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5th Edition

ESSENTIALS OF MEDICAL MICROBIOLOGY

As per the Revised Competency-based Medical Education Curriculum (NMC)

Apurba S Sastry
Sandhya Bhat



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CHAPTER

Enteric Fever

30

Chapter Outline

At the end of reading this chapter, students will be able to answer:

- Classification and Nomenclature
- Antigenic Structure
- Typhoidal *Salmonella*

Case-based Learning

A 20-year-old student presents with fever for 7 days. The fever has gradually increased in a "step-ladder" pattern and is associated with frontal headache, abdominal discomfort. On examination, he has relative bradycardia, coated tongue, mild hepatosplenomegaly. Blood culture sent on admission, grows H_2S-producing gram-negative bacilli, later identified as *Salmonella* Typhi. In the second week, Widal test shows markedly elevated O and H agglutinin titers. Why is blood culture most useful early, while serology and stool culture become more relevant later in the disease? (refer Annexure 12 for brief answer).

Enteric fever is a potentially fatal multisystem illness caused by *Salmonella* Typhi (typhoid fever) and, *S.* Paratyphi A, B and C (paratyphoid fever).

CLASSIFICATION AND NOMENCLATURE

Salmonella is a gram-negative bacterium, belongs to the family Enterobacteriaceae.

- The credit of discovery of '*Salmonella*' goes to Salmon and Smith (1885).
- The most important serotype of *Salmonella*, *S.* Typhi, was first observed by Eberth (1880) and Gaffky (1884) and hence was formerly called Eberth-Gaffky bacillus or *Eberthella* Typhi.

Salmonella is antigenically complex. The classification and nomenclature of salmonellae have undergone several modifications over the past years. There are several classifications proposed so far.

Clinical Classification

It is the oldest, user-friendly classification which is still widely used. It divides salmonellae into two groups:

1. **Typhoidal *Salmonella*:** It includes serotypes *S.* Typhi and *S.* Paratyphi. They are restricted to human hosts, in whom they cause enteric fever (typhoid/paratyphoid fever).
2. **Non-typhoidal salmonellae or NTS:** The remaining serotypes can colonize the intestine of a broad range of animals, including mammals, reptiles, birds and occasionally insects. They also infect humans causing food-borne gastroenteritis and septicemia.

Antigenic Classification (Kauffmann–White Scheme)

The classification within the genus *Salmonella*, is based on the presence of different somatic (O) and flagellar (H) antigens which can be detected by agglutination with the respective antisera **(Table 30.1)**.

- **Serogroups:** Based on O antigen, salmonellae are classified into serogroups. There are up to 67 serogroups, each containing group-specific O antigen, for example:

Table 30.1: Kauffmann–White antigenic classification for *Salmonella*.

Serogroup		Serotype name	O Ag*	Vi Ag	H Ag*	
New	Old				Phase 1	Phase 2
2	A	*S.* Paratyphi A	1, 2, 12	–	a	[1,5]
4	B	*S.* Paratyphi B	1, 4, [5], 12	–	b	1,2
		S. Typhimurium	1, 4, [5], 12	–	i	1,2
7	C1	*S.* Paratyphi C	6, 7	+	c	1,5
		S. Choleraesuis	6, 7	–	c	1,5
9	D1	*S.* Typhi	9, 12	+	d	–
		S. Enteritidis	1, 9, 12	–	g,m	[1,7]

Note: *Antigen in brackets are not always present. Only some representative serotypes are given in the table.
There are >2,500 serotypes of salmonellae. Only the important human pathogens are enumerated in this table.
(Ag: antigen).

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- Serogroup-2 (formerly, serogroup A)—contains group specific O antigen type 2.
- Serogroup-4 (formerly, serogroup B)—contains group-specific O antigen type 4.
- Serogroup-9 (formerly, serogroup D)—contains group specific O antigen type 9.

❖ **Serotypes:** Each serogroup is further differentiated into serotypes, based on the type of flagellar antigens present. Currently, there are more than 2,500 serotypes of salmonellae.

Molecular Classification

Based on DNA hybridization studies, the genus *Salmonella* consists of two species—(1) *Salmonella enterica,* and (2) *S. bongori.*

❖ Within the species *S. enterica,* there are six subspecies; namely *enterica*, *salamae*, *arizonae*, *diarizonae*, *houtenae* and *indica*.

❖ Each subspecies is further differentiated into serotypes (based on O and H antigens according to the Kauffmann–White scheme).

❖ Most of the pathogenic typhoidal and non-typhoidal *Salmonella* serotypes are placed under species *enterica* and subspecies *enterica.*

Nomenclature

Taxonomically, the correct nomenclature of the members of salmonellae is very much complicated, e.g. ***Salmonella* species *enterica* subspecies *enterica* serotype Typhi**.

However, for routine use a simplified format is followed where only the genus and serotype names are included, for example *Salmonella* serotype Typhi or in short, *S.* Typhi.

ANTIGENIC STRUCTURE

Salmonellae possess three important antigens on their cell wall, based on which they are classified. The antigens are:

1. Somatic antigen (O)
2. Flagellar antigen (H)
3. Surface envelope antigen (Vi)—found in some species.

The O and H antigens are described in **Table 30.2**.

Table 30.2: Differences between somatic (O) and flagellar (H) antigen.

Somatic (O) antigen	Flagellar (H) antigen
It is a part of cell wall lipopolysaccharide (LPS)	Made up of protein flagellin It confers motility to the bacteria
In Widal test, O antigen of *S.* Typhi is used	In Widal test, H antigens of *S.* Typhi, *S.* Paratyphi A and B are used
It is less immunogenic	It is more immunogenic
O antibody appears early, disappears early: indicates recent infection	H antibody appears late, disappears late: indicates convalescent stage
When O antigen reacts with O antibody, it forms compact, granular, chalky clumps • Agglutination takes place slowly • Optimum temperature for agglutination is 55°C	When H antigen reacts with H antibody, it forms large, loose, fluffy clumps • Agglutination takes place rapidly • Optimum temperature for agglutination is 37°C
Serogrouping of salmonellae is based on the O antigen	Serogroups are differentiated into serotypes based on H antigen

Vi Antigen

Vi antigen is a surface polysaccharide envelope or capsular antigen covering the O antigen. The naming is due to the belief that Vi antigen is related to virulence.

❖ It is expressed in only few serotypes, such as *S.* Typhi, *S.* Paratyphi *C, S.* Dublin and some stains of *Citrobacter freundii* (the Ballerup-Bethesda group).

❖ As Vi antigen is **poorly immunogenic** and antibody titers are low, it is not helpful in the diagnosis of cases. Hence, the Vi antigen is not employed in the Widal test.

❖ However, it is believed that the complete absence of the Vi antibody in a proven case of typhoid fever indicates poor prognosis.

❖ The Vi antibody usually disappears early in convalescence, but if persists, it may indicate the development of the carrier state.

❖ Vi antigen can also be used for vaccination.

TYPHOIDAL SALMONELLA

Typhoidal salmonellae include *S.* Typhi and *S.* Paratyphi A, B and C which cause enteric fever. Non-typhoidal salmonellae cause mainly gastrointestinal manifestations and have been discussed in Chapter 41.

Pathogenesis

Salmonellae are transmitted by oral route, through ingestion of contaminated food or water.

❖ **Infective dose of** *Salmonella* is higher than that of *Shigella*. Minimum 10^3–10^6 bacilli are needed to initiate the infection.

❖ **Risk factors** that promote transmission include the conditions that decrease:

- Stomach acidity (<1 year age, antacid ingestion, or achlorhydria or prior *Helicobacter pylori* infection).
- Compromised intestinal integrity (inflammatory bowel disease, prior GIT surgery or suppression of the intestinal flora by antibiotics).

❖ **Entry through epithelial cells (M cells)** lining the intestinal mucosa—Salmonellae can trigger the formation of **membrane ruffles** on the cell membrane of M cells. These ruffles reach out and enclose the adherent bacteria within the large vesicles. This process of uptake is called **bacteria-mediated endocytosis (BME)**, which is mediated by a specialized type III secretion system.

❖ ***Salmonella*-containing vacuole (SCV):** After entry, *Salmonella* remains within a vacuole called *Salmonella*-containing vacuole (SCV). Inside the SCV, the organism avoids intracellular killing and modifies the vacuole for its survival.

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- **Inflammation:** In intestinal epithelial cells, non-typhoidal *Salmonella* commonly induces strong inflammation, leading to neutrophil influx, diarrhea, and mucosal damage. In contrast, *S.* Typhi produces less local inflammation and is better adapted for systemic spread.
- **Entry into macrophages:** Salmonellae containing vacuoles cross the epithelial layer to reach submucosa, where they are phagocytosed by the macrophages.
- **Survival inside the macrophages:** *S.* Typhi induces certain alterations on its surface (in LPS), so that it is no longer susceptible to the lysosomal enzymes of macrophages.
- **Primary bacteremia:** Salmonellae contained inside the macrophages spread via the lymphatics to enter the bloodstream (transient primary bacteremia).
- **Spread:** Then, the bacilli disseminate throughout the reticuloendothelial tissues (liver, spleen, lymph nodes and bone marrow) and other organs, such as gallbladder, kidneys and lungs where further multiplication takes place.
- **Secondary bacteremia** occurs from the seeded organs, which leads to the onset of clinical disease.
- **Re-invasion into gut:** From the gallbladder, organisms are excreted in bile and reinvade the intestine, causing Peyer's patch ulceration and fecal shedding. Persistent gallbladder colonization, especially with gallstones, results in the carrier state.

Clinical Manifestations of Enteric Fever

Incubation period is about 7–14 days. Enteric fever is named after the mode of transmission (enteric route) of its causative agent. However, the disease itself involves multiple systems, including the intestines.

- **Fever (step ladder pattern of remittent fever):** Fever rises gradually to a higher level with every spike; then falls down, but does not touch normal.
- **Other symptoms/signs:** Headache, chills, cough, sweating, myalgia, arthralgia, and a coated tongue, a classical finding in enteric fever.
- **Rashes** (called **rose spots):** Faint, salmon-colored, blanching, maculopapular rash on the trunk and chest seen in 30% of patients at the end of the first week.
- **Early intestinal manifestations** such as abdominal pain, nausea, vomiting, constipation or diarrhea.
- **Important signs** include hepatosplenomegaly, epistaxis and relative bradycardia.
- **Complications:** Gastrointestinal bleeding and perforation may occur in the third–fourth weeks due to ulceration of terminal ileal Peyer's patches.
- **Neurologic manifestations** occur rarely which include meningitis, cerebellar ataxia and neuropsychiatric symptoms such as paranoid psychosis, delirium, etc.

Epidemiology

- **Host:** Humans are the only natural hosts.
- **Transmission:** It is transmitted by ingestion of contaminated water and food with infected feces or urine. Person to person transmission is extremely rare.
- **Incidence:** As per WHO, typhoid fever affects an estimated 9 million people globally each year, causing about 1.1 lakh deaths. India bears a major burden, with an estimated 49 lakh cases and 7,850 deaths in 2023.
- **Locality and age:** Enteric fever is:
  - More common in urban than rural areas.
  - More common among young children and adolescents than in adults.
- **Factors** that favor transmission include: Poor sanitation and contaminated water, food and drinks; lack of hand washing and poor toilet access.
- **Typhi vs Paratyphi:** *S.* Typhi infection is more common than *S.* Paratyphi A (ratio is 4:1). However, *S.* Paratyphi A appears to be increasing, especially in India; may be due to increased vaccination for *S.* Typhi.
- **Carriage:** Up to 10% of untreated patients become carriers and excrete *S.* Typhi in feces or urine.
  - **Carriers are of two types:**
    1. Fecal carriers: Typhoid bacilli multiply in the gallbladder and are excreted in the feces. Fecal carriers are more common.
    2. Urinary carriers: Multiplication takes place in kidneys and bacilli are excreted in urine. Urinary carriers are rare.
  - **Duration of shedding:** Carriers continue to shed the bacilli in feces and urine for:
    - Convalescent carriers for 3 weeks to 3 months (after clinical cure).
    - Temporary carriers for 3 months to 1 year.
    - Chronic carriers for more than 1 year.

Chronic Carriers

Chronic carriers shed S. Typhi in either urine or stool for more than 1 year; seen up to 2–5% of patients. Chronic carriage is more common in:

- Women, infants, elderly individuals and patients with biliary disease.
- Biliary tract abnormalities which leads to increased fecal excretion—Salmonellae form biofilms on gallstones and chronic carriage is associated with an increased risk of gallbladder cancer.
- Abnormalities of the urinary tract and associated *Schistosoma haematobium* infection of the bladder—Leads to increased urinary excretion.

Please refer Chapter 8, for further details regarding carriers of infectious diseases.

  - **Food handlers or cooks** who become chronic carriers are particularly dangerous as they can excrete the bacilli for many years. The best known example of such typhoid carrier was Mary Mallon **('Typhoid Mary'),** a New York cook who gave rise to more than 50 cases during her lifetime causing several outbreaks.

LABORATORY DIAGNOSIS — Enteric fever

- **Specimen collection:** Blood or bone marrow culture (1st week of illness), serum for serology (2nd or 3rd week of illness), and urine and stool culture (third/fourth week of illness).

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- **Culture isolation**
  - Blood and bone marrow culture (in first week of illness):
    - Conventional: BHI broth/agar
    - Automated blood culture systems—BACTEC or BacT/ALERT).
  - Stool culture (in 3rd–4th weeks of illness):
    - Enrichment broth such as Selenite F broth, tetrathionate broth and gram-negative broth
    - Low selective medium: MacConkey agar (NLF colonies)
    - Highly selective media: DCA, XLD agar, etc.
  - Urine culture (in 3rd–4th weeks of illness)—on MacConkey agar.
- **Culture smear and motility:** Motile, gram-negative bacilli.
- **Identification:** By conventional biochemical tests or automated systems (MALDI-TOF or VITEK).
- **Slide agglutination test:** To confirm the serotype.
- **Serum antibody detection (Widal test):** 2nd–3rd weeks of illness.
  Antibodies are detected against TO, TH, AH, BH antigens
  - In *S.* Typhi infection: ↑TO and TH antibodies
  - In *S.* Paratyphi A infection: ↑TO and AH antibodies
  - In *S.* Paratyphi B infection: ↑TO and BH antibodies.

  Result and interpretation
  - O antibodies: Produce granular chalky clumps when they react with O Ag
  - H antibodies: Produce cottony woolly clumps when they react with H Ag.
- **Antigen detection (serum and urine):** By ELISA.
- **Molecular methods:** PCR detecting *flagellin (fliC)* gene and *iroB* gene.
- **Nonspecific findings:** For example, neutropenia.
- **Antimicrobial susceptibility testing.**

Laboratory Diagnosis

Type of specimen to be collected depends on the duration of illness. The preferred specimen(s) to be collected are:

- **First week of illness:** Blood culture, bone marrow or duodenal aspirate culture.
- **Second/third week of illness:** Serum specimen for serology (e.g. Widal test).
- **Third/fourth week of illness:** Urine and stool culture.

Culture and Identification

Blood Culture

Blood culture is the ideal method for diagnosis in the first week of fever, which becomes positive in about 90% of cases. There after the positivity declines to 75% in the second week and 60% in the third week and 25% till the fever subsides. The specimen collection and procedure of blood culture is discussed in **Figure 29.1, Chapter 29**.

- **Blood culture bottles:** 8–10 mL of blood is collected in blood culture bottle; either conventional bottle (brain heart infusion medium—monophasic or biphasic) or automated bottle (e.g. BacT/ALERT) **(Figs. 29.2A to C, Chapter 29)**.
- **Incubation:** Blood culture bottles are incubated at 37°C. Salmonellae are nonfastidious, growth may occur within 24 hours. Subcultures are made from positively flagged blood culture broth, on to blood agar and MacConkey agar.
- **Colony appearance:**
  - Blood agar: Nonhemolytic moist colonies.
  - MacConkey agar: Colonies are round, translucent, pale and non-lactose fermenting.

Stool and Urine Culture

It is useful for the isolation of *Salmonella* in the third and fourth weeks of illness. They remain positive even after antibiotic treatment. Stool and urine culture are also done for the detection of carriers.

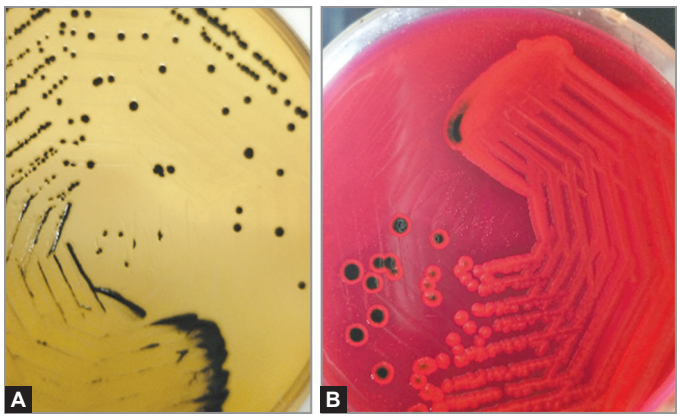
Urine culture seldom becomes positive as salmonellae are shed in urine infrequently. Urine is centrifuged and the deposit is inoculated onto MacConkey agar.

Stool culture is done similar to the method followed for *Shigella* (described in Chapter 41). Appropriate media should be used to inhibit the commensals in the stool.

- **Enrichment broth** such as Selenite F broth, tetrathionate broth and gram-negative broth are used.
- **Selective media** such as:
  - **Low selective media** such as MacConkey agar.
  - **Highly selective media:** Growth of *S.* Typhi occurs as follows **(Figs. 30.1A and B)**:
    - **DCA** (deoxycholate citrate agar): Produces non-lactose fermenting pale colonies with black center.
    - **XLD agar** (xylose lysine deoxycholate): Produces red colonies with black center.
    - **Wilson Blair's** brilliant green bismuth sulfite medium is particularly useful for the isolation of *S.* Typhi from heavily contaminated specimens.

Other Specimens

- **Bone marrow** culture is employed during the first week of illness (55–90% sensitive) when blood culture is negative, especially when patient is on antibiotics.
- **Duodenal aspirate** culture is recommended during first week of illness if both blood and bone marrow cultures turn negative.



Figs. 30.1A and B: Colonies of *S.* Typhi: (A) DCA (Deoxycholate citrate agar) showing pale colonies with black center; (B) XLD agar (Xylose lysine deoxycholate) showing red colonies with black center.

Source: Department of Microbiology, JIPMER, Puducherry (*with permission*).

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- **Combination** of blood, bone marrow, and intestinal secretions culture is the best method in the first week, which shows a sensitivity of more than 90%.

Culture Smear and Motility Testing

Gram-stained smear made from colonies reveals gram-negative, non-sporing bacilli. They are motile with peritrichous flagella.

Identification

Identification of *Salmonella* from the colonies is made either by automated identification systems such as MALDI-TOF or VITEK; or by conventional biochemical tests as described below.

- It is catalase positive and oxidase negative.
- Indole test (negative), citrate test (negative), urease test (negative).
- TSI (triple sugar iron test) for *S.* Typhi shows: Alkaline/acid, gas absent and speck of H_2S present at the junction of slant and butt.
- MALDI-TOF can identify *Salmonella* up to genus level. However it poorly differentiates between serotypes as they share the same ribosomal proteins.

Slide Agglutination Test

Identification of *Salmonella* at genus level can be confirmed by slide agglutination using polyvalent O antisera. Then, the serotypes can be identified by using type specific O antisera.

- *S.* Typhi: Agglutinates with O9 antisera.
- *S.* Paratyphi A: Agglutinates with O2 antisera.
- *S.* Paratyphi B: Agglutinates with O4 antisera.

Flagellar antigens can also be determined by using type-specific H antisera.

Antimicrobial Susceptibility Testing (AST)

AST is performed by disk diffusion method (on Mueller–Hinton agar) or by automated MIC detection method by microbroth dilution (e.g. by VITEK).

Widal Test (Detection of Serum Antibodies)

Widal test is indicated in the 2nd to 3rd weeks of illness. It is a tube agglutination test, that detects antibodies in the patient's serum against antigens of *Salmonella* Typhi and *S.* Paratyphi.

- **Antigens used:** Four antigens are used
  1. O antigens of *S.* Typhi (TO)
  2. H antigens of *S.* Typhi (TH)
  3. H antigens of *S.* Paratyphi A (AH)
  4. H antigens of *S.* Paratyphi B (BH).

  Note: The paratyphoid O antigens cross-react with the typhoid O antigen due to their sharing of factor 12, hence they are not used in the test.
- **Procedure:** Serial dilutions of patient serum are mixed with four different *Salmonella* antigens (TO, TH, AH, and BH) and the test tubes are incubated in the water bath at 37°C for 16–20 hours.
- **Result:** The result is read using a concave mirror. If corresponding antibodies are present, then an agglutination reaction will occur leading to matt formation. The absence of antibodies would leads to button formation **(Fig. 30.2)**.
  - O antibodies: Produce granular chalky clumps when react with O Ag.
  - H antibodies: Produce cottony woolly clumps when react with H Ag.
- **Significant titer:** Widal cut-offs vary with endemicity and local baseline antibody levels. In many Indian settings, **H titer ≥160** and **O titer ≥80** are considered significant. Lower titers may represent baseline antibodies due to endemic exposure or cross-reactions and should be ignored. In nonendemic areas, lower titers may be significant **(Fig. 30.3)**.
- **Interpretation:** The results are interpreted as given in **Table 30.3**.
- **False-positive:** Widal test may occur due to:
  - ***Anamnestic response:*** It refers to a transient rise of titer due to unrelated infections (malaria, dengue) in persons who have had prior enteric fever.

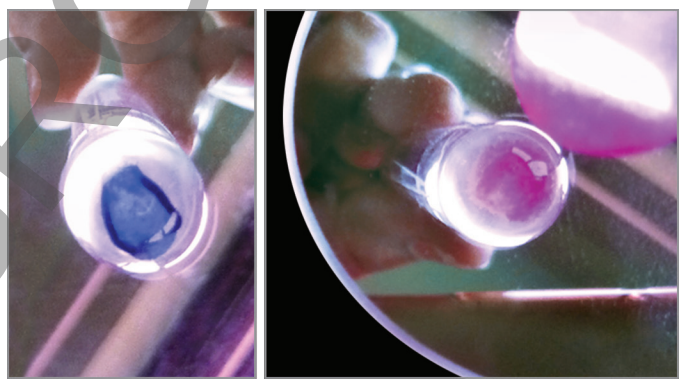

Fig. 30.2: O and H agglutination in Widal test (reading taken in a mirror).

Source: Department of Microbiology, Pondicherry Institute of Medical Sciences.

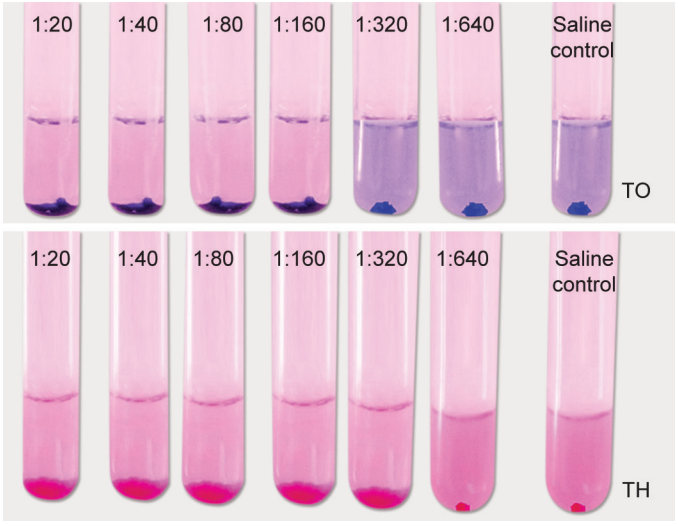

Fig. 30.3: Widal test showing titer of TO 1:160 and TH 1:320.

(TO and TH: antibody titer to *S.* Typhi O and H antigens in patient's serum).

Source: Department of Microbiology, Pondicherry Institute of Medical Sciences.

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Table 30.3: Interpretation of Widal test.	
Widal test result	**Suggestive of**
Rise of TO and TH antibody	Enteric fever due to *S.* Typhi
Rise of TO and AH antibody	Enteric fever due to *S.* Paratyphi A
Rise of TO and BH antibody	Enteric fever due to *S.* Paratyphi B
Rise of only TO antibody	Recent infection: Due to *S.* Typhi or *S.* Paratyphi A or B
Rise of only TH antibody	? Convalescent stage/anamnestic response
Rise of all TH, AH, BH antibodies	Post TAB vaccination

- If bacterial antigen suspensions contain fimbriae.
- Persons with inapparent infection or
- Persons with prior immunization (with TAB vaccine).

❖ **A fourfold rise** in antibody titer demonstrated by testing paired sera at 1-week interval is more meaningful than a single high titer. Rise in titers in anamnestic responses are transient that usually falls after 1 week whereas, in true infection, the titer increases by fourfold after 1 week.

❖ **False-negative:** Widal test may occur in:
- Early-stage (1st week of illness)
- Late-stage (after fourth week)
- Carriers (poor antibody stimulation)
- Patients on antibiotics
- Due to prozone phenomena (antibody excess); this can be obviated by serial dilution of sera.

❖ **Appearance:** O agglutinins appear early and disappear early and indicate recent infection. H agglutinins appear late and disappear late.

❖ **Serotype specificity:** O antibodies are serotype nonspecific. They are raised in all infections, i.e. *S.* Typhi, *S.* Paratyphi A and B. H antibodies are specific. TH, AH and BH antibodies are raised in *S.* Typhi, *S.* Paratyphi A and B infections respectively.

Other Antibody Detection Tests

Apart from the Widal test, other antibody detection tests include:

❖ **Rapid antibody detection tests** such as **Typhidot** (dot enzyme immunoassay) detects IgM/IgG antibodies against 50-kDa OMP of *S.* Typhi, while **TUBEX** detects anti-O9 IgM by inhibition magnetic binding immunoassay.

❖ **Antigen detection** (in serum and urine): By ELISA.

❖ **Molecular methods:** Several polymerase chain reaction (PCR) based methods (e.g. nested PCR) are available to detect and differentiate typhoidal salmonellae by targeting various genes, such as *flagellin (fliC)* gene and *iroB* gene.

❖ **Nonspecific findings:** Neutropenia is seen in 15–25% of cases. Leukocytosis is more common among children, during early phase and in cases complicated by intestinal perforation or secondary infection.

❖ **Endoscopic findings:** Edematous, hyperemic mucosa with multiple terminal ileal/ileocecal ulcers; bleeding may be seen.

Detection of Carriers

Carriers of *S.* Typhi can be detected by culture and Vi antibody testing.

❖ **Culture:** By stool and bile culture (for detecting fecal carriers) and urine culture (detects urinary carriers).

❖ **Detection of Vi antibodies:** It is done by tube agglutination test by using *S.* Typhi suspension carrying Vi antigen (Bhatnagar strains). Even a titer of 1:10 is also considered as significant. However, the diagnosis should always be confirmed by culture.

❖ **Isolation of salmonellae from sewage:** It is carried out to trace the carriers in the communities. It can be done by:
- *Sewer–swab technique:* Gauze pads left in sewers are cultured on highly selective media, such as Wilson and Blair media.
- *Filtration:* Sewage can be filtered through Millipore membranes and the membranes are cultured on highly selective media.

TREATMENT — **Enteric fever**

Prompt administration of appropriate antibiotics prevents severe complications and reduces the mortality to <1%.

Treatment of cases depends on the susceptibility of the strains. The currently recommended drugs are as follows:

❑ Third generation cephalosporins: Ceftriaxone is the drug of choice for empirical treatment; given 2 g/day, IV, for 10–14 days; alternative being cefotaxime and cefixime.

❑ Azithromycin: Alternative drug for empirical therapy. Advantage is, it is given orally, 1 g/day for 5 days.

❑ Fluoroquinolones, e.g. ciprofloxacin: Because of increased drug resistance, it should not be given empirically. It can be given only if, found susceptible. It is given as 500 mg twice a day oral for 5–7 days.

Drugs previously used for treatment, such as chloramphenicol, amoxicillin, and cotrimoxazole, were discontinued due to the emergence of bacterial resistance; however they can still be used if found sensitive.

Treatment of carriers: Chronic carriers require 4-week oral quinolones (drug of choice); amoxicillin for 4–6 weeks may be used for quinolone-resistant strains. Surgical correction of biliary/renal stones is often needed.

Drug Resistance in Typhoidal Salmonellae

Antimicrobial resistance in typhoidal salmonellae is a global problem.

❖ **Multidrug-resistant (MDR) *S.* Typhi:** It is defined as resistance to chloramphenicol, ampicillin and cotrimoxazole. These antibiotics were commonly used to treat enteric fever in the past.

❖ **Fluoroquinolone (FQ) resistance:** Ciprofloxacin was used as a drug of choice for MDR *Salmonella* since the year 1990 and this led to the emergence of drug resistance to FQs.
- In India, ciprofloxacin resistance in *Salmonella* is very high (>90% in 2026).
- The key mechanisms responsible for FQ resistance are mutations in *gyrA* and *parC* genes.

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- **Resistance to ceftriaxone:** It is very rare (<1%) in India, but in some countries like Pakistan, it is very high (22–55%). Both extended spectrum β-lactamases (ESBLs) and AmpC β-lactamase producing *S.* Typhi have been detected. Meropenem (or azithromycin) is given in such cases.
- **Old is gold:** Interestingly, it is noticed that many strains reverted susceptible to the olden days drugs (amoxicillin, chloramphenicol, cotrimoxazole) as they were not in use for long time.

Prophylaxis

Theoretically, it is possible to control or eliminate enteric fever since the agents survive only in the human hosts and are spread by contaminated food and water. There are three lines of prophylactic measures.

Control of Reservoir

Control of the reservoir is achieved by early detection and effective management of cases and carriers.

Control of Cases

- By early diagnosis and prompt effective treatment.
- Disinfection of stool or urine soiled clothes with 5% cresol, 2% chlorine or by steam sterilizer.
- Follow-up examination of stool and urine culture to detect carriers (twice, at 3–4 months and at 12 months).

Control of Carriers

- Early detection of carriers by stool/urine culture or by detection of Vi antibodies.
- Effective treatment of carriers by:
  - Ampicillin or amoxicillin plus probenecid for 6 weeks. These drugs get concentrated in bile and may eliminate 70% of carrier state.
  - Cholecystectomy plus ampicillin is regarded as the most effective approach for carrier state elimination.

Sanitation Measures

Sanitation measures are the best method of preventing transmission, which include:

- Protection and purification of drinking water supplies.
- Handwashing and improvement of basic sanitation.
- Promotion of food hygiene.
- Health education.

Vaccine

Immunization provides short time protection. It is indicated in following situations:

- Travelers going to endemic areas
- People attending *melas* and *yatras*
- Household contacts
- People at increased risk (school children)
- People living in endemic area (optional).

There are three types of vaccines available (see below).

Typhoid Vaccines

At present, three types of typhoid vaccines are available.

- **Vi polysaccharide vaccine:** It contains purified Vi capsular polysaccharide antigen of *S.* Typhi. It is given as a single intramuscular or subcutaneous dose. Commercially available as—Typhim VI (Sanofi Pasteur); Typherix (GSK).
  - *Timeline:* The minimum age for administration is 2 years. Protection lasts for about 2 years, and a booster dose is recommended every 2 years.
  - *Poorly immunogenic:* Since it is a polysaccharide vaccine, it produces a T-cell independent immune response and is therefore poorly immunogenic in young children. However, for *immunocompromised persons*, it is preferred over the live oral Ty21a vaccine.
  - *For travellers*, it is given at least two weeks before travel.
- **Typhoid conjugate vaccine (TCV):** It contains Vi antigen conjugated to a carrier protein such as tetanus toxoid, diphtheria toxoid or CRM197. Examples include Typbar-TCV, Zyvac-TCV and PedaTyph.
  - *Schedule:* It is given as a single IM dose.
  - *Immunogenic:* Conjugation improves immunogenicity and produces better immune memory. Therefore, this vaccine is effective in younger children and can be given from 9 months of age.
- **Oral live attenuated Ty21a vaccine** (e.g. Typhoral): It contains a live attenuated mutant strain of *S.* Typhi. The vaccine is available in lyophilized form as enteric coated capsules.
  - *Schedule:* It is given orally on alternate days—1, 3,5, 7. The last dose should be taken at least 1 week before travel. Each capsule should be swallowed whole (not chewed) about an hour before meals with cold or lukewarm water.
  - *Mechanism:* On ingestion, it multiplies for some time, initiates the immune response but self-destructs (dies of its own after 4–5 cell divisions, due to lack of Gal E enzyme) and therefore cannot induce any pathogenesis.
  - *Precautions:* The minimum age is 6 years. It should be avoided in immunocompromised persons and pregnant women. A booster series is recommended every 5 years.

Paratyphoid fever: There is no licensed vaccine for paratyphoid fever. Typhoid vaccines do not protect against paratyphoid fever. The older parenteral TAB vaccine (contains *S.* Typhi, *S.* Paratyphi A and B) is no longer preferred because it is highly reactogenic.

NON-TYPHOIDAL SALMONELLAE

Non-typhoidal salmonellae cause mainly gastrointestinal manifestations, and have been described in Chapter 41.

However, up to 8% of patients with NTS gastroenteritis develop into bacteremia; which can lead to either endovascular infection or seedling to various organs leading to metastatic infections.

Risk factors for bacteremia include:

- **NTS serotype:** Most common being *S.* Choleraesuis (source—pig) and *S.* Dublin (source—cattle).
- **Age:** Infants and elderly people are at higher risk.
- **Immunity:** HIV and other conditions with low immunity.
- **People with pre-existing valvular heart disease:** NTS can cause endovascular infection such as endocarditis and arteritis.

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EXPECTED QUESTIONS

I. Write essay on:

Case Study Enteric Fever

1. Meena, a young adult female was admitted to the hospital with intense headache, abdominal discomfort for the past 5 days. She had also developed fever which is of remittent type with gradual rise in a step ladder fashion. On examination, she was toxic with temperature of 101°F, tongue was coated and mild splenomegaly was present.
   a. What is the most probable etiological diagnosis?
   b. Describe the pathogenesis of this condition.
   c. Mention sample collection and laboratory diagnosis in detail.
   d. Add a note on treatment and vaccination available for this clinical condition.

II. Write short notes on:

1. The kitchen staff in a healthcare facility were screened for enteric pathogens which yielded *Salmonella* Typhi in stool culture. Discuss the types of typhoid carriers and the methods available for laboratory diagnosis.
2. Drug resistance in salmonellae.
3. Vaccines for typhoid fever.

III. Multiple choice questions (MCQs):

1. *S.* Typhi is the causative agent of typhoid fever. The infective dose of *S.* Typhi:
a. One bacillus b. 10^3 –10^6 bacilli
c. 10^8 –10^{10} bacilli d. 1–10 bacilli

2. In a patient with typhoid, diagnosis in the first week of onset of fever is best done by:
a. Blood culture b. Stool culture
c. Urine culture d. Widal test

3. Antibodies against which of the following antigens appear early following infection with *S.* Typhi?
a. Vi antigen b. O antigen
c. H antigen d. Capsular antigen

4. In Widal test, rise of TO and AH indicates infection with:
a. *S.* Typhi b. *S.* Paratyphi A
c. *S.* Paratyphi B d. *S.* Paratyphi C

5. Antibodies against which of the following antigens appear in typhoid carrier?
a. Vi antigen b. O antigen
c. H antigen d. Capsular antigen

6. Currently the drug of choice for enteric fever is:
a. Ciprofloxacin b. Azithromycin
c. Ceftriaxone d. Chloramphenicol

7. True about transmission of *Salmonella* Typhi is:
a. *S.* Paratyphi A infection is more common than *S.* Typhi
b. Humans are the only natural hosts
c. More common in rural areas than urban areas
d. Infection uncommon in children

8. Salmonellae in first week of illness can be isolated from all, *except*:
a. Bone marrow b. Blood
c. Duodenal aspirate d. Stool

9. In Widal test, large loose fluffy cotton woolly clumps, with clear supernatant fluid was noted. It indicates agglutination with:
a. O antibodies b. H antibodies
c. Vi antibodies d. Any of the above

10. Causes for false-positive Widal test are all, *except*:
a. Malaria b. Immunization
c. Unrelated infection d. 3rd week of illness

11. Which virulence factor enables *Salmonella* Typhi to survive within macrophages?
a. Cytochrome oxidase
b. Type III secretion system
c. Coagulase
d. M protein

12. The most sensitive specimen for culture in enteric fever, even after prior antibiotic therapy, is:
a. Blood b. Stool
c. Bone marrow d. Urine

13. The chronic carrier state of typhoid is most commonly associated with:
a. Kidney b. Gallbladder
c. Spleen d. Bone marrow

14. Which one of the following vaccines is a live attenuated oral vaccine against typhoid?
a. Typhoid conjugate vaccine
b. Vi polysaccharide vaccine
c. TAB vaccine
d. Ty21a vaccine

15. A patient recovering from typhoid fever continues to excrete *Salmonella* Typhi in stool for more than one year despite being asymptomatic. This condition is termed:
a. Convalescent carrier
b. Temporary carrier
c. Chronic carrier
d. Healthy contact

Answers

1. b **2.** a **3.** b **4.** b **5.** a **6.** c **7.** b **8.** d **9.** b **10.** d **11.** b **12.** c **13.** b **14.** d **15.** c

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