Bacterial Zoonosis Transmitted by *Salmonella enterica* Serovar *Typhimurium*

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Abstract

Salmonellosis is a zoonotic disease caused by *Salmonella*, a rod-shaped gram-negative bacterium from the *Enterobacteriaceae* family. It affects both people and animals. Salmonellosis affects around 1.3 billion people worldwide each year. *Salmonella* is a major public health concern due to its drug resistance, zoonotic spread, and several clinical symptoms. Over 60% of human diseases are zoonotic, influenced by environmental factors and human activities like land use, population expansion, and international travel. *Salmonella enterica* serovar *Typhimurium* is a well-known bacterial zoonotic disease that has a considerable influence on global public health. This pathogen predominantly causes foodborne diseases, with animals such as poultry, livestock, and reptiles acting as primary reservoirs. Transmission is mostly via the fecal-oral route, which includes infected food items such as meat that has been undercooked and eggs. Infections usually appear as gastroenteritis, which causes diarrhea, stomach pains, and fever, with serious cases possibly leading to bacteremia, especially in vulnerable groups. Diagnosis is based on stool cultures and molecular tests such as PCR, and treatment is mostly supportive, with drugs intended for serious cases due to rising resistance to antibiotics. Preventive efforts are critical, including proper handling of food, strict hygiene in animal production, and public awareness programs.

Keywords: Salmonellosis, Zoonosis, Public health, Foodborne illness, *Salmonella Typhimurium*.

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Introduction

Bacterial zoonoses are bacteria borne diseases that can spread from animals to people, posing considerable public health risks. *Salmonella enterica* serovar *Typhimurium* is a common source of foodborne illness, distinguished by its global distribution and ability to infect a variety of hosts. This chapter discusses the epidemiology, transmission mechanisms, clinical signs, diagnosis, treatment, and preventative strategies related to *S. Typhimurium*, emphasizing its importance as a zoonotic agent (Aqeel et al., 2024). *Salmonella enterica* is a species of *Enterobacteriaceae* that includes several serovars such as *Typhimurium, Enteritidis,* and *Typhi*. *S. Typhimurium* is one of the most common serovars seen in both human and animal infections worldwide. It is defined as a Gram-negative rod-shaped bacterium with motility due to the presence of flagella (Woudstra & Granier, 2023). The bacteria have a high genetic diversity, allowing it to adapt to many hosts and environmental situations.

Salmonella was discovered in the late nineteenth century, with Theobald Smith making the first identification in 1885. *S. Typhimurium* has expanded its importance in zoonotic diseases throughout the years, particularly as industrial farming techniques and food supply chains have become more globalized. Understanding the pathogen's origins and evolution is crucial for understanding its current effect on public health. *S. Typhimurium* is found all across the world, with incidence varying greatly depending on geography, manufacturing practices, and sanitary standards (Celis-Giraldo et al., 2024). The World Health Organization (WHO) has identified this as the leading cause of bacterial gastroenteritis, involving millions of cases recorded each year. In many impoverished nations, the burden is disproportionately high due to poor sanitation and food security measures. Cattle, pigs, and poultry are the principal reservoirs for *S. Typhimurium*, and they frequently carry the infection asymptomatically. Infections can result from infected eggs and meat products. Rodents, birds, and reptiles act as natural reservoirs, contaminating the environment and functioning as vectors for spreading diseases between domestic animals and humans (Ali et al., 2022).

The reptiles as well as certain mammals may release *S. Typhimurium* in their feces, potentially leading to zoonotic transmission.

The fecal-oral route is the main means of transmission for *S. Typhimurium*, and it involves three important pathways. Food items that have been contaminated, especially raw meats, eggs, and dairy products, are important sources of illness. Inadequate methods of handling and cooking food might lead to outbreaks (Ali et al., 2022). People who work in veterinary clinics or with cattle are more vulnerable. Taking care of sick animals, especially reptiles, is dangerous as well, especially for small children. Transmission can be aided by contaminated soil and water sources, particularly in agricultural environments. Systems of surveillance are essential for keeping an eye on the prevalence of *S. Typhimurium* infections (Alfituri et al., 2024). The public health organizations look into epidemics on a regular basis to find causes, pathways of transmission, and efficient containment strategies. The case studies of large-scale epidemics have yielded important insights into the mechanics of transmission and the significance of quick response tactics.

Infection with *S. Typhimurium* usually results in salmonellosis in humans. The symptoms, which typically include diarrhea, cramping in the abdomen, fever, nausea, and vomiting, usually show up 6 to 72 hours after exposure. The majority of instances are self-limiting, and after a week, the symptoms go away. *S. Typhimurium* can infiltrate the bloodstream in some populations, especially the elderly or those with compromised immune systems (Eydi & Tukmechi, 2024). This can result in life-threatening sickness, organ failure, and the need for hospitalization. After a salmonellosis infection, some people may develop reactive arthritis, which is characterized by inflammation and discomfort in the joints. Severe sickness is more likely to strike young children and the elderly. People who have compromised immune systems are more vulnerable to serious consequences (Ali et al., 2024). The severity of salmonellosis can be increased by gastrointestinal disorders or diseases that already exist.

Stool culture is the gold standard for detecting salmonellosis because it makes *S. Typhimurium* identifiable and isolated. Usually, this process takes a whole day or two. *S. Typhimurium* can be quickly detected using polymerase chain reaction (PCR) assays, which can also identify several serovars at once. Investigations into outbreaks and the diagnosis of patients who have previously received antibiotic therapy are using PCR testing more and more. The majority of salmonellosis patients resolve on their own, and supportive care is the mainstay of treatment (Kumar et al., 2024). It's important to keep the balance of electrolytes and fluids stable, particularly if there is a lot of vomiting or diarrhea. It is advised to gradually resume solid food when symptoms subside. Usually, bacteremia, infections in immunocompromised people, or severe instances are the only situations where antibiotics are used. Antibiotics like azithromycin and ciprofloxacin are frequently used (Gonmei et al., 2023).

A multifaceted strategy is needed to prevent *S. Typhimurium* infections, especially in the area of food safety: To ensure that the bacteria are killed, cook meats to safe temperatures, which should be at least 165°F/75°C (Zhang et al., 2019). Adopt stringent hygiene procedures, such as washing your hands thoroughly after handling food and utilizing distinct cutting boards for raw meat and vegetables. Bacterial development can be avoided by properly refrigerating perishable items. Reducing transmission requires maintaining hygiene in animal habitats and when handling animals (Adem, 2022). The frequent surveillance of animals for *S. Typhimurium* can aid in the detection of carriers and mitigate the potential for human infection. Incidence rates can be decreased by public health initiatives that inform the public about proper handling of food and the dangers of coming into touch with reptiles.

Current investigations into the molecular mechanisms behind *S. Typhimurium* virulence can shed light on the pathogenicity of the organism and aid in the creation of focused treatments (Woodford et al., 2024). Comprehending the genetic foundation of antibiotic resistance is crucial for devising effective public health approaches. Although there aren't any readily accessible vaccinations against *S. Typhimurium* for humans at the moment, work is being done to create efficacious vaccines for both humans and livestock. A successful immunization program could drastically lower the prevalence of salmonellosis (Abd El-Ghany, 2020). To effectively address the issues presented by *S. Typhimurium*, a One Health approach that integrates the health of humans, animals, and the environment must be implemented. Environmental scientists, veterinary professionals, and public health officials can work together to improve surveillance and response tactics.

1. Transmission

Salmonella is a serious foodborne illness that kills 370,000 people annually and infects 115 million people worldwide. The two most frequent causes of non-typhoidal salmonellosis in humans worldwide are *Salmonella enterica* serovar *Typhimurium* (*S. Typhimurium*) and *Salmonella* serovar *Enteritidis* (*S. Enteritidis*). *Salmonella* quick global spread has had a significant impact on both human and animal health. Both domestic and wild animals, including pigs, chickens, cattle, and turtles, as well as pets like cats, dogs, birds, and reptiles, are known to harbor *Salmonella* (Sheng et al., 2023). The organism can go from primary production or animal feed to homes or food service establishments along the entire food chain (Branchu et al., 2018). *Salmonella* is typically acquired in humans by consuming tainted animal-based foods like milk, meat, poultry and eggs.

Table 1: Transmission of *Salmonella enterica* serovar *Typhimurium*

Animal	Pathogen	Transmission rout	Shedding	Reference
Cattle	*S. Typhimurium*	Seeder contact	Unknown	(Bäumler & Fang, 2013)
Swine	*S. Typhimurium*	Seeder contact, Environment	10^8 CFU/g of feaces	(Singh, 2013)
Chicken	*S. Typhimurium*	Seeder contact, Environment and vertical transmission	10^5 CFU/g of cecum	(Jajere, 2019)
Mouse	*S. Typhimurium*	Seeder contact	10^9 CFU/g	(Kingsley & Bäumler, 2000)
Human	*S. Typhimurium*	Seeder contact	10^7 CFU/g	(Eswarappa et al., 2008)

The fecal-oral pathway is one way that salmonellosis can spread from person to person. This might happen notably among preschoolers in daycare centers or among playmates in the neighborhood or at home, when infected individuals with diarrhea neglect to properly wash their hands after urinating (Francisco et al., 2024). The disease can be spread by humans through interaction with infected animals that do not exhibit symptoms. About 3% of diseases in people and animals are contracted through direct or indirect contact with animals, but the majority are foodborne as shown in Table 1. With the intestines and/or reproductive tracts as targets, the organism spreads widely among animals, increasing the likelihood of sickness and transmission (Abebe et al., 2020).

Living organisms that can spread infectious diseases are known as vectors of transmission, whereas non-living items or materials tainted with the virus that can spread the illness from animals to humans or between humans are known as vehicles of transmission for salmonellosis (Fu et al., 2022). Frogs, toads, and salamanders are examples of carnivorous amphibians that mostly consume potentially *Salmonella*-contaminated fish, mice, cockroaches, earthworms, crickets, flies, moths, and cockroaches. They then develop into asymptomatic carriers that contaminate humans who come into contact with them or their contaminated materials through touch or ingestion, as well as other domestic and wild animals and the water bodies they live in (Wang et al., 2023). There have been reports of reptiles, insects, food vendors, wildlife, and other household animals as vectors and transports.

The incubation period for non-typhoidal salmonellosis ranges from 6 to 72 hours, although it is often between 12 and 36 hours. There are additional reports of incubation times exceeding three days (Frahm et al., 2015). Although the typical range is 1-2 weeks, the incubation period for typhoid fever caused by *S. Typhimurium* is typically between 3 days and 1 month, depending on the infecting dosage. In contrast, the incubation period for paratyphoid fever is 1-10 days. *Salmonella* may be spread by the host once it has established itself (Kagambèga et al., 2018). The mechanism of transmission is intricate and involves elements of the host and the pathogen. The effective dissemination and sustenance of the organism within a host population are guaranteed by host-to-host pathogen transmission route.

A pathogen must overcome a number of obstacles in order to colonize a host, including the host's innate immune system, the local microbiota, and its capacity to replicate inside the new host and continue the cycle of multiplication. Although the transovarial route has been documented in poultry, the fecal-oral route is the primary route of *Salmonella* infection in humans (Bhat et al., 2021). Ingestion of any food or drink tainted with human or animal excrement is the most frequent way for the disease to spread between humans and animals. Raw fruits and vegetables are among these foods. *Salmonella* can also be chronically carried by pets and wildlife as shown in Figure 1 (Simon et al., 2023). Additionally, person-to-person transmission can happen, particularly between prescholers attending daycare and members of the same home.

Increased resistance to antibiotics, the capacity to cross-contaminate living and non-living materials, and the organism long-term survival are the elements that sustain *Salmonella* transmission, particularly in a food processing setting (Sabri et al., 2020). Another significant contributing element to the spread of *Salmonella* spp. is the intermittent shedding of the organism by infected hosts. After infection of the host, the mean shedding duration of *Salmonella* may be eight months or longer (Balasubramanian et al., 2019). The dynamic pattern of illness transmission is influenced by the prolonged infection period and moderate infectiousness. Humans can act as chronic carriers, as demonstrated by the study of *S. Paratyphi A*, in which carrier workers and infected migrant patients disseminate the organism during their travels, particularly when cleanliness and hot, humid conditions are combined (El-Sharkawy et al., 2017).

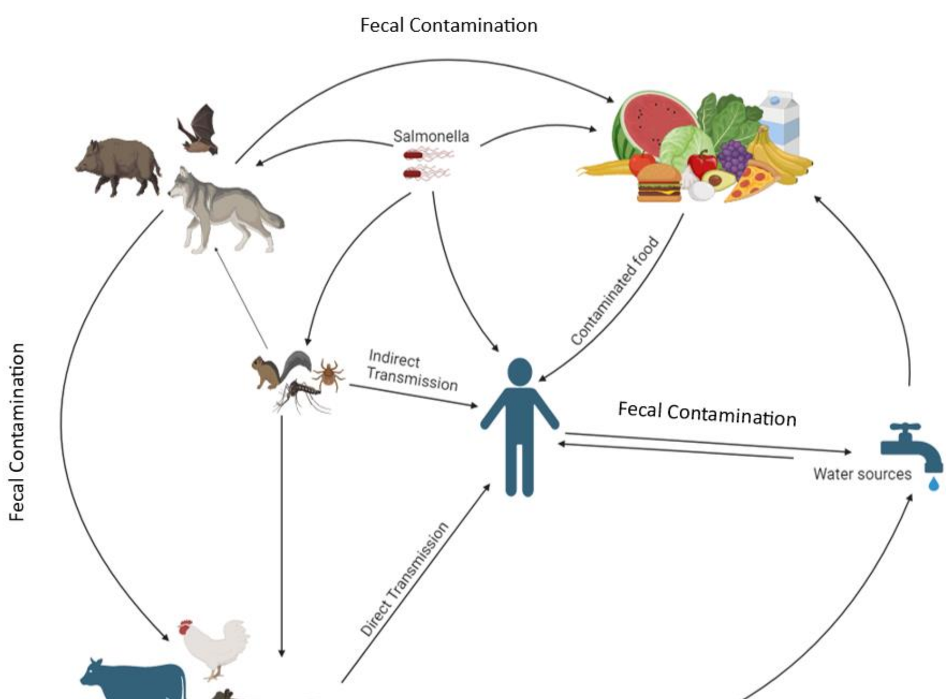

Figure 1. Zoonotic transmission of Salmonella (Retrieved from biorender)

2. Pathogenesis

The outcome of a *Salmonella* infection mostly depends on three variables: the infectious dosage, the host-influencing predisposing factor, and the degree of immunity. The most frequent way for cattle to become infected is via consuming tainted feed or water. It can spread to the host's other bodily parts through blood or lymph fluid, and it typically results in bacterial discharge in the feces (Dos Santos et al., 2019). The high levels of volatile fatty acids and the rumen typical pH of less than 7 typically prevent *Salmonella*. After passing through the epithelium of the intestine, the bacteria penetrate the underlying lymphoid tissue's macrophages, where they are discharged to the nearby lymph nodes, which serve as crucial barriers to further spread. If this barrier is broken, the bacteria survive and multiply inside the macrophages before reaching the reticuloendothelial tissue that contains the organs (Bhunia & Bhunia, 2018).

The bacteria in humans enter the stomach and move on to the intestine, where they enter the cells and give their infected host body diarrhea (Eng et al., 2015). The early stages of salmonellosis, when *Salmonella* enters nonphagocytic cells by inducing invasion and penetration of the gastrointestinal epithelium, depend on '*Salmonella* Pathogenicity Island' (SPI1) activity. Additionally, the development of diarrheal symptoms during localized gastrointestinal infections depends on SPI1 function. Later phases of the infection, including as systemic dissemination and host organ colonization, depend on SPI2 activity (Lima et al., 2019). This stage of pathogenesis seems to depend on SPI's function in host phagocyte survival and replication.

Salmonella capacity to infiltrate host cells and withstand phagocyte digestion and complement system destruction is a key component of its pathogenicity (Dar et al., 2017). The *Salmonella* virulence strain benefits from the particular 'O' antigen because it reduces its vulnerability to phagocytosis and its capacity to activate the alternative complement pathway. Endotoxin, enterotoxin, and cytotoxin are three toxins that are crucial to *Salmonella* pathogenesis (Hassan et al., 2021). Fever is caused by endotoxins, cell culture mucosal injury is caused by enterotoxins, and protein synthesis is inhibited by cytotoxins.

Animals are the source of most infectious diseases that affect humans. These infections are a major risk to human health in addition to causing illnesses in animals. Due to growing human-wild animal contact, a number of zoonotic diseases frequently arise and reappear as a result of altered eating habits, climatic change, and environmentally unfavorable human operations as shown in Table 2.

Table 2: Common Zoonotic diseases, their symptoms, source of transmission and risk factors

Zoonotic disease	Symptoms in human	Source of transmission	Risk factors	References
Salmonellosis	Vomiting, fever, diarrhea, abdominal pain, nausea	contaminated food, water, livestock products, contact with infected animals	Poor living conditions, lack of hygiene	(Arshad et al., 2022)
Anthrax	Fever, headache, chills, nausea, sore throat, neck swelling, hoarseness, painful swallowing, vomiting, and diarrhea.	Bacillus anthracis: a soil-borne bacteria, transmitted via herbivores, spores, or via an infected carcass	Direct contact with anthrax spores	(Pal et al., 2024)
Food-borne E. coli infection	Fever, diarrhea, vomiting, and respiratory issues.	Contaminated water, food, livestock products, contact with infected animals	Living conditions, lack of hygiene	(Ramos et al., 2020)
Leptospirosis	Fever, headache, nausea, loss of appetite, jaundice, swollen limbs, chest pain, shortness of breath, and coughing up blood.	contaminated soil and water with animal urine	Skin lesions/injuries, occupational exposure	(Pal et al., 2021)
Bovine TB	Fever, weakness, loss of appetite, weight loss, intermittent cough, diarrhea, and big visible lymph nodes	contaminated water, food, livestock products, unpasteurized dairy products, and direct contact with infected animals	Animal husbandry, living conditions, occupational exposure, wildlife reservoirs	(Quadri et al., 2021)

Since *Salmonella* infection is common in many food animal production facilities, it is vital to improve the animals' resistance to *Salmonella* infection or colonization in addition to preventing further introduction and reintroduction. *Salmonella* spp. colonization and reintroduction into the environment have been successfully decreased by live attenuated and inactivated vaccination of cattle and poultry to boost immunity (Hausmann & Hardt, 2019). Not only can fewer *Salmonella* contaminate food, but fewer *Salmonella* will be available to infect other farm animals or poultry if the amount of *Salmonella* in the animals' surroundings is decreased. Therefore, biosecurity, rodent control, and feed should all be part of the farm's strategy to prevent *Salmonella* spp. in food animals (Pal et al., 2024).

In sick animal hosts, *Salmonella* germs reside as intracellular pathogens. When *Salmonella* germs come into contact with epithelial cells, their hair-like projections, called pili, inject bacterial proteins into the cytoplasm of the host cell. Enterocytes or Mcells absorb *Salmonella* organisms as a result of this occurrence, which sets off a signal transduction cascade that causes the cytoskeleton to temporarily disassemble and reorganize (Frasson et al., 2016). *Salmonella* is restricted to endocytic vacuoles after internalization; nonetheless, these infected vacuoles travel from the host cell apical to basal surfaces, releasing *Salmonella* organisms into the submucosal compartment. The bacterial chromosome contains *Salmonella* invasion genes arranged in contiguous, functionally linked regions (Russini et al., 2022). These genes are helpful targets in polymerase chain reaction-based *Salmonella* detection systems because they are evolutionarily conserved among *Salmonella* species.

3. Clinical Manifestation

Salmonellosis is a clinical disorder caused by the bacterium *Salmonella enterica* serovar *Typhimurium*, which can cause bacterial zoonosis in both people and animals. The main way that this infection is spread is via coming into touch with tainted food, drink, or animals. One of the main symptoms is frequently watery or even bloody diarrhea. It's usual to experience abdominal ache and cramping. Vomiting and nausea are common, particularly while the virus is still in its early stages (Mlangeni et al., 2024). As the body battles the infection, a low to moderate fever frequently coexists with other symptoms. Patients frequently experience weakness and exhaustion, which can last past the acute stage. The systematic spread of infection may be accompanied by headache and muscle pain (Oludairo et al., 2023).

Dehydration can be a major consequence of severe diarrhea and vomiting, particularly in young children and elderly people (Rabsch et al., 2015). Serious consequences like septic shock may arise in situations where the germs penetrate the bloodstream and cause a widespread infection. Weeks following the original infection, joint discomfort and inflammation may manifest (Felgner et al., 2016). In vulnerable people, the infection can infrequently move to the brain or spinal cord and result in meningitis. There is a greater chance of developing a systemic infection, and symptoms may be more severe and persistent. The elderly people and children may have more severe symptoms and are more likely to suffer from complications and dehydration.

Salmonella Typhimurium is typically spread by consuming tainted food or water. Common sources include foods like unpasteurized milk, eggs, and undercooked chicken. Indirect or direct interaction with animals, specifically, animals that carry the bacteria, such as birds, reptiles, and livestock. Preventing problems, particularly in susceptible groups, requires early identification and treatment (Peng et al., 2018).

Conclusion

Salmonella Typhimurium is the primary cause of foodborne salmonellosis and can produce pathogenesis in a wide variety of hosts. Its virulent characteristics allow it to infiltrate the host and persist for extended periods of time. Rapid and dependable solutions must be developed to safeguard human consumers, the poultry business, and animal health from the harmful impacts of *Salmonella* infections. Eliminating salmonellosis requires the availability of adequate detection procedures and techniques. Because it is a foodborne pathogen and zoonotic agent, *Salmonella enterica* serovar *Typhimurium* poses a serious threat to public health. For the purpose of creating efficient preventive and control strategies, it is essential to comprehend its epidemiology, dissemination pathways, and clinical impact. As science advances, reducing the hazards associated with this disease will require a cooperative strategy combining food safety, animal health, and public education. Our ability to lower the incidence of *S. Typhimurium* outbreaks and protect public health can be achieved by raising awareness and putting best practices into action.

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