.

21 Aiken AM, Mturi N, Njuguna P *et al*. Risk and causes of paediatric hospital-acquired bacteraemia in Kilifi District Hospital, Kenya: a prospective cohort study. *Lancet* 2011; **378**: 2021–7.

22 WHO. *WHO Global Strategy for Containment of Antimicrobial Resistance*. 2001. http://www.who.int/drugresistance/WHO_Global_Strategy_English.pdf (23 March 2014, date last accessed).

23 Grundmann H, Klugman KP, Walsh T *et al*. A framework for global surveillance of antibiotic resistance. *Drug Resist Updates* 2011; **14**: 79–87.

24 Cornaglia G, Hryniewicz W, Jarlier V *et al*. European recommendations for antimicrobial resistance surveillance. *Clin Microbiol Infect* 2004; **10**: 349–83.

25 Holloway K, Mathai E, Gray A *et al*. Surveillance of community antimicrobial use in resource-constrained settings—experience from five pilot projects. *Trop Med Int Health* 2011; **16**: 152–61.

26 Holloway K, Mathai E, Gray A *et al*. Surveillance of antimicrobial resistance in resource-constrained settings—experience from five pilot projects. *Trop Med Int Health* 2011; **16**: 368–74.

27 Hedt BL, van Leth F, Zignol M *et al*. Multidrug resistance among new tuberculosis cases. *Epidemiology* 2012; **23**: 293–300.

28 Djie-Maletz A, Reither K, Danour S *et al*. High rate of resistance to locally used antibiotics among enteric bacteria from children in northern Ghana. *J Antimicrob Chemother* 2008; **61**: 1315–8.

29 Obi CL, Coker AO, Epoke J *et al*. Distributional patterns of bacterial diarrhoeagenic agents and antibiograms of isolates from diarrhoeaic and non-diarrhoeaic patients in urban and rural areas of Nigeria. *Cent Afr J Med* 1998; **44**: 223–9.

30 Bercion R, Mossoro-Kpinde D, Manirakiza A *et al*. Increasing prevalence of antimicrobial resistance among Enterobacteriaceae uropathogens in Bangui, Central African Republic. *J Infect Dev Ctries* 2009; **3**: 187–90.

31 Germani Y, Minssart P, Vohito M *et al*. Etiologies of acute, persistent, and dysenteric diarrheas in adults in Bangui, Central African Republic, in relation to human immunodeficiency virus serostatus. *Am J Trop Med Hyg* 1998; **59**: 1008–14.

32 Olukoya DK, Daini OA, Niemogha MT. Preliminary epidemiological studies on tetracycline resistant plasmids isolated from enteric bacteria in Nigeria. *Trop Geogr Med* 1993; **45**: 117–20.

33 Urio EM, Collison EK, Gashe BA *et al*. *Shigella* and *Salmonella* strains isolated from children under 5 years in Gaborone, Botswana, and their antibiotic susceptibility patterns. *Trop Med Int Health* 2001; **6**: 55–9.

34 Rowe JS, Shah SS, Motlhagodi S *et al*. An epidemiologic review of enteropathogens in Gaborone, Botswana: shifting patterns of resistance in an HIV endemic region. *PLoS One* 2010; **5**: e10924.

35 Lamikanra A, Ako-Nai AK, Ola JB. Transmissible trimethoprim resistance in strains of *Escherichia coli* isolated from cases of infantile diarrhoea. *J Med Microbiol* 1990; **32**: 159–62.

36 Bonfiglio G, Simporè J, Pignatelli S *et al*. Epidemiology of bacterial resistance in gastro-intestinal pathogens in a tropical area. *Int J Antimicrob Agents* 2002; **20**: 387–9.

37 Asrat D. *Shigella* and *Salmonella* serogroups and their antibiotic susceptibility patterns in Ethiopia. *East Mediterr Health J* 2008; **14**: 760–7.

38 Abera B, Bezabih B, Dessie A. Antimicrobial susceptibility of *V. cholerae* in north west, Ethiopia. *Ethiop Med J* 2010; **48**: 23–8.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

39 Tiruneh M. Serodiversity and antimicrobial resistance pattern of *Shigella* isolates at Gondar University teaching hospital, northwest Ethiopia. *Jpn J Infect Dis* 2009; **62**: 93–7.

40 Mache A. Antibiotic resistance and sero-groups of *Shigella* among paediatric out-patients in southwest Ethiopia. *East Afr Med J* 2001; **78**: 296–9.

41 Wolday D, Erge W. Antimicrobial sensitivity pattern of *Salmonella*: comparison of isolates from HIV-infected and HIV-uninfected patients. *Trop Doct* 1998; **28**: 139–41.

42 Pitman C, Amali R, Kanyerere H *et al*. Bloody diarrhoea of adults in Malawi: clinical features, infectious agents, and antimicrobial sensitivities. *Trans R Soc Trop Med Hyg* 1996; **90**: 284–7.

43 Urassa WK, Mhando YB, Mhalu FS *et al*. Antimicrobial susceptibility pattern of *Vibrio cholerae* O1 strains during two cholera outbreaks in Dar es Salaam, Tanzania. *East Afr Med J* 2000; **77**: 350–3.

44 Vila J, Vargas M, Casals C *et al*. Antimicrobial resistance of diarrheagenic *Escherichia coli* isolated from children under the age of 5 years from Ifakara, Tanzania. *Antimicrob Agents Chemother* 1999; **43**: 3022–4.

45 Simango C, Mbewe C. *Salmonella enteritidis* diarrhoea in Harare, Zimbabwe. *Trop Med Int Health* 2000; **5**: 503–6.

46 Sire JM, Macondo EA, Perrier-Gros-Claude J-D *et al*. Antimicrobial resistance in *Shigella* species isolated in Dakar, Senegal (2004–2006). *Jpn J Infect Dis* 2008; **61**: 307–9.

47 Sire JM, Garin B, Macondo EA. Low-level resistance to ciprofloxacin in non-Typhi *Salmonella enterica* isolated from human gastroenteritis in Dakar, Senegal (2004–2006). *Int J Antimicrob Agents* 2008; **31**: 581–2.

48 Lefebvre N, Gning SB, Nabeth P *et al*. [Clinical and laboratory features of typhoid fever in Senegal. A 70-case study]. *Médecine Trop Rev Corps Santé Colon* 2005; **65**: 543–8.

49 Dromigny J-A, Macondo EA, Juergens-Behr A *et al*. The distribution and antibiotic susceptibility of *Shigella* isolates in Dakar, Senegal (2000–2002). *Int J Antimicrob Agents* 2004; **24**: 307–8.

50 Gassama A, Aïdara-Kane A, Chainier D *et al*. Integron-associated antibiotic resistance in enteroaggregative and enteroinvasive *Escherichia coli*. *Microb Drug Resist* 2004; **10**: 27–30.

51 Dromigny J-A, Perrier-Gros-Claude J-D. Antimicrobial resistance of *Salmonella enterica* serotype Typhi in Dakar, Senegal. *Clin Infect Dis* 2003; **37**: 465–6.

52 Cardinale E, Perrier Gros-Claude JD, Rivoal K *et al*. Epidemiological analysis of *Salmonella enterica* ssp. *enterica* serovars Hadar, Brancaster and Enteritidis from humans and broiler chickens in Senegal using pulsed-field gel electrophoresis and antibiotic susceptibility. *J Appl Microbiol* 2005; **99**: 968–77.

53 Onyango D, Machioni F, Kakai R *et al*. Multidrug resistance of *Salmonella enterica* serovars Typhi and Typhimurium isolated from clinical samples at two rural hospitals in western Kenya. *J Infect Dev Ctries* 2008; **2**: 106–11.

54 Kariuki S, Revathi G, Kariuki N *et al*. Characterisation of community acquired non-typhoidal *Salmonella* from bacteraemia and diarrhoeal infections in children admitted to hospital in Nairobi, Kenya. *BMC Microbiol* 2006; **6**: 101.

55 Brooks JT, Ochieng JB, Kumar L *et al*. Surveillance for bacterial diarrhea and antimicrobial resistance in rural western Kenya, 1997–2003. *Clin Infect Dis* 2006; **43**: 393–401.

56 Kariuki S, Revathi G, Kariuki N *et al*. Invasive multidrug-resistant non-typhoidal Salmonella infections in Africa: zoonotic or anthroponotic transmission? *J Med Microbiol* 2006; **55**: 585–91.

57 Bii CC, Taguchi H, Ouko TT *et al*. Detection of virulence-related genes by multiplex PCR in multidrug-resistant diarrhoeagenic *Escherichia coli* isolates from Kenya and Japan. *Epidemiol Infect* 2005; **133**: 627–33.

58 Brooks JT, Shapiro RL, Kumar L *et al*. Epidemiology of sporadic bloody diarrhea in rural western Kenya. *Am J Trop Med Hyg* 2003; **68**: 671–7.

59 Shapiro RL, Kumar L, Phillips-Howard P *et al*. Antimicrobial-resistant bacterial diarrhea in rural western Kenya. *J Infect Dis* 2001; **183**: 1701–4.

60 Kariuki S, Gilks CF, Kimari J *et al*. Plasmid diversity of multi-drug-resistant *Escherichia coli* isolated from children with diarrhoea in a poultry-farming area in Kenya. *Ann Trop Med Parasitol* 1997; **91**: 87–94.

61 Engels D, Madaras T, Nyandwi S *et al*. Epidemic dysentery caused by *Shigella dysenteriae* type 1: a sentinel site surveillance of antimicrobial resistance patterns in Burundi. *Bull World Health Organ* 1995; **73**: 787–91.

62 Scrascia M, Pugliese N, Maimone F *et al*. Cholera in Ethiopia in the 1990s: epidemiologic patterns, clonal analysis, and antimicrobial resistance. *Int J Med Microbiol* 2009; **299**: 367–72.

63 Mandomando I, Jaintilal D, Pons MJ *et al*. Antimicrobial susceptibility and mechanisms of resistance in *Shigella* and *Salmonella* isolates from children under five years of age with diarrhea in rural Mozambique. *Antimicrob Agents Chemother* 2009; **53**: 2450–4.

64 Mandomando I, Espasa M, Vallès X *et al*. Antimicrobial resistance of *Vibrio cholerae* O1 serotype Ogawa isolated in Manhiça District Hospital, southern Mozambique. *J Antimicrob Chemother* 2007; **60**: 662–4.

65 Casalino M, Nicoletti M, Salvia A *et al*. Characterization of endemic *Shigella flexneri* strains in Somalia: antimicrobial resistance, plasmid profiles, and serotype correlation. *J Clin Microbiol* 1994; **32**: 1179–83.

66 Musiime V, Kalyesubula I, Kaddu-Mulindwa D *et al*. Enteric bacterial pathogens in HIV-infected children with acute diarrhea in Mulago referral and teaching hospital, Kampala, Uganda. *J Int Assoc Physicians AIDS Care* 2009; **8**: 185–90.

67 Mwansa JCL, Mwaba J, Lukwesa C *et al*. Multiply antibiotic-resistant *Vibrio cholerae* O1 biotype El Tor strains emerge during cholera outbreaks in Zambia. *Epidemiol Infect* 2007; **135**: 847–53.

68 Mwansa J, Mutela K, Zulu I *et al*. Antimicrobial sensitivity in enterobacteria from AIDS patients, Zambia. *Emerg Infect Dis* 2002; **8**: 92–3.

69 Tuttle J, Ries AA, Chimba RM *et al*. Antimicrobial-resistant epidemic *Shigella dysenteriae* type 1 in Zambia: modes of transmission. *J Infect Dis* 1995; **171**: 371–5.

70 Sang WK, Oundo V, Schnabel D. Prevalence and antibiotic resistance of bacterial pathogens isolated from childhood diarrhoea in four provinces of Kenya. *J Infect Dev Ctries* 2012; **6**: 572–8.

71 Centers for Disease Control and Prevention. Antibiotic resistance among nasopharyngeal isolates of *Streptococcus pneumoniae* and *Haemophilus influenzae*—Bangui, Central African Republic, 1995. *MMWR Morb Mortal Wkly Rep* 1997; **46**: 62–4.

72 Abera B, Biadeglegne F. Antimicrobial resistance patterns of *Staphylococcus aureus* and *Proteus* spp. isolated from otitis media at Bahir Dar Regional Laboratory, north west Ethiopia. *Ethiop Med J* 2009; **47**: 271–6.

73 Tanon-Anoh MJ, Kacou-Ndouba A, Yoda M *et al*. Particularities of bacterial ecology of acute otitis media in an African subtropical country (Cote d'Ivoire). *Int J Pediatr Otorhinolaryngol* 2006; **70**: 817–22.

74 Ringertz S, Muhe L, Krantz I *et al*. Prevalence of potential respiratory disease bacteria in children in Ethiopia. Antimicrobial susceptibility of the pathogens and use of antibiotics among the children. *Acta Paediatr Oslo Nor* 1993; **82**: 843–8.

75 Ndiaye AG, Boye CS, Hounkponou E *et al*. Antimicrobial susceptibility of select respiratory tract pathogens in Dakar, Senegal. *J Infect Dev Ctries* 2009; **3**: 660–6.

76 Echave P, Bille J, Audet C *et al*. Percentage, bacterial etiology and antibiotic susceptibility of acute respiratory infection and pneumonia among children in rural Senegal. *J Trop Pediatr* 2003; **49**: 28–32.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

77 Kariuki S, Muyodi J, Mirza B *et al*. Antimicrobial susceptibility in community-acquired bacterial pneumonia in adults. *East Afr Med J* 2003; **80**: 213–7.

78 Jordens JZ, Paul J, Bates J *et al*. Characterization of *Streptococcus pneumoniae* from human immunodeficiency virus-seropositive patients with acute and recurrent pneumonia. *J Infect Dis* 1995; **172**: 983–7.

79 Yoshimine H, Oishi K, Mubiru F *et al*. Community-acquired pneumonia in Ugandan adults: short-term parenteral ampicillin therapy for bacterial pneumonia. *Am J Trop Med Hyg* 2001; **64**: 172–7.

80 Adeleye A, Uju L, Idika N *et al*. Cotrimoxazole resistance in *Streptococcus pneumoniae* isolated from sputum of HIV-positive patients. *West Indian Med J* 2008; **57**: 497–9.

81 Enweronu-Laryea CC, Newman MJ. Changing pattern of bacterial isolates and antimicrobial susceptibility in neonatal infections in Korle Bu Teaching Hospital, Ghana. *East Afr Med J* 2007; **84**: 136–40.

82 Adejuyigbe EA, Ako-Nai AK, Adisa B. Bacterial isolates in the sick young infant in Ile-Ife, Nigeria. *J Trop Pediatr* 2004; **50**: 323–7.

83 Kesah C, Ben Redjeb S, Odugbemi TO *et al*. Prevalence of methicillin-resistant *Staphylococcus aureus* in eight African hospitals and Malta. *Clin Microbiol Infect* 2003; **9**: 153–6.

84 Mokuolu AO, Jiya N, Adesiyun OO. Neonatal septicaemia in Ilorin: bacterial pathogens and antibiotic sensitivity pattern. *Afr J Med Med Sci* 2002; **31**: 127–30.

85 Ako-Nai AK, Adejuyigbe EA, Ajayi FM *et al*. The bacteriology of neonatal septicaemia in Ile-Ife, Nigeria. *J Trop Pediatr* 1999; **45**: 146–51.

86 Obi CL, Iyiegbuniwe AE, Olukoya DK *et al*. Antibiograms and plasmids of *Staphylococcus aureus* and coagulase negative staphylococci isolated from different clinical sources. *Cent Afr J Med* 1996; **42**: 258–61.

87 Holliman RE, Liddy H, Johnson JD *et al*. Epidemiology of invasive pneumococcal disease in Kumasi, Ghana. *Trans R Soc Trop Med Hyg* 2007; **101**: 405–13.

88 Ndip RN, Dilonga HM, Ndip LM *et al*. *Pseudomonas aeruginosa* isolates recovered from clinical and environmental samples in Buea, Cameroon: current status on biotyping and antibiogram. *Trop Med Int Health* 2005; **10**: 74–81.

89 Rowe AK, Schwartz B, Wasas A *et al*. Evaluation of the Etest as a means of determining the antibiotic susceptibilities of isolates of *Streptococcus pneumoniae* and *Haemophilus influenzae* from children in the Central African Republic. *J Antimicrob Chemother* 2000; **45**: 132–3.

90 Okuonghae HO, Nwankwo MU, Offor EC. Pattern of bacteraemia in febrile children with sickle cell anaemia. *Ann Trop Paediatr* 1993; **13**: 55–64.

91 Wood SM, Shah SS, Bafana M *et al*. Epidemiology of methicillin-resistant *Staphylococcus aureus* bacteremia in Gaborone, Botswana. *Infect Control Hosp Epidemiol* 2009; **30**: 782–5.

92 Antia-Obong OE, Utsalo SJ, Udo JJ *et al*. Neonatal septicaemia in Calabar, Nigeria. *Cent Afr J Med* 1992; **38**: 161–5.

93 Antia-Obong OE, Utsalo SJ. Bacterial agents in neonatal septicaemia in Calabar, Nigeria: review of 100 cases. *Trop Doct* 1991; **21**: 169–70.

94 Shitaye D, Asrat D, Woldeamanuel Y *et al*. Risk factors and etiology of neonatal sepsis in Tikur Anbessa University Hospital, Ethiopia. *Ethiop Med J* 2010; **48**: 11–21.

95 Ali J, Kebede Y. Frequency of isolation and antimicrobial susceptibility pattern of bacterial isolates from blood culture, Gondar University teaching hospital, northwest Ethiopia. *Ethiop Med J* 2008; **46**: 155–61.

96 Yismaw G, Tiruneh M, Kassu A *et al*. A retrospective analysis of prevalence and antimicrobial susceptibility patterns of *Staphylococcus aureus* in Gondar teaching hospital, 2001–2005. *Ethiop Med J* 2008; **46**: 143–8.

97 Aires-de-Sousa M, Conceição T, de Lencastre H. Unusually high prevalence of nosocomial Panton–Valentine leukocidin-positive *Staphylococcus aureus* isolates in Cape Verde Islands. *J Clin Microbiol* 2006; **44**: 3790–3.

98 Seid J, Asrat D. Occurrence of extended spectrum β-lactamase enzymes in clinical isolates of *Klebsiella* species from Harar region, eastern Ethiopia. *Acta Trop* 2005; **95**: 143–8.

99 Gebreselassie S. Patterns of isolation of common gram positive bacterial pathogens and their susceptibilities to antimicrobial agents in Jimma Hospital. *Ethiop Med J* 2002; **40**: 115–27.

100 Asrat D, Amanuel YW. Prevalence and antibiotic susceptibility pattern of bacterial isolates from blood culture in Tikur Anbassa Hospital, Addis Ababa, Ethiopia. *Ethiop Med J* 2001; **39**: 97–104.

101 Tenssay ZW. Staphylococci: frequency of isolation and antibiotic susceptibility patterns in Jimma Hospital, south-west Ethiopia. *Ethiop Med J* 2000; **38**: 175–84.

102 Geyid A, Lemeneh Y. The incidence of methicillin resistant *S. aureus* strains in clinical specimens in relation to their β-lactamase producing and multiple-drug resistance properties in Addis Abeba. *Ethiop Med J* 1991; **29**: 149–61.

103 Randrianirina F, Soares J-L, Ratsima E *et al*. In vitro activities of 18 antimicrobial agents against *Staphylococcus aureus* isolates from the Institut Pasteur of Madagascar. *Ann Clin Microbiol Antimicrob* 2007; **6**: 5.

104 Van Oosterhout JJG, Laufer MK, Graham SM *et al*. A community-based study of the incidence of trimethoprim-sulfamethoxazole-preventable infections in Malawian adults living with HIV. *J Acquir Immune Defic Syndr* 2005; **39**: 626–31.

105 Gordon MA, Walsh AL, Chaponda M *et al*. Bacteraemia and mortality among adult medical admissions in Malawi-predominance of non-Typhi salmonellae and *Streptococcus pneumoniae*. *J Infect* 2001; **42**: 44–9.

106 Walsh AL, Phiri AJ, Graham SM *et al*. Bacteremia in febrile Malawian children: clinical and microbiologic features. *Pediatr Infect Dis J* 2000; **19**: 312–8.

107 Blomberg B, Manji KP, Urassa WK *et al*. Antimicrobial resistance predicts death in Tanzanian children with bloodstream infections: a prospective cohort study. *BMC Infect Dis* 2007; **7**: 43.

108 Blomberg B, Mwakagile DSM, Urassa WK *et al*. Surveillance of antimicrobial resistance at a tertiary hospital in Tanzania. *BMC Public Health* 2004; **4**: 45.

109 Anglaret X, Sylla-Koko F, Bonard D *et al*. Susceptibilities to co-trimoxazole of pathogens isolated from blood and stool specimens in Abidjan, Ivory Coast, 1994 to 1996. *J Clin Microbiol* 1997; **35**: 1915.

110 Simango C, Lucas J. Susceptibility of *Klebsiella* species to quinolones and cephalosporins. *Cent Afr J Med* 2001; **47**: 137.

111 Simango C, Mvududu F. Penicillin resistant *Streptococcus pneumoniae* isolates in Harare, Zimbabwe. *Cent Afr J Med* 1999; **45**: 100–2.

112 Obi CL, Mazarura E. Aerobic bacteria isolated from blood cultures of patients and their antibiotic susceptibilities in Harare, Zimbabwe. *Cent Afr J Med* 1996; **42**: 332–6.

113 Nathoo KJ, Chigonde S, Nhembe M *et al*. Community-acquired bacteremia in human immunodeficiency virus-infected children in Harare, Zimbabwe. *Pediatr Infect Dis J* 1996; **15**: 1092–7.

114 Petit PL, Schneeberger P, Lidala V *et al*. Bacteriology of infections in a rural tropical area of Kenya: isolates and antibiotic susceptibility. *East Afr Med J* 1991; **68**: 500–6.

115 Antonio M, Dada-Adegbola H, Biney E *et al*. Molecular epidemiology of pneumococci obtained from Gambian children aged 2–29 months with invasive pneumococcal disease during a trial of a 9-valent pneumococcal conjugate vaccine. *BMC Infect Dis* 2008; **8**: 81.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

116 Ikumapayi UN, Antonio M, Sonne-Hansen J *et al*. Molecular epidemiology of community-acquired invasive non-typhoidal Salmonella among children aged 2–29 months in rural Gambia and discovery of a new serovar, *Salmonella enterica* Dingiri. *J Med Microbiol* 2007; **56**: 1479–84.

117 Hill PC, Onyeama CO, Ikumapayi UNA *et al*. Bacteraemia in patients admitted to an urban hospital in West Africa. *BMC Infect Dis* 2007; **7**: 2.

118 Adegbola RA, Hill PC, Secka O *et al*. Serotype and antimicrobial susceptibility patterns of isolates of *Streptococcus pneumoniae* causing invasive disease in the Gambia 1996–2003. *Trop Med Int Health* 2006; **11**: 1128–35.

119 O'Dempsey TJ, McArdle TF, Lloyd-Evans N *et al*. Pneumococcal disease among children in a rural area of west Africa. *Pediatr Infect Dis J* 1996; **15**: 431–7.

120 Seydi M, Soumaré M, Sow AI *et al*. [*Escherichia coli* meningitis during bacteremia in the Ibrahima-Diop-Mar infectious diseases clinic, Dakar Fann National Hospital Center (Senegal)]. *Médecine Mal Infect* 2005; **35**: 344–8.

121 Benbachir M, Benredjeb S, Boye CS *et al*. Two-year surveillance of antibiotic resistance in *Streptococcus pneumoniae* in four African cities. *Antimicrob Agents Chemother* 2001; **45**: 627–9.

122 Fashae K, Ogunsola F, Aarestrup FM *et al*. Antimicrobial susceptibility and serovars of *Salmonella* from chickens and humans in Ibadan, Nigeria. *J Infect Dev Ctries* 2010; **4**: 484–94.

123 Mengo DM, Kariuki S, Muigai A *et al*. Trends in *Salmonella enterica* serovar Typhi in Nairobi, Kenya from 2004 to 2006. *J Infect Dev Ctries* 2010; **4**: 393–6.

124 Feikin DR, Jagero G, Aura B *et al*. High rate of pneumococcal bacteremia in a prospective cohort of older children and adults in an area of high HIV prevalence in rural western Kenya. *BMC Infect Dis* 2010; **10**: 186.

125 Talbert AWA, Mwaniki M, Mwarumba S *et al*. Invasive bacterial infections in neonates and young infants born outside hospital admitted to a rural hospital in Kenya. *Pediatr Infect Dis J* 2010; **29**: 945–9.

126 Kariuki S, Revathi G, Kiiru J *et al*. Decreasing prevalence of antimicrobial resistance in non-typhoidal *Salmonella* isolated from children with bacteraemia in a rural district hospital, Kenya. *Int J Antimicrob Agents* 2006; **28**: 166–71.

127 Scott JAG, Mwarumba S, Ngetsa C *et al*. Progressive increase in antimicrobial resistance among invasive isolates of *Haemophilus influenzae* obtained from children admitted to a hospital in Kilifi, Kenya, from 1994 to 2002. *Antimicrob Agents Chemother* 2005; **49**: 3021–4.

128 Bejon P, Mwangi I, Ngetsa C *et al*. Invasive Gram-negative bacilli are frequently resistant to standard antibiotics for children admitted to hospital in Kilifi, Kenya. *J Antimicrob Chemother* 2005; **56**: 232–5.

129 Kariuki S, Revathi G, Kariuki N *et al*. Increasing prevalence of multidrug-resistant non-typhoidal salmonellae, Kenya, 1994–2003. *Int J Antimicrob Agents* 2005; **25**: 38–43.

130 Oundo JO, Muli F, Kariuki S *et al*. Non-Typhi *Salmonella* in children with severe malaria. *East Afr Med J* 2002; **79**: 633–9.

131 Dougle ML, Hendriks ER, Sanders EJ *et al*. Laboratory investigations in the diagnosis of septicaemia and malaria. *East Afr Med J* 1997; **74**: 353–6.

132 Ndinya-Achola JO, Omari MA, Odhiambo FA *et al*. Survey of penicillin resistant pneumococci at Kenyatta National Hospital, Nairobi. *East Afr Med J* 1997; **74**: 151–3.

133 Kariuki S, Gilks C, Corkill J *et al*. Multi-drug resistant non-Typhi salmonellae in Kenya. *J Antimicrob Chemother* 1996; **38**: 425–34.

134 Paul J, Bates J, Kimari J *et al*. Serotypes and antibiotic susceptibilities of *Streptococcus pneumoniae* in Nairobi, Kenya. *J Infect* 1996; **32**: 139–42.

135 Mandomando I, Sigaúque B, Morais L *et al*. Antimicrobial drug resistance trends of bacteremia isolates in a rural hospital in southern Mozambique. *Am J Trop Med Hyg* 2010; **83**: 152–7.

136 Roca A, Sigaúque B, Quintó L *et al*. Invasive pneumococcal disease in children <5 years of age in rural Mozambique. *Trop Med Int Health* 2006; **11**: 1422–31.

137 Simac C, Picot S, Farny K *et al*. [Antimicrobial resistance of *Streptococcus pneumoniae* strains isolated in the Reunion Island during 2004]. *Médecine Mal Infect* 2006; **36**: 47–51.

138 Mayanja BN, Todd J, Hughes P *et al*. Septicaemia in a population-based HIV clinical cohort in rural Uganda, 1996–2007: incidence, aetiology, antimicrobial drug resistance and impact of antiretroviral therapy. *Trop Med Int Health* 2010; **15**: 697–705.

139 Onipede AO, Onayade AA, Elusiyan JB *et al*. Invasive bacteria isolates from children with severe infections in a Nigerian hospital. *J Infect Dev Ctries* 2009; **3**: 429–36.

140 Bachou H, Tylleskär T, Kaddu-Mulindwa DH *et al*. Bacteraemia among severely malnourished children infected and uninfected with the human immunodeficiency virus-1 in Kampala, Uganda. *BMC Infect Dis* 2006; **6**: 160.

141 Mugalu J, Nakakeeto MK, Kiguli S *et al*. Aetiology, risk factors and immediate outcome of bacteriologically confirmed neonatal septicaemia in Mulago hospital, Uganda. *Afr Health Sci* 2006; **6**: 120–6.

142 Falade AG, Lagunju IA, Bakare RA *et al*. Invasive pneumococcal disease in children aged <5 years admitted to 3 urban hospitals in Ibadan, Nigeria. *Clin Infect Dis* 2009; **48** Suppl 2: S190–6.

143 Campbell JD, Kotloff KL, Sow SO *et al*. Invasive pneumococcal infections among hospitalized children in Bamako, Mali. *Pediatr Infect J* 2004; **23**: 642–9.

144 Ozumba UC. Antimicrobial resistance problems in a university hospital. *J Natl Med Assoc* 2005; **97**: 1714–8.

145 Meremikwu MM, Nwachukwu CE, Asuquo AE *et al*. Bacterial isolates from blood cultures of children with suspected septicaemia in Calabar, Nigeria. *BMC Infect Dis* 2005; **5**: 110.

146 Ogunlesi TA, Okeniyi JA, Oyelami OA. Pyogenic meningitis in Ilesa, Nigeria. *Indian Pediatr* 2005; **42**: 1019–23.

147 Ouédraogo A-S, Dakouré-Kissou A, Poda GEA *et al*. [Epidemiology, microbiology, and outcomes of septicemia in children treated at the Charles de Gaulle University Pediatric Hospital in Burkina Faso]. *Santé Montrouge Fr* 2011; **21**: 221–5.

148 Tabu C, Breiman RF, Ochieng B *et al*. Differing burden and epidemiology of non-Typhi *Salmonella* bacteremia in rural and urban Kenya, 2006–2009. *PLoS One* 2012; **7**: e31237.

149 Thriemer K, Ley B, Ame S *et al*. The burden of invasive bacterial infections in Pemba, Zanzibar. *PLoS One* 2012; **7**: e30350.

150 Gross U, Amuzu SK, de Ciman R *et al*. Bacteremia and antimicrobial drug resistance over time, Ghana. *Emerg Infect Dis* 2011; **17**: 1879–82.

151 Mhada TV, Fredrick F, Matee MI *et al*. Neonatal sepsis at Muhimbili National Hospital, Dar es Salaam, Tanzania; aetiology, antimicrobial sensitivity pattern and clinical outcome. *BMC Public Health* 2012; **12**: 904.

152 Cornick JE, Everett DB, Broughton C *et al*. Invasive *Streptococcus pneumoniae* in children, Malawi, 2004–2006. *Emerg Infect Dis* 2011; **17**: 1107–9.

153 Ogunlesi TA, Ogunfowora OB, Osinupebi O *et al*. Changing trends in newborn sepsis in Sagamu, Nigeria: bacterial aetiology, risk factors and antibiotic susceptibility. *J Paediatr Child Health* 2011; **47**: 5–11.

154 Lunguya O, Lejon V, Phoba MF *et al*. *Salmonella* Typhi in the Democratic Republic of the Congo: fluoroquinolone decreased susceptibility on the rise. *PLoS Negl Trop Dis* 2012; **6**: e1921.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

155 Randrianirina F, Vaillant L, Ramarokoto CE *et al*. Antimicrobial resistance in pathogens causing nosocomial infections in surgery and intensive care units of two hospitals in Antananarivo, Madagascar. *J Infect Dev Ctries* 2010; **4**: 74–82.

156 Andhoga J, Macharia AG, Maikuma IR *et al*. Aerobic pathogenic bacteria in post-operative wounds at Moi Teaching and Referral Hospital. *East Afr Med J* 2002; **79**: 640–4.

157 Ojulong J, Mwambu TP, Joloba M *et al*. Relative prevalence of methicillin resistant *Staphylococcus aureus* and its susceptibility pattern in Mulago Hospital, Kampala, Uganda. *Tanzan J Health Res* 2009; **11**: 149–53.

158 Nahirya P, Byarugaba J, Kiguli S *et al*. Intravascular catheter related infections in children admitted on the paediatric wards of Mulago Hospital, Uganda. *Afr Health Sci* 2008; **8**: 206–16.

159 Muvunyi CM, Masaisa F, Bayingana C *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* 2011; **84**: 923–8.

160 Emele FE. Etiologic spectrum and pattern of antimicrobial drug susceptibility in bacterial meningitis in Sokoto, Nigeria. *Acta Paediatr* 2000; **89**: 942–6.

161 Akpede GO, Adeyemi O, Abba AA *et al*. Pattern and antibiotic susceptibility of bacteria in pyogenic meningitis in a children's emergency room population in Maiduguri, Nigeria, 1988–1992. *Acta Paediatr* 1994; **83**: 719–23.

162 Onyemelukwe NF. *Haemophilus influenzae* meningitis in parts of eastern Nigeria. *East Afr Med J* 1994; **71**: 129–31.

163 Muhe L, Klugman KP. Pneumococcal and *Haemophilus influenzae* meningitis in a children's hospital in Ethiopia: serotypes and susceptibility patterns. *Trop Med Int Health* 1999; **4**: 421–7.

164 Adjei O, Agbemadzo T. Susceptibility of *Streptococcus pneumoniae* strains isolated from cerebrospinal fluid in Ghana. *J Antimicrob Chemother* 1996; **38**: 746–7.

165 Camara B, Diouf S, Faye PM *et al*. [Prevalence and sensitivity of bacteria responsible for purulent meningitis in a pediatric hospital of Dakar (Senegal)]. *Arch Pédiatrie Organe Off Sociéte Fr Pédiatrie* 2003; **10**: 354–6.

166 Commey JO, Rodrigues OP, Akita FA *et al*. Bacterial meningitis in children in southern Ghana. *East Afr Med J* 1994; **71**: 113–7.

167 Mwangi I, Berkley J, Lowe B *et al*. Acute bacterial meningitis in children admitted to a rural Kenyan hospital: increasing antibiotic resistance and outcome. *Pediatr Infect Dis J* 2002; **21**: 1042–8.

168 Mirza NB, Estambale BB, Wamola IA *et al*. Bacterial meningitis in children admitted in hospitals within Nairobi. *East Afr Med J* 1998; **75**: 73–6.

169 Roca A, Bassat Q, Morais L *et al*. Surveillance of acute bacterial meningitis among children admitted to a district hospital in rural Mozambique. *Clin Infect Dis* 2009; **48** Suppl 2: S172–180.

170 Roca A, Quintó L, Abacassamo F *et al*. Invasive *Haemophilus influenzae* disease in children less than 5 years of age in Manhiça, a rural area of southern Mozambique. *Trop Med Int Health* 2008; **13**: 818–26.

171 Sigaúque B, Roca A, Sanz S *et al*. Acute bacterial meningitis among children, in Manhiça, a rural area in Southern Mozambique. *Acta Trop* 2008; **105**: 21–7.

172 Kisakye A, Makumbi I, Nansera D *et al*. Surveillance for *Streptococcus pneumoniae* meningitis in children aged <5 years: implications for immunization in Uganda. *Clin Infect Dis* 2009; **48** Suppl 2: S153–161.

173 Karou SD, Balaka A, Bamoké M *et al*. Epidemiology and antibiotic resistance of bacterial meningitis in Dapaong, northern Togo. *Asian Pac J Trop Med* 2012; **5**: 848–52.

174 Ibarz-Pavón AB, Morais L, Sigaúque B *et al*. Epidemiology, molecular characterization and antibiotic resistance of *Neisseria meningitidis* from patients ≤15 years in Manhiça, rural Mozambique. *PLoS One* 2011; **6**: e19717.

175 Mullan PC, Steenhoff AP, Draper H *et al*. Etiology of meningitis among patients admitted to a tertiary referral hospital in Botswana. *Pediatr Infect Dis J* 2011; **30**: 620–2.

176 Brown BJ, Asinobi AO, Fatunde OJ *et al*. Antimicrobial sensitivity pattern of organisms causing urinary tract infection in children with sickle cell anaemia in Ibadan, Nigeria. *West Afr J Med* 2003; **22**: 110–3.

177 Musa-Aisien AS, Ibadin OM, Ukoh G *et al*. Prevalence and antimicrobial sensitivity pattern in urinary tract infection in febrile under-5s at a children's emergency unit in Nigeria. *Ann Trop Paediatr* 2003; **23**: 39–45.

178 Adeyemo AA, Gbadegesin RA, Onyemenem TN *et al*. Urinary tract pathogens and antimicrobial sensitivity patterns in children in Ibadan, Nigeria. *Ann Trop Paediatr* 1994; **14**: 271–4.

179 Adjei O, Opoku C. Urinary tract infections in African infants. *Int J Antimicrob Agents* 2004; **24** Suppl 1: S32–4.

180 Hima-Lerible H, Ménard D, Talarmin A. Antimicrobial resistance among uropathogens that cause community-acquired urinary tract infections in Bangui, Central African Republic. *J Antimicrob Chemother* 2003; **51**: 192–4.

181 Assefa A, Asrat D, Woldeamanuel Y *et al*. Bacterial profile and drug susceptibility pattern of urinary tract infection in pregnant women at Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia. *Ethiop Med J* 2008; **46**: 227–35.

182 Tessema B, Kassu A, Mulu A *et al*. Predominant isolates of urinary tract pathogens and their antimicrobial susceptibility patterns in Gondar University Teaching Hospital, northwest Ethiopia. *Ethiop Med J* 2007; **45**: 61–7.

183 Moges F, Mengistu G, Genetu A. Multiple drug resistance in urinary pathogens at Gondar College of Medical Sciences Hospital, Ethiopia. *East Afr Med J* 2002; **79**: 415–9.

184 Wolday D, Erge W. Increased incidence of resistance to antimicrobials by urinary pathogens isolated at Tikur Anbessa Hospital. *Ethiop Med J* 1997; **35**: 127–35.

185 Ringertz S, Bellete B, Karlsson I *et al*. Antibiotic susceptibility of *Escherichia coli* isolates from inpatients with urinary tract infections in hospitals in Addis Ababa and Stockholm. *Bull World Health Organ* 1990; **68**: 61–8.

186 Randrianirina F, Soares J-L, Carod J-F *et al*. Antimicrobial resistance among uropathogens that cause community-acquired urinary tract infections in Antananarivo, Madagascar. *J Antimicrob Chemother* 2007; **59**: 309–12.

187 Obi CL, Tarupiwa A, Simango C. Scope of urinary pathogens isolated in the Public Health Bacteriology Laboratory, Harare: antibiotic susceptibility patterns of isolates and incidence of haemolytic bacteria. *Cent Afr J Med* 1996; **42**: 244–9.

188 Sire JM, Nabeth P, Perrier-Gros-Claude J-D *et al*. Antimicrobial resistance in outpatient *Escherichia coli* urinary isolates in Dakar, Senegal. *J Infect Dev Ctries* 2007; **1**: 263–8.

189 Dromigny JA, Nabeth P, Juergens-Behr A *et al*. Risk factors for antibiotic-resistant *Escherichia coli* isolated from community-acquired urinary tract infections in Dakar, Senegal. *J Antimicrob Chemother* 2005; **56**: 236–9.

190 Dromigny JA, Ndoye B, Macondo EA *et al*. Increasing prevalence of antimicrobial resistance among Enterobacteriaceae uropathogens in Dakar, Senegal: a multicenter study. *Diagn Microbiol Infect Dis* 2003; **47**: 595–600.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024

191 Dromigny JA, Nabeth P, Perrier-Gros-Claude JD. Distribution and susceptibility of bacterial urinary tract infections in Dakar, Senegal. *Int J Antimicrob Agents* 2002; **20**: 339–47.

192 Aboderin OA, Abdu AR, Odetoyin BW *et al*. Antimicrobial resistance in *Escherichia coli* strains from urinary tract infections. *J Natl Med Assoc* 2009; **101**: 1268–73.

193 Adeleke SI, Asani MO. Urinary tract infection in children with nephrotic syndrome in Kano, Nigeria. *Ann Afr Med* 2009; **8**: 38–41.

194 Van Dyck E, Rossau R, Duhamel M *et al*. Antimicrobial susceptibility of *Neisseria gonorrhoeae* in Zaire: high level plasmid-mediated tetracycline resistance in central Africa. *Genitourin Med* 1992; **68**: 111–6.

195 Otubu JA, Imade GE, Sagay AS *et al*. Resistance of recent *Neisseria gonorrhoeae* isolates in Nigeria and outcome of single-dose treatment with ciprofloxacin. *Infection* 1992; **20**: 339–41.

196 Tadesse A, Mekonnen A, Kassu A *et al*. Antimicrobial sensitivity of *Neisseria gonorrhoea* in Gondar, Ethiopia. *East Afr Med J* 2001; **78**: 259–61.

197 Behets FM-TF, Andriamiadana J, Randrianasolo D *et al*. Laboratory diagnosis of sexually transmitted infections in women with genital discharge in Madagascar: implications for primary care. *Int J STD AIDS* 2002; **13**: 606–11.

198 Brown LB, Krysiak R, Kamanga G *et al*. *Neisseria gonorrhoeae* antimicrobial susceptibility in Lilongwe, Malawi, 2007. *Sex Transm Dis* 2010; **37**: 169–72.

199 Zachariah R, Harries AD, Nkhoma W *et al*. Behavioural characteristics, prevalence of *Chlamydia trachomatis* and antibiotic susceptibility of *Neisseria gonorrhoeae* in men with urethral discharge in Thyolo, Malawi. *Trans R Soc Trop Med Hyg* 2002; **96**: 232–5.

200 Van Dyck E, Crabbé F, Nzila N *et al*. Increasing resistance of *Neisseria gonorrhoeae* in west and central Africa. Consequence on therapy of gonococcal infection. *Sex Transm Dis* 1997; **24**: 32–7.

201 Gomo E, Ndamba J, Murahwa S *et al*. In vitro activity of several antimicrobial agents against *Neisseria gonorrhoeae* and comparison of cost of treatment. *Cent Afr J Med* 1995; **41**: 83–6.

202 Cao V, Ratsima E, Van Tri D *et al*. Antimicrobial susceptibility of *Neisseria gonorrhoeae* strains isolated in 2004–2006 in Bangui, Central African Republic; Yaoundé, Cameroon; Antananarivo, Madagascar; and Ho Chi Minh Ville and Nha Trang, Vietnam. *Sex Transm Dis* 2008; **35**: 941–5.

203 Adegbola RA, Sabally S, Corrah T *et al*. Increasing prevalence of penicillinase-producing *Neisseria gonorrhoeae* and the emergence of high-level, plasmid-mediated tetracycline resistance among gonococcal isolates in the Gambia. *Trop Med Int Health* 1997; **2**: 428–32.

204 Ison CA, Pepin J, Roope NS *et al*. The dominance of a multiresistant strain of *Neisseria gonorrhoeae* among prostitutes and STD patients in the Gambia. *Genitourin Med* 1992; **68**: 356–60.

205 Addy PA. Susceptibility pattern of *Neisseria gonorrhoeae* isolated at the Komfo, Anokye Teaching Hospital, Ghana to commonly prescribed antimicrobial agents. *East Afr Med J* 1994; **71**: 368–72.

206 Van Hall MA, Petit PL, van Hall HN *et al*. Prevalence of resistance of *N. gonorrhoeae* to penicillin and three other antibiotics in a rural area in Kenya. *East Afr Med J* 1991; **68**: 853–9.

207 Massenet D, Aboubakar AB. Disappearance of vancomycin-sensitive strains of *Neisseria gonorrhoeae* in Djibouti. *Acta Trop* 1999; **72**: 317–8.

208 Apalata T, Zimba TF, Sturm WA *et al*. Antimicrobial susceptibility profile of *Neisseria gonorrhoeae* isolated from patients attending a STD facility in Maputo, Mozambique. *Sex Transm Dis* 2009; **36**: 341–3.

209 Bogaerts J, Van Dyck E, Mukantabana B *et al*. Auxotypes, serovars, and trends of antimicrobial resistance of *Neisseria gonorrhoeae* in Kigali, Rwanda (1985–93). *Sex Transm Infect* 1998; **74**: 205–9.

210 Van Dyck E, Karita E, Abdellati S *et al*. Antimicrobial susceptibilities of *Neisseria gonorrhoeae* in Kigali, Rwanda, and trends of resistance between 1986 and 2000. *Sex Transm Dis* 2001; **28**: 539–45.

211 Desai PJ, Morrison JA, Fleming AF. Penicillinase-producing *Neisseria gonorrhoeae* in Ndola, Zambia. *Trans R Soc Trop Med Hyg* 1990; **84**: 131.

212 Lagace-Wiens PRS, Duncan S, Kimani J *et al*. Emergence of fluoroquinolone resistance in *Neisseria gonorrhoeae* isolates from four clinics in three regions of Kenya. *Sex Transm Dis* 2012; **39**: 332–4.

213 Mehta SD, Maclean I, Ndinya-Achola JO *et al*. Emergence of quinolone resistance and cephalosporin MIC creep in *Neisseria gonorrhoeae* isolates from a cohort of young men in Kisumu, Kenya, 2002 to 2009. *Antimicrob Agents Chemother* 2011; **55**: 3882–8.

214 Duncan S, Thiong'o AN, Macharia M *et al*. High prevalence of quinolone resistance in *Neisseria gonorrhoeae* in coastal Kenya. *Sex Transm Infect* 2011; **87**: 231.

215 Alonge TO, Salawu SA, Adebisi AT *et al*. The choice of antibiotic in open fractures in a teaching hospital in a developing country. *Int J Clin Pr* 2002; **56**: 353–6.

216 Komolafe OO, James J, Kalongolera L *et al*. Bacteriology of burns at the Queen Elizabeth Central Hospital, Blantyre, Malawi. *Burns J Int Soc Burn Inj* 2003; **29**: 235–8.

217 Smith S, Ganiyu O, John R *et al*. Antimicrobial resistance and molecular typing of *Pseudomonas aeruginosa* isolated from surgical wounds in Lagos, Nigeria. *Acta Med Iran* 2012; **50**: 433–8.

Downloaded from https://academic.oup.com/jac/article/69/9/2337/2911304 by guest on 25 April 2024