Leptospirosis: A Zoonotic Disease with Reproductive Implications

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ABSTRACT

Leptospirosis, a long-standing zoonotic threat that has been recognized for more than a century, has drawn more attention because of its significant effects on public health, especially when it comes to reproductive health. This bacterial disease, that is caused by the spirochete bacterium of genus Leptospira, is quite common around the world and affects both developed and developing countries. The complex nature of leptospirosis transmission, which is deeply intertwined with eco-epidemiological contexts, demands comprehension of its multiple manifestations. The disease's diverse epidemiology is attributed to the vectors that carry it from urban to rural areas, including contaminated water sources and rats. Within the complex landscape of pathogenesis, leptospirosis presents as an acute bacterial septicemic febrile sickness that affects multiple organs and systems. The disease's severity is highlighted by its chronic form, referred as Weil's syndrome, which affects both people and animals. It also has a major impact on reproductive health, since it increases the risk of infertility, abortion, and stillbirth in females. Diagnostic techniques, essential for prompt intervention, involves dark-field microscopy and serological testing. The diagnosis is complicated, necessitating careful specimen collection. The zoonotic nature of the disease, as evidenced by the facts, demands heightened awareness, especially among the people who are at risk. Effective control strategies such as vaccination, chemoprophylaxis, and herd management are crucial since the disease can impact a wide range of populations, including farmers, sewage workers, and medical personnel. This chapter offers a thorough examination of leptospirosis, covering its etiology, epidemiology, pathophysiology, diagnostics, and complex zoonotic network. The emphasis on reproductive implications highlights the need for more knowledge and investigation to improve animal and human health outcomes in the face of this persistent public health issue.

Keywords: Leptospirosis, Reproductive implications, Weil's syndrome, Zoonotic nature, Public health.

CITATION

Younas K, Saeed L, Umer T, Shah SHR, Umar Z, Adil MT, Noor T, Qamar MH, Jamil H and Umer S, 2023. Leptospirosis: a zoonotic disease with reproductive implications. In: Altaf S, Khan A and Abbas RZ (eds), Zoonosis, Unique Scientific Publishers, Faisalabad, Pakistan, Vol 4: 342-355. https://doi.org/10.47278/book.zoon/2023.160

CHAPTER HISTORY Received: 25-Jan-2023 Revised: 12-April-2023 Accepted: 05-July-2023

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1. INTRODUCTION

Leptospirosis is a zoonotic disease that has been recognized as a public health threat for over a century (Bharti et al., 2003). Both humans and animals are infected by the disease caused by the *spirochete* bacterium of genus Leptospira (Adler & de la Peña Moctezuma, 2010). This disease is commonly found in livestock, wild animals, pets and can infect humans who come into contact with infected animals. Leptospirosis is prevalent in many parts of the world, with more than one million cases reported annually (Picardeau, 2015). The transmission of leptospirosis occurs through direct or indirect contact with the urine of infected animals and contaminated water or soil (Hartskeerl, Collares-Pereira, & Ellis, 2011). The disease can cause a wide range of clinical symptoms, from mild flu-like illness to severe multisystem organ failure (Gouveia et al., 2008). However, recent studies have found that leptospirosis can have significant reproductive implications, especially in women.

Leptospirosis is a global public health concern with an estimated incidence of 1.03 million cases and 58,900 deaths annually (Costa et al., 2015). The disease occurs in both developed and developing countries, with higher incidence rates reported in low- and middle-income countries. Studies have suggested that leptospirosis can cause infertility, abortion, stillbirth, premature birth, and other complications in women (Puliyath & Singh, 2012). Study conducted in Brazil showed that women with a history of leptospirosis infection had a higher risk of miscarriage and premature birth compared to the uninfected ones (Plank & Dean, 2000). In boars, the disease can lead to epididymitis and decreased sperm quality (Cilia, Bertelloni, Cerri, & Fratini, 2021) . Recently, Lilenbaum and Loureiro proposed that the silent reproductive type of leptospirosis, also known as bovine genital leptospirosis, should be treated as a separate disease (Loureiro & Lilenbaum, 2020). It is most frequently caused by strains of the Sejroe serogroup that have modified, and it is connected to early embryonic losses and subsequent oestrus repetition, perhaps as a result of inflammation of the uterus or Leptospira attack on the embryo directly (Libonati, Santos, Souza, Brandão, & Lilenbaum, 2018; Mori et al., 2017). In recent times, it was shown that sheep with leptospirosis had substantial levels of oxidative damage, which contributed to the pathophysiology of reproductive disruption (Silva et al., 2019). Like other ruminants, abortion is the most significant clinical outcome of caprine leptospirosis (Dehkordi & Taghizadeh, 2012). Stillbirth and abortion are two reproductive problems, and the delivery of diseased foals is a frequent outcome in horses (Whitwell, Blunden, Miller, & Errington, 2009). Furthermore, the presence of Leptospira in the uterine environment has related to a localized inflammatory reaction that results in pregnancy losses (Pinna, Martins, Souza, & Lilenbaum, 2013).

Despite growing evidence of the reproductive implications of leptospirosis, the disease remains under-recognized in this context. This chapter aims to provide a comprehensive overview of leptospirosis as a zoonotic disease with reproductive implications. It will review the current epidemiology, transmission, diagnosis, and treatment of leptospirosis, with a specific focus on its impact on reproductive health. It will also discuss the prevention and control strategies for leptospirosis in the context of its reproductive implications.

Overall, this chapter will highlight the need for increased awareness and research into the reproductive implications of leptospirosis to improve health outcomes for animals and humans.

2. EPIDEMIOLOGY: THE PREVALENCE OF LEPTOSPIROSIS

Leptospiral transmission can occur in a variety of eco-epidemiological contexts, including urban, rural, recreation-related, and disaster-related situations. Rats infesting sewage networks, sewage overflowing

during rainstorms, flooded roads, and human being exposed to flooded roadways all contribute to a perfect environment for leptospirosis transmission in urban settings. The source of leptospiral infection in rural areas is frequently agricultural contact with moist fields that may be polluted with rat or farm animal urine (Himani, Suman, & Mane, 2013).
The attack rate, afflicted population, and predominate pathogenic serogroups of leptospirosis in Israel have all altered during the past 15 years. In Israel, the reported assault rate dropped from 2 to 3.6 per 100,000 people between 1950 and 1970, to 0.2 per 100,000 people in the 1980s, and to about 0.05 per 100,000 people throughout the time of their investigation (Kariv, Klempfner, Barnea, Sidi, & Schwartz, 2001). Over the course of the research period, leptospirosis epidemics extended widely and were more frequent, especially in tropical ecoregions. Due to the frequent occurrence of massive outbreaks and high death rates, the effect may be substantial (Munoz-Zanzi et al., 2020).

3. TRANSMISSION

Leptospirosis may be spread by nearly all animals, which contain and expel the organisms from their proximal tubules of the kidneys (Haake & Levett, 2014). The rat is by far the most significant vector of leptospirosis in humans. Because they are found close to human homes and they frequently excrete significant amounts of microorganisms, even months after becoming infected. The most frequent way the disease transferred to people is by skin abrasions and mucous membranes coming in contact with water that has been polluted with infected rat urine. Because they are accidental hosts, people are more at risk when they work or live near the maintenance hosts, particularly rats and farm animals (Rajapakse, 2022).
Leptospirosis transmission can be done either by direct contamination with infected rodents and carrier animals or indirect transmission through environment. Routes of transmission of leptospirosis are illustrated in Fig. 1.

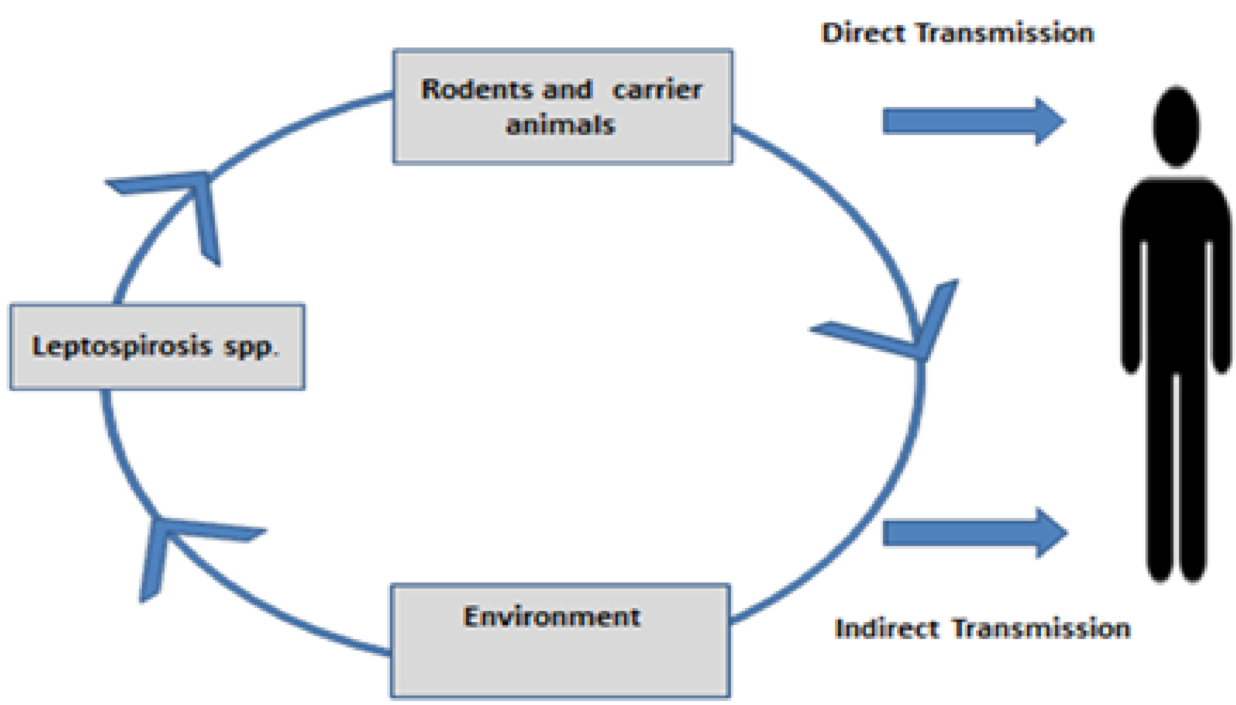

Fig. 1: Routes of Transmission of Leptospirosis.

Some researchers found that a high rate of leptospirosis in cattle presents a significant risk to both human health and agriculture economics (Talpada et al. 2003). *L. interrogans* can be spread to human beings and other animals by being excreted in the urine of sheep and goats (Haji et al. 2022).

4. PATHOGENESIS: UNDERSTANDING THE MECHANISMS OF LEPTOSPIROSIS

Pathogenic leptospires are the source of acute bacterial septicemic febrile illness known as leptospirosis, which can affect both humans and animals worldwide (Costa et al., 2015). Direct contact with infected animals can result in transmission, but this is less common. Instead, transmission is more likely to occur when infected animals' urine contaminates water or soil. The Weil syndrome is the chronic form of leptospirosis, characterized by multiorgan impairment, including renal, vascular, skeletal muscle injury, hepatic, and pulmonary (Goris et al., 2013). Widespread in nature, pathogenic species of Leptospira are maintained in the environment by their life cycles, which involve hematogenous and intercellular diffusion to the proximal kidney tubules of the numerous reservoir hosts.

Leptospira is frequently discharged through urine for short periods of time by humans, who are accidental hosts (Levett, 2015). The urine contaminated soil is cleaned of leptospires after heavy rains and deposited in water bodies, which is the cause of epidemics of leptospira infection. Leptospires can be removed from environmental water sources such as sewage, agricultural fields, wet soil, lakes, water dams, ponds, springs, rivers and decorative water fountains (Escandón-Vargas, Bustamante-Rengifo, & Astudillo-Hernández, 2019). Most severe symptoms of human leptospirosis, including fever, icterus, renal failure, and mortality, are referred to as Weil's disease (O'Toole, Pathak, Toms, Gelding, & Sivaprakasam, 2015). Similar to Weil's disease, domestic animals are susceptible to contracting this acute, potentially lethal illness. Significant kidney damage may develop, especially in dogs under certain circumstances. Horses have persistent uveitis (Verma et al., 2012) and have lower physical ability (Hamond, Martins, Lilenbaum, & Medeiros, 2012). The acute and life-threatening type of leptospirosis in cattle, like that in other ruminants, is uncommon and mainly associated with sporadic outbreaks in calves triggered by accidental strains (Loureiro & Lilenbaum, 2020). In fact, a subclinical chronic form of animal leptospirosis, which is frequently neglected, is the most typical presentation. In this type, reproductive symptoms predominate (Adler & de la Peña Moctezuma, 2010). The chronic form of Leptospira causes significant reproductive abnormalities as a result of colonizing the reproductive canal, which has contributed to economic decline (Mori et al., 2017).

Sant'Anna et al. showed that (living in endemic areas) subclinical leptospiral infection in dogs may be linked to chronic renal disease (Sant'Anna, Vieira, Oliveira, & Lilenbaum, 2019). Cuts and abrasions, mucous membranes like the conjunctiva, weak, wet skin, and mucous membrane of the nose are the primary routes for leptospires into the body. A 7-day bacteraemia is typical. Although thought to be comparable to that in humans and dogs, the pathophysiology of the disease in cats is yet unclear (Murillo, Goris, Ahmed, Cuenca, & Pastor, 2020).

5. CLINICAL MANIFESTATIONS: SYMPTOMS AND DIAGNOSIS OF LEPTOSPIROSIS

Between 20% and 40% of acute febrile diseases are caused by Leptospira (Abela-Ridder, Sikkema, & Hartskeerl, 2010). Weil's Disease, commonly described as a febrile sickness with no discernible symptoms, to multiorgan failure with renal and pulmonary signs (Holla et al., 2018). Additionally, pathophysiological anomalies such as increased blood creatinine levels, hyperbilirubinemia, thrombocytopenia and leukocytosis were seen (Holla et al., 2018; Organization, 2003).

Subfertility and early embryonic mortality are two modest symptoms that are frequently linked to bovine leptospirosis (Loureiro & Lilenbaum, 2020). Although abortion does occur, the chronic phase of an adapted infection seems to be silent. Cattle breeders and doctors commonly ignore it since it usually manifests in a subclinical form (Ellis, 2015). Adapted leptospiral infection in animals has related to less evident reproductive failures such as early embryonic losses and the resulting estrus repeat. Despite the complex aetiology of these symptoms, two recent investigations on cattle have found a substantial correlation between estrus recurrence and seroreactivity against the Sejroe serogroup (Libonati et al., 2018; Mori et al., 2017). Horses may also be affected with genital leptospirosis, which is a quiet chronic reproductive illness that is frequently misdiagnosed and untreated. The main cause of EGL (Equine Genital Leptospirosis) globally is Serovar Bratislava. The most frequent consequences are estrus recurrence and subfertility (Di Azevedo & Lilenbaum, 2022). Long-term reproductive production of herds can be negatively affected by genital leptospirosis (Loureiro & Lilenbaum, 2020). However, severity of the disease varies based on the species that is afflicted and the infecting strain (Ellis, 2015). Researchers have discovered *L. santarosai* in the testes and semen of a boar's reproductive system. As the animal was not excreting significant numbers of leptospires at the time of urine collection and the emphasis of the infection appeared to have been in the reproductive system, they were also able to find the bacteria in kidney tissue but not in urine (Diaz et al., 2022). Ruminant leptospirosis can manifest as an acute illness or, more frequently, subclinically. Loss of appetite, irritability, diarrhea, opaque furs, epidemic abortions, and milk drop syndrome are all symptoms of acute illness (G Martins, Brandão, Hamond, Medeiros, & Lilenbaum, 2012). Severe sickness is typically linked to accidental serovars, primarily Pomona, Ballum, Icterohaemorrhagiae, or Grippotyphosa, and is frequently associated with lambs and goat kids (Vermunt, West, Cooke, Alley, & Collins-Emerson, 1994). Subclinical infection, on the other hand, is mostly characterized by reproductive issues, such as infertility, an increase in the number of services per conception, longer calving intervals, abortion, and the frequency of stillbirths and poor lambs/goat kids (Gabriel Martins & Lilenbaum, 2014). In women, the results of pregnancies have been as diverse, including foetal loss and miscarriage (often within the first few months of pregnancy) (Carles, Montoya, Joly, & Peneau, 1995; Shaked, Shpilberg, Samra, & Samra, 1993), congenital infection (Shaked et al., 1993), stillbirth (Baytur et al., 2005) and oligohydramnios, as well as successful deliveries of healthy newborns (Gaspari et al., 2007). Foetal CTG (cardiotocography) monitoring also seems relevant, especially in late pregnancy and severe stages of illness, given the potentially bad pregnancy outcomes of stillbirth and miscarriage linked with leptospirosis in pregnancy (Koe, Tan, & Tan, 2014). A diagrammatic representation of disease manifestation is shown in Fig. 2.

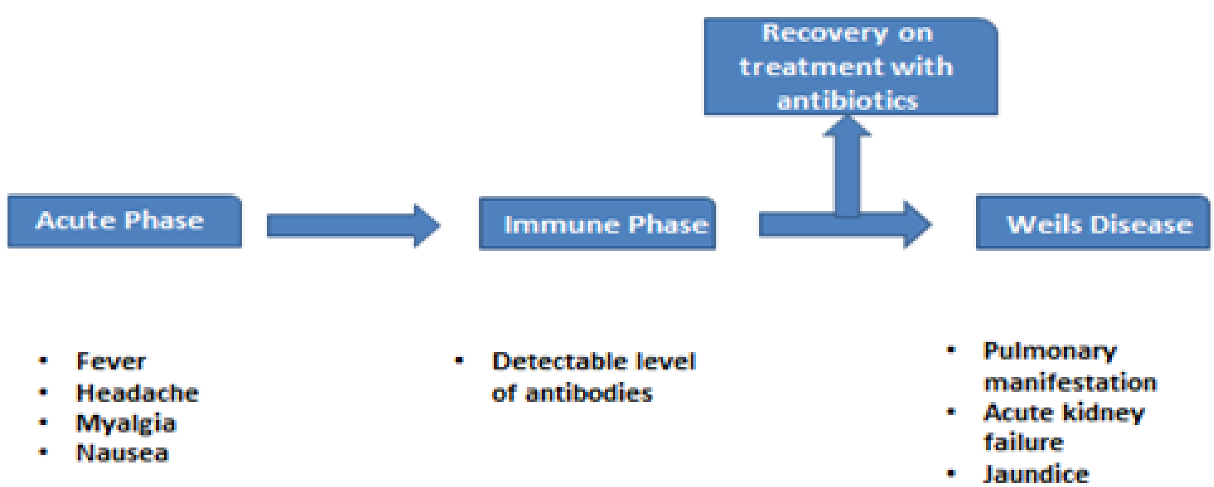

Fig. 2: Diagrammatic Representation of Disease Manifestation.

6. DIAGNOSIS

Leptospirosis diagnostic success is influenced by the kind and timing of specimen collection. During the acute phase, the organism is known to spread quickly into bodily fluids and tissues including CSF (cerebrospinal fluid) and blood (Mullan & Panwala, 2016). Blood, bodily fluids, and urine are the specimens that were collected. The information on specimen collecting is provided in Table 1.

Table 1: Specimen Collection Guide: Comprehensive Information Table for Proper Sampling.

Sample	Objective	Collection Time	Preservatives
Blood	Culture, dark field microscopy, and isolation. Serological test	Prior to seven days of antibiotic treatment.	Fresh within 4h. Chilled and fresh within 4h
Serum	Serological test	After 5 to 7 days	Chilled and fresh within 4h.
Urine	Culture, DFM, and isolation	After 5 to 7 days	Urine is collected immediately after urination and then diluted with phosphate-buffered saline (pH7.2). Within 4 hours, you must arrive at the lab.
CSF	Serological test	After 10 days	Chilled and fresh within 4h.
Aqueous humor	Serological test	After 10 days	Fresh, chilled, within 4h. Aqueous humor tends to gel.

7. DETECTION METHODS

Serological procedures, such as the Microscopic Agglutination Test (MAT), culture isolation of Leptospira, genomic DNA identification using molecular methods, antibody detection, and dark-field microscopy (DFM), are used to diagnose leptospirosis. Fig. 3 shows pictorial representation of diagnostic methods.

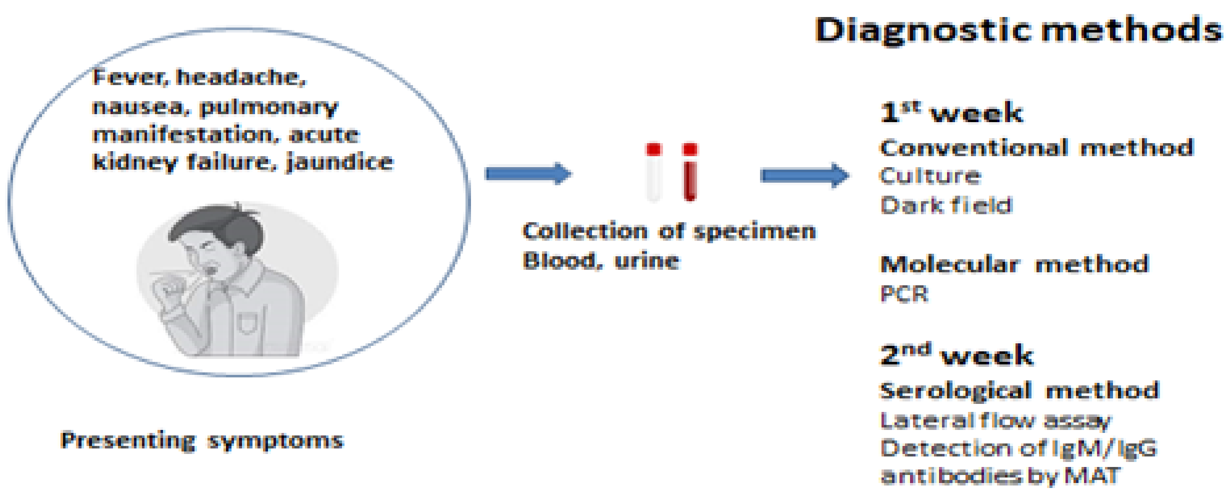

Fig. 3: A Pictorial Representation of Diagnostic Methods

For the diagnosis of leptospirosis, there are two conventional methods i.e, dark field microscopy (DFM) and cultural method (Pinto et al., 2022). Using DFM, it is possible to show that Leptospira is present in bodily fluids such as blood, serum, urine, and CSF. Clinical specimens must be analyzed using experienced people who must recognize the organisms, a sophisticated dark field microscope, and the clinical samples must be handled with biosafety (Niloofa et al., 2015). Biological fluids isolation and culture of Leptospira including blood, CSF, and urine are regarded as standard methods for the diagnosis of leptospirosis (Gökmen, Soyal, Kalayci, Önlen, & Köksal, 2016). Serological tests such as microscopic agglutination tests, IgM ELISA, and rapid diagnostic tests are used for the diagnosis of leptospirosis. Some molecular methods are used for the diagnosis of leptospirosis such as polymerase chain reaction (PCR), chip-based RC-PTR kit, real-time PCR, and loop-mediated isothermal amplification (LAMP) (Pinto et al., 2022). Leptospirosis can be detected by various techniques as described in Table 2.

Table 2: Comparative Analysis of Different Diagnostic Techniques

Tests for Diagnosis	Specimen required	Advantages	Disadvantages	Reference
Microscopic agglutination test	Serum CSF Aqueous humor	• Easily available • Determines serogroup	• Only in specialized laboratory • May be negative for the first 5-7 days • Cross-reaction might lead to unclear interpretation	(Cole Jr, Sulzer, & Pursell, 1973)
ELISA	serum	• May detect infection earlier than MAT	• Not serogroup specific • Not widely available	(Rosa et al., 2017)
Indirect Haemagglutination	Serum	• May detect an infection before MAT • Effective in a variety of host species	• Not serogroup specific • Not easily available	(Sykes, Reagan, Nally, Galloway, & Haake, 2022)
Bacterial culture	Urine Blood Serum Tissue CSF Aqueous humor	• Clearly demonstrated presence of the organisms	• Technically challenging • Long turnaround time	(Bhatia, Umapathy, & Navaneeth, 2015; Fornazari et al., 2012)
Dark field microscopy	Urine Blood CSF Aqueous humor	• Fast results	• Handling of potentially infective samples	(Bhatia et al., 2015)
Polymerase chain reaction	Urine Tissue Plasma	• Fast results • Available at specific laboratories	• Not serogroup specific	(Brown et al., 1995)
Real time PCR	Urine Plasma Tissue	• Early acute disease • Detects response to treatment	• Not serogroup specific • Equipment cost	(Riediger et al., 2017)
LAMP assay and modification	Plasma	• Acute stage • To recognize relatedness of leptospira	• Not serogroup specific • Lack of specificity	(Sengupta et al., 2017)
Lateral flow assay	Serum	• Pen side test • Screening test • No specialized equipment/training	• High titer is mandatory • Low stability • Only qualitative detection	(Deenin et al., 2022)

8. ZOONOTIC NATURE: THE ROLE OF ANIMALS IN THE TRANSMISSION OF LEPTOSPIROSIS

Since both domestic and wild animals can carry leptospires, everyone is at risk of contracting the disease. Those most at risk include medical professionals, people who care for animals, farmers and agricultural workers, fishermen, rodent catchers, water sports enthusiasts, members of the National Disaster Response Force (NDRF), volunteers for rescue efforts in flood-affected areas, sanitary and sewage workers, etc. (Karpagam & Ganesh, 2020). Direct human-to-animal contact has a lower risk of transmitting Leptospira than indirect contact. Leptospira infection in humans is spread by accidental or intentional contact with contaminated water or soil by carrier animals (De Brito, Silva, & Abreu, 2018). Domestic animals, wild animals, and peri-domestic animals that are asymptomatic carriers keep a variety of Leptospira spp. in their renal tubules and excrete them in their urine for a period of time that can vary from a few weeks to a few months. In rare cases, life-long perseverance without an animal carrier has been observed (Herman, Mehta, Cardenas, Stewart-Ibarra, & Finkelstein, 2016). In urban slum areas, rats are the most common carrier and infection source because they show no symptoms. They spread disease by urinating in public places, contaminating soil and water sources, and acting as a reservoir for the pathogen. There are reports of 104-107 leptospires in the urine of infected or carrier rats (Witchell et al., 2014).
Leptospires are carried from the urine-contaminated ground and deposited in water bodies by heavy rain, which is the reason leptospire infection epidemics are usually linked to floods and storms. Environmental water sources including sewage, farm fields, moist soil, ponds, rivers, lakes, streams, water reservoirs, springs, and even beautiful water fountains may all be treated to eliminate leptospires (Escandón-Vargas et al., 2019). When there are floods, rain washes the fertilizer out of the soil and raises the pH, which encourages leptospire development and survival (Shekatkar, Harish, Menezes, & Parija, 2010). Pathogenic leptospires may live in fresh water and damp soil for weeks to years, particularly in slightly alkaline conditions (Trueba, Zapata, Madrid, Cullen, & Haake, 2004). Humans can become infected by contact with contaminated water and soil, as well as very infrequently through ingestion and inhalation while engaging in work- or leisure-related activities. Only a few cases of leptospirosis spreading between people and indirectly through animal bites have been reported. (Musso & La Scola, 2013). (i) exposure at work, such as farmers, veterinarians, slaughterhouse workers, animal caretakers, gardeners, fishers, sewage workers, and rice mill laborers; (ii) traveler exposure, such as those who visit leptospirosis endemic areas without taking the necessary precautions; (iii) freshwater sports participation, such as canoeing, caving, surfing, etc.; and (iv) Volunteers that labor in flooded areas to provide disaster assistance (Karpagam & Ganesh, 2020). The zoonotic nature of the disease is illustrated in Fig. 4.

9. REPRODUCTIVE IMPLICATIONS: EFFECTS OF LEPTOSPIROSIS ON REPRODUCTIVE HEALTH

Host-adapted leptospires infections, such as those caused by strains from the Sejroe serogroup, are frequently linked to bovine leptospirosis. Adapted strains of bovine leptospirosis can cause abortions, foetal deaths, premature births, and the birth of weak and/or underweight calves, however these symptoms are less common and are more closely associated to subfertility and early embryonic death (Loureiro & Lilenbaum, 2020). Leptospirosis frequently results in no or only mild acute clinical symptoms after bacterial contact to mucosal membranes. Serovar Hardjo infection can cause abortions, stillbirths, or the birth of weak calves, however these effects often only manifest themselves in pregnant cows that get the infection for the first time (Grooms, 2006). In Rio de Janeiro, Brazil, leptospirosis has recently been identified as the most prevalent and potentially the main disease affecting reproductive in small ruminants (G Martins et al., 2012). Some researchers find out, in several of Rivers State's coastal settlements, caprine leptospirosis is endemic. These goats have subclinical Leptospira infections, which are extremely important for public health and affect the reproductive health of goat (Oruene & Bekwele, 2020).

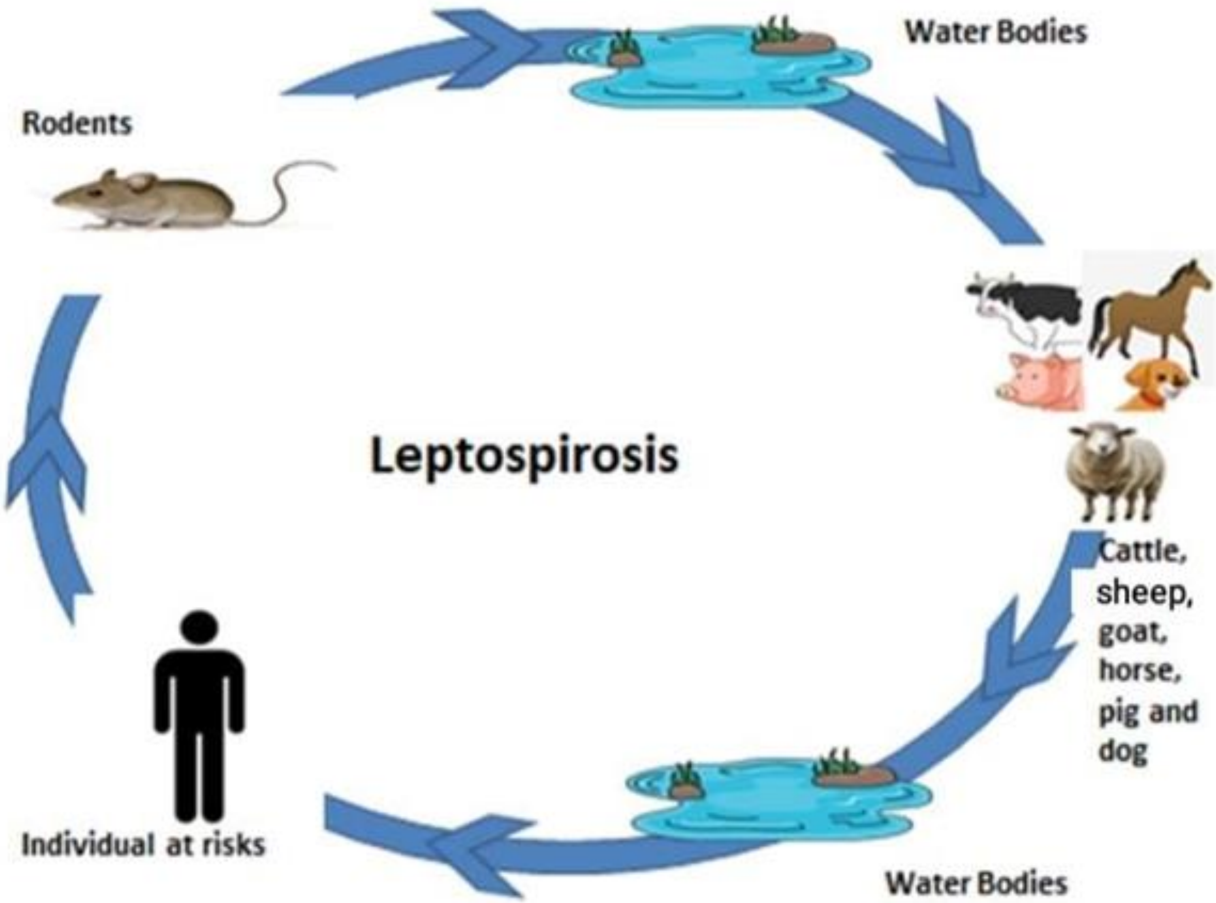

Fig. 4: Zoonotic Nature: Illustrating the Interspecies Nature of the Disease"

Leptospirosis is a serious condition that affects the reproductive system in horses. It causes significant economic damage because of the high cost of treatment, animal fatalities, and, most importantly, decreased reproductive efficiency that is characterised by subfertility, abortion, foetal death, and a poor incidence of embryo recovery (Di Azevedo & Lilenbaum, 2022). The majority of seropositive animals were over 6 years old, and females were more likely to get the disease than males. However, location, breeds, interaction with dogs or other domestic animals, and gender were not risk factors for infection (Da Silva et al., 2020). Leptospirosis in pigs is typically a subclinical disease that contributes significantly to economic losses for pork producers in the form of stillbirths, abortions, and abnormalities in the estrous cycle (Moreno et al., 2017). Pigs have been shown to have infections from Leptospira interrogans, L. borgpetersenii, and serogroups such Canicola, Pomona, Australis, and Tarassovi (Fernandes et al., 2020). The current study's findings confirm that the genital-urinary system is a significant extrarenal source of leptospire infection. The recent identification of L. interrogans serogroups suggests that this serovar is linked to infections of the reproductive system and has to be taken into consideration in swine production enterprises (Gomes et al., 2022).

Dogs are frequently affected by leptospirosis, although studies on chronic infection have just currently been studied. Reproductive failure is also included (Johnston et al. 2019), but less frequently than in ruminants. Leptospira infection has also been related to feline stillbirth (Reilly et al. 1994).

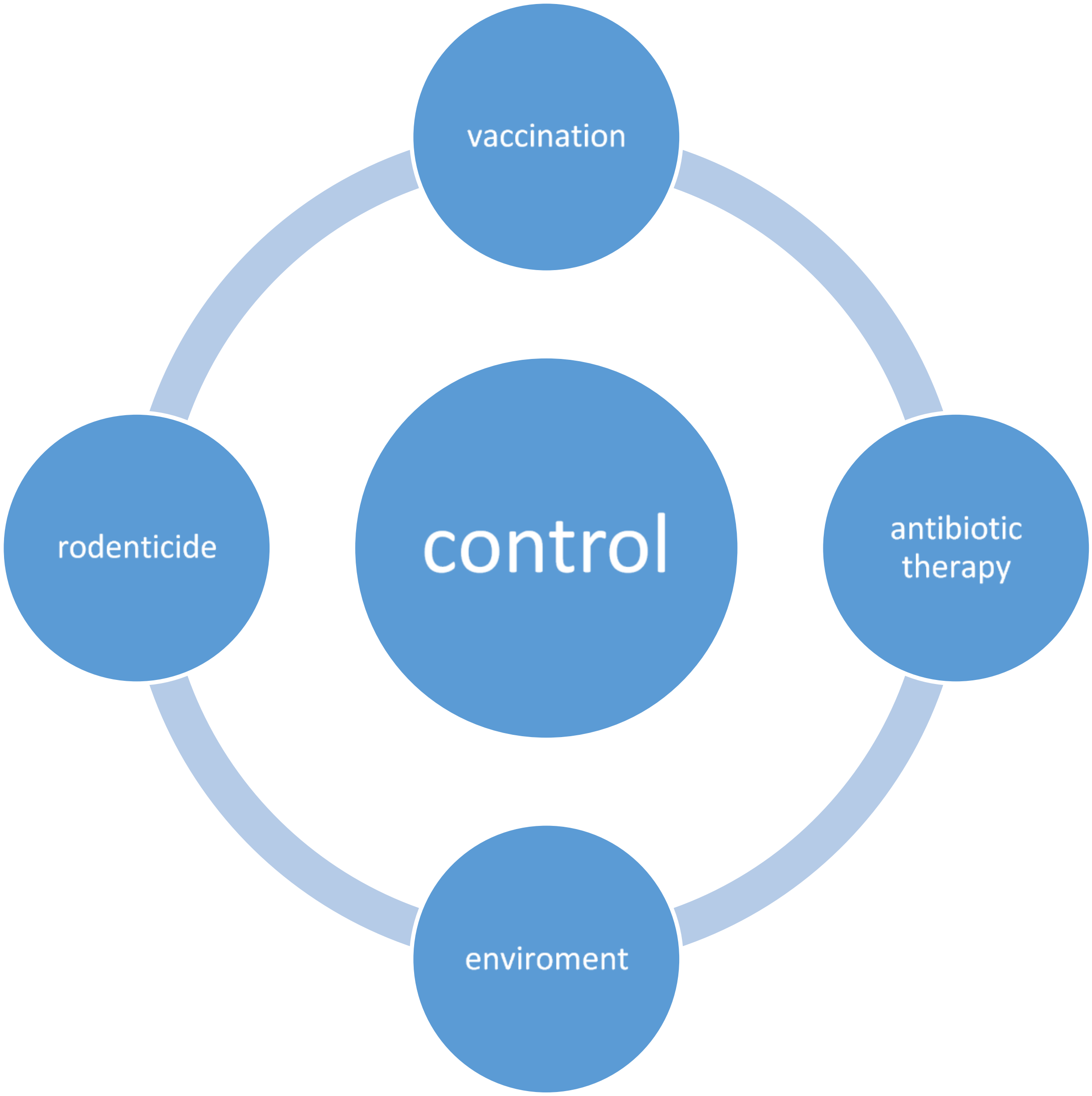

Fig. 5: Effective Disease Control Strategies

10. TREATMENT

The main goal of therapy is to stop the infection before liver and kidney damage becomes severe. When symptoms appear, antibiotic treatment is suggested as soon as possible. The results of treatments are frequently unsatisfactory since animals typically are brought in for treatment after the septicemia has subsided. The secondary goal of therapy is to control carrier animals' leptospiruria and make them safe to remain in the group. Leptospirosis treatment depends only on the type of pathogen involved and how severe the illness is (Grassmann, Souza, & McBride, 2017). Oral azithromycin, doxycycline, ampicillin, and amoxicillin are all choices in a moderate case of leptospirosis (Charan, Saxena, Mulla, & Yadav, 2013). The recommended medications for severe leptospirosis include doxycycline, tetracycline, ampicillin, amoxicillin, penicillin, and azithromycin, which is also very effective against Leptospira species in the early stages of the disease. Leptospirosis-related fever and acute renal failure in horses have been effectively treated with ticarcillin, penicillin, and enrofloxacin (Frellstedt & Slovis, 2009).

11. CONTROL STRATEGIES

There are not any general recommendations for the prevention and management of leptospirosis in humans because of the complicated and dynamic epidemiology. Domestic animal control methods, however, are frequently much simpler since they may be applied to populations and have the potential to isolate those populations. A few successful strategies are now being used to eradicate the illness. One of the preventative ways to manage the illness in healthy individuals is vaccination. There is no vaccine for leptospirosis in humans, but there are a variety of animal vaccines that can prevent the disease, although they are more effective in preventing disease in domestic animals than in wild animals. Controlling the incidence of the disease in domestic and wild animals will help to eradicate it in people (Bashiru & Bahaman, 2018). Chemoprophylaxis is used with doxycycline 200mg once a week when there is a high chance of exposure to illness. While it might be feasible for travellers, it is more critical in a big city (Gopi, Sri, Krupamai, Magesh, & Dhanaraju, 2021). Further abortions in beef herds are prevented by vaccination and antibiotic treatment of all animals, but in dairy herds, only diseased animals are typically treated because of the probable loss of milk sales.

Wearing protective clothing (such as gloves, safety glasses and boots) helps stop the spread of the disease, although this is not always feasible; for instance, wearing boots in a paddy field is not an option (Hartskeerl et al., 2011).

The only way to control rodent populations is to handle them constantly and actively. The use of rodenticides is dangerous (creation of resistance population) and requires expertise of such control (Painter et al., 2004). Herd management techniques can lower the risk of disease transmission inside and between domestic animals. These consist of vaccination and/or carrier treatment. Effective control strategies are illustrated in Fig. 5.

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