Artykuł przeglądowy *Review*

European hedgehog (*Erinaceus europaeus*) as a reservoir of zoonotic and potentially zoonotic pathogens

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Summary

The steadily increasing urbanization raises the risk of human contact with wild animals. This article describes nineteen species of bacteria, six viruses, and five species of fungi identified in wild European hedgehog (*Erinaceus europaeus*). The selection was based on the varying zoonotic potential and ability to cause severe diseases in humans. The data came from thirteen countries in Europe and were published between the years 1991 and 2025. The study aimed to expand knowledge about pathogens transmitted by hedgehogs, including those showing antibiotic resistance, to improve human health protection.

Keywords: *Erinaceus europaeus*, hedgehog pathogens, zoonotic pathogens, hedgehog zoonoses

The continuously growing global population contributes to the increasing urbanization of rural and forested areas, which serve as habitats for various wildlife species, including the European hedgehog. The hedgehog is a synanthropic mammal (35, 54), meaning it has adapted to living close to humans. This increases the risk of human contact with wild animals, particularly affecting workers in wildlife rehabilitation centres and veterinarians. Climate change results in the transmission of new diseases through vectors (59). Emerging infectious diseases of wildlife have markedly increased in the last few decades (43). Among other factors is a rising temperature. It contributes to variations in animal host diversity, leading to increased diversity of the tick virome, and vertebrate-associated viruses (51). Zoonotic pathogens pose a significant threat to health and can even be fatal, as exemplified by the rabies virus. In addition, wild animals may indirectly contribute to the spread of antimicrobial resistance (AMR) genes (15).

Bacteria are the most common pathogens in hedgehogs. The most frequently detected bacteria were *Anaplasma phagocytophilum* and *Borrelia* spp. *A. phagocytophilum* was detected in 96.4% of individuals in the Czech Republic (39), and in 61.8% of individuals from Germany and the UK (61). They are a suitable reservoir host for *A. phagocytophilum*. It is an important tick-borne zoonotic agent of humans granulocytic anaplasmosis (39). It is primarily transmitted by *Ixodes* ticks in Europe. *Borrelia* spp. have been detected in five strains. *Borrelia afzelii*, *Borrelia bavariensis*, and *Borrelia burgdorferi sensu lato* were detected in hedgehogs in the Czech Republic, Germany, and the UK (63). Additionally, in Germany, *Borrelia garinii* and *Borrelia spielmanii* were identified (62). Studies in Belgium have confirmed the presence of *B. afzelii*, *B. bavariensis*, and *B. spielmanii* (67). *Borrelia* spp. has also been detected in 92.3% from Switzerland (27). Hedgehogs are reservoir hosts of *Borrelia* spp. *B. burgdorferi sensu lato* is the causative agent of Lyme borreliosis. In humans, it can cause erythema migrans, borrelial lymphocytoma, acrodermatitis chronica atrophicans, arthritis, facial palsy, lymphocytic meningitis, and cardiac conduction disturbances (23).

S. aureus and the *Enterobacterales* order are key contributors to antimicrobial resistance. *S. aureus* is an opportunistic pathogen (68). In studies conducted in Sweden, 60% of hedgehogs carried *mecC*-MRSA (20). Research also conducted in Sweden reports that Methicillin-resistance MRSA was isolated from 64% of tested individuals (9). A study from Denmark showed that European hedgehogs may constitute a reservoir for methicillin-resistant *S. aureus* (MRSA). 61% of hedgehogs carried *mecC*-MRSA, but none of the rehabilitators were infected (56). This suggests that MRSA is a potentially zoonotic bacterium, even though it can cause infections in humans (70). The greatest occurrence of mecC-MRSA cases in humans has been reported in Denmark, where they predominantly result in skin and soft tissue infections (52). As for *Enterobacterales*, European hedgehogs represented an important reservoir of Extended-spectrum β-lactamases and AmpC-type β-lactamases (ESBL/AmpC), producing *E. coli* and other *Enterobacteriacae* (15). In Spain, *E. coli* was isolated in 38.9% of hedgehogs. Additionally, studies in Spain found cephalosporin resistance genes in 13.5% of hedgehogs, and *Enterobacter cloacae* was isolated in 2.2% of hedgehogs (25). In hedgehogs, it causes gastrointestinal symptoms. *Enterobacterales* harbor a variety of CR genes and OXA-48-mediated carbapenem resistance, all of them frequently associated with nosocomial human infections (15). The next dangerous bacterium is *K. pneumoniae*. It was isolated in 20% of hedgehogs in Spain. *K. pneumoniae* were multi-resistant, with co-resistance to fluoroquinolones, tetracycline, sulfonamides, and aminoglycosides (15). In another study, *K. pneumoniae* was also found in 42.2% of hedgehogs in Spain. Hedgehogs are carriers (25). It most commonly causes pneumonia and bloodstream infections in pediatric patients from Turkey (5).

The frequency of occurrence of *Leptospira* spp. and *Salmonella* spp. varies depending on the strain and the country in which they were detected. Strains of *Leptospira interrogans* and *Leptospira borgpetersenii* were isolated in studies conducted in Denmark (22). In Scotland, *Leptospira bratislava* was detected (12). In studies conducted in France, 37.5% of hedgehogs were carriers of *L. interrogans* serogroup *Australis* (7). In Italy, it was detected in 54% of hedgehogs (53). Infected hedgehogs had a higher body weight and displayed chronic shedding (6). Leptospires spread through the bloodstream, mainly lodging in organs such as the liver, kidneys, and lungs, thus establishing a systemic infection (1, 40). *Salmonella typhimurium* was detected in a hedgehog in studies conducted in Spain (50), and in the UK (36). In Norway, it was found in 40% of hedgehogs (29). *Salmonella enteritidis* was isolated in 26% of hedgehogs studied in the UK. For *Salmonella* spp., positive samples accounted for 3%. In hedgehogs, the symptoms of *Salmonella* spp. infection include lymph node enlargement, lymph node abscessation, gastritis, enteritis, peritonitis, and pyelonephritis. Humans can contract *Salmonella* from hedgehogs, but they are not a primary source of infection (38). In humans, *Salmonella* spp. causes gastroenteritis (60).

Rickettsia spp. can be indirectly transmitted from hedgehogs. The DNA of *R. asembonensis* was detected in 55 fleas collected from hedgehogs in a study conducted in Portugal. European hedgehogs are exposed to *Rickettsia massiliae* transmitted by ticks and *R. asembonensis* through fleas (8). *Rickettsia helvetica* was detected in 11.7% of the tested hedgehogs (64). *Rickettsia* sp. is the causative agent of Q fever, a zoonotic disease that can manifest in acute or chronic forms in humans (69).

Four bacterial species have been identified in a notable percentage of hedgehogs in Spain. *Shigella* spp. were isolated in 1.1% of individuals (25). Infections remain endemic in places with poor sanitation and are a leading cause of diarrheal mortality globally (56). *Proteus mirabilis* was isolated in 3.3% of hedgehogs (25). This is one of the most important causative pathogens associated with complicated urinary tract infections in humans (57). *Serratia* spp. were isolated in 4.4% of cases (25). In humans and animals, they can cause opportunistic infections (4). *C. freundii* was isolated in 5.6% of hedgehogs (25). In humans, it can induce urinary tract infections, neonatal sepsis, meningitis leading to brain abscess, respiratory tract infections, gastrointestinal infections, and central nervous system infections in neonates and immunocompromised patients (11). *Citrobacter* spp. infections are often nosocomially acquired, seen in patients with significant underlying diseases, and isolates are commonly drug-resistant (49).

Eight bacterial species were identified in individual cases. *Bordetella bronchiseptica* was isolated in one hedgehog in the UK (36). It causes multifocal pneumonia in humans (48). *Streptococcus pyogenes* was isolated from hedgehog in studies conducted in Germany (10). In England, the *S. pyogenes emm28* strain was identified in a hedgehog. It has been reported to cause multiple abscesses in the liver and on the lymph nodes (24). *S. pyogenes* remains one of the top ten causes of mortality from infectious diseases in Ethiopia (26). *Yersinia pseudotuberculosis* was discovered in two hedgehogs in the UK (36). While *Yersinia* causes acute gastroenteritis in humans, it has also been suspected of having an association with Kawasaki disease (KD), a multisystemic vasculitis primarily affecting infants and young children (71). *Trueperella pyogenes* was detected in three hedgehogs during studies in Belgium (45). It is a rare causative organism of infectious endocarditis in humans (66). *Corynebacterium ulcerans* was isolated from all four hedgehogs in studies conducted in Germany (10). The study group was too small to determine a high frequency of occurrence. In hedgehogs, it causes Hedgehog Diphtheric Disease (HDD), which is an ulcerative skin disease with a high fatality rate (67). This bacterium can cause respiratory and cutaneous diphtheria in humans (10, 68). Studies in Belgium revealed that *C. ulcerans* can be present in the mouth of asymptomatic hedgehogs and might be a constituent of their commensal oral flora (67). *Listeria monocytogenes* was detected in five hedgehogs from the UK. The risk to immunocompetent people of contracting listeriosis from hedgehogs is considered very low to negligible (31). *Mycobacterium avium* was also detected in five hedgehogs in the UK (46). *M. avium* complex (MAC) is a prevalent infectious agent that causes non-tuberculous mycobacterial infections, predominantly affecting the lungs in humans (47).

Viruses are less common in hedgehogs than bacteria. The most frequently detected virus in wild hedgehogs was Coronavirus. It was isolated in 58.3% of individuals examined in studies conducted in Italy (17). They take part in the transmission of Middle East Respiratory Syndrome Coronavirus (MERS-CoV) between bats and humans (65). Hedgehogs serve as wild reservoirs for MERS-like CoVs (17). It has been proved that the primary representative of the *Merbecovirus* subgenus, MERS-CoV, is zoonotic and pathogenic to humans (30). Additionally, MERS-CoV mediates immunologic reactions and diseases such as type 2 diabetes mellitus, obesity, and hypertension, which have been identified as major risk factors for cardio-cerebrovascular diseases (14).

The second most frequently detected virus was *Herpesvirus*. It was detected in 46% of individuals tested in the UK. *Hedgehog gammaherpesvirus 1* (HGHV-1) is endemic there. In Sweden and Switzerland, the presence of *Alphaherpesviruses* was detected, and Swiss hedgehogs were found to be infected with *Human alphaherpesvirus 1*. It causes neurological symptoms in hedgehogs (32). In humans, herpesviruses cause primary and recurrent herpes, including painful erythematous papules or vesicles, itching, sore throat, genitalia, and dysuria (in genital herpes). These symptoms are often accompanied by systemic symptoms such as fever, malaise, and myalgia (16).

In addition to *Coronavirus*, *Mammarenavirus* and *Parvovirus* have also been detected in Italy. *Mammarenavirus* was detected in 3.3% of individuals examined (18). The zoonotic potential has not yet been confirmed in hedgehogs. Additionally, there is no data on the progression of the disease in infected individuals (42). This virus is known to cause severe viral hemorrhagic fevers in humans (18). *Hedgehog chaphamaparvovirus* (HhChPV) was detected in 19.6% of the tested individuals (19). *Parvoviruses* cause a wide spectrum of diseases in humans and animals, including gastrointestinal disorders, immunosuppression, and immune-related pathologies (37). Additionally, hedgehogs serve as reservoirs for *flavivirus*, which causes tick-borne encephalitis (58), and *Rabies virus* which causes rabies (21).

Fungi are less common in hedgehogs than viruses. In Poland (28), isolated dermatophyte species showed that the *Trichophyton erinacei* was the most frequent species (29.9%). It was also detected In the United Kingdom (36). In humans, it causes dermatomycosis, characterized by progressive skin lesions on the hands (33). The second frequently species was *Trichophyton mentagrophytes* (17.9%), which caused a highly inflammatory form of tinea pedis (13). *Trichophyton benhamiae* (13.4%) causes tinea cruris and skin infections (2), and multiple, mildly pruritic lesions on the neck, submandibular region, left forearm, and right scapular region (41). The less frequently detected species are: *Nannizzia gypsea* (11.9%), *Microsporum canis* (10.4%), *Nannizzia nana* (7.5%), and *Nannizzia fulva* (3.0%). Both *Nannizzia* and *M. canis* cause tinea capitis, a common fungal infection (28, 72). *Paraphyton cookei*was detected in of 6.0% hedgehogs (28). Unfortunately, its pathogenicity in humans is not yet fully understood.

The least frequently isolated fungus was *H. capsulatum*. It was detected only in one hedgehog in Germany (34). Dermatophyte infection can be asymptomatic, but it may also result in skin lesions such as spike loss, crusty skin, and erythema (28). In humans, it causes jaundice in the skin and mucous membranes, hepatomegaly, and bilateral pulmonary infiltrates with consolidations and nodular lesions (44).

As for interactions between pathogens, studies in Sweden presented that *T. erinacei* isolated from Swedish hedgehogs can produce benzylpenicillin, which co-occurred with mecC-MRSA. Through this

Tab. 1. Zoonotic and Potentially Zoonotic Pathogens with Public Health Significance

Bacteria	Viruses	Fungi
Anaplasma phagocytophilum (39, 61)	*Coronavirus* (17)	*Histoplasma capsulatum* (34)
Bordetella bronchiseptica (36)	*Flavivirus* (58)	*Nannizzia* spp. (28)
Borrelia spp. (27, 62, 68)	*Herpesvirus* (16)	*Microsporidium canis* (28)
Citrobacter freundii (25)	*Mammarenavirus* (18, 32)	*Paraphyton cookei* (28)
Corynobacterium ulcerans (10, 67)	*Parvovirus* (19)	*Trichophyton* spp. (13,28,36)
Enterobacterales (15, 25)	*Rabies virus* (21)	
Kleibsiella pneumoniae (15, 25)		
Leptospira spp. (6, 12)		
Listeria monocytogenes (31)		
Mycobacterium avium (46)		
Proteus mirabilis (25)		
Rickettsia spp. (8, 64)		
Salmonella spp. (29, 36, 38, 50)		
Serratia sp. (25)		
Shigella sp. (25)		
Staphylococcus aureus (9, 20, 55, 68)		
Streptococcus pyogenes (10)		
Trueperella pyogenes (45)		
Yersinia pseudotubeculosis (36)		

study a high occurrence of mecC-MRSA among hedgehogs has been reconfirmed (20). Infections with *B. burgdorferi sensu lato* were 3.92 times more likely to be detected in HDD (67).

Among other factors, rising temperatures contribute to variations in animal host diversity, leading to increased diversity of the tick virome and vertebrate-associated viruses (51). Among the identified pathogens, bacteria were the most prevalent, with *A. phagocytophilum* being the most frequently isolated. The most commonly detected virus was coronavirus, while the dominant fungal species was *T. erinacei*. The research was conducted in Belgium, the Czech Republic, Denmark, France, Germany, Italy, Norway, Poland, Portugal, Sweden, Switzerland, Spain, and the United Kingdom. *Erinaceus europaeus* is a species that remains insufficiently studied. Due to the cross-sectional nature of the article and limitations in the availability of literature, there was insufficient information provided for all tested hedgehogs to definitively determine the symptoms caused by specific pathogens. Modern technologies play a crucial role as they enable real-time monitoring, the prediction of outbreak risks, early anomaly detection, rapid diagnosis, and targeted interventions during outbreaks (71). The One Health approach is also significant, as it enhances early warning systems by monitoring wildlife.

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