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Prevalence and Antimicrobial Susceptibility Patterns of *Salmonella Serovars (Typhi, Paratyphi* A & B, and Non-Typhoidal) Across Age and Gender Groups: A Retrospective Study

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Abstract

Introduction: Salmonella is a bacterial pathogen responsible for both typhoidal (e.g., typhoid fever) and non-typhoidal infections. While non-typhoidal Salmonella typically causes self-limiting gastrointestinal illness, typhoidal Salmonella, particularly Salmonella typhi and Salmonella paratyphi, can enter the bloodstream, leading to invasive systemic disease. This is particularly dangerous in young children, where it contributes significantly to morbidity and mortality. In recent years, the misuse and overuse of antibiotics have led to the emergence of multi-drug-resistant (MDR) strains of Salmonella, making treatment more complex and less effective. In such cases, third-generation Cephalosporins, such as Ceftriaxone, are commonly used due to their broad-spectrum efficacy. This study focuses on the incidence, serotype distribution, seasonal trends, and antimicrobial resistance patterns of Salmonella, with an emphasis on Ceftriaxone resistance, based on data from Dr. Lal Path Labs, Delhi, over a four-year period (January 2021 to December 2024).

Results and Discussion: A retrospective study conducted at Dr. Lal Path Labs between 2021 and 2024 analyzed 245,600 positive bacterial cultures from various clinical samples, identifying 6,332 cases (2.6%) as Salmonella species. The majority (99.1%) were isolated from blood, highlighting the invasive nature of typhoidal infections. Salmonella typhi accounted for 90.1% of cases, followed by other Salmonella spp. (4.9%), S. paratyphi A (3.8%), and S. paratyphi B (1.1%). A small number of isolates were also detected in abscesses, stool, and urine samples. Most cases occurred in males (58.9%) and in children aged <=12 years (49.1%). MDR strains were primarily seen in children under five, with no such cases reported in older age groups.

Seasonal analysis revealed peaks in spring and summer, with a notable increase in 2024, suggesting environmental influences such as water quality and hand hygiene playing a role in transmission. Despite the growing issue of antimicrobial resistance, most isolates remained susceptible to key antibiotics: Ampicillin (93%), Cefixime (97.4%), Ceftriaxone (95.4%), Ertapenem (98.6%), Cotrimoxazole (97.5%), Azithromycin (98.8%), and Chloramphenicol (97.8%). However, resistance to fluoroquinolones was alarmingly high with 99.8% to Ciprofloxacin, emphasizing the need for antibiotic stewardship and susceptibility-guided therapy.

Conclusion: This study highlights the ongoing public health burden of typhoid fever, particularly among children and during warmer months. The presence of multidrug-resistant Salmonella strains in young children further stresses the need for targeted preventive strategies. Effective management requires continued surveillance, responsible antibiotic use, and enhanced diagnostic capabilities to limit the spread of resistant infections and improve clinical outcomes.

Keywords: salmonella enterica serovar typhi (s. typhi); salmonella enterica serovar paratyphi a; b and c (s. paratyphi a; b and c); non- typhoidal salmonella species (NTS); invasive infection

Introduction

Salmonella is a gram-negative bacterium a foodborne pathogen from the Enterobacteriaceae family, affecting warm-blooded animals, with around 2,600 serovars classified as typhoidal or non-typhoidal [1, 6, 11, 13, 15]. The severity of Salmonella infections in humans depends on both the bacterial serotype and the host's immune status. Typhoidal infections, caused by *Salmonella enterica* serovar Typhi *(S. Typhi)* and *Salmonella enterica* serovar Paratyphi A, B and C *(S. Paratyphi)*, while non-typhoidal fever is caused by Non Typhoidal Salmonella species (*S. typhimurium* and *S. enteritidis*) typically result in acute symptoms like diarrhea, abdominal cramps, and fever leading to self-limiting gastroenteritis, resolving within 1 to 7 days without treatment. However, approximately 5% of cases, particularly in immunocompromised individuals, infants, and the elderly, may develop severe invasive infections, including bacteremia, meningitis, and osteomyelitis [1, 13, 14, 20, 21]. Typhoidal *Salmonella* can cause disseminated infections, presenting with prolonged fever, headache, gastrointestinal symptoms, loss of appetite, and relative bradycardia. While typhoid fever is prevalent in developing countries, non-typhoidal infections occur worldwide. Infants and young children are especially susceptible, usually through contaminated food or water [1, 4, 6, 8, 13].

It has a significant impact on global health and the economy. According to the World Health Organization (WHO), Salmonella is one of the four leading causes of diarrhea worldwide. Among 14 major foodborne pathogens, Salmonella ranks as the third largest contributor to economic burden, with an estimated annual cost of $3.3 billion [13]. Typhoid fever is a serious systemic infection that poses a significant global health threat. According to the World Health Organization (WHO, 2018), it affects an estimated 11 to 20 million people annually and causes between 128,000 and 161,000 deaths worldwide, with the highest burden observed among children in South-East Asia, and in the WHO African, Eastern Mediterranean, and Western Pacific Regions [18]. While Salmonella infections generally result in moderate morbidity and relatively low fatality rates, they still represent a notable public health. Infections tend to be more severe in vulnerable populations, including young children, the elderly, and immunocompromised individuals. Complications such as cholecystitis, pancreatitis, and appendicitis can progress to life-threatening conditions, including meningitis and sepsis. Prolonged fluid loss may lead to dehydration, particularly in newborns and older adults [13,25]

Despite the WHO's recommendation for typhoid vaccination since 2008, vaccine coverage remains low, particularly among young children. In 2018, the WHO reinforced the use of Vi polysaccharide-based typhoid conjugate vaccines, with a focus on countries experiencing the highest disease burden [2, 10, 11, 22, 26]. Current typhoid vaccines offer only moderate, short-term protection. High genetic diversity among *Salmonella* serotypes further complicates control efforts [13].

At the same time, growing resistance to Ampicillin, now commonly used due to fluoroquinolone resistance, and resistance to third-generation Cephalosporins, are becoming significant concerns [1, 9, 24, 26]. In India, which accounts for over half of the global typhoid burden, the implementation of public vaccination programs has been limited, partly due to a lack of comprehensive data on the current disease burden.

Methods:

A retrospective study was conducted in the Department of Microbiology at *Dr. Lal Path Labs*, Delhi, India, and a tertiary healthcare laboratory offering a full range of testing services. The study was carried out from January 2021 to December 2024. A total of 245,600 clinical isolates, collected from urine, pus, blood, sputum, vaginal swabs, and body fluids, were analyzed for routine culture in the microbiology department. Of these samples, 6,332 (2.6%) isolates were identified as Salmonella species.

Approximately Whole blood samples (1–5 mL for pediatric patients and 8–10 mL for adults) were collected and inoculated into (BD BACTEC™, BD) culture bottles—pediatric bottles (BD BACTEC™, BD) and adult bottles, respectively. The inoculated bottles were incubated in an automated blood culture system (BD BACTEC™) for up to five days. Upon a positive growth signal from the system, specimens were sub-cultured onto Blood agar, Mc Conkey, Choclate agar plates and incubated at 37 °C for 24 hours. Cultures showing no visible growth after 24 hours were further incubated for an additional 24 hours (total 48 hours) to ensure detection of slow-growing organisms. Pus, Body fluids, and miscellaneous samples were directly cultured onto blood agar, McConkey, Choclate and CHROM agar and incubated at 37 °C for 18–48 hours. Fresh stool samples were inoculated onto Selenite F broth and incubated for 4-6 hrs there after inoculated on XLD (Xylose Lysine Deoxycholate) agar plates and incubated at 37 °C for 18–48 hours. Urine samples inoculated on CHROM agar and incubated at 37 °C for 18–48 hours. Suspected colonies from all media were selected for further identification and antimicrobial susceptibility testing.

Bacterial identification was made using MALDI-TOF and Serotyping. Antimicrobial susceptibility was evaluated on VITEK® 2 with respective susceptibility cards (AST N235, BioMerieux, India) as per as CLSI M100-S33 [7]. The following antibiotics were used for the isolates, Ampicillin (AMP), Ciprofloxacin (CIP), Trimethoprim/Sulphomethoxazole(TM/SXT), Cefixime (CFM), Ceftriaxone (CTR), Azithromycin (AZM), Chloramphenicol(C) and Ertapenem (ETP). Standard strains of E. coli (ATCC 25922) were used routinely in this study as control. No data collected on the clinical background of the patients.

Statistical analysis:

The analysis done using the statistical software package Myla (Biomerieux) to compare age, antibiotic susceptibility pattern with MIC were included as variables in this study between various clinical isolates among Salmonella species.

Results:

A laboratory-based retrospective study was conducted from January 1, 2021, to December 31, 2024, at *Dr. Lal Path Labs*, Delhi. This study analyzes the distribution and antimicrobial susceptibility of Salmonella species isolated from a large number of clinical samples collected over a 60-month period as part of routine analyses from unselected community patients (male and female of all ages and clinical conditions) residing in northern India.

Over the five-year period, the Microbiology department identified 2,45,600 positive bacterial growths from various clinical samples, of which 6,332 (2.6%) were Salmonella species. Of these, 6,277 (99.1%) were isolated from blood, followed by 20 from pus, 17 from stool, 9 from urine, and 9 from other body fluids (see Table 1).

Total (N=6332)	Blood (n= 6277)	Pus (n= 20)	Fluid (n= 9)	stool (n= 17)	Urine (n= 9)
Salmonella Typhi, N=5706 (90.1%)	5674	12	6	9	5
Salmonella Paratyphi A, N=242 (3.8%)	241	0	0	1	0

Salmonella Paratyphi B, N=69 (1.08%)	**69**	**0**	**0**	**0**	**0**
Non Typhoidal Salmonella species, N=315 (4.9%)	**293**	**8**	**3**	**7**	**4**

Table 1: Distribution of Salmonella species isolated from diverse samples at Dr Lal Path Labs during 4 years.

Among these isolates, *S. typhi* was the most common species, accounting for 5,706 (90.1%) of the cases, followed by Salmonella species (315, 4.9%), *S. paratyphi A* (242, 3.8%), and *S. paratyphi B* (69, 1.1%) [Table 1]. This data highlights that *Salmonella Typhi* and *Salmonella Paratyphi A* are predominantly found in blood cultures, signifying their dominant role in bloodstream infections. *Salmonella Paratyphi B* also shows a similar pattern, with the highest occurrence in blood samples. Other *Salmonella* species were most commonly found in blood cultures (93.8%), but were also detected in abscesses (2.5%), stool (2.2%) and urine (1.2%).These findings suggest that while these species are mainly associated with bloodstream infections, they may occasionally contribute to extra-intestinal infections, such as abscesses or urinary tract infections.

Age Groups (MDRO %)	Total No. of Salmonella Species N=6332 (%)	Male N=3734 (58.9%)	Female N= 2598 (41.1%)
0-5 (5.6%)	1262 (19.9%)	798	464
6-12 (4.7%)	1848 (29.2%)	1085	763
13-35 (3.4%)	2603 (41.1%)	1574	1029
36-50 (**)	413 (6.5%)	189	224
51-65 (**)	168 (2.7%)	72	96
>=66 (**)	38 (0.6%)	16	22

Table 2: Age and Gender wise prevalence of Salmonella species isolated from diverse sample during Jan 2021 - Dec 2024.

The total prevalence of *Salmonella* species in male patients was found to be 3,734 (58.9%), while in female patients, it was 2,598 (41.1%). These results indicate a higher prevalence of *Salmonella* infection in male patients compared to females. The most affected age group, regardless of gender, was 0-12 years (49.1%), and followed by 13-35 years (41.1%), 36-50 years (6.5%), and those aged 51 years and above (3.3%). The retrospective data from this study also highlights the distribution of multi-drug-resistant organisms (MDROs) across different age groups and genders. The prevalence of MDROs was higher in younger age groups, particularly in the 0-5 years range, and decreased with age. No MDRO prevalence was observed in older age groups [Table 2].

Antibiotics	Range	*Salmonella Typhi* (n=5706)		*Salmonella Paratyphi A* (n=242)		*Salmonella Parayphi B* (n=69)		*Non typhoidal Salmonella species* (n =315)	
		MDRO n=240 (4.2%)		MDRO n=1 (0.4%)		MDRO 0%		MDRO n =43 (13.6%)	
		%S	MIC 50/90	%S	MIC 50/90	%S	MIC 50/90	%S	MIC 50/90
Ampicillin	**≤ 8 -≥32**	**93.8**	<=2/8	**93.4**	<=2/8	**92.7**	<=2/8	**91.7**	<=2/8
Cefixime	**≤ 1 -≥ 4**	**97.3**	<=0.25/0.5	**98.6**	<=0.25/0.5	**98.6**	<=0.25/0.5	**94.9**	<=0.25/0.5
Ceftriaxone	**≤ 1 -≥4**	**95.6**	1/1.	**100**	1/1.	**100**	1/1.	**86.1**	<=2/8.
Ciprofloxacin	**≤ 0.06 -≥1**	**0**	1/4.	**0.4**	1/4.	**0**	1/4.	**0.3**	1/4.
Ertapenem	**≤ 0.5-≥2**	**98.7**	0.5/0.5	**100**	0.5/0.5	**100**	0.5/0.5	**95.4**	0.5/0.5
TM/SXT	**≤ 40 -≥80**	**96.6**	<=20/<=20	**100**	<=20/<=20	**100**	<=20/<=20	**93.6**	<=20/<=20
Azithromycin*		**98.7**	NA	**100**	NA	**100**	NA	**96.2**	NA
Chloramphenicol*		**95.6**	NA	**100**	NA	**100**	NA	**95.4**	NA

* Antibiotic susceptibility testing by Disc diffusion, NA: Not applicable

Table 3: Cumulative interpretation with cumulative MIC (50/90) of antimicrobial susceptibility pattern among Salmonella species in diverse samples during 4 year period.

The [Table 3] presents data on the antibiotic susceptibility patterns of *Salmonella* species, specifically *Salmonella Typhi (90.1%)*, *Salmonella Paratyphi A (3.8%)*, *Salmonella Paratyphi B (1.08%)*, and other *Salmonella* species (4.8%). It also highlights the prevalence of multi-drug-resistant organisms (MDROs) within each group. A total of 6,332 isolates were analyzed, and the prevalence of MDROs across different *Salmonella* species was assessed. Of the 5,706 cases of *Salmonella Typhi*, 4.2% were identified as multi-drug-resistant. *Salmonella Typhi*, which had the highest number of cases, demonstrated a mixed resistance pattern across various antibiotics.

Among 242 *Salmonella Paratyphi A* isolates, 0.4% were identified as multidrug-resistant organisms (MDRO), while none of the 69 *Salmonella Paratyphi B* isolates exhibited MDRO characteristics. Both serovars demonstrated very low resistance, particularly to first-line antibiotics such as Cefixime and Ampicillin. Additionally, 13.6% of the 315 cases of various *Non typhoidal Salmonella species* were found to be MDRO. This indicates that while *Salmonella Typhi* had the highest number of cases, the overall prevalence of MDROs was more pronounced in the broader category of *Salmonella* species. Other *Salmonella* species showed the highest resistance rates, particularly to Ceftriaxone (13.9%) and Ciprofloxacin (99.7%).

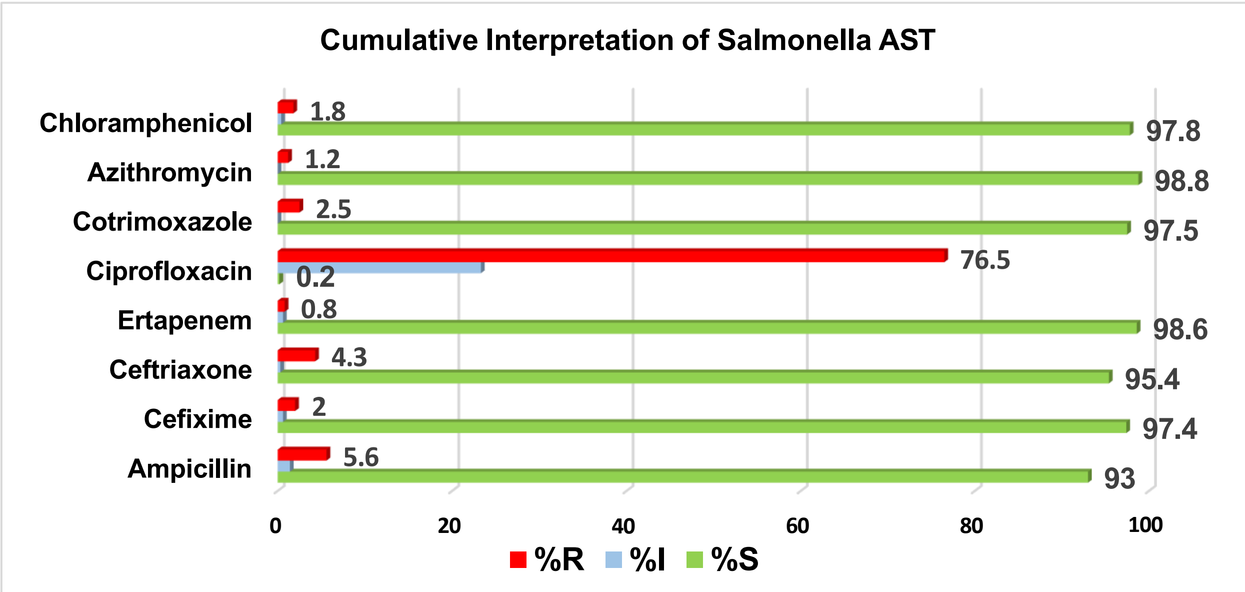
Resistance to Azithromycin and Chloramphenicol was notable in *Salmonella Typhi and Non typhoidal Salmonella species,* while other species showed full susceptibility. A significant concern was the high resistance to Ciprofloxacin with nearly all species exhibiting elevated resistance to these drugs.

	Salmonella spp. Isolates AST pattern

Antibiotics	Ranges	Total	S	%S	MIC50/90	I	%I	R	%R
Ampicillin	**≤ 8 -≥32**	6332	5888	93	<=2/8	88	1.4	356	5.6
Cefixime	**≤ 1 -≥ 4**	6332	6167	97.4	<=0.25/0.5	38	0.6	127	2

Ceftriaxone	**≤ 1 -≥ 4**	6332	6040	95.4	1/1	18	0.3	274	4.3
Ertapenem	**≤ 0.5-≥2**	6332	6244	98.6	0.5/0.5	38	0.6	50	0.8
Ciprofloxacin	**≤ 0.06 -≥1**	6332	13	0.2	1/4	1476	23.3	4843	76.5
Cotrimoxazole	**≤ 40 -≥80**	6332	6173	97.5	<=20/<=20	0	0	159	2.5
Azithromycin	**	2335	2307	98.8	**	0	0	28	1.2
Chloramphenicol	**	2335	2283	97.8	**	9	0.4	43	1.8

Table 3: Cumulative interpretation with cumulative MIC (50/90) of antimicrobial susceptibility pattern among Salmonella species in diverse samples during 4 year period.

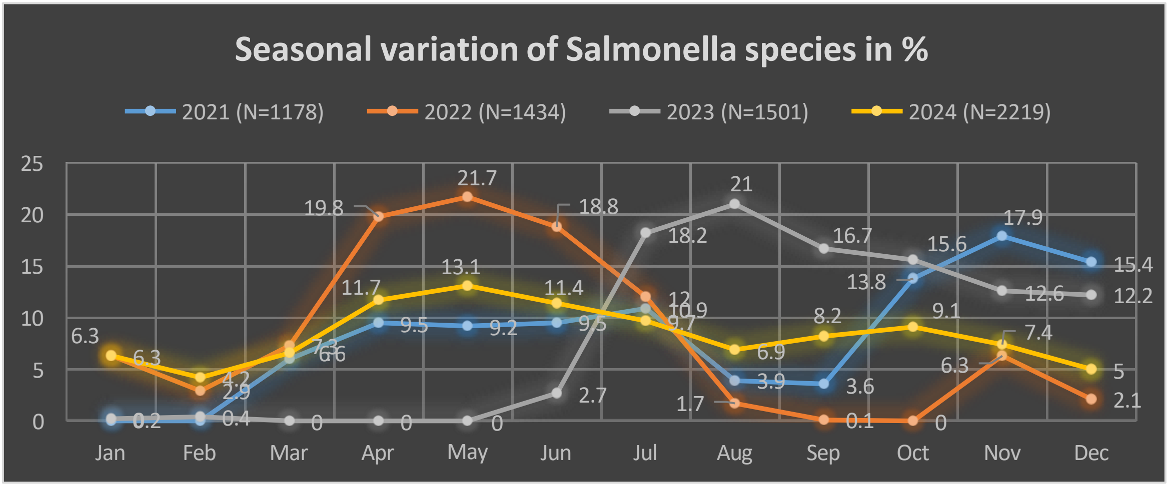


The antibiotic resistance and susceptibility patterns of *Salmonella* species reveal varying degrees of effectiveness across different drugs. For Ampicillin, 93% of isolates are susceptible, while 7% exhibit resistance. Cefixime shows a high susceptibility rate of 97.4 %, with only 2% resistance. Similarly, Ceftriaxone demonstrates good effectiveness with 95.4% susceptibility and 4.3% resistance. Ertapenem shows a very high susceptibility rate of 98.6%, indicating minimal resistance. Cotrimoxazole shows high efficacy with 97.5% susceptibility and 2.5% resistance. Azithromycin is similarly effective, with 98.8% susceptible isolates and 1.2% resistance. Chloramphenicol remains effective (97.8% susceptible), though 1.8% resistance and 0.4% intermediate susceptible are noted. While these antibiotics are generally effective for treating Salmonella, susceptibility testing is recommended, particularly for Azithromycin and Chloramphenicol, due to occasional resistance.

Ciprofloxacin exhibit high resistance rates in all Salmonella species**,** with 76.5% resistance for Ciprofloxacin. Only a small percentage of isolates are susceptible **(**0.2% for Ciprofloxacin**),** while intermediate is observed (23.3% for Ciprofloxacin).Due to the high resistance rates, Ciprofloxacin may not be effective for treating Salmonella infections in this population. Alternative therapies should be explored, and susceptibility testing should guide treatment decisions.

No. of Salmonella isolates (N=6332)				
Year	**2021 (N=1178) (%)**	**2022 (N=1434) (%)**	**2023 (N=1501) (%)**	**2024 (N=2219) (%)**
Jan	0	91 (6.3)	4 (0.2)	141 (6.3)
Feb	0	43 (2.9)	7 (0.4)	93 (4.2)
Mar	71 (6)	105 (7.3)	0	148 (6.6)
Apr	112 (9.5)	285 (19.8)	0	261 (11.7)
May	109 (9.2)	311 (21.7)	0	292 (13.1)
Jun	112 (9.5)	271 (18.8)	41 (2.7)	253 (11.4)
Jul	129 (10.9)	173 (12)	274 (18.2)	215 (9.7)
Aug	46 (3.9)	24 (1.7)	316 (21)	154 (6.9)
Sep	43 (3.6)	2 (0.1)	251 (16.7)	183 (8.2)
Oct	163 (13.8)	7 (0.5)	235 (15.6)	204 (9.1)
Nov	211 (17.9)	91 (6.3)	189 (12.6)	164 (7.4)
Dec	182 (15.4)	31 (2.1)	184 (12.2)	111 (5)

Table 3: Cumulative analysis of seasonal patterns in Salmonella species across various samples over a 4-year period.



The table presents the number of Salmonella isolates recorded each month from 2021 to 2024, with a total of 6332 isolates across all four years. The data reflects monthly fluctuations and highlights significant peak periods throughout the years. Over the years, there is a noticeable increase, with 2024 recording the highest number at 2,219 isolates, compared to 1,178 isolates in 2021, which had the lowest count. This indicates a steady rise in Salmonella infections year by year.

In 2024 generally shows an upward trend compared to 2021, with significant increases in early months (January, February, March), though it does not always surpass peaks from 2022 and 2023. Notable peaks were recorded in March, April, May, June, and July, particularly in 2022 and 2024.

In 2021, 1,178 isolates were recorded, with significant peaks in October (13.8%) and November (17.9%), but early months (January and February) showed no isolates, indicating a slow start to the year. 2022 saw an increase to 1,434 isolates, with sharp peaks in April (19.8%) and May (21.7%), highlighting a significant rise in spring. However, December experienced a sharp decline to 2.1%, while mid-year months like June (18.8%) remained relatively steady.

In 2023, 1,501 isolates were recorded, with the highest peaks in August (21%), July (18.2%), and September (16.7%), marking peak seasonal activity during summer and fall. Early months again showed lower numbers (January: 0.2% and February: 0.4%), similar to previous years. 2024 saw the highest total of 2,219 isolates, with notable increases in early months like January (6.3%), February (4.2%), and March (6.6%), signaling an early rise compared to earlier years. The trend continued into April (11.7%) and May (13.1%), although August (6.9%) and October (9.1%) showed a decrease compared to the previous years.

Despite a decrease in August and October 2024 compared to 2023, 2024 still had higher counts than 2022, which reported the lowest values for these months. The overall data indicates a gradual increase in Salmonella isolates, with 2024 showing the highest total number of isolates. However, certain months like August still saw a dip compared to 2023, which had the highest counts for July and August across all years.

A clear seasonal pattern is evident, with higher rates of Salmonella isolates in spring and summer (April-May), especially in 2022 and 2023. The early rise in 2024 during January-April suggests either an increase in Salmonella infections or improved detection methods. Over the four-year period, 2021 had the fewest isolates and a slow start, while 2022 and 2023 experienced significant surges, especially in spring and summer. Despite some months showing a decline in 2024, the data reveals a general upward trend in Salmonella infections, with distinct seasonal peaks and fluctuations, particularly in July-September.

In conclusion, the data reflects a consistent increase in Salmonella infections, with 2024 having the highest total number of isolates. The clear seasonal peaks, especially in spring and summer, along with significant fluctuations, point to both seasonal trends and potential improvements in detection methods.

Discussion

Typhoid fever remains a significant public health concern in developing countries, with an estimated 11–20 million cases and 128,000 to 161,000 deaths as well as Paratyphoid fever cause 6 million cases and 54,000 deaths every year worldwide. Though there is no licensed vaccine for Paratyphoid fever, the World Health Organization recommended the use of typhoid conjugate vaccine in 2017 for typhoid fever **[2,10,13]** *Salmonella enterica* serovar Typhi (*S. Typhi*) is the primary etiological agent, often leading to bloodstream infections [10, 11,16]. Our retrospective study underscores the fact that Salmonella organisms represent a major health threat across all age groups, with an estimated prevalence of 2.6%. These findings are consistent with those of previous research [10, 24]

Global data show that Salmonella is the fourth most common pathogen in blood infections, with *Salmonella Typhi* being the most frequently isolated bacterium in cases of bacteremia (responsible for 99% of these cases). In our study, *Salmonella ser. Typhi* was the most commonly identified strain (n = 5706, 90.1%), followed by other Salmonella species (n = 315, 4.9%), *Salmonella Paratyphi A* (n = 242, 3.8%), and *Salmonella Paratyphi B* (n=69, 1.08%), a distribution that mirrors the trends found in other studies **[6, 9, 10, 11, 16, 22].** Most research agrees with our findings, identifying Salmonella typhi as the predominant pathogen, particularly among males in the community constituting more than half (*n* = 3734, 58.9%) of the cases, with similar observations made in countries such as South asia and African countries, as well as in a population-based enteric fever surveillance [5,18,10,19, 26]. Our study also shows a higher incidence of Salmonella infections in children 6-12 years, who comparatively have a higher exposure to the external environment and outdoor activities than younger ones (<=5 years). Similarly to the findings with other studies **[6, 10, 15].** The age-related variation in our findings highlights the possibility of reduced documentation of the disease, poor clinical suspicion, prior antimicrobial treatment before blood culture, and difficulty in withdrawing blood resulting in poor laboratory and clinical outcomes, along with immunological reasons such as immature and unstable gut microbiome and gut immune function in children between 1 and 5 years of age, easily exposing them to bacterial infections such as *S. typhi* in comparison to older ones **[14, 18].**

The data on Salmonella isolates from 2021 to 2024 reveals notable trends in both annual and seasonal distributions. A significant increase in the total number of isolates is observed over the four-year period, rising from 1,194 in 2021 to 2,246 in 2024. This upward trajectory suggests a growing incidence of Salmonella infections, which may be attributed to factors such as population growth, enhanced diagnostic capabilities, or changes in environmental conditions and also restricted movement during 2020-2021 because of pandemic.

Seasonal analysis indicates a higher prevalence of Salmonella isolates during the months of April to June and July to September. This pattern aligns with findings from a study conducted in other country, which reported the highest incidence of enteric fever cases during these periods, corresponding to the dry and monsoon seasons, respectively. The increased incidence during these seasons could be linked to factors such as elevated ambient temperatures and increased humidity, which may facilitate the proliferation of Salmonella bacteria. Additionally, the monsoon season often leads to contamination of water sources, further elevating the risk of infection. Our findings were concordant with studies conducted in South Asia **[11,18],** where cases were seen throughout the year with increased frequency during the peak of the wet months (July–October). The isolation of the bacteria throughout the year in our study with comparatively higher prevalence during spring could be subjected to the microbial contamination of drinking water above the recommended levels.

The observed fluctuations in monthly isolate counts, including the absence of isolates in certain months (e.g., March to May 2023 and September 2022), warrant further investigation. These anomalies could result actual decreases in infection rates during those periods. Understanding the underlying causes of these fluctuations is essential for implementing targeted public health interventions.

Emerging ceftriaxone, a third-generation cephalosporin resistance commonly used to treat invasive Salmonella infections by disrupting bacterial cell walls, in both typhoidal and Non-typhoidal Salmonella is a rising concern for healthcare providers, highlighting the need for continuous monitoring and alternative treatment options **[1, 6, 8, 23, 17].** It has a cure rate of 72%-97%, with no relapses when used for 8–14 days. However, Ceftriaxone resistance, mainly driven by β-lactamase production, has been reported in several *Salmonella* serovars, including *S. Typhimurium*, *S. Enteritidis*, and *S. Newport*. Alarmingly, these ceftriaxone-resistant strains often show multidrug resistance, including resistance to Ampicillin, Chloramphenicol, and even Azithromycin. Such resistance patterns have now been documented in over 43 countries, including the USA, France, Turkey, and various regions of Asia, highlighting the global spread of antimicrobial-resistant (AMR) *Salmonella* **[1, 14, 17, 24, 26].** Since the 1980s, fluoroquinolones and cephalosporins have been the preferred treatments for multi-drug-resistant *Salmonella* strains. Among these, ciprofloxacin and other fluoroquinolones were more commonly prescribed than Cephalosporins, largely due to their oral availability and lower cost. However, the effectiveness of fluoroquinolones has been increasingly compromised due to rising resistance in *Salmonella enterica*, including *S. Typhi*, *S. Paratyphi A*, *S. Paratyphi B*, and non-typhoidal *Salmonella* (NTS) strains. Our findings align with global studies reporting similar resistance patterns [**1, 5, 6, 12, 13, 18, 20, 24].**

Historically, first-line antibiotics such as chloramphenicol, ampicillin, and trimethoprim-sulfamethoxazole were commonly used to treat Salmonella infections **[1, 6, 9].** Interestingly, our study observed low resistance to Chloramphenicol, reflecting a renewed susceptibility of *Salmonella* strains to older first-line antibiotics. Historically regarded as the gold standard for treating uncomplicated typhoid fever, chloramphenicol may be regaining effectiveness likely due to its reduced usage, especially in pediatric cases, over concerns about its adverse effects. Recent evidence of increased sensitivity to traditional antibiotics has revived interest in reintroducing them for treatment, a concept known as "antibiotic recycling" **[3, 6, 19, 25].** Our findings support this trend, advocating for the reconsideration of older antimicrobials in current treatment protocols. However, some studies, such as Amsalu's [2] report contrasting results, with 83% resistance observed against chloramphenicol, which disagrees with our findings.

Azithromycin, once a promising treatment for typhoid fever with cure rates of 81–100%, is now showing emerging resistance in some *Salmonella* serovars. The rise of MDR *Salmonella Typhi* and Non-typhoidal *Salmonella* (NTS) has prompted evaluation of alternative antimicrobials. Azithromycin is increasingly used in areas with high MDR and fluoroquinolone resistance. Our findings align with other studies supporting the use of azithromycin for empiric treatment of uncomplicated enteric fever **[6, 25].**

The prevalence of MDR *S. Typhi* and non-typhoidal *Salmonella* species has been reported to be high in Africa, South Asia, Central Asia, and the Middle East **[6, 9, 12, 13, 15, 16, 19, 21, 25, 26].** In contrast, our study demonstrated a lower MDR prevalence, showing discordance particularly with data from South Asia, Central Asia, and the Middle East. Importantly, no XDR cases were detected in our findings.

Salmonella Paratyphi A remains largely sensitive to most antibiotics, unlike Salmonella Typhi, which has developed greater resistance over time [24]. Because typhoid and paratyphoid fever have nearly identical symptoms, physicians often use broad-spectrum antibiotics like ceftriaxone and azithromycin to treat both conditions. Our study found that Salmonella paratyphi A continues to respond well to older antibiotics such as Ceftriaxone, Chloramphenicol, and Cotrimoxazole, though reduced sensitivity was noted with ampicillin. [Bhatia, manoharan] Notably, none of the isolates were resistant to all three of these older drugs. While 99% of isolates showed decreased susceptibility to fluoroquinolones, all remained fully sensitive to both azithromycin and ceftriaxone. These findings are consistent with results from other studies **[5, 17, 22].**

Effective therapeutic options include Ertapenem, Chloramphenicol, and Azithromycin, with third-generation Cephalosporins still viable. However, emerging resistance to Cephalosporins and Ampicillin highlights the critical need for continuous surveillance and the development of new treatment strategies.

Conclusion

The increasing prevalence of *Salmonella* Typhi, Paratyphi A and B, and non-typhoidal *Salmonella* (NTS), along with rising antimicrobial resistance, underscores the urgent need for improved surveillance, sanitation, and vaccination. Typhoid fever remains a significant public health issue, particularly among children and during high-risk seasons. The emergence of multidrug-resistant strains in younger populations highlights the importance of targeted preventive measures through vaccination, improving water quality and food safety, especially during monsoon season. While third-generation Cephalosporins and Azithromycin are still effective, growing resistance calls for continuous monitoring and exploration of alternative therapies. Effective control requires rational antibiotic use, enhanced diagnostic capacity, and focused public health interventions in vulnerable groups.

Ethical Approval: It is not applicable.

Conflicts of Interest: There are no conflicts of interest.

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