MANAGEMENT OF SALMONELLOSIS IN REPTILES: THERAPEUTIC APPROACHES

MANEJO DA SALMONELOSE EM RÉPTEIS: ABORDAGENS TERAPÊUTICAS

MANEJO DE LA SALMONELOSIS EN REPTILES: ENFOQUES TERAPÉUTICOS

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ABSTRACT

This study is characterized as a narrative literature review aimed at compiling and discussing the most recent scientific evidence on the management and therapeutic approaches to salmonellosis in reptiles. Salmonella spp. is the second most common zoonotic agent, and reptiles are asymptomatic natural reservoirs, representing a public health challenge (Reptile-Associated Salmonellosis – RAS). Clinical manifestations in reptiles are nonspecific and variable. Management is hindered by the growing antimicrobial multidrug resistance observed (especially to sulfonamides and aminoglycosides), although resistance to last-resort drugs such as colistin remains low. The therapeutic approach should be cautious, individualized, and, whenever possible, guided by culture and antimicrobial susceptibility testing, focusing on clinical control and mitigation of zoonotic risk rather than complete eradication of the agent, which is considered unlikely. Non-pharmacological strategies, such as strict hygiene, owner education, and quarantine, are crucial. The findings reinforce the importance of a “One Health” approach and the role of reptiles as environmental sentinels in the circulation of strains with zoonotic potential.

Keywords: Salmonellosis. Reptiles. Zoonosis. One Health.

RESUMO

Este estudo configura-se como uma revisão bibliográfica narrativa com o objetivo de compilar e discutir as evidências científicas mais recentes sobre o manejo e as abordagens terapêuticas da salmonelose em répteis. A Salmonella spp. é o segundo agente zoonótico mais comum, e os répteis são reservatórios naturais assintomáticos, representando um desafio para a saúde pública (Salmonelose Associada a Répteis - RAS). As manifestações clínicas nos répteis são inespecíficas e variáveis. O manejo é dificultado pela crescente multirresistência antimicrobiana observada (especialmente a sulfonamidas e

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aminoglicosídeos), embora a resistência a fármacos de última instância, como a colistina, ainda seja baixa. A abordagem terapêutica deve ser cautelosa, individualizada e, sempre que possível, guiada por cultura e antibiograma, focando no controle clínico e na mitigação do risco zoonótico, em vez da erradicação completa do agente, que é considerada improvável. Estratégias não farmacológicas, como higiene rigorosa, educação dos tutores e quarentena, são cruciais. Os achados reforçam a importância de uma abordagem "Saúde Única" (One Health) e do papel dos répteis como sentinelas ambientais na circulação de cepas com potencial zoonótico.

Palavras-chave: Salmonelose. Répteis. Zoonose. Saúde Única.

RESUMEN

Este estudio se configura como una revisión bibliográfica narrativa con el objetivo de compilar y discutir las evidencias científicas más recientes sobre el manejo y los enfoques terapéuticos de la salmonelosis en reptiles. Salmonella spp. es el segundo agente zoonótico más común, y los reptiles son reservorios naturales asintomáticos, lo que representa un desafío para la salud pública (Salmonelosis Asociada a Reptiles – RAS). Las manifestaciones clínicas en los reptiles son inespecíficas y variables. El manejo se ve dificultado por la creciente multirresistencia antimicrobiana observada (especialmente a sulfonamidas y aminoglucósidos), aunque la resistencia a fármacos de última línea, como la colistina, aún es baja. El enfoque terapéutico debe ser cauteloso, individualizado y, siempre que sea posible, guiado por cultivo y antibiograma, centrándose en el control clínico y en la mitigación del riesgo zoonótico, más que en la erradicación completa del agente, considerada improbable. Las estrategias no farmacológicas, como la higiene rigurosa, la educación de los tutores y la cuarentena, son cruciales. Los hallazgos refuerzan la importancia de un enfoque de “Una Salud” (One Health) y del papel de los reptiles como centinelas ambientales en la circulación de cepas con potencial zoonótico.

Palabras clave: Salmonelosis. Reptiles. Zoonosis. Una Salud.

1 INTRODUCTION

Salmonella *spp.* It is considered the second most common zoonotic agent in human infections, leading to more than 90 million confirmed cases per year. Considering that, according to the World Health Organization, about 60% of emerging diseases are zoonoses, the relevance of salmonellosis cannot be overlooked. The importance in public health and the only one worldwide, and the non-existence of vaccines, points to the need to maintain the production of studies on the epidemiology of the disease and its vectors (Cota et al., 2021; Pawlek et al., 2023).

The most commonly reported transmission of *Salmonella spp.* It is through contaminated food, however, contact with infected animals is another way to be discussed. Contact with contaminated pets can lead to the disease, and this currently includes more and more reptiles (Cota et al., 2021).

Salmonellosis in reptiles represents a unique challenge for veterinary medicine and public health, as these animals are natural reservoirs of a wide diversity of *Salmonella enterica* serovars (Mlangeni et al., 2024). In most cases, the presence of the bacterium does not result in clinical signs in the host, establishing an asymptomatic carrier state that facilitates environmental spread and the risk of zoonotic transmission (Pawlak et al., 2024). Reptile-Associated Salmonellosis (RAS) has gained prominence due to the increased popularity of these animals as pets, resulting in often severe human outbreaks, especially in vulnerable populations such as children and immunosuppressed people (Paphitis et al., 2023; Bruning et al., 2023).

It is essential to distinguish intestinal colonization by Salmonella spp., which is often asymptomatic, from the occurrence of systemic clinical infection. Most reptiles act as carriers, with intermittent elimination of the agent, while progression to clinical disease depends on individual and environmental factors. This distinction is essential for therapeutic decision-making, as not all colonized animals benefit from pharmacological intervention (Pees et al., 2023; Paphitis et al., 2023).

The transmission of *Salmonella enterica* from pet reptiles to their owners is related to the level of contact with owners, hygiene measures adopted, the animal's environment, and issues not yet understood regarding the reptiles' immune system and the factors that influence the transmission of the disease (Pees et al., 2023). Hygiene conditions, avoiding overcrowding, controlling means of contamination, avoiding stress and management errors, and not encouraging the consumption of meat from contaminated reptiles, should be measures to be implemented to reduce the zoonotic risk of salmonellosis in reptiles kept in captivity (Pees et al., 2023; Pawlak et al., 2024).

The clinical manifestations in reptiles, as in most diseases, are nonspecific and variable, and may involve pneumonia, enterocolitis, abscesses, septicemia, osteomyelitis, hepatitis, among others. The most frequent clinical signs are lethargy, anorexia, wasting, paresis, dyspnea, and sudden death (Pees et al., 2023). In the pathology and histology of cases associated with *Salmonella* , necrotizing inflammation of various tissues is observed in most species. Granulomatous necrotizing inflammation is also reported in snakes and sea turtles (Pees et al., 2023)

One of the most reported species in studies associated with RAS was the bearded dragon (*Pogona vitticeps)* (Pees et al., 2023; Paphitis et al., 2023), however, this was also the most popular reptile species in a study analyzing the reptile market as pets (Valdez, 2021).

Therapeutic and preventive management is hampered by the complexity of interactions between the pathogen and the host, as well as the growing concern about antimicrobial resistance (AMR). Recent studies indicate that reptile isolates, both wild and captive, have multidrug-resistant antibiotic profiles of clinical importance, which limits treatment options and reinforces the need for biosecurity-based control strategies and genomic monitoring (Bertelloni et al., 2022; Małaszczuk et al., 2025). In addition, the genetic and phenotypic heterogeneity of *Salmonella enterica* in reptiles is associated with different virulence and antimicrobial resistance profiles, which limits therapeutic standardization and reinforces the need for individualized decisions in clinical and sanitary management. (Mlangeni et al., 2024; Bertelloni et al., 2022). Thus, understanding the prevalence, virulence factors, and drug sensitivity is essential for the development of effective management protocols that mitigate risks to animal and human health.

According to the study by (Pawlak et al., 2024) points out that one of the most relevant vertebrates from an epidemiological point of view regarding the spread of *Salmonella spp.* These are reptiles, in an asymptomatic character, that is, asymptomatic carriers, salmonellosis, when associated with reptiles, occurs in greater predominance in children under 5 years of age, the elderly and immunosuppressed patients. When it enters the gastrointestinal tract, it can cause clinical signs of vomiting and diarrhea in humans, according to reports described by people in the United States and other countries.

2 METHODOLOGY

This study is a narrative literature review, structured with the objective of compiling and discussing the most recent scientific evidence on the management and therapeutic approaches of salmonellosis in reptiles. The research was conducted by consulting the PubMed database, using the descriptors "Salmonellosis", "Reptiles" and "Treatment",

articulated by the Boolean operator AND, according to the standardization of the Medical Subject Headings (MeSH). The selection included articles published from 2021 to 2025, available in full text in Portuguese or English, with a direct focus on the epidemiology and control of *Salmonella* in reptile populations. Studies that did not have a direct link with the theme, duplicate publications, and reviews with low academic rigor were excluded. The screening process involved careful analysis of titles and abstracts, followed by exhaustive evaluation of the selected manuscripts to ensure the reliability of the data. The information was synthesized and organized in a descriptive and integrative way.

3 RESULTS AND DISCUSSION

The prevalence of *Salmonella spp.* In reptiles, it varies geographically and between species, but detection rates remain high in several scenarios. In wild reptile populations in South Africa, the prevalence reached 57.1%, with a diversity of serovars that includes *S.* Typhimurium and *S.* Muenchen (Mlangeni et al., 2024). In contexts of wildlife translocation in New Zealand, screening during quarantine revealed that 11.8% of animals were carriers, highlighting that feedlot management and stress can influence bacterial excretion (Baling & Mitchell, 2021).

Environmental and physiological factors have an extreme impact on the evolution of bacterial and viral contamination. Stress, improper handling, thermal variations, capture handling are some elements that favor immunosuppression and increase bacterial susceptibility and elimination by animals (Baling & Mitchell, 2021). In addition, the confirmation of the presence of salmonella in feces and habitat surfaces demonstrates that the environment can act as a secondary reservoir and can be a direct factor for the spread of zoonotic pathologies to humans (Bruning, et al., 2023). Thus, systematic disinfection and maintenance of hygiene of quarantines, breeding sites and habitats, combined with good animal welfare practices are effective measures for the control of salmonellosis (Paphitis et al,. 2023).

From an epidemiological point of view, the colonization of *Salmonella spp.* in reptiles, it is characterized by high complexity, since the same individual can harbor multiple serovars simultaneously (Pulford et al., 2019). This intra-host coexistence, described both in free-living reptiles and in animals kept in captivity, expands the circulating genetic diversity and makes it difficult to interpret studies based on single isolates, directly impacting health surveillance and zoonotic risk assessment (Mlangeni et al., 2024; Małaszczuk et al., 2025).

Regarding the therapeutic approach, antimicrobial resistance is the main limiting factor. Isolates from snakes in Poland have demonstrated significant resistance to

sulfonamides and aminoglycosides, as well as have a high survivability in human serum, which underlines the invasive potential of these microorganisms (Małaszczuk et al., 2025). Although resistance to drugs of last resort, such as colistin, is still considered low in animal populations (Bertelloni et al., 2022), the presence of multidrug resistance (MDR) genes in free-living isolates suggests increasing environmental contamination that impacts clinical management (Mlangeni et al., 2024).

Considering the variability of the resistance profiles observed in Salmonella spp. isolates from reptiles, the performance of antimicrobial susceptibility tests (antibiogram) is a relevant tool to support the therapeutic choice, especially in clinical cases that require pharmacological intervention. Culture- and antibiogram-guided therapy is associated with reducing treatment failures and limiting the spread of multidrug-resistant strains (Mlangeni et al., 2024; Bertelloni et al., 2022).

The characterization of virulence factors, such as the *invA* and *mgtC* genes, confirms that reptile isolates have the genetic arsenal necessary to trigger pathologies in both the host and humans (Pawlak et al., 2024). For this reason, genomic surveillance through Whole Genome Sequencing (WGS) has become an indispensable tool in the management of outbreaks, allowing accurate tracing of the source of infection, as evidenced in cases of human urinary tract infection associated with pet snakes and multi-state outbreaks linked to bearded dragons (*Pogona vitticeps*) (Bruning et al., 2023; Paphitis et al., 2023).

Additionally, recent studies indicate that strains of *Salmonella spp.* Reptile isolates may have a high capacity to evade the human immune system, regardless of the classic antimicrobial resistance profile. Structural modulation of lipopolysaccharide (LPS) and expression of genes associated with virulence and survival in human serum suggest that the zoonotic potential of these strains is related not only to antibiotic resistance but also to adaptive mechanisms that favor systemic spread after transmission (Pawlak et al., 2024; Małaszczuk et al., 2025). These findings reinforce the need for an integrated approach in the assessment of the health risk associated with reptiles, in line with the principles of the One Health strategy.

Another relevant aspect evidenced in recent studies refers to the role of reptiles as environmental sentinels for the circulation of *Salmonella spp.* in natural and anthropized ecosystems. The detection of rare and genetically diverse serovars in free-living populations suggests that these animals reflect the environmental dynamics of the pathogen, including the influence of human activities such as water contamination and anthropogenic pressure on natural habitats (Mlangeni et al., 2024; Małaszczuk et al., 2025). Thus, the systematic inclusion of reptiles in epidemiological surveillance programs can contribute not only to the

prevention of salmonellosis associated with exotic animals, but also to a broader understanding of the environmental dispersion of strains with zoonotic potential, strengthening preventive strategies from the perspective of one health.

In addition to genetic determinants and virulence, functional studies indicate that strains of *Salmonella spp.* isolates from reptiles have a high capacity to evade the human complement system, independent of the classic antimicrobial resistance profile (Krzyżewska-Dudek et al., 2022). This immunological fitness increases the risk of extraintestinal infections in humans and reinforces and reinforces that the evaluation of zoonotic potential must consider not only the presence of the pathogen, but also its ability to survive and systemic dissemination after transmission (Worley et al., 2023).

In contrast to free-living populations, specimens of reptiles kept in captivity exhibit significantly higher rates of colonization by *Salmonella* spp. Although these animals act predominantly as asymptomatic carriers, the elimination of the pathogen occurs intermittently via the gastrointestinal tract, representing a challenge to sanitary control (Paphitis et al., 2022). The dynamics of fecal bacterial shedding is severely influenced by biological and environmental stressors, including overhandling, adverse transport conditions, and the presence of comorbidities, factors that compromise the animal's immune homeostasis and facilitate the proliferation and dispersion of the pathogen in the environment (Paphitis et al., 2022).

The mitigation of the risks of salmonellosis associated with reptiles depends intrinsically on the dissemination of technical-scientific information at the time of animal acquisition. Providing clear guidelines on the biological risks of reptiles allows owners to make informed decisions regarding the choice of species and the indispensable sanitary precautions (Paphitis et al., 2022). The information should detail household biosecurity protocols and identify the most vulnerable population profiles, aiming to minimize the zoonotic transmission chain (Bruning et al., 2023).

Non-pharmacological management strategies, such as establishing quarantine periods of at least 14 to 21 days for translocated animals, are recommended to reduce the risk of introducing new serovars into naïve populations, although prolonged quarantine should be balanced against the risk of decline in body condition of the animals (Baling & Mitchell, 2021). Clinical management, therefore, should prioritize strict hygiene and education of tutors, reserving the use of antimicrobials for cases of proven systemic disease, in order to avoid worsening bacterial resistance.

In view of the ecological complexity and persistence capacity of Salmonella spp. in reptiles, therapeutic management should be oriented towards clinical control and mitigation

of zoonotic risk, and not towards complete bacterial eradication, which is considered unlikely in most cases, due to the wide environmental adaptation and genetic diversity of reptile-associated isolates (Pawlak et al., 2024; Małaszczuk et al., 2025).

It is worth noting that the detection of *Salmonella spp.* in reptiles should be interpreted with caution, since these animals often act as asymptomatic carriers, with variable bacterial elimination, which may result in underdiagnosis when the evaluation is based on single sampling (Bruning et al., 2023; Bertelloni et al., 2022). These findings reinforce the need for an integrated approach to sanitary management, especially in contexts of quarantine, translocation, and captive maintenance.

According to Bertelloni et al (2022) it is an antimicrobial that has aroused concerns due to the resistance of some pathogens, as found to be more frequent resistant genes in the E.coli strain, as well as in Salmonella genes.

4 CONCLUSION

The results of this study confirm that salmonellosis is a frequent and complex infection in reptiles, due to the possibility of multiple serovars in the same host. The zoonotic relevance is evident, considering the increase in contact between humans and reptiles and the already reported cases of transmission between species. Clinical management should be cautious, especially in view of the antimicrobial resistance to sulfonamides and aminoglycosides observed in certain populations, which limits conventional therapeutic protocols.

Although resistance to drugs of last resort is still considered low, the presence of multidrug resistance genes in free-living populations suggests a warning in clinical management. Non-pharmacological strategies, such as isolation of translocated animals, and strict hygiene measures for humans in contact are key. Finally, the detection of Salmonella spp. in reptiles should be interpreted with caution, since these animals can act as asymptomatic carriers.

Additionally, the findings reinforce that the therapeutic approach to salmonellosis in reptiles should be individualized and, whenever possible, guided by bacterial culture and antimicrobial susceptibility testing, in order to reduce therapeutic failures and limit the spread of multidrug-resistant strains. Considering the wide genetic diversity, the presence of rare serovars, and the environmental persistence capacity of Salmonella spp., management should prioritize clinical control and zoonotic risk mitigation, to the detriment of the attempt to completely eradicate the agent. Thus, the integration between laboratory surveillance, biosecurity, and health education is essential to cope with reptile-associated salmonellosis from the perspective of one health.

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