

## EPIDEMIOLOGY AND ZONOTIC IMPACT OF BRUCELLOSIS IN RUMINANTS FROM A ONE HEALTH PERSPECTIVE

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Submitted: February 25, 2026; Revised: March 30, 2026; Accepted: April 4, 2026; Published: April 30, 2026

### ABSTRACT

Brucellosis is a global chief zoonotic infection that plagues all ruminants and humans and results in reproductive problems like infertility, abortions, and low milk manufacturing in livestock sector, and febrile diseases with chronic complications in humans. This disease has developed in a significant economic problem and a health concern within the community. Especially in endemic areas where the people have very close contact with the animals and the consumption of unpasteurized dairy products is dominant. The key reservoirs are ruminants that spread from animal-to-animal and animal-to-human infections and environmental persistence of *Brucella* continues to keep its transmission. The risk factors are reproductive management, biosecurity of farm, Herd size, occupational exposure and informal livestock trades. The test, vaccination, and slaughter policies with increased farm hygiene and public awareness campaigns is necessary to decrease the source of the infection and the transmission of Brucellosis. One Health is a framework that includes animal health systems, human health systems, and environmental health systems. One health is vital to the coordination of initial identification, surveillance and the application of evidence-based interventions. The significance of policies, diagnosis, establishment of intersectoral cooperation, and the promotion of epidemiological, and vaccine efficiency in the research improves the achievement of the control and eradication programs. A universal One Health way out to the current issue of brucellosis is not only the reduction of the burden in animal and human health but also sustainable livestock management, resilience of people and economic sustainability. This review provides zoonotic effect, current synthesis of the epidemiology, and control and regulatory measures against brucellosis in ruminants and humans with main accent on the relevance of interdisciplinary tactics in the management of the brucellosis.

**Keywords:** Brucellosis, Zoonotic disease, Ruminants, One health approach, Epidemiology.

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### INTRODUCTION

Brucellosis is a chief bacterial zoonotic disease with global significance, both in livestock, and in humans. Brucellosis cause severe problems to the animal production system and public health. The disease has the ruminants such as cattle, sheep and goats are the main reservoirs among domestic animals. The brucellosis Infection in animals causes reproductive disorders like low milk production, infertility abortion. This results in great losses to livestock industries and farmers. The brucellosis is a

feverish disease in humans which is characterized by a wide range of clinical issues mild like conditions to chronic complications and cause difficulty in quality of life [1]. Brucellosis is of specific concern in areas where livestock rearing is absolutely a main source of living in rural living areas and where a use of consuming unpasteurized dairy products is mainly preferred [2].

The epidemiological research has been focused mainly toward the ruminants. Since it is not only a

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cause of infection to humans but a key indicator of disease prevalence among livestock. The people and animals living together in rural, and urban environments increases the spread of the transmission of every zoonotic infection such as Brucellosis. This highlights the importance of combined control strategies [3]. The Brucellosis is extremely important to human health as it is risk to the veterinarian, abattoir staffs, and farmers. Because the animals are traded unofficially in livestock sector, poor farm biosecurity and limited access of veterinary services in the developing countries. This play a vital role in spread of the disease and persistence of the disease [1].

Since Brucellosis is complex zoonotic disease. It transmits by many sources and is multifactorial. Hence it needs a one health approach that integrate animal, human, and environmental health [4]. One Health approach aids the use of coordinated and organized strategies to deal with human health outcome and animal reservoirs. Furthermore, the environment factor may cause for transmission of disease. Such an integrated framework is necessary for developing effective control measures and thus strengthening surveillance system. Ultimately reducing the disease burden [5, 6].

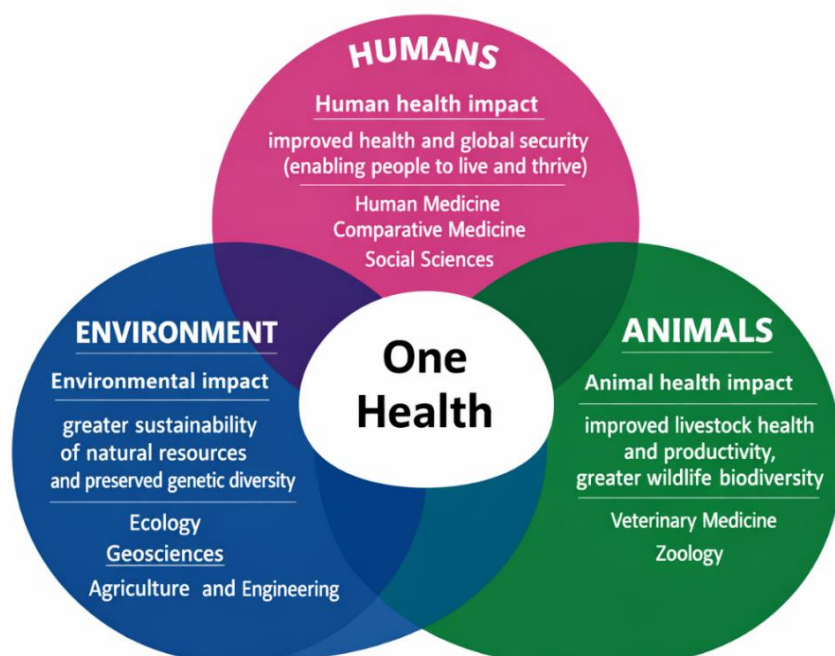
## ETIOLOGY AND MICROBIOLOGICAL CHARACTERISTICS

### Brucella Species Affecting Ruminants

Brucella is the genus of bacteria which cause Brucellosis. Brucella is small, gram negative, non-motile and is facultative intracellular coccobacilli.

The uniqueness of this bacteria is the probability to multiply and survive in the macrophages of the host body. The genus contains several species that have a ideal host and then they are the actual cause of infection in a broad spectrum way in wild and domestic animals[7]. Further in ruminants, the only Brucella species are chiefly involved and causes the reproductive disorders and systemic disease. The microbiological properties of organisms are important for the epidemiology of the disease, the diagnosis of the disease, and the formation of effective methods for its control[8].

The Brucella species are usually responsible for causing disease in ruminants such as B suis, B.melitensis B. abortus .Basically B. abortus is a disease-causing organism in cattle which leads to infertility, abortion, and low milk production[9]. The Brucella melitensis is primarily a pathogen of sheep and goats. It is considered the most pathogenic species of the genus Brucella for humans and can cause severe disease when transmitted through zoonotic way exposure [10]. B. suis is a primary infection of the swine. Although small ruminants are infected occasionally.it is seen in mixed farming systems and all of the species have individual virulence factors which includes smooth outer membrane of lipopolysaccharide. This increases resistance to host immune responses and enables its survival in the cell. Virulence and Host specificity differ in their effect on clinical outcome and brucellosis epidemiology, and both in humans and animals [11].



**Figure 1:** Conceptual overview of the One Health approach to brucellosis in ruminants, highlighting the interrelationship among human, animal, and environmental health.

### **Pathogenesis in Ruminants**

The Pathogenesis of Brucellosis in ruminants is severely associated with its reproductive predilection. After entering the body The macrophages absorb the Brucella bacteria and carried them to the spleen, lymph nodes and reproductive organs after entering in the body via skin cuts or mucous membranes [12]. The Brucella bacteria have a preference towards the placenta in pregnant animals. Where they multiply at high rate causing abortion .The infected Men have epididymitis and orchitis that leads to low fertility in men. The Persistence of brucella bacteria in the reticuloendothelial system results into intermittent bacteremia and prolonged shedding in reproductive secretions, urine and milk. These characteristics make ruminants effective reservoirs and facilitating transmission among the Human beings and herds [13].

### **GLOBAL AND REGIONAL EPIDEMIOLOGY**

#### **Global Distribution**

Brucellosis is considered as one of the most prevalent zoonotic disease affecting Humans and Animals population The Brucellosis shows significant variation because in some regions it is almost eradicated while in some area highly endemic [14]. The Brucellosis disease is spread in South Asia, and Latin America, Middle East. The livestock farming is a major livelihood activity in these area. These areas continue to suffer from brucellosis because of the Poor awareness among farmers, poor immunization program, and lack of proper veterinary facilities availability. Whereas the brucellosis is almost inhibited by developed nations. The regions in these developed Countries have extensively implemented vaccination program, developed strict importation regulation, and slaughter policies [15].

#### **Epidemiology in Developing Countries**

Socioeconomic and structural factors have made brucellosis a major challenge in developing countries. n rural region, particularly in smallholder farming system and mixed farming system the absence of basic biosecurity measures have made easier for infection to occur and spread among them and in herds [2]. Due to Informal livestock trade and uncontrolled animal movements are major pathways for introducing infected animals into susceptible populations. The widespread intake of dairy products and unpasteurized milk constitutes a major route for zoonotic infection in humans. The reporting and surveillance systems in such areas is usually very weak resulting in a poor assessment of the actual disease burden. Therefore, , the health of the population, and rural economies, the livestock productivity in developing countries is still affecting by Brucellosis[16].

#### **Epidemiology in Pakistan**

The prevalence of brucellosis among ruminants in Pakistan is endemic and it shows considerable

variation in livestock species and across provinces Brucellosis primarily affects cattle, sheep, and goats and its incidence is higher in large and semi-intensive farms than in small-scale holdings farms [17]. Factor such as insufficient regular vaccination, high herd density, poor management practices, and poor veterinary care leads to the persistence of disease transmission. Brucellosis in humans is most commonly observed among consumers of raw milk, livestock handlers, and dairy workers. The high incidence of the disease in Pakistan underscores the need for integrated interventions involving in the Policy approaches, public health, and veterinary services [18].

### **TRANSMISSION DYNAMICS**

#### **Animal-to-Animal Transmission**

The spread of brucellosis in ruminants occur through direct contacts with the secretions and infected ruminants [19]. The Brucella organisms are present at higher level in the milk of infected animal, vaginal discharge and in the aborted fetuses. This than provide a source for transmission to livestock [12]. Particularly in large or semi intensive agricultural systems the close contact of herd increases rapid spreading. The transmission is further promoted by having watering stations, and residential facilities, and common grazing grounds. This is especially susceptible to young animals and the disease infect at an early stage causing them to become more chronic carriers. This adds to the long-term presence of the disease in the herds. Appropriate animal-animal transmission knowledge is a crucial to successful implementation of herd-level control measures and preventing new infections [20].

#### **Animal-to-Human Transmission**

Basically Brucella is transmitted to humans due to indirect or direct contacts with infected the animals. Dairy handlers, abattoir workers, Farmers, and veterinarians are exposed to occupational Brucella infection through contact with dairy products, infected tissues, consumption of unpasteurized milk and parturition [21]. The pathogen of Brucella chiefly causes infection in humans by entering into the body either through skin abrasions, ingestion or by mucous membranes [22]. Zoonotic risk is particularly high in regions where the consumption of raw milk is culturally accepted practice. Consumption of dairy products, handling of aborted materials without protective measures, and exposure during slaughter or veterinary activities are additional risk factors that are responsible for human infection The Knowledge of the animal-human transmission mechanisms is necessary to the development and improvement of specific interventions aimed at promoting human health and training at-risk groups of individuals [23].

### **ZOONOTIC IMPACT IN HUMANS**

#### **Clinical Manifestations**

Human brucellosis can present with a broad range of clinical symptoms from mild and nonspecific to

severe and chronic complications. Brucellosis often begins initially with symptoms like headache, periodic fever, malaise, exhaustion, and joint pain, or muscle pain. Spondylitis Chronic brucellosis may persist for months or year causing long-term malaise, impaired quality of life and recurrent fever. The disease poses a serious health concern in endemic regions due to different clinical manifestations and the potential for delayed presentation [22].

#### **High-Risk Groups**

Certain groups are more susceptible to brucellosis due to or lifestyle factors or occupational exposure. Workers such as abattoir workers, Livestock handler, farmers, and veterinarians are actually at a higher risk of contact with the infected animal or contaminate animal product and particularly susceptible to brucellosis. People who used to drink raw or unpasteurized milk and dairy products and dairy workers are also at high risk [24]. In rural areas, where domestic animals are closely integrated into daily life, women and children are at risk of exposure to brucellosis while performing household chores such as feeding, milking, or cleaning animal stables. Identifying these high-risk groups is essential for implementing targeted educational campaigns, preventive measures, and early diagnostic interventions.

#### **Public Health Burden**

Brucellosis has a substantial impact on human health and remains highly prevalent in regions where the disease is endemic and effective control measures are deficient. Because the symptoms of brucellosis are often non-specific, the disease is frequently misdiagnosed, leading to prolonged illness, unnecessary treatments, and increased healthcare costs. The Chronic brucellosis leads to loss of productivity long-term disability and adverse socioeconomic consequences at both the community levels and household Furthermore, brucellosis contributes to the cycle of poverty in rural areas by reducing people's ability to work and make income from the livestock production. Inadequate diagnostic capabilities, lack of effective surveillance, and underreporting make it challenging to accurately determine the true burden of human brucellosis [25].

#### **ECONOMIC IMPACT**

##### **Livestock Sector Losses**

Brucellosis has long been a major economic burden on the livestock industry because of its direct effects on animal health and animal productivity. Ruminants infected with the brucellosis causes decrease milk production, infertility, still birth, abortion and reduced farm productivity. Frequent reproductive failures in herds cause increase cost of culling and replacement and further straining farm finances. Chronic infection can also affect meat production by reducing growth rates and compromising carcass quality. The economic impact is particularly severe in regions with ruminant

populations, where livestock production constitutes a primary source of revenue generation. The overall effects of brucellosis on the livestock industry may impede agricultural output in a country and negatively affecting food security and the economic conditions of rural populations [26].

#### **Household-Level Impact**

The presence of brucellosis in the domestic livestock production system affect adversely household income, food security and livelihoods. Even a single loss for a smallholder farmer is very costly as they rely limited number of animals breeding stock, milk and meat. Abortions and decrease milk productions directly leads to decrease household income thereby limiting the capacity to buy food, healthcare and education. The chronic human brucellosis serves as an additional complication as it increases the healthcare costs and decreases the working power. This may result in a dual economic burden on families living in endemic area because the disease affects human health and livestock productivity. This cycle of losses leads to Persistent poverty and social vulnerability, especially among rural populations that mainly depend on livestock for their livelihood [27].

#### **National Economic Burden**

The widespread economic impact of brucellosis on the national level also occurs on the health systems of the population, the trade and the agricultural productivity. Governments incur high expenses in controlling of the outbreaks including diagnostic, vaccination and treatment services to human beings and animals. Brucellosis serves as a problem in the trade of livestock because infected herds have a lower marketability and basically may not be allowed to leave or enter in the domestic and foreign markets. The economic impact also includes indirect costs like the loss of human workforce productivity through illness. These cumulative losses can be gigantic in nations where brucellosis is endemic and this needs strategic interventions involving policy interventions, veterinary and public health to reduce the economic impacts[26].

#### **DIAGNOSIS AND SURVEILLANCE**

##### **Diagnostic Tests in Animals**

In ruminants the brucellosis cannot be controlled and managed without proper diagnosis. Variety of serological tests are routinely used to identify the presence of antibodies against *Brucella* species The Rose Bengal Plate Test is a very common test. Which is used to identify *Brucella* antibodies. This can be quickly conducted and is also relatively inexpensive specially when used in the routine diagnosis process. The ELISA tests are usually more specific and sensitive and it can be used to undertake mass herd surveillance [28].The molecular methods for detection such as polymerase chain reaction .This make it possible to detect bacterial DNA and differentiate between *Brucella* species. This is useful in outbreak investigations and

epidemiological research. Both widely used diagnosis techniques have strengths and weaknesses and their decision is usually determined by the availability of population size, resources and the objective of testing [29].

#### **Diagnosis in Humans**

Human brucellosis is also challenging to diagnose because it has nonspecific signs and as they may resemble with other febrile diseases. The diagnosis performed through laboratory is based on use of serological tests that's includes the standard agglutination test and ELISA. Both of this identify *Brucella* antibodies. Blood culture is the ultimate diagnostic method but has limitations such as long incubation period, lack of the sensitivity and it needs special laboratory facilities. Molecular diagnostic technique such as PCR, are also being used more and more frequently to test the infection and determine the types of *Brucella* infection. Proper and Timely diagnosis is critical to successful treatment , to minimized problems, and prevention of further disease transmission and especially in high-risk groups individual [30].

#### **Surveillance Challenges in Developing Countries**

Surveillance on brucellosis in humans and ruminants is critical in determining the prevalence of the disease, control measures, detection of outbreaks. Even so, the developing countries have great problems for establishing an effective surveillance system. Barriers to early and accurate case identification include lack of skilled staff, insufficient and poor laboratory facilities. Human and Animal cases are regularly underreported because of poor awareness, misdiagnosis and the absence of compulsory reporting systems. Additionally, the public health and veterinary services are disjointed and hindering the combination between human and animal data. Thus, making it to find a comprehensive image of disease burden. The Surveillance is complicated by other environmental elements like dispersed rural communities and informal livestock trading. To overcome these obstacles, it is important to invest in coordinated reporting systems , staff training, laboratory capacity and public awareness campaigns to encourage citizen participation in surveillance programs [31].

### **PREVENTION AND CONTROL STRATEGIES**

#### **Vaccination Programs**

Vaccination plays a vital part of brucellosis management amongst the ruminants. Vaccines of different kinds have been formulated and introduced to lower down the rate of infection and reproductive loss. *B. abortus* strain 19 (S19) type vaccine is commonly used in cattle and *B. melitensis* Rev-1 vaccine is used in goats and in sheep [32]. The goals of vaccination programs are to establish herd immunity, eliminate shedding of the bacteria, and minimize the risk of zoonotic disease transmission.

Vaccination is critically important such as time of the vaccination, level of coverage of vaccine and the recommended procedure of vaccine administration have a significant effect on the effectiveness of the program. vaccination has been proven effective by improving livestock productivity, reducing disease prevalence and enhances human health outcomes when implemented systematically [33].

#### **Test-and-Slaughter Policy**

The test-and-slaughter approach requires identifying infected animals through serological testing and removing them out of the herd to reduce the further spread of the disease. This strategy has really worked very well in countries that possess sufficient resources, enforcement of regulations and veterinary facilities availability. On the other hand, in developing nations, test-and-slaughter policies face several challenges including limited financial resources, high cost and high compensation package for farmers, the existence of informal livestock markets, and the lack of much money. These limitations notwithstanding, infected animal selective culling in conjunction with vaccination and biosecurity approaches has been an important element in integrated brucellosis control programs [34].

#### **Farm Biosecurity**

Effective biosecurity measures at the farm level are necessary to reduce the transmission and introduction of brucellosis within and among herds. Biosecurity practices including the segregation of newly purchased or returning animals, placental tissues, and safe disposal of aborted fetuses and placental tissues that are aborted, regular sanitation of animal housing, and controlled grazing management play a crucial role in minimizing and reducing the risk of infection. Hygiene practices are also applied when feeding, handling of animals, and milking. Thus effective farm biosecurity reducing contamination with bacteria. To realize biosecurity measures, farmers need to be committed, trained aware and the veterinary authority has to support them. The Farm biosecurity is especially critical in the semi intensive systems and smallholder systems where the proximity of the animals and communal facilities make the transmission more probable [35].

#### **Public Awareness and Food Safety**

Human brucellosis can be reduced with the help of food safety interventions and public education. The public campaign to rural population, dairymen, and educate farmers involves ways of ensuring that animals are handled safely, their protection during the parturition, and the need of pasteurizing milk prior to its consumption. Encouragement of good hygienic production and processing of milk decreases the chances of transmission of brucellosis. Furthermore, awareness among high-risk population about the symptoms of brucellosis and the importance of seeking early medical care boosts the treatment and diagnosis. This is achieved through

the integration of veterinary control measures with the public awareness which provides multi-layered approach to the brucellosis that focuses on both human health and animal health [2].

## **ONE HEALTH FRAMEWORK FOR BRUCELLOSIS CONTROL**

### **Integration of Human and Veterinary Health Systems**

The One Health approach highlights interrelation between animal health, human health, and environmental health and suitable in the control of brucellosis [36]. Veterinary and human health systems can be integrated to provide timely exchange of information, coordinated surveillance and development of joint response plans for the control of Brucellosis. Veterinary services monitor disease prevalence in livestock, whereas public health system track human cases. This allows a more complete picture of the epidemiological situation of brucellosis. This type of integration will facilitate the control of zoonotic transmission by targeting both human population and animal reservoirs at risk of Brucellosis. The work of collaborative diagnostic networks, common databases and communication channels between sectors increases the ability to identify outbreaks at start and control the situation [37].

### **Intersectoral Collaboration**

The effective management of Brucellosis requires collaboration among multiple sectors, such as the human health, agriculture, environmental departments, and wildlife management. The effective coordination can be achieved through the integrated planning and resource allocation, enabling stakeholder engagement, farm biosecurity programs, and vaccination campaigns. By Involving farmers, local governments, and healthcare providers ensures that interventions are realistic and culturally acceptable. One Health approach allow better control of brucellosis through the establishment of partnerships across sectors. This leverages expertise and resources, and results in more sustainable and comprehensive brucellosis control [38].

### **Policy Gaps and Recommendations**

Despite widespread awareness of brucellosis as a significant Zoonotic disease, policy gaps exist in most of the disease-infested regions. The weak implementation of livestock hygiene codes, lack of compensation for slaughtered animals, and low rate of vaccination undermine the control measures. Brucellosis receives low attention in public policies due to insufficient awareness and competing issues. To fill these gaps, it is crucial to design the national strategies including the goals of human and veterinary health. These strategies should allocate resources for surveillance and vaccination programs. Additionally, farmers who implement biosecurity measures should be supported to ensure effective disease control. By improving control measures and

enhancing compliance at all levels requires effective policies. Such policies should promote education, community involvement and collaboration among all sectors needed [39].

### **Research Gaps and Future Directions**

Significant research gaps continue to hinder the optimization of brucellosis control strategies [40]. Further Research on molecular epidemiology is required to improve understanding of the brucellosis. This includes transmission mechanism, diversity of strains, and the development of new variants [41]. The effectiveness of current vaccines in the brucellosis control as well as the development of new vaccines to improve immunization remain important areas of research. Also policy can be informed by socio-economic studies on the affordability of control programs such as brucellosis control and barriers for their implementation [26]. Future studies should adopt interdisciplinary approaches that integrate veterinary science, public health, and social sciences within the One Health framework [42].

The One Health approach provide a holistic strategy for controlling brucellosis by integrating health systems, addressing policy gaps, promoting intersectoral collaboration and prioritize focus on specific research. The one health model and approach recognizes that animal, human, and environmental health cannot be discussed separately. But all three areas should work with the coordination to achieve the similar objectives that will reduce disease burden, and effectively improve public health outcomes. The One Health approach does not only enhance brucellosis control and it also provides a framework for managing other zoonotic diseases within complex socio ecological system [43].

## **CONCLUSION**

Ruminant brucellosis is a significant global zoonosis that adversely affect the productivity of human health, animal health and socio-economic welfare particularly endemic areas. The multi-factorial interaction among human contact, animal reservoirs, human and environmental factors play a very key role in persistence of brucellosis, highlighting the need for a holistic approach to its epidemiology. Ruminants are considered to be primary sources of infection with their reproductive disorders cause's substantial economic losses. While Zoonotic transmission is a significant issue of public health concern.

Brucellosis require multidimensional approach for the effective control and management. Test and slaughter policies, farm biosecurity, vaccination public education are essential measures to reduce the prevalence of brucellosis and prevent human infection. A One Health approach integrating of veterinary and human health systems improves and strengthen surveillance, and early detection, while improving coordination of interventions across all

sectors. It is mandatory to address policy gaps and encourage intersectoral collaboration. As well as fund specific research to make long-term brucellosis and other zoonotic disease control programs stronger.

In summary, a holistic One Health approach that recognizes the connections between humans, animals, and the environment is vital for reducing the burden of brucellosis. By addressing the health of people and animals together, such an approach also supports sustainable livestock practices,

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strengthens communities economically, and enhances the overall resilience of public health.

**Authors Contribution:** data collection, KB Arsalan and Ehsanullah; supervision and resources, RN Dawood and HM Hamayun; review and editing, F Mehnoor; proofreading, I Kashif.

**Funding:** No funding involved.

**Ethical Approval:** Not applicable

**Conflict of Interest:** Nil.

**Consent for Publication:** All authors approved the manuscript for publication.

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