SALMONELLA ENTERICA (ALL SEROVARS)

AETIOLOGY

Classification of the causative agent

Salmonella enterica is a Gram-negative, motile, non-sporulating aerobic or facultatively anaerobic rod-shaped bacterium in the family *Enterobacteriaceae*. There are six known subspecies of *S. enterica*: *S. enterica enterica* (I), *S. enterica salamae* (II), *S. enterica arizonae* (IIIa), *S. enterica diarizonae* (IIIb), *S. enterica houtenae* (IV), and *S. enterica indica* (VI). There are over 2600 *S. enterica* serovars that are found in both clinically healthy and sick animals alike. Serovars are referred to as *Salmonella* followed by the capitalized and unitalicized serovar name (e.g. *S*. Typhimurium).

Resistance to physical and chemical action

Temperature: Depending on the serovar, can survive between 2°-54°C

pH: pH 3.7-9.4

Chemicals/Disinfectants: Acetic acid and propionic acid; administering chlorine at 20-50 ppm can prevent the formation of biofilms on stainless steel

Survival: Survives for extended periods of time in dry environments

EPIDEMIOLOGY

S. enterica serovars have the ability to infect several different animal species. *S*. Typhimurium is frequently found in birds, reptiles, fish, and amphibians. *S*. Anatum and *S*. Newport are also known to infect rodents and birds. In general, *Salmonella* spp. outbreaks cause massive mortality events in several wildlife species, especially passerines. The following is not an exhaustive list of possible hosts:

Hosts

- Birds
  - Order *Anseriformes*
  - Order *Columbiformes*
  - Order *Falconiformes*
  - Order *Passeriformes*
  - Order *Sphenisciformes*
- Black rhinoceroses (*Diceros bicornis*)
- Chickens (*Gallus gallus*)
- Domestic canines (*Canis lupus familiaris*)
- Domestic cattle (*Bos taurus*)
- Domestic felines (*Felis catus*)
- Domestic swine (*Sus scrofa domesticus*)
- Elephants
  - African elephants (*Loxodonta africana*)
  - Indian elephants (*Elephas maximus*)
- Hedgehogs (family *Erinaceidae*)
- Reptiles
  - Order *Crocodilia*

    - Order *Squamata*
    - Order *Testudines*
- Seals (*Pinnipedimorpha*, subclade *Pinnipediformes*)
- Turkeys (*Meleagris gallopavo*)
- Wild boars (*Sus scrofa*)
- Wild deer
    - Red deer (*Cervus elaphus*)
    - Reindeer (*Rangifer tarandus*)
    - Roe deer (*Capreolus capreolus*)
    - White-tailed deer (*Odocoileus virginianus*)

Transmission

- Consuming infected carcasses
    - Generally, raptors contract *S. enterica* by eating infected animals
- Consuming particles from refuse dumps, landfills, or sewage
    - Gulls (family *Laridae*) may become infected via food scraps from areas such as landfills, garbage dumps, and sewage outlets
    - Waterfowl are at risk of sewage contamination while swimming
- Faecal-oral route
    - In pigeons (*Columba livia domestica*), this is thought to be the main route of transmission
- Vertical transmission has been reported in reptiles and commercial poultry

Sources

- Faeces
- Infected carcasses
- Human sewage
- Refuse dumps

Occurrence

S. Havana is a serotype that is generally associated with raptors and is the most common serovar among wild and captive raptors in central Spain. Similarly, *S*. Havana was found in captive raptors at a raptor center in Italy. In February and March 2010 in Switzerland, there was a large die-off of Eurasian siskins (*Spinus spinus*) due to *S*. Typhimurium, and also a rise in the incidence of this serovar in domestic cats. *S*. Amager has been found in peregrine falcons (*Falco peregrinus*) in Sweden.

Songbirds are thought to be the cause of infection in humans and livestock in New Zealand, with the country seeing an increase in the incidence of salmonellosis since 2000. In passerines, salmonellosis is associated with increasing use of bird feeders. *S*. Typhimurium causes high mortality rates in songbird populations. In 2009, *S*. Typhimurium was responsible for a die-off of pine siskins (*Spinus pinus*) and American goldfinches (*Spinus tristis*) on the Atlantic coast of the United States. Black headed gulls (*Larus ridibundus*) are considered to be a reservoir for *S.* Typhimurium in Europe.

In Antarctica, wild Adélie penguins (*Pygoscelis adeliae*) have been found to be infected with a number of *S. enterica* serovars, including Blockley, Enteritidis, Infantis, Johannesburg, and Panama. *S*. Newport has been isolated from fur seals (*Arctocephalus gazella*). Additionally, Antarctic krill are thought to harbour *S. enterica* species, which are eaten by and spread to penguins and seals. *S. enterica* in Antarctic animals is likely due to human activities such as whaling, sealing, fishing, and hunting with dogs.

Salmonellosis has been reported in farmed Nile crocodiles (*Crocodylus niloticus*).

Death in a black rhinoceros and two African elephants in Nairobi Game Park, Kenya were due to *S*. Typhimurium and *S*. Enteritidis, respectively. The deaths were linked to interaction with humans because wild

animals such as these do not generally experience clinical salmonellosis. Salmonellosis has also been reported in Indian elephants.

For more recent, detailed information on the occurrence of this disease worldwide, see the OIE World Animal Health Information System - Wild (WAHIS-Wild) Interface [http://www.oie.int/wahis_2/public/wahidwild.php/Index].

DIAGNOSIS

The pathology of *S. enterica* in birds is incompletely understood but is thought to be due to the bacteria entering and replicating in macrophages, after which they travel via the reticulo-endothelial cell system to organs throughout the body. Healthy avian carriers, such as waterfowl, are thought to be the major reservoirs of *S. enterica*. Avian species with salmonellosis may present with poor body condition, septicaemia, endotoxaemia, lethargy, and ruffled feathers. Morbidity and mortality in passerines is normally caused by *S*. Typhimurium. Finches appear to be particularly susceptible to infection.

In raptors, coinfection with other pathogens such as avian pox, herpesvirus, and *Chlamydophila psittaci* is thought to make the birds more susceptible to *S. enterica* infection. Birds in the *Fringilidae* family have been found co-infected with *Trichomonas*. *S. enterica* infections are commonly subclinical in adult pigeons but cause mortality in squabs. In black headed gulls, infection usually does not present with clinical signs.

Reptiles infected with *Salmonella* may not develop lesions unless they become septicaemic. These animals have *Salmonella* in their intestines and faeces as a normal commensal organism.

Mortality due to *S*. *enterica* has been appreciated in white-tailed deer (*Odocoileus virginianus*) fawns and red deer (*Cervus elaphus*) fawns.

Clinical diagnosis

Salmonellosis in birds can present as haemorrhagic diarrhoea, anorexia, polyuria, lethargy, joint swelling, and conjunctivitis. Clinical signs in fawns include depression and dehydration. Infection with *S*. *enterica* in farmed Nile crocodiles can cause lethargy and anorexia.

Lesions

- Birds
    - Hepatomegaly
    - Perihepatitis
    - Splenomegaly
    - Nephritis
    - Multifocal necrosis on liver, spleen, intestine, or proventriculus
    - Multifocal necrosis of the crop and oesophagus (up to 4mm in diameter)
    - Epicarditis and pericarditis
    - Muscle necrosis
    - Purulent arthritis
- Deer
    - Lungs
        - Congestion
        - Oedema
        - Serosal petechiation
    - Intestinal meteorism
- Reptiles
    - Green iguanas (*Iguana iguana*)
        - Oophoritis
        - Myocarditis
        - Endocarditis of the aortic valve

        - Nephritis
    - Horned lizards (*Phrynosoma solare*)
        - Splenomegaly
    - Snakes
        - Hepatitis
        - Necrotising enteritis
- Wild boar (infected with *S*. Choleraesuis)
    - Splenomegaly
    - Yellow foci in liver
    - Ulcerative ileitis, typhlitis, and colitis with serosal petechiation

Differential diagnoses

- Birds
    - Trichomoniasis
    - Avian influenza
    - *Escherichia coli*
    - *Yersinia* spp.
    - *Pasteurella* spp.
    - Coccidiosis
    - Giardiasis
    - Toxins, including lead and zinc
- Crocodiles (nonspecific signs, including anorexia and lethargy)
    - Chlamydiosis
    - *Mycoplasma crocodyli*
    - Adenovirus
- Deer
    - *Escherichia coli*
    - Coccidiosis
    - Cryptosporidiosis
    - Bovine-like coronaviruses
    - Giardiasis
    - Corn toxicity
- Other reptiles
    - Trichomoniasis
    - *Monocercomonas* spp.
    - *Strongyloides* spp.
    - *Entamoeba* spp.
    - *Kalicephalus* spp.

Laboratory diagnosis

Samples

For isolation of agent

- Small intestine
- Colon
- Liver
- Spleen
- Mesenteric lymph nodes
- Faeces
- Rectal/cloacal swab (live animals)

Serological tests

- Serum

Procedures

Identification of the agent

- Bacterial culture
    - Pre-enrichment: Use buffered peptone water
        - This step is used for environmental samples or faeces
    - Enrichment: modified semi-solid Rappaport-Vassiliadis (MSRV), Muller-Kauffman broth, selenite cystine, selenite F, semi-solid Salmonella medium, or Rappaport-Vassiliadis broth
    - Isolation: XLD, Brilliant green agar, Rambach agar, or Hectoen enteric agar
        - Selective media inhibit the growth of other bacteria
- Biochemical tests
    - *S. enterica* ferments sorbitol, dulcitol, maltose, arabinose, glucose, and mannitol
    - Most *S. enterica* serovars produce hydrogen sulfide (H_2S) and are negative for urease, negative for indole production, and positive for methyl red
- Serotyping
    - Antigens: somatic (O), flagellar (H), and virulence (Vi)
        - There may be cross-reactivity between *S. enterica* serovars themselves or other bacteria
    - Serovar determined by White-Kauffmann-LeMinor method
- Multi-locus sequence typing (MLST)
- Phage typing
- Polymerase chain reaction (PCR)
- Pulsed-field gel electrophoresis (PFGE)
- Whole genome sequencing (WGS)

Serological tests

Serology can be used to screen a population suspected of harbouring *S. enterica* serovars.

- Competitive enzyme-linked immunosorbent assay (ELISA)
    - Can be used in all animal species
- Antigen capture ELISA
    - Available for mammals and domestic poultry
- Serum agglutination test
- Rapid slide agglutination test

For more detailed information regarding laboratory diagnostic methodologies, please refer to Chapter 3.9.8 Salmonellosis in the latest edition of the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals.

PREVENTION AND CONTROL

Sanitary prophylaxis

- Inspect meat for *S. enterica* serovars before feeding to carnivores or raptors, or utilising as bait while hunting.
- Ensure that sewage is treated and not accessible to wildlife (e.g., does not get dumped into ponds).
- Rodents are known carriers of *S. enterica*; rodent control is important to prevent bacterial spread on livestock operations and zoos.
    - Bait, trap, and remove rodents
    - Destroy rodent nests
    - Remove rodent faeces
- Regularly sanitize and keep areas around bird feeders clean to prevent spread of *S. enterica* among wild avian species.
    - Thoroughly clean bird feeders at least twice a month by using a brush and hot, soapy water and rinse with clean water

    - To disinfect, soak feeders in a solution of one part liquid chlorine bleach/nine parts warm water for 2-3 minutes, rinse with clean water, and air dry
    - Wear rubber gloves when performing these activities and thoroughly wash and disinfect hands after cleaning to prevent contraction of *Salmonella* spp.
- Remove bird feeders during *Salmonella* spp. outbreaks.

Medical prophylaxis

- For crocodile farms, maintain a low-stress environment, including reduction of heat stress, provision of high-quality feed, proper stocking density, et cetera to prevent clinical salmonellosis.
- *Salmonella* vaccines are available for use in livestock but have not been used in wildlife.

POTENTIAL IMPACTS OF DISEASE AGENT BEYOND CLINICAL ILLNESS

Risks to public health

- While dressing game, hunters should avoid contaminating animal carcasses with faeces or intestinal contents.
- While *S. enterica* is often contracted via contaminated food, it may also be contracted via contaminated water, snow, faeces, or contact with infected animals.
- Pet African pygmy hedgehogs (*Atelerix albiventris*) have been implicated in outbreaks of salmonellosis in the United States and Canada; outbreaks in the United States have also been caused by guinea pigs (*Cavia porcellus*), hamsters (family *Cricetidae*), mice (*Mus* spp.), and rats (*Rattus* spp.).
- In Norway, wild European hedgehogs (*Erinaceous europaeus*) were thought to have caused a *S.* Typhimurium outbreak in humans; the hedgehogs were thought to have contaminated residential outdoor spaces.
- Reptiles, especially red-eared slider turtles (*Trachemys scripta elegans*), bearded dragons (*Pogona* spp.), and amphibians, such as African dwarf frogs (*Hymenochirus* spp.), harbour several *S. enterica* serovars in their gastrointestinal tracts and have been implicated in several *Salmonella* outbreaks worldwide, especially in children who keep these animals as pets.
- Petting zoos, where many livestock and wildlife species are co-housed, have been sources of *S. enterica* outbreaks in humans, particularly in children.

Risks to agriculture

- It is believed that wildlife reservoirs contaminate crops consumed by humans and animals.
- *S. enterica* is a risk to human health through the food supply. Several serovars have been implicated in foodborne outbreaks, including: Braenderup, Enteritidis, Heidelberg, Infantis, Javiana, Montevideo, Muenchen, Newport, Saintpaul, and Typhimurium, with the highest percentage of outbreaks occurring due to Enteritidis and Typhimurium.

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The OIE will periodically update the OIE Technical Disease Cards. Please send relevant new references and proposed modifications to the OIE Science Department (scientific.dept@oie.int). Last updated 2020. Written by Samantha Gieger and Erin Furmaga with assistance from the USGS National Wildlife Health Center.