Reptile- and Amphibian-Associated Salmonellosis

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Importance

Salmonella are bacterial pathogens that can be found in the digestive tracts of many vertebrates ranging from poikilotherms, such as amphibians and reptiles, to birds and mammals. While they are often carried asymptomatically, these organisms sometimes cause gastroenteritis, especially when large numbers of organisms are ingested or conditions in the gastrointestinal tract are disordered, and opportunistic invasion of other tissues can result in diseases ranging from focal infections to life-threatening septicemia. Invasive diseases tend to be particularly common in very young or old individuals and those with other health issues. Gastroenteritis is generally self-limited if the host is healthy, but dehydration can be a concern, particularly in the young, if fluid replacement for vomiting and diarrhea is inadequate.

Salmonella carriage rates among reptiles and amphibians vary, though they are generally higher among animals in captivity. Most infections in these animals are asymptomatic, but there are occasional reports of clinical cases. Bacteria from reptiles and amphibians can also affect humans. Small turtles, which were popular pets for children in the 1960s and 1970s, have been associated with some outbreaks, but various lizards, snakes, frogs and other species are also involved. Many cases involve younger children, who are more likely to interact with animals in ways that could result in fecal contamination of the mucous membranes. Infants are highly susceptible, and may become infected indirectly when a caregiver inadvertently transfers the organism on contaminated hands or other fomites. Hygiene and good animal husbandry can reduce the risk to humans, but awareness varies among reptile and amphibian owners.

Etiology

Members of the genus *Salmonella* are Gram negative rods in the family Enterobacteriaceae. Naming practices have varied over the years, but the two currently recognized species are *Salmonella bongori* (also called subspecies V) and *Salmonella enterica*. *S. enterica* contains six subspecies, which may be referred to by either a name or a number: *S. enterica* subsp. *enterica* (subspecies I), *S. enterica* subsp. *salamae* (II), *S. enterica* subsp. *arizonae* (IIIa), *S. enterica* subsp. *diarizonae* (IIIb), *S. enterica* subsp. *houtenae* (IV) and *S. enterica* subsp. *indica* (VI). *S. enterica* subsp. *arizonae* and *S. enterica* subsp. *diarizonae* previously belonged to the genus *Arizona*. Salmonellae are also classified into more than 2600 serovars, some with names such as Newport, Poona or Typhimurum, and others described only by technical terms (e.g., 43:z4,z32). Most of the known serovars belong to *S. enterica* subsp. *enterica*, while other subspecies have from < 20 (*S. enterica* subsp. *indica)* to several hundred serovars each. Each serovar can contain multiple strains, which may differ in virulence.

Some species and serovars of *Salmonella* tend to be found in certain hosts, though they can also infect others. *S. enterica* subsp. *salamae*, *S. enterica* subsp. *arizonae*, *S. enterica* subsp. *diarizonae* and *S. enterica* subsp. *houtenae* are common in reptiles, but they can also carry *S. enterica* subsp. *enterica*, which is the major subspecies in mammals and birds, and rarely, *S. enterica* subsp. *indica* or *S. bongori*. Certain serovars of *S. enterica* subsp. *enterica*, such as Abony, Fluntern, Poona or Weltevreden seem to be associated with reptiles and/or amphibians; however they can also be infected with some of the same serovars as mammals and birds, such as the livestock-associated serovar Typhimurium or the poultry-associated serovar Enteritidis. Some reptiles simultaneously carry two or more different *Salmonella*.

Note: Reptiles are occasionally infected with a *S. enterica* subsp. *enterica* serovar named Paratyphi B var Java (formerly known as serovar Java), which should not be confused with the serovar Paratyphi A, an organism maintained in people that causes enteric fever.

Species Affected

Salmonella spp. have been found in in a wide variety of reptiles including various snakes, lizards, chelonians (turtles, tortoises), and crocodilians. They have also been detected in some amphibians, such as frogs, toads and newts. Some animals appear more likely to carry certain organisms than others. For instance, wild geckos in Asia

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seem to be important reservoirs for *S. enterica* subsp. *enterica* Weltevreden, and some studies have found that *S. enterica* subsp. *arizonae* and *S. enterica* subsp. *diarizonae* are more common in snakes than lizards or turtles.

Zoonotic potential

Human infections can be caused by most or all species and subspecies of *Salmonella*, though their frequency varies and some, such as *S. bongori*, appear to be very rare. Reptile-associated outbreaks have involved a variety of organisms, including some *S. enterica* subsp. *enterica* serovars that are most often associated with birds or livestock. Reverse zoonoses (transmission from humans to reptiles and amphibians) also appear possible.

Geographic Distribution

Salmonella can be found in reptiles and amphibians worldwide, though serovars may differ between locations.

Transmission

Salmonella spp. are usually carried asymptomatically in the intestines of reptiles and amphibians. Reptiles can shed these organisms either continuously or intermittently in the feces, and shedding can be increased by stress. Most infections are thought to be acquired orally, via ingestion of feces, prey or contaminated food, water, soil and other fomites; however, other sites of entry, such as the respiratory tract, may account for some clinical cases. Reptiles sometimes become colonized with the same organisms as the parent at hatching, via mechanisms that could include transovarial transmission, contamination of the egg contents during passage through the cloaca, or perinatal acquisition from contaminated eggshells. The mechanisms may differ between species, with some studies finding *Salmonella* inside the eggs of some hosts, while others detected it only on the eggshell.

People usually become infected orally with *Salmonella*, but entry through other orifices, mucous membranes or broken skin is thought to account for some clinical cases. In addition to direct or indirect (fomite-mediated) contact with reptiles and amphibians, cases have been reported after the ingestion of raw or undercooked reptile or amphibian meat and after blood (platelet) transfusions. People can shed *Salmonella* in the feces for several days to several weeks, and occasionally for several months or longer.

Salmonellae have been reported to survive for several weeks to a few months or more in some terrestrial or aquatic environments, as well as on certain food items. In particular, organisms remained viable for 6 weeks to 6 months in reptile feces, and for 6 weeks in aquarium water after the removal of a turtle. *Salmonella* can multiply outside the host for up to a year under favorable conditions, for example, in compost when competition with other microorganisms has been eliminated by autoclaving.

Disinfection

Salmonella spp. can be killed by many disinfectants effective against Gram negative bacteria, such as sodium hypochlorite, 70% ethanol, iodides, phenolics, 2% peracetic acid, hydrogen peroxide, quaternary ammonium compounds, glutaraldehyde and formaldehyde. Consideration should also be given to the safety of the agent when there may be contact with reptiles or amphibians, as certain disinfectants safe for mammals may be contraindicated in this situation.

Infections in Animals

Incubation Period

Salmonella can be carried subclinically for long periods in reptiles and amphibians, and the clinical signs, if any, develop after varying lengths of time.

Clinical Signs

Salmonella carriage in the intestines of reptiles and amphibians is usually asymptomatic. Clinical cases in reptiles are uncommon but diverse, with reported syndromes such as septicemia, bone and joint infections (osteomyelitis, osteoarthritis), pneumonia, gastroenteritis (e.g., necrotizing enterocolitis in juvenile American alligators), hepatitis, splenitis, coelomitis, salpingitis and abscesses in various locations including the skin and subcutaneous tissues. Renal involvement was reported in wild olive ridley turtles (*Lepidochelys olivacea*), though it was not clear whether Salmonella was the primary agent or a secondary invader.

Many affected reptiles have only nonspecific signs of illness such as anorexia, weight loss and lethargy. Dermatitis is common in reptiles that become debilitated from any cause, and some animals may have other signs such pale mucous membranes, serous nasal discharge, diarrhea and dyspnea. Multiple subcutaneous abscesses have been seen in some cases of septicemia. Other signs are related to the tissue(s) affected, such as impaired mobility, sensory deficits and absence of defecation in snakes with vertebral involvement. Reptiles may die soon after the onset of the clinical signs, and outbreaks in some groups of animals, including hatchlings, may be characterized mainly by elevated mortality.

Post-Mortem Lesions

The gross lesions of salmonellosis, which result from necrotizing and/or granulomatous inflammation, are not pathognomonic, and are similar to those caused by some other bacteria. Some of the lesions reported in various reptiles include yellowish fibrinonecrotizing plaques in the oral cavity; catarrhal or fibrinonecrotizing gastroenteritis or enterocolitis, with erythema, thickening and discoloration of the intestinal tract and, in some cases, mucosal ulcers, yellowish plaques, mucosal and submucosal granulomas and/or the formation of diphtheritic membranes; pulmonary edema or pneumonia; diffuse, purulent or multifocal necrotizing hepatitis with yellowish-white punctate areas, nodules, abscesses and/or coalescing lesions; splenomegaly,

sometimes with pale areas of necrosis on cut surface; granulomatous osteomyelitis and/or osteoarthritis; renal involvement with granulomas, abscesses or purulent or necrotizing nephritis; granulomatous, necrotic and/or fibrinous myocarditis, pericarditis or epicarditis; perivisceral edema; coelomic effusion; and subcutaneous or intramuscular abscesses. Some cases of osteomyelitis of the spinal column in snakes were characterized by proliferative lesions that also involved the intervertebral discs, ribs and adjacent muscles, and sometimes resulted in replacement of the spinal cord by purulent or necrotic material.

Diagnostic Tests

Clinical cases can be confirmed by isolating *Salmonella* from the blood or affected tissues. The liver, spleen and mesenteric lymph nodes, as well as any visibly affected organs, are often sampled at necropsy. Organisms can also be found in cloacal swabs or feces; however, carriage at this site is common in healthy reptiles, as well as those that are sick. Culture conditions, including agar types and incubation temperatures, may need to be optimized for the recovery of some organisms found in poikilotherms, and various pre-enrichment and enrichment methods can increase the probability that small numbers of organisms will be detected. Colonies can be identified with biochemical tests, and the serovar identified by serology or genetic methods. Phage typing, plasmid profiling and genotyping methods such as multiple-locus variable number of tandem repeats analysis (MLVA) have been used to characterize isolates during outbreak investigations, but are only available for some *Salmonella* serovars.

PCR to detect nucleic acids can also be used on clinical samples, and some researchers reported that immunohistochemistry could diagnose infections from tissue samples when the histopathology suggested salmonellosis but culture was unavailable. Serology is generally not useful for diagnosing clinical cases in reptiles.

Treatment

Clinical cases can treated with various antibiotics, combined with supportive care. The choice of drugs should, whenever possible, be based on susceptibility testing, as resistance to various antibiotics may be common in some countries. Nevertheless, some zoos have found that the usual empirical antibiotic choices while awaiting lab results were often successful. Gentamicin resistance may be linked to indiscriminate use of this agent to reduce *Salmonella* carriage on reptile eggs.

Control

Disease reporting

Veterinarians who suspect an animal is infected with *Salmonella* should follow their national and/or local guidelines for disease reporting. State authorities should be consulted in the U.S.

Prevention

Good management, with suitable environmental conditions for the species, may help to reduce *Salmonella* shedding from reptiles. Antibiotic treatment of healthy reptiles is not recommended, as it can promote antibiotic resistance, is unlikely to result in animals that are permanently *Salmonella*-free, and may have undesirable effects on the normal gut flora. Attempts to raise *Salmonella*-free reptiles for the pet trade have had limited success.

Morbidity and Mortality

Estimates of *Salmonella* carriage in reptiles vary, but with a few exceptions, studies generally report that carriage is more common in animals held in captivity than those living in the wild. Carriage rates around 15-60% are common in published surveys, but estimates in individual species range from < 5% to more than 80-90%. Snakes and lizards usually have significantly higher carriage rates than chelonians, with the lowest rates in crocodilians. Tortoises are more likely to be carriers than turtles; though studies have occasionally reported high carriage rates in the latter animals, for instance in small red-eared sliders (*Trachemys scripta elegans*) in pet shops. One study of red-eared sliders, a species that has been associated with human outbreaks, recovered *Salmonella* from a high percentage of newly-hatched animals, apparently after acquisition of the organism from contaminated eggshells; however, the number of colonized hatchlings then declined significantly. The authors speculated that this decline may have been associated with the establishment of the normal intestinal flora in turtles. Some studies suggest that food sources and temperature may influence *Salmonella* carriage, but one study found no difference between iguanas (*Iguana* sp.) housed on natural substrate vs elevated wire.

Clinical cases in reptiles seem to be relatively infrequent. Stressors including other illnesses or infections, transportation or poor husbandry (e.g., crowding, food deprivation, sudden change of feed, exposure to cold) have been implicated in some cases. Oral antibiotics may also precipitate disease in an asymptomatic carrier.

Information about *Salmonella* in amphibians is more limited. Estimates of carriage rates are highly variable, with some studies reporting that *Salmonella* could be found in less than 10-15% of these animals, with a number of species apparently colonized at rates of 0-2%, while others reported much higher rates, from around 35% to nearly 70%. Some studies have also found large differences in carriage between amphibians residing in different habitats.

Infections in Humans

Incubation Period

Salmonella gastroenteritis usually begins several hours to about 3 days after exposure. The incubation period for localized conditions, such as osteomyelitis, is variable.

Clinical Signs

In humans, salmonellosis varies from self-limited gastroenteritis to invasive conditions including septicemia. Asymptomatic intestinal carriage can also be seen, including in some children. Gastroenteritis, the most common form, is characterized by nausea, vomiting, cramping abdominal pain and diarrhea, which is occasionally reported to be bloody in reptile-associated outbreaks. It may be accompanied by other nonspecific signs such as headache, fever, chills and myalgia. In healthy people, the symptoms are usually self-limited, resolving spontaneously in 1-7 days. However, dehydration can be an issue when fluid replacement is inadequate, and the illness can be more serious in those who are very young, elderly, pregnant or have other health conditions.

Reptile-associated *Salmonella* can also cause invasive conditions, including septicemia and focal infections, most often but not exclusively among those in high risk groups. The signs of septicemia are nonspecific and can lead to complications such as meningitis, vascular involvement (e.g., aortic aneurism) or invasion of the joints, other tissues and organs. It can be fatal if not treated quickly. Isolated focal infections are varied, with syndromes such as septic arthritis, osteomyelitis, hepatic or splenic involvement, urinary tract infections, abscesses in various locations, endocarditis and other vascular conditions, pneumonia or empyema, and meningitis, as well as unusual syndromes such as isolated otitis (thought to have been acquired from swimming in a lake) and sinusitis.

A condition known as enteric fever is usually caused by two organisms that are adapted to humans and not normally carried in reptiles, *S. enterica* subsp. *enterica* serovars Typhi and Paratyphi A. However, there are very rare case reports of enteric fever from reptile-associated organisms such as *S. enterica* subsp. *arizonae* (formerly *Arizona hinshawii*). Common signs of enteric fever, which may occur after a bout of gastroenteritis, include fever, anorexia, headache, lethargy, myalgia, hepatosplenomegaly and tenderness of the abdomen, a dry cough and alterations in bowel habits ranging from diarrhea (most common in children) to constipation.

Diagnostic Tests

Salmonellosis in humans is diagnosed similarly to infections in animals, by culture and/or PCR. Organisms may be found in the feces, as well as in blood or bone marrow aspirates in cases of bacteremia or septicemia, and in various clinical samples and aspirates from localized sites of infection, including urine and cerebrospinal fluid.

Treatment

Otherwise healthy patients with uncomplicated gastroenteritis are usually treated supportively, with fluids and other measures as needed. Antibiotics are not generally administered to these patients, as they prolong bacterial shedding and do not shorten the illness. However, antibiotics are used to treat septicemia and focal infections, and they may also be given to gastroenteritis patients who are at elevated risk for invasive disease.

Prevention

Prevention of salmonellosis generally relies on good reptile management and personal hygiene, to minimize shedding and avoid contaminating the mucous membranes with these organisms. In addition to the organisms found in feces, fecal contamination can result in *Salmonella* on the animals' skin or in their environment, including water. While most people become infected by ingestion, there are occasional reports of other routes. For instance, one case of meningitis was thought to have occurred after contamination of a craniotomy incision.

Some practical measures include washing the hands after handling reptiles and amphibians, their cages, water or other fomites; avoiding activities that might accidentally bring organisms to the mouth (e.g., eating, smoking) while interacting with these animals; and not allowing reptiles and amphibians to roam freely throughout the house. In particular, they should be kept out of kitchens and other food preparation areas, and if a bathtub is used to wash cages or other fomites, it should be thoroughly cleaned afterward. The use of a dedicated tub to bathe or swim reptiles has been recommended. In addition, authorities advise that those who are at higher risk, such as children under 5 years and immunocompromised persons, avoid all contact with reptiles. People who handle reptiles and amphibians should take care not to inadvertently transfer *Salmonella* to highly susceptible groups, for instance by changing their clothing and washing before contact with infants.

A few countries, such as the U.S., have banned or restricted the ownership of certain reptiles associated with outbreaks, small turtles in particular. Other countries concentrate on education campaigns for reptile owners. Bans can decrease human cases of reptile-associated salmonellosis, at least in the short term. However, they also have some drawbacks, including circumvention by informal reptile sales and the possibility of reduced access to veterinary care, potentially limiting the opportunities to educate reptile owners on hygiene and other preventive measures.

Morbidity and Mortality

Salmonellosis is a common disease in humans, and while most cases are associated with contaminated food, reptiles also account for a significant number of illnesses. Estimates of the percentage of reptile-associated cases in North American or European countries range from around 2% to 6%. Reptile-associated *Salmonella* are diverse and likely to differ in virulence; however, some authors report that certain species or serovars seem to be more virulent than the serovars commonly associated with food. Conversely, some organisms found in reptiles might not infect people readily, as they seem to be uncommon in clinical cases.

While salmonellosis can affect all ages, the incidence and severity of disease, and the risk of invasive disease, are significantly higher in young children, the elderly, and people who are immunocompromised, have debilitating

diseases or impaired gastric acid production. Gastroenteritis, the most common form, usually requires the ingestion of a large number of organisms, as Salmonellae are destroyed by gastric acids in the stomach and must also overcome competition from the normal intestinal flora. Invasive conditions such as septicemia or localized tissue infections have been estimated to occur in 10% of all cases, 18% of cases in the elderly, and 15% of reptile-associated cases in healthy children. Infants are particularly susceptible, with one analysis reporting that invasive syndromes in children had a median age of 0.2 years, compared to 2 years for gastroenteritis. The overall mortality rate for salmonellosis is less than 1%, but some syndromes, such as septicemia or meningitis, are life-threatening.

Outbreaks in people have been caused by a wide variety of reptiles including bearded dragons (*Pogona* spp.) chameleons, iguanas, geckos, Chinese water dragons (*Physignathus coincinus*) and other lizards, as well as turtles and snakes. Some species, such as bearded dragons, currently seem to account for a disproportionate number of cases; however, this may be caused by their popularity as pets, as well as the increased opportunities for handling a relative docile species. While turtles are generally less likely to be colonized with *Salmonella* than most other groups of reptiles, a number of outbreaks in the 1960s and 1970s were associated with small turtles in genera such as *Trachemys* (formerly *Pseudemys*). While this could have been caused by elevated carriage rates among young animals in crowded environments like pet shops, another plausible explanation is that aquatic environments may result in increased opportunities for exposure from splashing. Bans on small turtles resulted in a major decline in the number of reptile-associated salmonellosis cases in the U.S., but this decrease was temporary, with later outbreaks caused by other reptiles. At least one outbreak in the U.S. was associated with exotic pet amphibians (African dwarf frogs). Cases associated with tortoises seem to be infrequent.

Internet Resources

Association of Reptile and Avian Veterinarians (ARAV)

ARAV. *Salmonella* in reptiles and amphibians. Veterinary guidelines

eMedicine.com *Salmonella* infection (Salmonellosis)

Public Health England. Reducing the risks of *Salmonella* infection from reptiles

Public Health Agency of Canada. Pathogen Safety Data Sheets

The Merck Manual

The Merck Veterinary Manual

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