International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2024; SP-9(5): 160-165

www.veterinarypaper.com
Received: 14-06-2024
Accepted: 23-08-2024

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Q fever in small ruminants and its public health significance

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DOI: https://doi.org/10.22271/veterinary.2024.v9.i5Sc.1697

Abstract
Coxiellosis, or Q fever, is a significant global zoonotic disease caused by *Coxiella burnetii*. It ranks among the top 13 global priority zoonoses and poses an increasing threat to high-risk individuals worldwide. *Coxiella burnetii* is frequently detected in animal-derived foods (such as bulk milk, eggs, and meat) and tick vectors. The disease can lead to spontaneous abortions in humans and reproductive issues in livestock, causing production losses. In developing countries, Q fever is prevalent but underreported and neglected, especially in regions like the Indian subcontinent (including Sri Lanka, Bhutan, Pakistan, Nepal, Maldives, and Myanmar). Policymakers and funding agencies often do not prioritize this disease, despite its public health significance. This review emphasizes the importance of recognizing and addressing the occurrence and epidemiology of Q fever.

Keywords: *Coxiella burnetii*, Goats, Q fever, Sheep, Zoonosis

Introduction
Coxiella burnetii is an obligate intracellular bacterium causing Q fever in humans and coxiellosis in animals, reported globally except in New. It belongs to the class Gammaproteobacteria, order Legionellales, family Coxiellaceae, and is the sole species in the genus *Coxiella*. Humans typically acquire infection through airborne transmission from animal reservoirs, especially domestic ruminants (OIE, 2010) [35].
Q fever is considered a neglected zoonotic disease in many developing countries and is notifiable by the OIE. However, it remains non-notifiable in some nations (Njeru *et al*., 2016) [33]. The International Livestock Research Institute (ILRI) identifies it as "the most contagious disease" due to its extremely low infectious dose (ILRI, 2012) [25]. Classified as a Category B bioterrorism agent by the CDC, *Coxiella burnetii* primarily infects ruminants, with small ruminants being significant reservoirs. Infected sheep and goats release millions of bacteria through placenta, amniotic fluid, fetal membranes, and lochia following birth or abortion. (Bauer *et al*., 2016) [33]. In India, the Indian Council 1of Medical Research (ICMR) established a Task Force on Rickettsioses in 2002 to enhance research on Q fever diagnosis, prevention, and control. However, limited research has been conducted on *C. burnetii* in sheep, goats, and humans.

Transmission of *Coxiella burnetii*
The organism is secreted in milk, making the ingestion of contaminated raw milk and dairy products a source of infection for humans. Individuals in close contact with farm animals, such as veterinarians, farm workers, butchers, and laboratory personnel, are at heightened risk (Hatchette *et al*., 2001). Goats typically contract the infection through inhalation of aerosols or environmental exposure, often showing no symptoms. Sheep and goats serve as primary reservoirs of the pathogen. Recent research indicates that goats primarily excrete *C. burnetii* through milk, whereas sheep predominantly do so via vaginal mucus or feces (Rodolakis, 2009) [38]. High-risk groups for Q fever include livestock farmers, shepherds, sheep shearers, animal by-product processors, meat plant employees, abattoir workers, veterinarians, and researchers handling the pathogen or samples.

While the bacterium can infect various animals, birds, and arthropods, ruminants are considered the major reservoirs (VandenBrom *et al.*, 2015) [45]. Guatteo *et al.* (2011) [22] found that the prevalence of *C. burnetii* was slightly higher in cattle (20%) compared to small ruminants (15%), though this may be influenced by the design of existing studies

Morphology

Coxiella burnetii is an obligate intracellular gram-negative bacterium with pleomorphic rods measuring approximately 0.2-0.4 µm in diameter and 0.4-1.0 µm in length. The bacterium exists in two forms the large cell variant (LCV) and the small cell variant (SCV). The LCV is metabolically active and replicative, while the SCV, a spore-52 like form, is highly resistant to environmental stresses such as high temperatures, UV radiation, and osmotic pressure (McCaul and Williams, 1981) [28]. The SCV is associated with the presence of lipopolysaccharide (LPS), which is also found in the LCV (Coleman *et al*., 2007) [12]. The two LPS phenotypes that are displayed by organism are phase 1 (smooth) and phase 2 (rough), the latter lacking the O-antigenic region (Toman *et al.*, 2009) [43]. Phylogenetically, *C. burnetii* has been reclassified from the *Rickettsiales* order to the *Legionellales* order.

History

The term "Q fever" was coined by Edward Holbrook Derrick in 1935, following investigations of febrile illness in abattoir workers in Brisbane, Australia (Derrick, 1973) [14]. The bacterium was first observed by Macfarlane Burnet in infected guinea pigs' spleens, with Burnet and Mavis Freeman initially hypothesizing it as a Rickettsial agent. Concurrently, Gordon Davis isolated the pathogen from Dermacentor andersoni ticks, and in 1938, Cox propagated the agent in embryonated eggs.

Epidemiology

Q fever outbreaks occurred during World War II among troops in Europe, with over 20,000 cases reported in Italy (Babudieri, 1959) [7]. In farm settings, individuals involved in birth assistance, handling dead animals and cleaning are exposed to *C. burnetii*. Slaughterhouse workers and veterinarians, who frequently handle infected animals, are at higher risk, with field veterinarians showing a high seroprevalence (22.2%) (Whitney *et al*., 2009) [48]. *Coxiella burnetii* is endemic in over 51 countries, including India, and remains a significant public health issue due to poor disease surveillance (Malik *et al*., 2014; Maurin and Raoult, 1999) [26, 27]. The infection is often underestimated due to its pleomorphic clinical presentation and reliance on physician awareness and diagnostic capabilities (Fournier *et al*., 1998) [17]. Infected ruminants, particularly during parturition, are major sources of infection for other livestock and humans. Transmission is facilitated by animal trade and milk products. The pathogen can survive for over a year at temperatures below -20 °C and requires fewer than 10 organisms to establish an infection (Bauer *et al*., 2016; Meadows *et al*., 2015) [33, 30].

Pathogenesis

Coxiella burnetii exists in two phases: phase I (virulent, smooth) and phase II (avirulent, rough). Phase variation involves differences in surface antigens, primarily lipopolysaccharides (LPS). Phase I bacteria have full-length LPS O-chains, crucial for cell internalization and survival in the phagosome, while phase II bacteria lack these chains (Thompson *et al*., 2003; Coleman *et al*., 2007) [42, 12]. Upon entering the host cell by phagocytosis, phase I small cell variants (SCVs) transform into large cell variants (LCVs), multiply by binary fission, and prevent host cell apoptosis, persisting for a long time (Arricau-Bouvery, 2005) [6]. As the organism is highly infectious, with an infectious dose as low as one organism (McQuiston *et al*., 2002) [29], primary multiplication occurs in regional lymph nodes, leading to bacteraemia lasting 5-7 days, then localizing in mammary glands and the placenta of pregnant animals (Babudieri, 1959) [7]. Acute human infections often involve atypical pneumonia and hepatitis, with the bacteria spreading to various organs and forming granulomatous lesions, especially in the liver and bone marrow (Maurin and Raoult, 1999) [27]. Chronic infections can lead to endocarditis. The immune response involves both humoral and cellular immunity. Antibodies against phase II bacteria develop within three weeks post-infection (Dupuis *et al*., 1985) [15]. Cellular immunity, particularly involving T-cells and cytokines like interferon gamma (IFN-γ), plays a key role in clearing the infection (Honstettre *et al*., 2004) [24].

In animals, *C. burnetii* is often contracted from the environment or ticks, leading to primary infections with minimal clinical signs. The bacteria persist in infected females, shedding large numbers during pregnancy. Experimental studies show the organism can be recovered from various organs during early pregnancy, with high multiplication rates in the placenta at term (Freick *et al*., 2017) [18]. Infected pregnant goats exhibit severe inflammation in the allantochorion, with aborted fetuses appearing normal but the placenta showing significant pathological changes (Palmer *et al*., 1983) [36].

Clinical Signs

Humans

Q fever in humans can be either acute or chronic, often presenting sub clinically or with mild symptoms. Approximately 50% of those infected develop clinical disease, with an incubation period ranging from 14 to 39 days (Dupuis *et al*., 1985) [15]. Acute symptoms include prolonged fever, abdominal pain, nausea, vomiting, weight loss, lower respiratory infection, chills, sweating, coughing, chest pain, pharyngitis, myalgia, disorientation, and severe headache (Graves and Islam, 2016) [21]. Pneumonia occurs in 30-50% of cases, and some may develop granulomatous hepatitis. Common acute manifestations are flu-like symptoms, high-grade fever, fatigue, headache, and myalgia (Njeru *et al*., 2016) [33]. Atypical pneumonia is characterized by a nonproductive cough, fever, and minimal auscultatory abnormalities. Hepatitis in Q fever presents in three forms: infectious hepatitis with hepatomegaly, asymptomatic hepatitis, and prolonged fever of unknown origin with granulomas on liver biopsy. Myocarditis, accounting for 0.5-1% of cases, can be life-threatening (Urrutia *et al*., 1991) [44]. Rarely, Q fever presents with pericarditis, skin rash, encephalitis, meningoencephalitis, or encephalomyelitis. Other less common symptoms include hemolytic anemia, thyroiditis, pancreatitis, and neurological diseases. Chronic Q fever, persisting for six months or more, can develop years after initial infection, often resulting in endocarditis in high-risk patients (Njeru *et al*., 2016) [33]. Pregnant women may experience reactivation of the infection, leading to

complications such as abortion and low birth weight (Zeman *et al*., 1989) [49].

Animals

In ruminants, Q fever is usually asymptomatic but can cause abortion and stillbirth in small ruminants. Approximately 50% of pregnant animals may abort within a flock or herd (Van den Brom *et al*., 2015) [45]. Other signs include uterine infection, premature births, and weak offspring. *Coxiella burnetii* also causes abortion in wild ruminants, with 27.3% of North African gazelles with a history of abortion testing positive for the bacterium (McQuiston *et al*., 2002) [29].

Diagnosis

Identification by Microscopy

Gimenez's stain is used to identify *C. burnetii* in smears from infected chicken embryos, liver, and spleen, showing pink-stained coccobacillary bodies against a blue or green background (OIE, 2004) [34]. Electron microscopy distinguishes between SCV and LCV forms of the bacterium.

Serological Diagnosis

Antibody levels in serum, detectable from five days post-infection, help identify Q fever. Phase II antibodies appear 7-15 days after symptom onset, subsiding after 3-6 months. Primary is indicated by a 4-fold increase in phase II IgG or IgM antibodies, with significant titers being IgG ≥200 and IgM ≥50 (Fournier *et al*., 1998) [17]. Chronic Q fever shows elevated phase I IgG titers (≥1:800) (Freick *et al*., 2017) [18].

Complement Fixation Test (CFT)

CFT detects phase I and II antibodies, used for diagnosing chronic Q fever. A titer of >1/10 is positive, while >1/80 indicates progressive infection. CFT has been largely replaced by ELISA and IFA due to its poor sensitivity (OIE, 2004; Emery *et al*., 2012) [34, 16].

ELISA

ELISA is more sensitive than CFT and quicker than IFA. It serves as an epidemiological screening tool (Mohan *et al*., 2017). Studies show varying prevalence rates in cattle, sheep, goats, and farm workers using ELISA (Dhaka *et al*., 2019) [32].

AlShaibani *et al.* (2024) [3] conducted a study on 250 staff workers and 263 goats in slaughterhouses in Dhamar city, Yemen. Using Immuno DOT and ELISA tests, they found a seroprevalence of 5.2% in staff workers and 8.57% in goats. Higher seroprevalence in staff was noted among those aged 31-40, with 6-10 years of experience, and butchers. In goats, significant associations were found with sex, season, source, and tick presence.

Getachew *et al*. (2024) [20] examined 1350 ruminants (450 cattle, 450 goats, and 450 sheep) across three 1districts in the South Omo zone, Ethiopia. They used ELISA testing to determine seroprevalence rates, finding 37.6% in cattle and 28.7% in small ruminants. The study also identified 2720 ticks (1299 from cattle, 1020 from goats, and 401 from sheep) as potential vectors for *C. burnetii*. The research highlighted a significant gap in community awareness, with only 43% of animal owners able to recognize Q fever symptoms, compared to 76.2% of animal health professionals who were aware 1of the causative agent. These findings underscore the widespread presence of and the urgent need for improved awareness and control measures for Q fever.

Kamaly *et al*. (2024) in his study investigated the seroprevalence of *C. burnetii* using ELISA among sheep in Egypt. The overall seroprevalence of Q fever in sheep was 37.5%, with higher prevalence in females (39.5%) compared to males (8.3%). Pregnant ewes had a higher seroprevalence (47.7%) compared to non-pregnant (31.4%) and abortive ewes (43.8%). Sheep older than 3 years showed significantly higher seroprevalence (71.2%).

Immunofluorescence Assay (IFA)

IFA is the reference test for Q fever, detecting phase I and II IgG and IgM antibodies. It can differentiate between acute and chronic infections. Studies indicate its effectiveness in various samples from animals and humans.

Other Serological Assays

New methods like Coxiella Immunospot assay and automated immunofluorescence assays have been developed, showing varied sensitivity and specificity (Bizzini *et al*., 2015) [9].

Molecular Diagnosis

Hybridization Technique: Fluorescent in-situ hybridization (FISH) uses specific probes to detect *C. burnetii* at the tissue level, targeting genes like 16s rRNA (Melenotte *et al*., 2016) [31].

Polymerase Chain Reaction (PCR)

PCR is a rapid, sensitive, and specific method for detecting *C. burnetii*. It targets genes such as IS1111, Com1, and 16s rRNA. Studies show PCR's effectiveness in various samples, including blood, milk, and placental tissue. Sánchez-Rodríguez *et al*. (2024) [39] conducted a study to determine the presence of *C. burnetii* DNA in vaginal samples from sheep that presented abortion and ram semen in five Central and Southern States of Mexico. A total of 180 vaginal exudate samples and 20 semen samples were tested. PCR amplification and sequencing of the IS1111 insertion sequence identified *C. burnetii* in 110 (61.1%) vaginal samples and 12 (60%) semen samples. This marks the first report of *C. burnetii* in sheep that aborted and in ram semen in Mexico. In Egypt, Kamaly *et al*. (2024) used PCR for molecular detection of the IS1111 gene in vaginal swabs of sheep and revealed the presence of the IS1111 gene in 20% of the vaginal swabs tested, with no significant statistical difference between aborted and non-aborted ewes. PCR results showed no significant association with age, pregnancy status, abortion history, or farm location.

Genome Sequencing

Sequencing genes like IS1111 and 16s rRNA helps differentiate *C. burnetii* strains and understand their spread. Whole genome sequencing has identified closely related strains in human and animal samples (Schets *et al*., 2013) [41].

Biosensors

The first biosensor for detecting the agent of Q fever, developed by Koo *et al*., utilizes a silicon micro ring resonator (SMR) that is optically interrogated by a feed wave-guide. The SMR detects changes in the refractive index near the wave-guide caused by the binding reaction of biomolecules immobilized on its surface alters the resonant wavelength. The assay employs DNA amplification (IDA) using recombines polymerase amplification (RPA). This highly

sensitive DNA amplification combined with advanced SMR detection addresses issues like false-negative reactions and low sensitivity due to inhibitors in blood plasma, such as hemoglobin, IgG fraction, and heparin. A recently described electrochemical biosensor for Q fever is based on the immobilization of the CBU_1718 (GroEL) protein (UniProtKB-P19421) onto a gold electrode modified by a self-assembled monolayer. The immobilization of the antigen on the gold electrode was optimized by adjusting parameters such as protein concentration and incubation time to achieve optimal performance. GroEL was selected for immobilization due to its higher expression yield (0.65 mg/mL) compared to the genetic region *Com1*. The sensor was tested with PBS, sera from blood donors, and patients with acute and chronic Q fever infections. It demonstrated the necessary discrimination ability for accurate serological detection of chronic Q fever, which is expected given the period of seroconversion.

Koo *et al.* functionalized the sensing chip with an amine group to immobilize *C. burnetii* DNA primers. DNA elongation and detection occurred on the SMR structure, addressing low pathogen concentration and inhibitor effects in clinical samples. Using samples from formaldehyde-fixed paraffin-embedded tissue and frozen blood plasma, *C. burnetii* was detected within 20 minutes with a sensitivity of 81-93% and a detection limit ten times higher than PCR methods.

Prevention and Control

Screening and vaccination are key strategies. Pasteurization of milk and proper heat treatment of milk products prevent infection. Vaccination reduces bacterial shedding and subsequent transmission. Separation of pregnant animals after abortion helps control the spread. Antibiotics like doxycycline are effective, especially when combined with hydroxychloroquine for chronic cases. Pregnant women are treated with co-trimoxazole. High-risk groups must adopt safety measures to prevent exposure (Alonso *et al*., 2015) [2].

Future Prospects

Research is needed to better understand the bacterium, its pathogenesis, and its transmission. Improved diagnostic methods, guidelines for practitioners, and preventive measures for medical staff are essential. Veterinary aspects, including the effectiveness of antibiotic treatment and the impact of Q fever on various animal species, require further investigation. Developing new vaccines and better management practices will reduce the zoonotic risk. Developing a "one health" strategy, establishing surveillance networks, and raising awareness are crucial.

Conclusion

Q fever remains a significant public health concern, particularly in developing countries. Increased surveillance, better diagnostic capabilities, and awareness among healthcare providers are essential for effective management and prevention of this zoonotic disease. Collaborative efforts between veterinarians, healthcare professionals, and public health officials can help mitigate the risks associated with Q fever and protect at-risk populations

Conflict of Interest

Not available

Financial Support

Not available

Reference

1. Panda BB, Gaur K, Kori ML, Tyagi LK, Nema RK, Sharma CS, *et al*. Anti-inflammatory and analgesic activity of Jatropha gossypifolia in experimental animal models. Global Journal of Pharmacology. 2009;3(1):1-5.
2. Alonso E, Etxaniz LI, Hurtado A, Liendo P, Urbaneja F, Aspiritxaga I, *et al*. Q fever outbreak among workers at a waste-sorting plant. PLOS One. 2015;10(9).
3. AlShaibani IRMS, Al-Houthi AAM, Al-Dhurani MYA, *et al*. Q fever among staff workers and goats in slaughterhouses at Dhamar city, Yemen. Yemeni Journal of Agriculture and Veterinary Sciences. 2024;5:1.
4. Alonso AR, Zendoia II, Barandika JF, Jado I, Hurtado A, López CM, *et al*. Monitoring *Coxiella burnetii* infection in naturally infected dairy sheep flocks throughout four lambing seasons and investigation of viable bacteria. Frontiers in Veterinary Science. 2020;7:352.
5. Angelakis E, Raoult D, *et al*. Q fever. Veterinary Microbiology. 2010;140(3-4):297-309.
6. Bouvery AN, Rodolakis A, *et al*. Is Q fever an emerging or reemerging zoonosis? Veterinary Research. 2005;36(3):327-349.
7. Babudieri B. Q fever: A zoonosis. Advances in Animal and Veterinary Sciences. 1959;5:81.
8. Bauer AE, Hubbard KR, Johnson AJ, Messick JB, Weng HY, Pogranichniy RM, *et al*. A cross-sectional study evaluating the prevalence of *Coxiella burnetii*, potential risk factors for infection, and agreement between diagnostic methods in goats in Indiana. Preventive Veterinary Medicine. 2016;126:131-137.
9. Bizzini A, Peter O, Baud D, Edouard S, Meylan P, Greub G, *et al*. Evaluation of a new serological test for the detection of anti-Coxiella and anti-Rickettsia antibodies. Microbes and Infection. 2015;17:811-816.
10. Aujoulat CT, Veas F, Jumas-Bilak E, Manguin S, *et al*. Bacterial diversity associated with wild caught Anopheles mosquitoes from Dak Nong province, Vietnam using culture and DNA fingerprint. PLOS One; c2015, 3.
11. Camacho MT, Outschoorn I, Kovacova E, Tellez A, *et al*. Distribution of immunoglobulin G (IgG) and A (IgA) subclasses following Q fever vaccination with soluble phase I *C. burnetii* extract. Vaccine. 2000;18:1773-1777.
12. Coleman SA, Fischer ER, Cockrell DC, Voth DE, Howe D, Mead DJ, *et al*. Proteome and antigen profiling of *C. burnetii* developmental forms. Infection and Immunology. 2007;75:290-298.
13. Cox HR. A filter-passing infectious agent isolated from ticks III. Description of organism and cultivation experiments. Public Health Reports. 1938;27:53-70.
14. Derrick EH. Q fever, a new fever entity: clinical features, diagnosis and laboratory investigation. The Medical Journal of Australia. 1937;2:281-299.
15. Dupuis G, Peter O, Peacock M, Burgdorfer W, Haller E, *et al*. Immunoglobulin responses in acute Q fever. Journal of Clinical Microbiology. 1985;22:484-487.
16. Emery MP, Ostlund EN, Schmitt BJ, *et al*. Comparison of Q fever serology methods in cattle, goats, and sheep. Journal of Veterinary Diagnostic Investigation. 2012;24:379-382.

17. Fournier PE, Marrie TJ, Raoult D, *et al*. Diagnosis of Q fever. Journal of Clinical Microbiology. 1998;36:1823-1834.
18. Freick M, Enbergs H, Walraph J, Diller R, Weber J, Konrath A, *et al*. Serological reactions and bacterial shedding in primiparous dairy cows in an endemically infected herd-impact on milk yield and fertility. Reproduction in Domestic Animals. 2017;52:160-169.
19. Kalou GP, Dyankov G, Krumova S, Simeonov K, Valkov T, Baymakova M, *et al*. Applicability of biosensor technologies in the detection of *Coxiella burnetii* infection in clinical samples. Biotechnology & Biotechnological Equipments. 2024;38:2350163.
20. Getachew S, Kumsa B, Getachew Y, Kinfe G, Gumi B, Rufael T, *et al*. Seroprevalence of *Coxiella burnetii* and potential tick vectors infesting domestic ruminants and community perception of the disease in pastoral areas of south Omo zone, southern Ethiopia. Parasitology Epidemiology and Control. 2024;26:00369.
21. Graves SR, Islam A. Endemic Q fever in New South Wales, Australia: A case series (2005-2013). American Journal of Tropical Medicine and Hygiene. 2016;95:55-59.
22. Guatteo R, Seegers H, Taurel AF, Joly A, Beaudeau F, *et al*. Prevalence of *C. burnetii* infection in domestic ruminants: a critical review. Veterinary Microbiology. 2011;149:1-16.
23. Hatchette T, Hudson R, Schezch WF, *et al*. Goat associated-Q fever: A new disease in Newfoundland. Emerging Infectious Diseases. 2001;7:413-419.
24. Honstettre A, Ghigo E, Moynault A, Capo C, Toman R, Akira S, *et al*. Lipopolysaccharide from *C. burnetii* is involved in bacterial phagocytosis, filamentous actin reorganization, and inflammatory responses through Toll-like receptor 4. Journal of Immunology Research. 2004;172:3695-3703.
25. ILRI [International Livestock Research Institute]. Mapping of poverty and likely zoonoses hotspots. Report to Department for International Development, UK; c2012, p. 250.
26. Malik SS, Das DP, Rawool D, Kumar A, Suryawanshi D, Negi M, Barbuddhe SB, *et al*. Screening of foods of animal origin for *C. burnetii* in India. International Journal of Epidemiology. 2014;34:8-27.
27. Maurin M, Raoult D. Q fever. Journal of Clinical Microbiology. 1999;12:518-553.
28. McCaul TF, Williams JC. Developmental cycle of *C. burnetii*: structure and morphogenesis of vegetative and sporogenic differentiations. Journal of Bacteriology. 1981;147:1063-1076.
29. McQuiston JH, Childs JE, Thompson HA, *et al*. Q fever. Journal of American Veterinary Medical Association. 2002;221:796-799.
30. Meadows S, Bitton JA, McEwen S, Jansen J, Menzies P, *et al*. *C. burnetii* seropositivity and associated risk factors in goats in Ontario, Canada. Preventive Veterinary Medicine. 2015;121:199-205.
31. Melenotte C, Million M, Audoly G, Gorse A, Dutronc H, Roland G, *et al*. B-cell non-Hodgkin lymphoma linked to *C. burnetii*. The Journal of American Society of Hematology. 2016;127:113-121.
32. Mohan V, Nair A, Kumar M, Dhaka P, Vergis J, Rawool DB, *et al*. Seropositivity of goats for coxiellosis in Bareilly region of UP India. Advances in Animal and Veterinary Sciences. 2017;5:226-228.
33. Njeru J, Henning K, Pletz M, Heller R, Neubauer H, *et al*. Q fever is an old and neglected zoonotic disease in Kenya: A systematic review. BMC Public Health. 2016;16:1-20.
34. OIE [Office International des Epizootics]. Q fever. In: Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. 2004;2:565-572.
35. OIE [Office International des Epizootics]. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. Q fever; c2010, p. 113.
36. Palmer NC, Kierstead M, Key DW, Williams JC, Peacock MG, Velland H, *et al*. Placentitis and abortion in goats and sheep in Ontario caused by *C. burnetii*. The Canadian Veterinary Journal. 1983;24:60-61.
37. Raoult D, Marrie TJ, Mege JL, *et al*. Natural history and pathophysiology of Q fever. The Lancet Infectious Diseases. 2000;5:219-226.
38. Rodolakis A. Q fever in dairy animals. Annals of the New York Academy of Sciences. 2009;1166:90-93.
39. Rodríguez SO, Resendiz PEG, Aparicio DE, Reynoso AB, Chavarría MLC, Serrano MG, *et al*. Molecular Detection of *Coxiella burnetii* in Vaginal Swab Samples from Sheep That Aborted. Journal of Vector Borne Diseases. 2024;35:145-162.
40. Sandoz KM, Sturdevant DE, Hansen B, Heinzen RA, *et al*. Developmental transitions of *C. burnetii* grown in axenic media. Journal of Microbiological Methods. 2014;96:104-110.
41. Schets FM, Heer DL, Husman DRAM, *et al*. *C. burnetii* in sewage water at sewage water treatment plants in a Q fever epidemic area. International Journal of Hygiene and Environmental Health. 2013;216:698-702.
42. Thompson HA, Hoover TA, Vodkin MH, Shaw EI, *et al*. Do chromosomal deletions in the lipopolysaccharide biosynthetic regions explain all cases of phase variation in *C. burnetii* strains? An update. Annals of the New York Academy of Sciences. 2003;990:664-670.
43. Toman R, Skultety L, Ihnatko R, *et al*. *C. burnetii* glycomics and proteomics tools for linking structure to function. Annals of the New York Academy of Sciences. 2009;1166:67-78.
44. Urrutia A, García JP, Collazos J, *et al*. Acute myopericarditis as a manifestation of Q fever. Medicina Clinica. 1991;96:319-329.
45. Brom VDR, Berends SI, Luttikholt S, Moll L, Engelen VE, Vellema P, *et al*. Bulk tank milk surveillance as a measure to detect *C. burnetii* shedding in dairy goat herds in the Netherlands between 2009 and 2014. Journal of Dairy Science. 2015;98:1-12.
46. Nadkarni KM. Indian Materia Medica. Edn 3, Vol. I. Popular Prakashan, Mumbai; c2000, p. 242-246.
47. Waag DM, Williams JC, Peacock MG, Raoult D. Methods of isolation, amplification, and purification of *Coxiella burnetii*. Q Fever, Volume II: The Biology of *Coxiella burnetii*. CRC Press; c1991, p. 78-98.
48. Whitney EAS, Massung RF, Candee AJ, Ailes EC, Myers LM, Patterson NE, Berkelman RL, *et al*. Seroepidemiologic and occupational risk survey for *C. burnetii* antibodies among US veterinarians. Clinical Infectious Diseases. 2009;48:550-557.

49. Zeman DH, Kirkbride CA, Leslie-Steen P, Duimstra JR, *et al*. Ovine abortion due to *C. burnetii* infection. Journal of Veterinary Diagnostic Investigation. 1989;1:178-180.

How to Cite This Article
Pushpa MB, Kumar MP, Sree PN. Q fever in small ruminants and its public health significance. International Journal of Veterinary Sciences and Animal Husbandry. 2024;SP-9(5):160-165.