SUPPLEMENT ARTICLE

Salmonella Infections in The Gambia, 2005–2015

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Background. There are large data gaps in the epidemiology of diseases caused by *Salmonella enterica* in West Africa. Regional surveillance of *Salmonella* infections is necessary, especially with the emergence and spread of multidrug-resistant clones.

Methods. Data on *Salmonella* isolated from various clinical specimens from patients from across The Gambia were collected and analyzed retrospectively from 2005 to April 2015. Antibiotic sensitivity testing of *Salmonella* isolates was performed by disk diffusion method. Serotyping and serogrouping of *Salmonella* isolates was performed using standard microbiology techniques.

Results. Two hundred three *Salmonella* isolates were isolated from 190 patients: 52% (106/203) from blood and 39% (79/203) from stool specimens. *Salmonella* was also isolated from urine, aspirates, cerebrospinal fluid, wounds, and abscesses. The prevalence of *Salmonella* in blood cultures was 0.8% (106/13 905). Of the serotyped salmonellae, 14% (21/152) were *Salmonella enterica* serovar Typhi, whereas 86% (131/152) were serovars other than Typhi (nontyphoidal *Salmonella*). Of the 102 typed NTS isolates, 40% (41) were *Salmonella enterica* serovar Typhimurium, 10% (10) were *Salmonella enterica* serovar Enteritidis, and 3% (3) were *Salmonella enterica* serovar Arizonae. Overall, 70% (142/203) of the salmonellae were pansusceptible. Multidrug resistance was found in 4% (9/203) of the isolates, 3 of which were *Salmonella* Enteritidis.

Conclusions. Salmonellae are associated with a wide spectrum of invasive and noninvasive infections across all ages in The Gambia. There is evidence of multidrug resistance in salmonellae that warrants vigilant monitoring and surveillance.

Keywords. *Salmonella enterica* serovar Typhi; nontyphoidal *Salmonella enterica*; multidrug resistance; invasive *Salmonella* disease.

Despite having among the largest burdens of *Salmonella* infections worldwide, there is limited comprehensive data on the prevalence and characteristics of invasive and noninvasive *Salmonella* disease across sub-Saharan Africa [1, 2]. These data gaps are even more apparent in West Africa where epidemiological and antibiotic resistance data are scarce [1, 3]. *Salmonella enterica* serovar Typhi causes typhoid fever and is responsible for >21 million infections and nearly 200 000 deaths annually [4]. *Salmonella enterica* is estimated to cause >93 million infections every year [5]. Nontyphoidal *Salmonella enterica* (NTS) is associated with life-threatening infections in sub-Saharan Africa including septicemia and meningitis. These serious infections appear to occur more frequently among young patients with malaria, anemia, malnutrition, and immunosuppression [6]. In recent years, the emergence and spread of multidrug-resistant (MDR) *Salmonella* in sub-Saharan Africa, including West Africa, has become a major public health issue [3, 7].

The importance of *Salmonella* as a pathogen causing serious infections and the emergence of MDR strains warrant structured disease monitoring and surveillance

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across the subcontinent. Implementation of such surveillance and monitoring systems may ironically be hampered by the lack of supporting data. In The Gambia, *Salmonella* has been previously described as an important cause of serious bacterial infections [8–11]; however, these studies primarily investigated bloodstream infections (BSIs). This study provides data on the spectrum of diseases caused by salmonellae in The Gambia and their phenotypic and antibiotic susceptibility characteristics. The data presented here provide 10-year baseline data as a basis for structured surveillance and monitoring of *Salmonella* infections and possibly vaccine trials in The Gambia and the West Africa subregion.

MATERIALS AND METHODS

Study Population and Samples

The study was conducted in 3 regions in The Gambia: the Western Region, the Lower River Region, and the Upper River region (Figure 1). From 2005 to 2015, salmonellae were isolated from various clinical specimens including blood, stool, urine, aspirates, cerebrospinal fluid (CSF), wounds, ear swabs, and abscesses. Isolates of *Salmonella* from blood, CSF, and aspirates were defined as invasive NTS. These isolates were cultured from specimens from outpatients and inpatients of all age groups who attended the Medical Research Council (MRC) Clinic in Fajara, Western Region. Isolates from different clinical specimens (eg, blood, CSF, and stool) from the same patients and/or clinical specimens collected at different times from the same patients were identified using the MRC Fajara clinic unique patient identifier. Each of the isolates from the same patient was assigned an laboratory identifier and processed independently. These facilities and the procedures have been described previously [9]. From 2007 to 2012, salmonellae were isolated from stool samples collected from children <5 years old with moderate to severe diarrhea who participated in the Global Enteric Multicentre Study (GEMS) conducted in the Upper River Region [12]. *Salmonella* was cultured from stool samples collected from malnourished children 9–24 months old from the Lower River Region of The Gambia. Information on the isolates is summarized in Table 1.

Ethical Approval

Ethical approval was obtained from the Joint MRC/Gambian Government Ethics Committee and the Institutional Review Board of the University of Maryland at Baltimore.

Bacteriologic Methods

Blood, CSF, and aspirate specimens were processed using a BACTEC 9050 automated blood culture system (Becton Dickinson, Temse, Belgium) according to the manufacturer's instructions. In brief, 1–3 mL of specimen was inoculated into commercially produced BD BACTEC PEDS PLUS/F culture for children and 3–10 mL was inoculated in each aerobic and anaerobic vial for adults as described previously [13]. Standard microbiological procedures were performed as previously described using standard media.

Other specimens including stool, urine, and wound swabs were directly cultured on xylose lysing deoxycholate agar, MacConkey agar, and selenite F broth overnight [13]. The Selenite broth was further cultured on xylose lysing deoxycholate agar for the selective culture of *Salmonella*. Any suspected *Salmonella* colony was inoculated on urea and triple sugar iron agar slope and, if suspected to be *Salmonella*, was then tested using the API 20E bacterial identification system (bioMérieux). Serology was

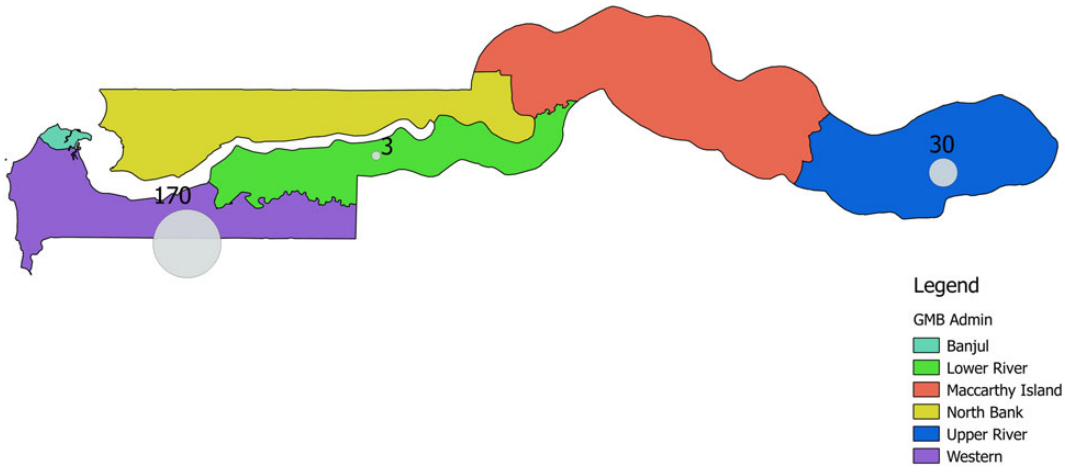

Figure 1. Map of The Gambia indicating regions where salmonellae were isolated. The area of each circle corresponds to the number of isolates. Abbreviation: GMB Admin, Gambia Administration.

Table 1. Characteristics of Patients From Whom *Salmonella* Was Isolated Between 2005 and 2015 in The Gambia, West Africa

Characteristics	Category	No. (N = 190)[a]	%
Location	West Coast Region	157	82.6
	Upper River Region	30	15.8
	Lower River Region	3	1.6
Source	Blood	98	51.6
	Stool	76	40.0
	Urine	7	3.7
	Abscess/wound	4	2.1
	Aspirate	3	1.6
	CSF	1	0.5
	Ear swab	1	0.5
Age	<1 y	26	13.7
	1 to <5 y	64	33.7
	5 to <15 y	23	12.1
	15 to <35 y	33	17.4
	35 to <60 y	30	15.8
	≥60 y	8	4.2
	NA	6	3.2
Sex	Male	103	54.2
	Female	86	45.3
	NA	1	0.5
Hospitalized	No	67	35.3
	Yes	86	45.3
	NA	37	19.5
Season	Dry	111	58.4
	Wet	79	41.6

Abbreviations: CSF, cerebrospinal fluid; NA, unknown.

[a] Ten patients had >1 isolate collected from different sources and/or the same source at different times. Where multiple isolates where collected from the same site, only the first isolate is included in this summary. Where multiple isolates were collected from various sites, only the most invasive is included (CSF, blood, or aspirate).

done if API 20E confirmed *Salmonella* species. All isolates were stored at −70°C.

Stored isolates were retrieved and recultured on Mueller-Hinton agar. Susceptibility testing and serotyping were repeated for uniformity, as different susceptibility interpretations and antisera may have been used in the past to type the isolates. Latex serotyping was done using Statens Serum Institut *Salmonella* Sero-Quik Group kit (groups A–G) and *Salmonella* Sero-Quick ID kit for serovars Typhimurium and Enteritidis (Statens Serum Institut, Copenhagen, Denmark) when API 20E confirmed *Salmonella* species following the manufacturer's protocol. Serotyping and susceptibility testing of the isolates were performed at the MCR Unit, The Gambia.

Antimicrobial susceptibility testing was performed by disk diffusion method targeting 7 antibiotics [10]. The patterns of susceptibility testing were determined by disc diffusion on Mueller-Hinton agar and interpreted according to Clinical and Laboratory Standards Institute guidelines on antimicrobial agents [14]. Antibiotics tested were ampicillin, gentamicin, tetracycline, cotrimoxazole, chloramphenicol, ciprofloxacin, and cefotaxime (BD Oxoid, Basingstoke, United Kingdom). *Salmonella* Enteritidis American Type Culture Collection (ATCC) 13076 or *Escherichia coli* ATCC 25922 were used as controls for the antibiotic susceptibility testing.

Data Management

Patient information, provisional diagnosis, and *Salmonella* culture data were collected from microbiology records for samples from the Western Region. The data on total number of blood cultures performed per year was collected from clinical microbiology logbooks. Data from GEMS [12] were collected and stored as previously described. The descriptive analyses for this study were performed using Stata version 12 and Microsoft Office Excel software.

RESULTS

Analysis was carried out on a total of 203 *Salmonella* isolated from 190 patients between January 2005 and April 2015 and archived at the MRC Unit, The Gambia. The characteristics of the patients are summarized in Table 1. More than 83% (170/203) of the salmonellae were isolated at the MRC Clinic at Fajara in the Western Region, whereas 16% (33/203) were isolated from the Upper River and Lower River regions (Figure 1). Salmonellae from the Western Region were isolated from various clinical specimens through passive surveillance from inpatients and outpatients who attended the MRC Clinic between 2005 and 2015. Invasive *Salmonella* isolated from blood (n = 106), CSF (n = 1), and aspirates (n = 3) accounted for 54% (110/203) of the isolates. Thirty *Salmonella* isolates from the Upper River Region were cultured from stool specimens collected from children with moderate to severe diarrhea. Three *Salmonella* isolates from the Lower River Region were isolated from the stool of moderately and severely malnourished children aged 9–24 months (n = 3).

Prevalence of Invasive and Noninvasive Salmonellae

The prevalence of *Salmonella* in blood was 0.8% (106/13 905) during the 10-year period (Figure 2*A*). The prevalence of salmonellae in blood cultures ranged from 0.4% in 2011 to 1% in 2006, 2007, and 2014 (Figure 2*A*). Half of invasive *Salmonella* infections occurred between September and November, which mirrors the high malaria transmission season from September to January in The Gambia (Figure 2*B*).

The prevalence of *Salmonella* in stool among children <5 years old with moderate to severe diarrhea was 2% (30/1938) in the Upper River Region between 2007 and 2012. More than 40% (13/30) of these *Salmonella* infections occurred

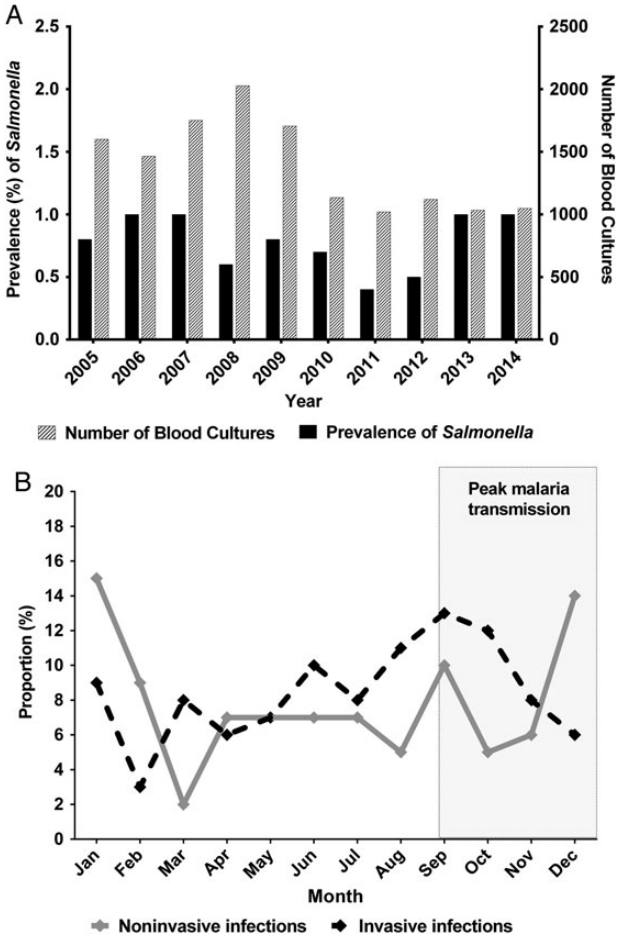

Figure 2. Annual and monthly trends in *Salmonella* infections, 2005–2015. *A*, Number of blood cultures and prevalence of *Salmonella* bloodstream infections by year. *B*, Proportion of invasive and noninvasive salmonellae by month.

between November and January, which coincides with the peak malaria transmission season in The Gambia. Salmonellae were isolated from 2% (3/140) of the stool specimens collected from moderately and severely malnourished children aged 9–24 months in the Lower River Region.

Phenotypic Characterization of Invasive and Noninvasive Salmonellae

Of 203 *Salmonella* isolates, 75% (152/203) were serotyped, and a quarter (51/203) could not be recovered from storage for serotyping. Of the serotyped salmonellae, 14% (21/152) were *Salmonella enterica* serovar Typhi, whereas 86% (131/152) were serovars other than Typhi (nontyphoidal Salmonella [NTS]). Of the 102 typed NTS isolates, 40% (41) were *Salmonella enterica* serovar Typhimurium, 10% (10) were *Salmonella enterica* serovar Enteritidis, and 3% (3) were *Salmonella enterica* serovar Arizonae. A significantly larger proportion of *Salmonella* Typhi isolates (70% [16/21]) were invasive compared with 48% (63/131) NTS that were invasive ($P = .004$; Figure 3). We also identified 3 *Salmonella* Arizonae infections, of which 1 was from urine, 1 was from stool, and 1 was another BSI in a patient with acute liver disease. Nearly all (90%) of the 10 *Salmonella* Enteritidis isolates were isolated from blood. Similarly, 80% (33/41) and 76% (16/21) of the *Salmonella* Typhimurium and *Salmonella* Typhi isolates, respectively, were from blood. A smaller proportion of untyped NTS isolates were from blood (23% [18/77]). A serogroup C NTS was isolated from a CSF specimen collected from a 4-month old infant.

Antibiotic Susceptibility Testing

Antibiotic susceptibility testing was performed on all 203 salmonellae isolated by disk diffusion method. Susceptibility to ciprofloxacin and to ceftriaxone was 98% (199/203) while susceptibility to gentamicin and chloramphenicol was 95% (193/203) and 94% (194/203), respectively. Susceptibility to each antibiotic (ampicillin, cotrimoxazole, and tetracycline) was 83% (169/203).

Overall, 70% (142/203) of the *Salmonella* isolates were susceptible to all the antibiotics tested, while the rest expressed intermediate resistance or resistance to at least 1 antibiotic. Intermediate and full resistance to ≥2 antibiotics was found in 18% (37/203) of the isolates. Multidrug resistance, defined as resistance to ampicillin, cotrimoxazole, and chloramphenicol, was found in 4% (9/203) of the isolates, 3 of which were *Salmonella* Enteritidis. One untyped NTS isolate from stool was only susceptible to gentamicin and ceftriaxone among the 7 antibiotics tested. Two of the 3 *Salmonella* Arizonae isolates had intermediate or full resistance to ampicillin, cotrimoxazole, and tetracycline. Susceptibility to each of the 7 antibiotics tested was ≥90% among the 41 *Salmonella* Typhimurium isolates (Figure 3). In contrast, susceptibility to ampicillin, cotrimoxazole, and chloramphenicol was 60%, 70%, and 70%, respectively, among the 10 *Salmonella* Enteritidis isolates. Susceptibility to each of the antibiotics tested was ≥80% among *Salmonella* Typhi and untyped NTS isolates (Figure 3). Between 2005 and 2014, there were differences in the susceptibilities to the panel of 7 antibiotics tested. The highest rates of intermediate and full resistance were found in isolates from 2011, whereas the lowest rates were found among 2013 salmonellae (Figure 4). Remarkably, all 15 of the 2013 isolates were susceptible to all the antibiotics, and susceptibility to all antibiotics was >90% among all 24 salmonellae from 2014.

Comorbidities and Repeated *Salmonella* Infections

Nearly half (86/203) of the salmonellae isolates were confirmed to be from hospitalized individuals. Noninvasive *Salmonella* isolates were primarily from stool (85% [79/93]). Other specimens included wounds and abscesses, urine, and an ear swab. Ten patients had 2 or 3 *Salmonella* isolates from different clinical specimens collected at the same time and/or from the same clinical specimens collected at different times (Table 2). Two

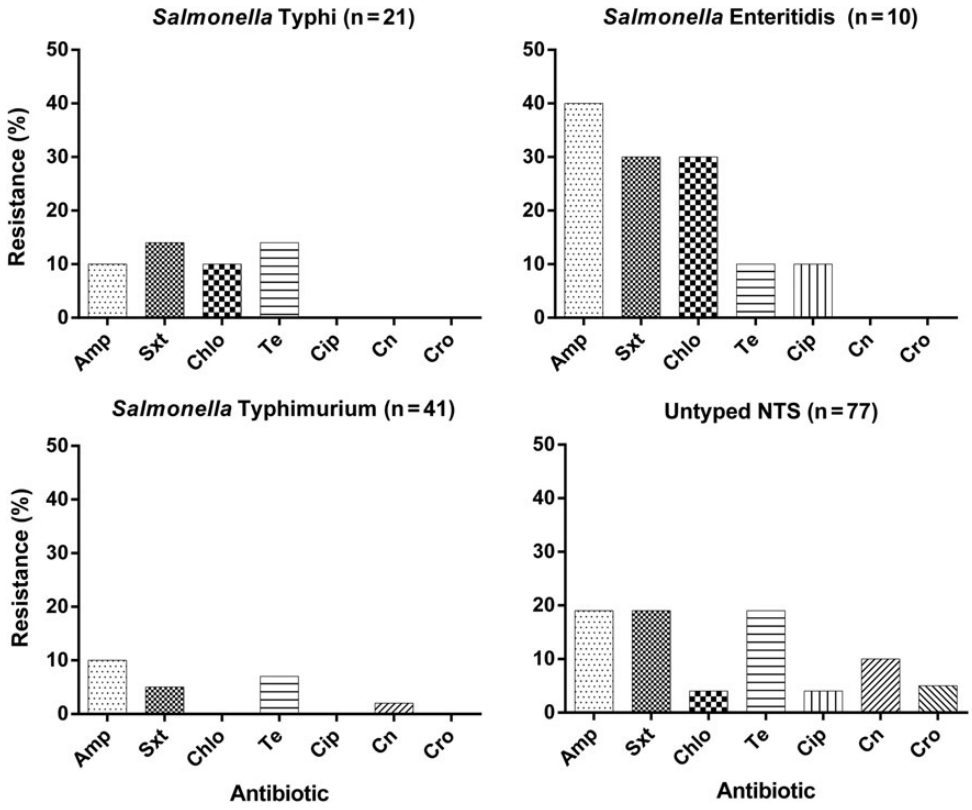

Figure 3. Antibiotic resistance patterns of *Salmonella* serovars found in The Gambia between 2005 and 2015. Abbreviations: Amp, ampicillin; Chlo, chloramphenicol; Cip, ciprofloxacin; Cn, gentamicin; Cro, ceftriaxone; NTS, nontyphoidal *Salmonella*; Sxt, cotrimoxazole; Te, tetracycline.

patients had concurrent isolation of salmonellae from stool and blood. Likewise, another patient had concurrent *Salmonella* infections in urine and blood, while yet another patient had concurrent abscess and bloodstream *Salmonella* infections (Table 2). Five patients had *Salmonella* isolated from blood specimens collected several days or months apart. For instance, patient 6 had *Salmonella* Typhimurium BSIs in January, March, and November of the same year; all 3 isolates were pansusceptible. Patient 4 had a pansusceptible *Salmonella* isolate from blood in April and a *Salmonella* isolate resistant to 4 of the 7 antibiotics tested isolated a month later (Table 2). A 10-month-old infant had *Salmonella* isolated from CSF 3 days after a *Salmonella* BSI was found. The records for provisional clinical diagnoses had several gaps for patients from the MRC Clinic in the Western Region, but among the 48 available records for provisional clinical diagnosis, the most common reports were sepsis (23% [11/48]), diarrhea/gastroenteritis (19% [9/48]), and malnutrition (21% [10/42]).

DISCUSSION

This study provides data on the trends and phenotypic characteristics of invasive and noninvasive *Salmonella* in The Gambia, West Africa. Data on the epidemiology and characteristics of salmonellae causing invasive and noninvasive disease is scanty in sub-Saharan Africa and even more so in the West Africa subregion [1]. For the first time, this study reveals the role of both *S.* Typhi and NTS in invasive and noninvasive disease in The Gambia. This study also shows that *Salmonella* may also be associated with a wide spectrum of infectious diseases, including meningitis, enteric infections, abscesses and wound infections, peritonitis, urinary tract infections, and otitis media, which also warrants further investigation. The findings of this study may provide justification for setting up systematic surveillance for both invasive and noninvasive *Salmonella* infections in the subregion.

In developed countries, NTS are associated with self-limiting diarrheal disease and rarely cause invasive infections such as sepsis [15]. Studies in West Africa and other parts of sub-Saharan Africa have shown that nontyphoidal salmonellae are among the leading causes of invasive disease across all age groups. The prevalence of *Salmonella* bacteremia in an urban hospital in Ghana was 6.5%, with >60% of the infections attributed to NTS [16]. In a study of invasive bacterial infections and malaria conducted in a rural hospital and health center in Burkina Faso, the prevalence of salmonellae in blood cultures was

Year	Amp	Sxt	Te	Chlo	Cip	Cn	Cro	(n)
2005	20%	20%	20%	10%	0%	0%	0%	20
2006	13%	21%	21%	13%	0%	4%	0%	24
2007	25%	15%	10%	5%	5%	5%	0%	20
2008	14%	9%	14%	9%	0%	0%	0%	22
2009	27%	23%	14%	9%	5%	9%	5%	22
2010	10%	29%	24%	0%	5%	14%	5%	21
2011	31%	15%	23%	15%	8%	15%	8%	13
2012	24%	18%	29%	0%	0%	0%	6%	17
2013	0%	0%	0%	0%	0%	0%	0%	15
2014	4%	8%	8%	0%	0%	4%	0%	24
*2015	40%	40%	40%	0%	0%	0%	0%	5

Figure 4. Antibiotic susceptibility of *Salmonella* isolates per year. *January–April 2015 data. Abbreviations: Amp, ampicillin; Chlo, chloramphenicol; Cip, ciprofloxacin; Cn, gentamicin; Cro, ceftriaxone; Sxt, cotrimoxazole; Te, tetracycline.

5% [17]. Among blood cultures from 871 patients who attended the MRC clinic between 2003 and 2005, the prevalence of NTS was 0.9% and that of *Salmonella* Typhi was 0.1% [9]. In the 10 years covered by this study, the prevalence of salmonellae in BSIs infections was 0.7%, slightly below what was previously reported [9, 10]. The prevalence of salmonellae in BSIs varied between 0.5% and 1% over the 10 years covered in this study. This study also confirms that *Salmonella* Typhi, although less prevalent than NTS, continues to cause BSIs in The Gambia.

Nearly half of the *Salmonella* infections found were in children <5 years old, and a third of the patients were between 15 and 60 years old. This is consistent with previous studies in The Gambia which showed that *Salmonella* is an important cause of invasive bacteremia across all age groups in this setting [8–11, 18]. From 2005 to 2015, 85% and 90% of *Salmonella* Typhimurium and *Salmonella* Enteritidis isolates, respectively, were isolated from blood specimens. In sharp contrast, less than a quarter of untyped NTS isolates were from blood specimens. This suggests that the largest burden of invasive NTS infections may be attributable to *Salmonella* Typhimurium and *Salmonella* Enteritidis in The Gambia.

In a study on community-acquired invasive NTS infections among children 2–29 months old conducted in the Upper River Region in 2006, Ikumapayi and colleagues found that 88% of all invasive NTS infections were attributed to *Salmonella* Enteritidis and *Salmonella* Typhimurium [10]. However, in contrast to the current study, where there were nearly 4-fold more *Salmonella* Typhimurium than *Salmonella* Enteritidis invasive infections, Ikumapayi and colleagues found that *Salmonella* Enteritidis invasive infections were 10 times more frequent than those caused by *Salmonella* Typhimurium [10]. A study conducted in a tertiary care setting between 2010 and 2013 in Ghana showed that 80% and 20% of NTS BSIs were attributed to *Salmonella* Enteritidis and *Salmonella* Typhimurium, respectively. Although data on the prevalence of NTS in sub-Saharan Africa is scarce, there is evidence that there are regional, temporal, and seasonal differences in the circulating *Salmonella* serovars [3, 19].

Salmonella invasive infections are associated with high case fatality rates (>20%), and rapid treatment with the appropriate antimicrobial therapy is vital [10, 16, 20–22]. As previously reported in The Gambia, antibiotic susceptibility among invasive salmonellae is >80% for ampicillin, tetracycline, cotrimoxazole, chloramphenicol, ciprofloxacin, and cefotaxime. This is in sharp contrast to reports from Ghana, Burkina Faso, and other parts of sub-Saharan Africa where resistance to ampicillin, tetracycline, and chloramphenicol can exceed 70% in invasive salmonellae [16, 17, 23, 24]. The highest rates of intermediate resistance and resistance were 15%–20% against ampicillin and cotrimoxazole, which were previously first-line treatments for invasive and enteric NTS infections [3]. Due to increasing prevalence of

Table 2. Characteristics of Patients From Whom *Salmonella* Was Isolated From Different Sources and/or at Different Times in The Gambia

				Source						Antibiogram						
Patient	Sex	Age, y	Date (Day/Month/Year)	CSF	Blood	Abscess	Urine	Stool	Isolate	Amp	Sxt	Cn	Te	Cip	Cro	Chlo
Patient 1[a]	Female	1	10/06/2014		X			X	*Salmonella* Typhimurium	S	S	S	S	S	S	S
Patient 2	Female	10	19/01/2006		X	X			*Salmonella*	S	S	S	R	S	S	S
Patient 3	Male	23	27/07/2005		X				*Salmonella*	R	S	S	S	S	S	R
			04/01/2006		X					R	R	S	S	S	S	R
Patient 4	Female	25	24/04/2006		X		X		*Salmonella*	S	S	S	S	S	S	S
			26/05/2006		X					R	R	R	R	S	S	R
Patient 5	Female	27	16/05/2007		X			X	*Salmonella* Typhi	S	S	S	S	S	S	S
Patient 6	Male	33	04/01/2006		X				*Salmonella* Typhimurium	S	S	S	S	S	S	S
			27/03/2006		X					S	S	S	S	S	S	S
			30/11/2006		X					S	S	S	S	S	S	S
Patient 7	Female	72	13/05/2009		X				*Salmonella* Enteritidis	R	R	S	S	S	S	R
			03/06/2009		X					R	R	S	S	S	S	R
Patient 8	Male	0.3	09/03/2009		X				*Salmonella* Typhimurium	S	S	S	S	S	S	S
			12/03/2009	X						S	S	S	S	S	S	S
Patient 9	Female	0.8	09/10/2008		X				*Salmonella* Typhimurium	S	S	S	S	S	S	R
			15/10/2008		X					S	S	S	S	S	S	S
Patient 10	Male	NA	21/02/2006					X	*Salmonella*	S	R	S	S	S	S	S
			23/02/2006					X		S	R	S	R	S	S	S

Abbreviations: Amp, ampicillin; Chlo, chloramphenicol; Cip, ciprofloxacin; Cn, gentamicin; Cro, ceftriaxone; CSF, cerebrospinal fluid; Sxt, cotrimoxazole; Te, tetracycline.

[a] *Salmonella* was isolated from 2 blood samples collected from patient 1 at 2 different times on the same day.

resistance, third-generation cephalosporins and fluoroquinolones are recommended for the treatment of NTS infections [3]. It is reassuring that nearly all the salmonellae were susceptible to chloramphenicol, ciprofloxacin, and cefotaxime.

However, the finding that 9 (4%) of the 203 *Salmonella* isolates were MDR is of great concern. MDR salmonellae may be associated with higher morbidity and pose a major public health concern in sub-Saharan Africa that requires continuous monitoring [3]. Although overall prevalence of resistance was low, nearly one-fifth of the isolates were not susceptible to at least 2 of the antibiotics tested and more than one-tenth were not susceptible to at least 3 antibiotics. One NTS isolate from stool was only susceptible to gentamicin and ceftriaxone of the 7 antibiotics tested. The presence, albeit low, of MDR *Salmonella* warrants continued surveillance and monitoring in The Gambia and subregion.

Interestingly, resistance to ampicillin and cotrimoxazole was at least 3-fold more prevalent in *Salmonella* Enteritidis compared with *Salmonella* Typhimurium isolates. Although a third of the *Salmonella* Enteritidis strains were resistant to chloramphenicol, all the *Salmonella* Typhimurium isolates were susceptible to this antibiotic (Figure 3). Furthermore, a third of the *Salmonella* Enteritidis isolates were MDR. Serovar differences in antibiotic susceptibility patterns have been reported previously in The Gambia, as have higher rates of antimicrobial resistance in *Salmonella* Enteritidis isolates [10].

We also identified 3 *Salmonella* Arizonae infections, of which 1 was a urinary tract infection and another a BSI in a patient with suspected acute liver disease. A serogroup C NTS was found in the CSF and blood of a 4-month old infant. Although rare, cases of *Salmonella* bacterial meningitis have been reported elsewhere in Africa and are often associated with high case fatality rates [25–28]. At least 5 patients had *Salmonella* isolated from blood specimens at intervals spanning several days and months (Table 2). In one instance, the second isolate had a distinct antimicrobial resistance pattern from the first. Whole-genome sequencing can be used to establish if these are exogenous reinfections or relapse [29]. This study has several limitations in design and laboratory methods. It is a retrospective study with large gaps in the metadata and clinical data, particularly for isolates from the MRC Clinic. All the invasive isolates were from the Western Region, and this may mask geographic differences in the salmonellae causing disease in The Gambia. Furthermore, 52 isolates were not serotyped to NTS or *Salmonella* Typhi, which means the actual prevalence of *Salmonella* Typhi may be underestimated in this study. Likewise, a large proportion of NTS isolates were not serogrouped, which could also have skewed the prevalence data presented here. The disk diffusion method was used to determine susceptibility, and minimum inhibitory concentrations were not used to confirm resistance, except for chloramphenicol and tetracycline. However, we previously showed that the disk diffusion susceptibilities for salmonellae are inexpensive and reliable for guiding treatment [10].

This retrospective study took advantage of archived salmonellae covering a 10-year period. This study, despite its limitations, provides some important insights into the phenotypic characteristics and antibiotic resistance patterns of salmonellae associated with invasive and noninvasive infections in this part of West Africa. The data presented here provide 10-year baseline data and justification for structured surveillance of *Salmonella* infections, antibiotic resistance, and possible vaccine trials in the future.

Notes

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Author contributions. B.-K. A., S. D., and M. A. wrote the manuscript. B.-K. A. prepared the figures and tables. All authors reviewed and contributed to the final manuscript.

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