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Prevalence, serotypes, and drug resistance of nontyphoidal *Salmonella* among paediatric patients in a tertiary hospital in Guangzhou, China, 2014–2016

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ABSTRACT

Purpose: Nontyphoidal *Salmonella* (NTS) is a common pathogen responsible for acute gastroenteritis among all ages; however, information on the prevalence, serotypes, and antibiotic susceptibility of NTS isolates is limited. We aimed to explore the characteristics of NTS isolated from paediatric patients in Guangzhou, China.

Methods: This was a retrospective study of 4586 stool culture collected at Guangzhou Women and Children's Medical Center from 2014 to 2016.

Results: We identified 220 (4.80%) NTS isolates in stool samples. Fourteen serotypes were identified among the 220 NTS isolates. *Salmonella* serotype Typhimurium was the most common serotype, representing 69.09%. The highest rate of resistance was recorded in relation to AMP (76.61%), followed by SXT (29.95%), CTX (29.93%), CHL (29.77%), CAZ (23.20%), CIP (7.51%), and CFS (7.18%). The resistance rates of NTS and serotype Typhimurium to CAZ in 2015 were significantly higher than those in 2014. The average hospitalisation duration of inpatients infected by NTS resistant to three or more clinically important agents was significantly longer than that of patients infected with NTS with less antibiotic resistance.

Conclusion: NTS represents a major cause of paediatric gastroenteritis in Guangzhou, China, and the high level of resistance to third-generation cephalosporins coupled with increasing resistance to quinolones among isolated NTS from paediatric gastroenteritis is a serious public health concern that requires continued monitoring and rational usage of antibiotics.

Introduction

High levels of morbidity and mortality worldwide are caused by the bacterial genus *Salmonella*. Most of the infections caused by *Salmonella* are due to *Salmonella enterica* (*S. enterica*). Based on the clinical symptoms they cause, *S. enterica* can be classified into the typhoidal *Salmonella* serotype and nontyphoidal *Salmonella* (NTS) serotype, and the latter has been estimated to be the most common bacterial cause of foodborne illness in China, responsible for 70–80% of cases [1]. In the United States, about 1.2 million infections, 23,000 hospitalisations, and 450 deaths are caused by NTS every year [2]. Though NTS is usually associated with self-limiting gastroenteritis [3,4], severe invasive NTS with complicated extra-intestinal illness, bacteraemia, and meningitis can occur in immunocompromised individuals, elderly patients, and children, accounting for 5%–11.8% of cases [5–8].

S. enterica comprises 42 serogroups and more than 2600 serotypes [9,10]. Serotypes in serogroup A–F are prevalent in China, accounting for 75.3% of serotypes [1]. Serotype Typhimurium and Enteritidis were reported to be the most prevalent serovars among NTS isolated from gastroenteritis cases in China [11,12]. Salmonellosis outcomes differ substantially according to serotype.

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NTS serotypes Mbandaka, Bredeney, Infantis, and Virchow were found to be more frequently associated with persistent infections [10]. The most common NTS serotypes isolated from blood cultures are serotypes Typhimurium and Enteritidis, and serotype Dublin has a much greater tendency to cause invasive disease than other serotypes [13,14].

It has been reported that antimicrobial-resistant infections increase the risk of bloodstream infection and hospitalisation [15]; thus, the appropriate antimicrobial treatment can be life-saving for those with invasive *Salmonella* infections, even though most NTS infections are mild. The recommended treatment for invasive *Salmonella* infections used to include ampicillin, trimethoprim-sulfamethoxazole, or chloramphenicol, but due to high levels of drug resistance, an extended-spectrum cephalosporin or a fluoroquinolone is currently recommended [5]. Extended-spectrum cephalosporins are considered drugs of choice because the use of fluoroquinolones is contraindicated in children. However, these drugs are still recommended for use as one of the last treatment options for multidrug-resistant *S. enterica* infections in patients younger than 18 years [16]. Thus, antibiotic-resistant NTS, especially the multidrug-resistant *Salmonella*, are of great concern worldwide.

Despite the great progress and efforts of the Chinese government in the prevention of foodborne diseases, China is still one of the 15 highest-burden countries for diarrhoea in the world [17]. As NTS has been among the most common pathogens responsible for acute gastroenteritis in children in China [18], knowledge on the serotype distribution and antibiotic resistance patterns is important to formulate appropriate therapeutic and control strategies. We aimed to explore the age distribution and sex ratio of paediatric patients with NTS gastroenteritis and investigate the seasonal tendency, serotype diversity, and antimicrobial resistance of NTS isolated from paediatric patients in Guangzhou, southern China.

Materials and methods

Study design and data collection

This was a retrospective study conducted at Guangzhou Women and Children's Medical Center, a tertiary paediatric medical centre in southern China. From January 2014 to December 2016, all stool samples from paediatric patients including inpatient and outpatient with acute gastroenteritis or diarrhoea submitted for culture testing were included. Faecal samples were streaked and incubated on Macconkey and Salmonella-Shigella selective agar plates (Guangzhou Detgerm Microbiology Technology Co., Ltd, Guangzhou, China) at 35 °C for 18–24 h. Suspected colonies were tested using standard biochemical methods and colonies considered to be *Salmonella* had the following biochemical phenotypes: growth on tripler-sugar-iron agar (acid from glucose, gas, production of H_2S); negative for lactose, sucrose, urease, oxidase, salicin, β-galactosidase and indole production; positive for nitrate reduction and lysine decarboxylase [19]. The organism was further confirmed and serotyped by slide agglutination with commercial antisera (Ningbo Tianrun Bio-Pharmaceutical Co., Ltd, Ningbo, China) [20]. The serotyping and antimicrobial susceptibility testing results of NTS from patients with positive stool cultures were collected and further analysed. To avoid duplication, consecutive stool culture samples and positive lab test results from the same patient were excluded. Clinical information was obtained from the medical records of patients with positive culture results, including information on age, sex, duration of hospitalisation. We defined resistance as "clinically important" if an isolate was resistant to one or more of the following agents: AMP, CTX, CAZ, CFS, CIP, and SXT [15,21]. Spring was defined from March to May, summer from June to August, autumn from September to November, and winter from December to the next February [22].

Statistical analysis

Statistical analysis was performed using SPSS 13.0 Data Editor. Categorical variables were described using frequencies and their proportions, and then compared using the chi-squared (χ^2) test. Continuous scaled data were described using the average ± standard deviation and compared using Student's *t-test*. $P \leq 0.05$ was considered statistically significant.

Results

Seasonal trends, sex and age distribution, and duration of hospitalisation

During the 3-year study period, 4586 stool culture samples from paediatric patients with acute gastroenteritis or diarrhoea at the Guangzhou Women and Children's Medical Center were analysed. In total, 220 NTS isolates were identified, for an NTS isolation rate of 4.80% (220/4586). The isolation rate was 4.30% (37/861) in spring, 5.49% (75/1366) in summer, 6.78% (91/1343) in autumn, and 1.57% (16/1060) in winter. The distribution ratio of the 220 NTS infections in children was highest in autumn (41.36%, 91/220) and lowest in winter (7.27%, 16/220). Among these 220 patients infected by NTS, 144 were male, and 76 were female, for a male to female ratio of 1.88:1. The ages of the 220 patients ranged from 9 days to 9 years, and the median age was 8 months; 59% were infants less than 1 year old, and 35.91% of them belonged to the age group of 6 months to 1 year (Table 1). Forty patients had their blood cultures summitted at the same time that the stool samples were taken; two were positive for NTS with the same serotype as the stool culture isolates: one of them was serotype Typhimurium, and the other was serotype Enteritidis.

Among these 220 patients infected by NTS, half (110/220) required hospitalisation due to their clinical symptoms. The overall mean duration of hospitalisation among inpatients (± standard deviation) was 6.84 ± 5.9 days, and the means were 7.08 ± 6.44 days and 6.29 ± 4.52 days for those who were less than 1 year old and more than 1 year old, respectively; the means for the last two groups were not significantly different ($P = 0.52$). However, antimicrobial-resistant NTS was associated with longer hospitalisations. The average duration of hospitalisation for inpatients infected with NTS resistant to three or more clinically important antibiotics was significantly longer ($P = 0.02$) at 8.93 ± 8.30 days compared to 6.05 ± 4.52 days for the others.

Serotypes

In total, 14 serotypes were identified among the 220 isolates. *Salmonella* serotype Typhimurium was the most common serotype, representing 69.09% (152/220) of all isolates, followed by serotype Enteritidis 10.45% (23/220), serotype Stanley 3.64% (8/220), and serotype Saintpaul 3.64% (8/220). These four serotypes accounted for 86.82% (191/220) of the NTS isolates in this study. Serotype Typhimurium predominated among all of the three years, all seasons of the year and all age groups. However, in the >3-years age group, the proportion of Typhimurium declined to 52.17%, whereas that of serotype Enteritidis increased to 34.78%. Additionally, 90.45% of the strains were isolated from cities in Guangdong Province with a wide distribution, while others were from neighbouring provinces. The proportions of serotype Typhimurium in Baiyun, Yuexiu and Huangpu districts were significantly lower than those in other areas of Guangzhou city, as shown in Table 2.

Table 1
Descriptive data of nontyphoidal *Salmonella* infections by serotypes among paediatric patients with gastroenteritis in a tertiary hospital in Guangzhou.

Variable	Typhimurium	Enteritidis	Stanley	Saintpaul	Bovismorbificans	Derby	Thompson	London	Infantis	Newport	Manhattan	Agona	Potsdam	Senftenberg	Untyped	Overall
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Season																
Spring	27(12.27)	4(1.82)	1(0.45)	1(0.45)	0(0.00)	2(0.91)	0(0.00)	0(0.00)	0(0.00)	1(0.45)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	1(0.45)	37(16.82)
Summer	50(22.73)	9(4.09)	3(1.36)	3(1.36)	1(0.45)	2(0.91)	0(0.00)	2(0.91)	1(0.45)	1(0.45)	0(0.00)	0(0.00)	1(0.45)	1(0.45)	2(0.91)	75(34.55)
Autumn	61(27.73)	10(4.55)	3(1.36)	3(1.36)	3(1.36)	0(0.00)	3(1.36)	1(0.45)	1(0.45)	0(0.00)	1(0.45)	1(0.45)	0(0.00)	0(0.00)	4(1.82)	91(41.36)
Winter	14(6.36)	0(0.00)	1(0.45)	1(0.45)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	16(7.27)
Year																
2014	53(62.35)	7(8.24)	3(3.53)	5(5.88)	3(3.55)	2(2.35)	1(1.18)	0(0.00)	2(2.35)	2(2.35)	1(1.18)	1(1.18)	1(1.18)	1(1.18)	3(3.65)	85(100)
2015	61(76.25)	8(10.00)	2(2.50)	1(1.25)	1(1.25)	1(1.25)	2(2.50)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	4(5.00)	80(100)
2016	38(69.09)	8(14.55)	3(5.45)	2(3.64)	0(0.00)	1(1.82)	0(0.00)	3(5.45)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	55(100)
Sex																
Male	105(47.73)	9(4.09)	5(2.27)	7(3.18)	3(1.36)	3(1.36)	1(0.45)	1(0.45)	1(0.45)	2(0.91)	1(0.45)	1(0.45)	0(0.00)	0(0.00)	5(2.27)	143(65.45)
Female	47(21.36)	14(6.36)	3(1.36)	1(0.45)	1(0.45)	1(0.45)	2(0.91)	2(0.91)	1(0.45)	0(0.00)	0(0.00)	0(0.00)	1(0.45)	1(0.45)	2(0.91)	76(34.55)
Age groups																
≤6 month	35(68.633)	5(9.80)	2(3.92)	0(0.00)	1(1.96)	1(1.96)	1(1.96)	1(1.96)	1(1.96)	0(0.00)	1(1.96)	0(0.00)	0(0.00)	1(1.96)	2(3.92)	51(23.18)
6 month–1 year	58(73.42)	3(3.80)	2(2.53)	3(3.80)	0(0.00)	1(1.27)	2(2.53)	2(2.53)	0(0.00)	2(2.53)	0(0.00)	1(1.27)	1(1.27)	0(0.00)	4(5.06)	79(35.91)
1–2 year	33(71.74)	3(6.52)	4(8.70)	3(6.52)	3(6.52)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	46(20.91)
2–3 year	14(66.67)	4(19.05)	0(0.00)	2(9.52)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	1(4.76)	21(9.55)
>3 year	12(52.17)	8(34.78)	0(0.00)	0(0.01)	0(0.02)	2(8.70)	0(0.00)	0(0.00)	1(4.35)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	23(10.45)

Table 2
Serotypes distribution of nontyphoidal *Salmonella* isolated from paediatric patients with gastroenteritis in a tertiary hospital in Guangzhou.

Serotypes locations	Typhimurium	Enteritidis	Stanley	Saintpaul	Bovismorbificans	Derby	Thompson	London	Infantis	Newport	Manhattan	Agona	Potsdam	Senftenberg	Untyped	Overall
Guangdong Province	137	22	8	8	4	3	3	3	2	1	0	1	1	0	6	199
Guangzhou City	80	13	5	4	3	1	1	2	1	1	0	1	0	0	3	115
Baiyun District	21	5	1	2	2	0	0	2	0	0	0	1	0	0	2	36
Liwan District	11	4	0	0	0	0	1	0	0	0	0	0	0	0	0	16
Yuexiu District	4	0	2	0	1	0	0	0	0	0	0	0	0	0	0	7
Tianhe District	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Haizhu District	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Panyu District	8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	9
Huangpu District	5	1	1	1	0	0	0	0	0	0	0	0	0	0	1	9
Zengcheng District	5	1	0	0	0	0	0	0	1	0	0	0	0	0	0	7
Huadu District	8	0	1	0	0	1	0	0	0	0	0	0	0	0	0	10
Conghua District	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nansha District	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Other citues in Guangdong	57	9	3	4	1	2	2	1	1	0	0	0	1	0	3	84
Other provinces	15	1	0	0	0	1	0	0	0	1	1	0	0	1	1	21
Above all	152	23	8	8	4	4	3	3	2	2	1	1	1	1	7	220
Percentage	69.09	10.45	3.64	3.64	1.82	1.82	1.36	1.36	0.91	0.91	0.45	0.45	0.45	0.45	3.18	100.00

Table 3
Antimicrobial susceptibility testing of nontyphoidal *Salmonella* isolated from paediatric patients with gastroenteritis in a tertiary hospital in Guangzhou.

Antibiotics	2014 (%)		2015 (%)		2016 (%)		Total (%)	
	R	I	R	I	R	I	R	I
AMP	76.47	0.00	74.68	0.00	79.63	0.00	76.61	0.00
CHL	35.80[a]	0.00	20.00	0.00	35.19	0.00	29.77	0.00
SXT	39.02[b]	0.00	18.75	0.00	32.73	0.00	29.95	0.00
CIP	9.76	7.32	6.33	3.80	5.77	5.77	7.51	5.63
CFS	7.32	10.98	8.47	0.00	5.00	2.50	7.18	5.52
CTX	27.40	1.37	37.84	2.70	27.03	0.00	29.93	1.36
CAZ	16.00[c]	0.00	31.43	4.29	22.45	6.12	23.20	3.09

Note: AMP, ampicillin; CHL, chloramphenicol; SXT, trimethoprim/sulfamethoxazole; CIP, ciprofloxacin; CFS, cefoperazone/sulbactam; CTX, cefotaxime; CAZ, ceftazidime. R, resistant; I, intermediate.

[a] $0.01 < P < 0.05$, rate of resistance to CHL in 2014 compared to that in 2015.
[b] $0.01 < P < 0.05$, rate of resistance to SXT in 2014 compared to that in 2015.
[c] $0.01 < P < 0.05$, rate of resistance to CAZ in 2014 compared to that in 2015.

Antibiotic susceptibility tests

In total, 220 NTS isolates were analysed to determine their antimicrobial susceptibility profiles (Table 3). The highest rate of resistance was recorded in relation to AMP (76.61%), followed by SXT (29.95%), CTX (29.93%), CHL (29.77%), CAZ (23.20%), CIP (7.51%), and CFS (7.18%); 77.27% (170/220) of isolates were found to be resistant to at least one clinically important antibiotic, and 22.27% (49/220) of them were resistant to three or more clinically important antibiotics. Annual resistance rates of AMP are relatively stable; however, the resistance rate of NTS to CAZ in 2015 (31,43%) was significantly higher than that in 2014 (16%), and the resistance rate of serotype Typhimurium to CAZ in 2015 was significantly higher than that in 2014. Resistance rates to CHL and SXT in 2015 were significantly decreased compared to those in 2014. The antibiotic susceptibility patterns of serotypes Typhimurium and Enteritidis as well as other serotypes are listed in Table 4. The rates of resistance to AMP among serotype Typhimurium and Enteritidis isolates were significantly higher than those in other serotypes, and the rate of resistance to SXT for serotype Enteritidis was also significantly higher than that in other serotypes. The rate of resistance to CHL for serotype Typhimurium was significantly higher than that for serotypes Enteritidis, which was sensitive to all CIP antibiotics. Five isolates (all were Typhimurium) were resistant to both fluoroquinolones and third-generation cephalosporins, accounting for 2.27% (5/220) of all isolates.

Discussion

In China, NTS is among the most common pathogens responsible for acute gastroenteritis in children [18] and clearly imposes a substantial burden on those affected. In our study, the isolation rate of NTS from paediatric patients with acute gastroenteritis in Guangzhou between 2014 and 2016 was 4.80% (220/4586), which was consistent with a laboratory-based surveillance reported by Deng et al. in the Guangdong Province in 2012 with an isolation rate of 4.0% [21]. Among these 220 patients infected by NTS, half of them (110/220) required hospitalisation due to their clinical symptoms, indicating that the bacteria have been prevalent and causing serious infections in children in Guangzhou in recent years.

A study conducted in Kazakhstan reported a linear association between the number of NTS infections and mean monthly temperature [23]. In the present study, the cases of NTS gastroenteritis mostly occurred in autumn, and the isolation rate was the highest 6.78% (91/1343) in autumn when the ambient air temperature was high. This is probably because the temperature in warm seasons is suitable for the growth of the bacteria; thus, they are more likely to contaminate food or the ambient environment. Because the main potential risk factors for the development of NTS gastroenteritis in children include consuming contaminated infant formula, and riding in a shopping cart next to meat or poultry, personal hygiene and targeted preventive education for children are still necessary to help prevent the occurrence of the infections, particularly in male children in Guangzhou [24] as the male to female ratio was 1.88:1 in the present study, which was much higher than that for children in Taiwan (1.08:1) [25]. The proportion of NTS infection was highest (35.91%) among children aged 6 months to 1 year, as this is the time when they learned to climb and walk. This behaviour results in frequent environmental contact with their limbs, which could then be contaminated by faeces or bodily fluids of companion animals or reptiles [26,27]. For the age group younger than 6 months, the proportion of NTS infection ranked second (23.18%), and the suspected source of infection was contaminated food or water, or person-to-person transmission from an asymptomatic caretaker [27,28].

In total, 14 serotypes were identified among the 220 isolates. *Salmonella* serotype Typhimurium was the most common serotype, representing 69.09% (152/220) of all isolates. Although the serotype Typhimurium was found to be predominant in a laboratory-based surveillance of the general population in Guangdong Province [21], the rate of this serotype among paediatric patients in this study was much higher. Serotype Enteritidis, accounting for 10.45% (23/220)

Table 4
Antimicrobial susceptibility testing of the serotypes Typhimurium, Enteritidis and other serotypes isolated from paediatric patients with gastroenteritis in a tertiary hospital in Guangzhou.

Antibiotics	Typhimurium								Enteritidis		Other types		All serotypes	
	2014 (%)		2015 (%)		2016 (%)		Total (%)		Total (%)		Total (%)		Total (%)	
	R	I	R	I	R	I	R	I	R	I	R	I	R	I
AMP	84.91	0.00	78.33	0.00	83.78	0.00	82.00[a]	0.00	86.96[b]	0.00	55.26	0.00	76.61	0.00
CHL	47.06	0.00	24.59	0.00	40.54	0.00	36.24[c]	0.00	13.64	0.00	19.44	0.00	29.77	0.00
SXT	43.14	0.00	21.31	0.00	31.58	0.00	31.33	0.00	13.04[d]	0.00	37.84	0.00	29.95	0.00
CIP	11.76	11.76	8.33	5.00	8.11	5.41	9.46	7.43	0.00	0.00	5.41	2.70	7.51	5.63
CFS	7.69	15.38	9.30	0.00	7.41	3.70	8.20	7.38	11.11	0.00	2.94	0.00	7.18	5.52
CTX	27.91	2.33	34.48	3.45	25.93	0.00	29.29	2.02	57.14	0.00	21.43	0.00	29.93	1.36
CAZ	12.77	0.00	31.48[e]	5.56	20.00	5.71	22.06	3.68	40.00	0.00	16.13	3.23	23.20	3.09

Note: AMP, ampicillin; CHL, chloramphenicol; SXT, trimethoprim/sulfamethoxazole; CIP, ciprofloxacin; CFS, cefoperazone/sulbactam; CTX, cefotaxime; CAZ, ceftazidime. R, resistant; I, intermediate.

[a] $P < 0.01$, rate of resistance to AMP for serotype Typhimurium compared to that of other serotypes.
[b] $0.01 < P < 0.05$, rate of resistance to AMP for serotype Enteritidis compared to that of other serotypes.
[c] $0.01 < P < 0.05$, rate of resistance to CHL for serotype Typhimurium compared to that for Enteritidis.
[d] $0.01 < P < 0.05$, rate of resistance to SXT for serotype Enteritidis compared to that for other serotypes.
[e] $0.01 < P < 0.05$, rate of resistance to CAZ for serotype Typhimurium in 2014 compared to that in 2015.

of all isolates, was ranked second in this study, which was consistent with the results of a survey among infants and children aged 1–3 years old [22]. However, the proportion of these two serotypes was inverted in the >3-year age group. This was probably due to the change in environment at ages older than 3 years, when they entered kindergarten.

Although NTS is usually associated with self-limiting gastroenteritis, severe invasive NTS with complicated extra-intestinal illness and bacteraemia can occur in children [5–8]. Among the 220 patients in this study, 40 patients had blood cultures obtained at the same time as the stool samples, two of which were positive for the same serotype as the stool cultures. One of these two was positive for serotype Typhimurium, and the other was serotype Enteritidis, which was consistent with previous findings that the most common NTS serotypes isolated from blood cultures were serotypes Typhimurium and Enteritidis [13,14].

Antimicrobial therapy is generally not indicated for patients with uncomplicated gastroenteritis caused by nontyphoidal *Salmonella* spp. because NTS is usually associated with self-limiting gastroenteritis and because antibiotic treatment has been shown to prolong the duration of bacterial excretion from the intestinal tract [29]. However, the appropriate antimicrobial treatment can be life-saving in case of life-threatening *Salmonella* infections in children. And extended-spectrum cephalosporins have been suggested as the drugs of choice for treating children with serious nontyphoidal *Salmonella* infections [30]. In a retrospective medical record review conducted on Taiwanese children for a 9-year period, the rates of resistance to AMP and third-generation cephalosporins were 30% for AMP and 4% for CTX [24]. However, in the present study, the resistance rates for these antibiotics were much higher, i.e., 76.61% for AMP and 29.93% for CTX. The resistance rates of NTS and serotype Typhimurium to CAZ in 2015 were significantly higher than those in 2014. High antimicrobial resistance to conventional antibiotics was also observed in 2009–2012 and 2013–2014 in two surveillances of non-typhoidal salmonella infections conducted by the Guangdong Provincial Center for Disease Control and Prevention. Those surveillances showed an increasing trend of antimicrobial resistance (AMP from 57.1% to 66.64%; CTX from 11.0% to 14.17%; CAZ from 7.4% to 8.61%; CIP from 8.5% to 8.58%) [28,31]. These findings suggest a high prevalence of extended-spectrum β-lactamases (ESBLs) or acquired AmpC β-lactamases, possibly due to inappropriate or frequent use of antibiotics, especially by intravenous infusion [32–35].

In the present study, the antimicrobial resistance rate varied greatly according to serotype. The rates of resistance to AMP among serotype Typhimurium and Enteritidis isolates were significantly higher than those in other serotypes, and the rate of resistance to SXT for serotype Enteritidis was also significantly higher than that in other serotypes. The rate of resistance to CHL for serotype Typhimurium was significantly higher than that for serotypes Enteritidis, which was sensitive to all CIP antibiotics. Therefore, continuous monitoring of circulating serotypes is necessary for proper treatment.

Moreover, in this study, co-resistance to fluoroquinolones and third-generation cephalosporins was also identified, accounting for 2.27% (5/220) of all isolates. In addition, 22.27% (49/220) of all isolates were resistant to three or more clinically important antibiotics, and the average duration of hospitalisation of inpatients with infections caused by NTS resistant to three or more clinically important agents was significantly longer ($P = 0.02$) at 8.93 ± 8.30 days compared to 6.05 ± 4.52 days for the other patients, suggesting that NTS resistant to multiple clinically important drugs is associated with longer hospitalisations probably because of the failure of empirical antimicrobial therapy and the persistence of symptoms [15].

Conclusion

The isolation rate of NTS was 4.80% (220/4586) among paediatric patients with acute gastroenteritis from 2014 to 2016. In total, 14 serotypes were identified among the 220 isolates. Salmonella serotype Typhimurium was the most common serotype, representing 69.09% (152/220) of all isolates, followed by serotype Enteritidis 10.45% (23/220). The highest rate of resistance was recorded in relation to AMP (76.61%), followed by SXT (29.95%), CTX (29.93%), CHL (29.77%), CAZ (23.20%), CIP (7.51%), and CFS (7.18%). Thus, NTS is one of the major causes of paediatric gastroenteritis in Guangzhou, China. Moreover, the high rate of resistance to third-generation cephalosporins coupled with increasing resistance to quinolones among NTS isolated from paediatric gastroenteritis in Guangzhou is a serious public health concern that requires continued monitoring and the rational usage of antibiotics.

Author contributions

- Bing-Shao Liang, Yong-Qiang Xie, and Shu-Jun He collected the data; analysed seasonal trends, sex, age distribution, and duration of hospitalisation; and prepared the manuscript.
- Jia-Liang Mai, Yan-Mei Huang, Li-Yuan Yang and Hua-Min Zhong analysed the serotype distribution.
- Qiu-Lian Deng and Shuwen Yao analysed the antibiotic susceptibility tests.
- Yan Long, Yi-yu Yang, and Si-Tang Gong assisted with the data analysis and the preparation of the manuscript.
- Zhen-wen Zhou wrote and revised the manuscript.

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Competing interests

None declared.

Ethical approval

The protocol for the present study was reviewed and approved by the Ethics Committee of Guangzhou Women and Children's Medical Center, and it conforms to the provisions of Declaration of Helsinki.

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