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ANIMAL AND PUBLIC HEALTH SIGNIFICANCE OF CHLAMYDIOSIS

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INTRODUCTION

Chlamydiaceae family has only one genus known as Chlamydia, which has eleven member species. Amongst those, *Chlamydia abortus (C. abortus)* occupies an important place due to its ability to induce abortion in sheep and goats and the risk of zoonosis (Sachse et al. 2015). The disease in sheep is known as Ovine Chlamydiosis, Ovine Enzootic Abortion (OEA) or Enzootic Abortion of Ewes (EAE). *C. abortus* is a Gram-negative bacterium with the characteristic of obligate intracellular relationship (Seth-Smith et al. 2017). Chlamydiosis causes acute placentitis and abortion in advance pregnancy, particularly in the last 2 to 3 weeks of gestation. There may be stillbirth or birth of weak lamb(s) if abortion does not occur (Aitken and Longbottom 2007). There are no specific symptoms or clinical expressions of the disease. Behavioral changes and vulvar discharge may be seen before abortion in some cases. The prominent sign of this disease is the expulsion of dead or weak lambs, peculiarly 2–3 weeks before expected lambing. The lambs usually look mature and normal but, in some cases, there may be 'pot-bellied' lambs due to subcutaneous edema. Moreover, in some cases, lamb fleece may also be covered with exudate, which is creamy pink, brown in appearance (Maley et al. 2009). However, sometimes lambs are born to live but prematurely, and are enough weak to survive beyond 24 hours. In this disease, the vaginal discharge and placenta are highly infectious, with placenta having dirty pinkish and reddish-yellow-colored exudates on its surface. Metritis, especially in goats, may also be found in this disease due to retention of placenta, which mainly is due to secondary bacterial infection. Abortion before 2-3 weeks of expected lambing could be the first detecting sign (Selim 2016). The environment is contaminated by uterine discharge and fetal fluids and the organisms are shed in the infected placenta.

Transmission of Chlamydiosis occurs through ingestion and inhalation of organisms from the contaminated material and environment (Navarro et al. 2004). The exact pathogenesis is still unknown. However, it is suggested that the organisms colonize in the trophoblast cells of the fetal cotyledons and spread the infection to the inter-cotyledon area of the chorion to produce necrotic placentitis and edema. This causes characteristic thickening of the placental membranes and cotyledons which impairs the exchange of nutrients and oxygen between fetus and mother (Buxton et al. 2002). Moreover, there are disturbances in the blood progesterone levels that lead to abortion (Soomro et al. 2015). The organisms may reside in lymphoid tissue in the latent or silent form in non-pregnant animals until the onset of pregnancy. The pathological changes in the placenta start to develop after 90 days of gestation but the infection remains subclinical (Essig and Longbottom 2015).

The products of abortions are sources of contamination for the environment and susceptible animals, as well as humans. The organisms can be found in large numbers in the vaginal fluids, placenta, and fleece of dead lambs. The live lambs may be carriers and a risk factor for naive sheep and goats (Caspe et al. 2020). The animals with abortion in their last pregnancy due to *C. abortus* may shed this infectious bacterium amid both the subsequent periovulation period and at the time of their next lambing, while this risk is minimal as proved by the latest molecular studies. The risk of venereal transmission by males is very low and has relatively no role in the spread of the disease. Although vertical transmission in ewes is possible but horizontal transmission has great havoc for susceptible animals. An aborting ewe can infect other pregnant ewes, however, the animals infected after 110–120 days of gestation will normally complete their gestation length.

Several Chlamydial species that belong to the genus Chlamydia and family *Chlamydiaceae* can cause various infectious diseases in humans, other mammals, and birds. Different species of genus Chlamydia can cause respiratory illness and reproductive problems in men (Joseph et al. 2015). In animals, they can cause abortion, keratoconjunctivitis, infertility, and respiratory disease (Girjes et al. 1988). As the diagnosis of the disease is not confirmatory, precautions should be taken to minimize the risk of infection for the ewes and humans.

The serological diagnosis in the past was mainly based on CFT, but it is less sensitive and less specific due to cross-reaction with other gram-negative bacteria and other Chlamydia species like *Chlamydia pecorum* having LPS antigens. At present, more sensitive and more specific serological ELISA-based test has been developed which uses major outer membrane protein (MOMP) and polymorphic outer membrane protein (POMP).

Table 1: Prevalence of *Chlamydia abortus* with different diagnostic techniques

Country	Prevalence percentage			The method used for diagnosis	Reference
	Tested	Positive	%		
Bosnia and Herzegovina	178	77	43.3	ELISA	Krkalić et al. (2016)
Ireland	201	42	20.9%	ELISA	O'Donovan and Forsythe (2015)
Iraq	124	12	11.1%	ELISA	Fahad and Salman (2017)
Jordan	25	13	52%	IHC and PCR	Hailat et al. (2018)
Saudi Arabia	399	30	7%	ELISA	Aljumaah and Hussein (2012)
Turkey	71	7	9.8%	PCR	Kalender et al. (2013)
Iran	364	20	5.71%	ELISA	Borujeni et al. (2019)
Mexico	246	12	4.9%	ELISA	Campos-Hernández et al. (2014)
	801	118	14.73% (Himachal Pradesh)		
	1221	60	4.91% (Andhra Pradesh)		
India	24	3	12.5% (Jammu and Kashmir)	AGPT	Chahota et al. (2015)
Belgium	958	38	4.05%	ELISA	Yin et al. (2014)
Egypt	675	93	13.7%	ELISA	Selim et al. (2021)
China	1732	323	18.65%	IHA	Qin et al. (2014)
Saxony (Germany)	1714	259	15.1%	ELISA	Runge et al. (2012)
Italy	27	3	11.1%	PCR	Greco et al. (2005)
Algeria	144	51	35.4%	ELISA	Merdja et al. (2015)
Costa Rica	359	19	5.29	ELISA	Villagra-Blanco et al. (2015)
Switzerland	235	10	4.2%	PCR	Borel et al. (2006)
Taiwan	112	37	33.3%	PCR	Wang et al. (2001)

Table 2: Human infections of *Chlamydia abortus*

Serial No.	Gender infected	Pregnancy duration	Symptoms	Reference	Country
1.	Female 22	24th week	Fever, headache, heartburn, shivering, sweating, vomiting, abortion	(Roberts et al. 1967)	UK
2.	Female 28	28th week	Fever, influenza-like illness, shock, renal failure, DIC, stillbirth	(Wong et al. 1985)	UK
3.	Female 25	Not available	Fever, dry cough, fatigue, malaise, Pneumonia	(Hyde and Benirschke 1997)	USA
4.	Female 20	26th week	Sepsis, respiratory distress, Preterm fetal loss	(Kampinga et al. 2000)	Netherlands
5.	Female 39	Non-pregnant	Lower abdominal pain, fatigue, intermittent fever, irregular menstrual cycle, hypochromic anemia, previous miscarriages	(Walder et al. 2003)	Austria
6.	Female 29	25th week	Abdominal pain, headache, dry cough, malaise, fever, renal and hepatic dysfunction, leukocytopenia, thrombocytopenia, and Increase C-reactive, Stillbirth	(Meijer et al. 2004)	Netherlands
7.	Female 32	16th week	High fever, Septicemia, dyspnea, Pneumonia, increase C-reactive, thrombocytopenia, fetal death	(Walder et al. 2005)	Italy
8.	Female	31st week	Fever, septic shock, respiratory distress, multiple organ failure, premature delivery	(Janssen et al. 2006)	Netherlands
9.	Male 47	NA	Respiratory distress, atypical pneumonia	(Ortega et al. 2016)	Spain
10.	Female 27	23rd week	Headache, cough, fever, in utero fetal death	(Pichon et al. 2020)	France

Prevalence

Chlamydia abortus is prevalent worldwide and is a major cause of abortion in sheep in many countries. Prevalence of *Chlamydia abortus* in different geographic regions of the world is shown in Fig. 1 and Table 1.

Transmission

Its unique biphasic developmental cycle has morphologically and functionally two different chlamydial forms; 1) an Elementary body that attaches to the eukaryotic host cell and initiates infection; 2) a Reticulate body. After getting entry into the host cell, the elementary body converts into the reticulate body, which is non-infectious but metabolically active. Reticulate bodies start to multiply by asexual binary fission in non-fusogenic vacuoles, which are also named as inclusions (Marschall et al. 2020). These elementary bodies keep growing until inclusions fill the cytoplasm of the host cell. Within 24-48 hrs, elementary bodies start to re-convert into reticulate bodies, which are then released from the host cell and may cause infection in nearby cells (Longbottom et al. 2019).

Aborted ewes are the main source of Chlamydial transmission to other animals (Pellerin et al. 2019). The product of abortion (uterine discharge, fetus, placental membranes, fetal fluids) are risk factors for the contamination of the environment. Such an environment is highly infectious for the naive ewes (Li et al. 2018). So, the new animals are at greater risk in such an environment. The organism may survive in the environment for several days under favorable climate (Gitsels et al. 2020).

The overwhelming courses of transmission can vary between Chlamydial species, infection disorders, and hosts. *C. abortus* is regularly transmitted to other creatures through aborted material; it can also spread

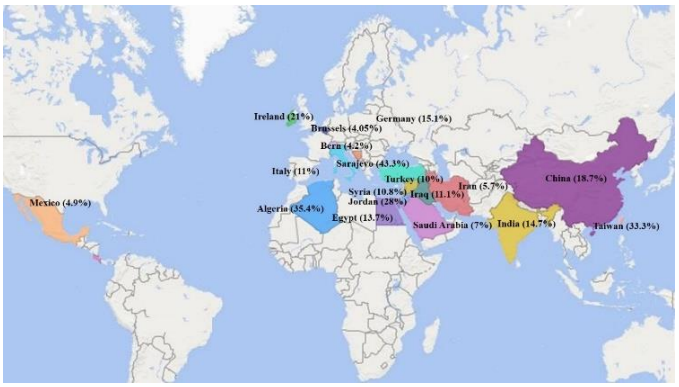

Fig. 1: GIS mapping of the prevalence of Chlamydiosis in different countries. infected materials (Longbottom and Coulter 2003; Sillis and Longbottom 2011). As most of the reported cases of C. *abortus* in humans have been through direct or indirect contact with animals, especially those with a history of abortion due to Chlamydial infection, women in pastoralist families must take precautionary measures while approaching the animals, especially during lambing season (Meijer et al. 2004: Essig and Longbottom 2015). The infection in humans is mostly associated with pneumonia, pulmonary edema, and placentitis. Histologically, inter-villositis and the presence of Chlamydial inclusion bodies in the placental trophoblasts are the most characteristic findings (Essig and Longbottom 2015). A review of clinical symptoms observed in most of the reported cases is presented in Table 2.

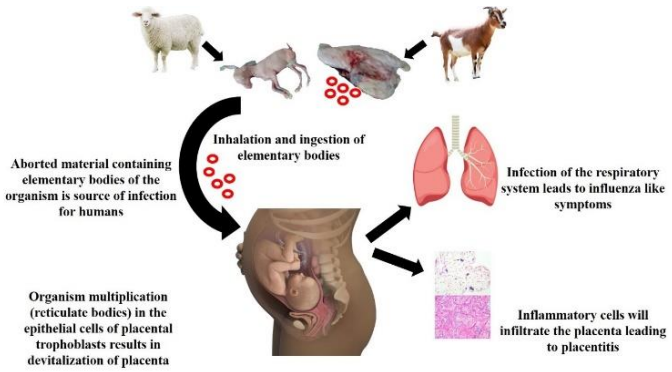

Fig. 2: Transmission of *Chlamydia abortus* from animals to humans.

through other secretions and excretions like feces, etc. Pregnant ruminants can shed a huge number of C. *abortus* within the placenta and vaginal liquids during normal and abnormal births. Shedding of a pathogen in vaginal fluid starts within two weeks before abortion of fetus especially in goats and may continue (often discontinuously) for many weeks afterward. Sheep and goats can be carriers of C. *abortus*, which cause persistent infection in sheep for at least 2-3 years. A few studies have reported that this organism can also be shed in small quantities at the time of estrus and during subsequent pregnancies of animals.

Aborted fetal membranes and fluids are the main sources of spreading infection. Transfer of this pathogen to susceptible ewes occurs after consumption of contaminated feed and water with aborted fluids and tissues (Arif et al. 2020). After ingestion, this infective agent can cause abortion within about 60 to 90 days and sometimes ewes that become infected late in the gestation period may give birth to weak lambs (Sargison et al. 2015). Once the aborted ewes recover, they show no signs of sickness, unless the secondary infection occurs.

The weak-born lambs should be isolated from the healthy herd, as they are also a source of infection for the susceptible animals. The infection becomes latent in healthy sheep and goats, without causing any illness until the next pregnancy and leads to abortion in the last month.

Aborting sheep can also be an infectious risk for the other pregnant sheep in the same lambing season, while the ewes which get infected in the last 1-2 months of pregnancy usually go on to normal delivery (Laroucau et al. 2018).

Pathogenesis

Chlamydia abortus is recognized as the main cause of abortion in the late-term pregnancy of sheep and goats. The other symptoms of *Chlamydia abortus* infection in sheep are conjunctivitis and other health pathologies (Singh et al. 2017). The organism gets into the body mainly through inhalation and rarely through ingestion or abrasions. It spreads to other body organs through blood or lymph. Initially, the organism affects the tonsils and nearby lymph nodes, causing inflammation of these organs, and resulting in the necrosis of cells. It shows biphasic development in the host cell (Essig and Longbottom 2015). It enters the host cell in the form of an elementary body (EB) and is converted to a reticulate body (RB), which is replicating and metabolically active but noninfectious stage and resides intra-cellularly as cytoplasmic inclusions bonded by lipid membranes. The cell cytoplasm becomes filled by these replicating vacuoles and RB re-condenses to EBs (Wheelhouse et al. 2012). The cell bursts, releasing the pathogens to infect the other cells (Wheelhouse et al. 2012).

The *Chlamydia abortus* presents a specific type of proteins named polymorphic membrane proteins (Pmps), also known as autotransporters (ATs), which are strongly immunogenic and cause the release of inflammatory mediators from cells. These proteins are of great importance in comprehending the pathogenesis and virulence of the organism (Wheelhouse et al. 2012). The fact that the infection with *Chlamydia abortus* before pregnancy or in early pregnancy does not show any clinical signs and remains latent can be correlated with the activation of the immune system of the host due to the high immunogenicity of these specific proteins. The infection during pregnancy becomes apparent due to the suppression of the immune mechanism of the body (Longbottom et al. 2013).

The clinical manifestation of Chlamydial infection is mainly characterized by placentitis, which leads to various complications such as septicemia, stillbirth, and abortion in advanced stages of pregnancy (Pan et al. 2017). As the ewes get pregnant, the latent infection reappears and triggers subclinical Chlamydiosis (Essig and Longbottom 2015). This leads to the infection and inflammation in the placental trophoblasts of chorionic

villi. The growth and pathogenesis of *C. abortus* are not obvious till day 90 of the pregnancy. The infection increases following the advancement of the pregnancy. The infection in the placenta may be correlated to the formation of hematoma in chorionic villi of the placenta (Essig and Longbottom 2015). The cause of these hematomas is the release of blood from capillaries in the hilus of ovine placentomes. The organism gets access to the trophoblastic epithelial cells through this route where they proliferate, and cytoplasmic inclusion bodies are produced. Inflammation and edema are produced in the placentomes and inter-cotyledonary tissues when the infection spreads to the surrounding tissues of the placentomes. The cotyledons and placental membranes appear reddened and thickened in response to the infection (Essig and Longbottom 2015; Caspe et al. 2020).

The exact mechanism of the abortion by *Chlamydia abortus* is not fully understood, however, one of the possible causes can be the devastation of the chorionic epithelium and placental membranes, leading to the mutilation of the function of placentomes and impairing the transport of oxygen and nutrients during the maternal-fetal exchange. The other possible underlying cause is the decrease in the release of progesterone in the infected dam. Progesterone is the main pregnancy hormone in the pregnant ewe and is mainly produced from epithelial cells of the chorionic villi. The progesterone release is decreased in response to the damage of these cells. The local production of PGE_2 and estradiol is increased (Caspe et al. 2020; Essig and Longbottom 2015). The inflammatory mediators, such as tumor necrosis factor and interleukin, are produced from the trophoblastic cells, causing the inflammation. The interaction of these hormones and mediators leads to early induction of parturition, resulting in premature birth or abortion. The organism also affects the liver, lungs, and brain of the fetus, impairing the function of these organs (Essig and Longbottom 2015).

Lesions

Grossly, the placental tissue shows purulent to necrotic placentitis. There is edema and hemorrhages of the placenta along with the presence of necrotic foci and purulent exudate in the cotyledons (Borel et al., 2018). Dissemination of infection to fetal tissues results in necrotic and inflammatory lesions in multiple fetal organs.

Histo-pathological examination shows the necro-suppurative placentitis with the infiltration of inflammatory cells, including neutrophils, monocytes, and macrophages (Livingstone et al. 2017). There is evidence of vasculitis and thrombosis in the inter-cotyledonary membranes. The mononuclear cells also invade and can be seen in the inflammatory exudate and affected arteries and arterioles (Essig and Longbottom 2015).

Diagnosis

There is no specific or characteristic sign of this disease, as the infection remains undetected. There may be vulvar discharge and behavioral changes just before the abortion, but this is not a specific sign (Villagra-Blanco et al. 2015). In some cases, there may be thickened cotyledonary membranes with reddish appearance due to edema having viscous creamy exudate, while in some cases inflamed and necrotic placenta can also be observed. These signs may be confused with other abortion-causing pathogens; therefore, laboratory confirmation is required for the exact diagnosis of *Chlamydia abortus* (Livingstone et al. 2017). The tumor necrosis factor can play a major role in the progression of abortion (Buxton et al. 2002).

The PCR and ZN staining can't detect infectious agents, as the excretion of the pathogens till the onset of abortion and maternal antibodies to *C. abortus* rapidly increase to develop the protective immunity. There are distinctive strategies for the clinical diagnosis of *C. abortus*. Serological detection is done by immunological techniques, like complement fixation test (CFT) and enzyme-linked immunosorbent assay (ELISA) (Rekiki et al. 2006).

Several methods and tests have been developed for the laboratory diagnosis of *C. abortus;* these are based on serum evaluation of aborted animals, examination of tissues taken from the aborted fetuses and other abortion products. Isolation and culture of the organism are highly reliable method, but it requires proper facilities and skillful expertise (Opota et al. 2015). Complement fixation test (CFT) is widely used for the serological diagnosis of *Chlamydia abortus,* but it tends to show higher sensitivity for the other gram-negative organisms like *C. pecorum*. Therefore, results can be confusing with other gram-negative organisms due to their low specificity (McCauley et al. 2007). Tissue samples from the fetus and placenta can be used for the isolation and identification of *C. abortus,* using Giemsa and immunohistochemical staining and specific monoclonal antibodies (Sargison et al. 2015). ELISA-based serological tests are now being used for the diagnosis of *Chlamydia abortus*. Blood samples from animals having a history of abortion are collected for ELISA-based serological assays. These assays detect the anti-chlamydial antibodies in serum. These tests use specific antigen proteins like MOMP (major outer membrane protein) and POMP (polymorphic outer membrane protein) for the identification of *C. abortus* (Livingstone et al. 2005) and to minimize the chances of cross-reactivity.

DNA of *Chlamydia abortus* can be detected through PCR by using vaginal swabs, aborted fetuses, placental tissues, and other fetal tissues. The organisms are present in large numbers in the abortion material and vaginal exudates. Vaginal swabs have some advantages to be used for PCR. Inoculation of organisms in chicken eggs is also used to identify the Chlamydia DNA (Kalender et al. 2013).

Polymerase chain reaction (PCR) is another new reliable method for the identification of *C. abortus* (Campos-Hernández et al. 2014). Recently, real-time PCR has become the technique of choice for many diagnostic laboratories due to its rapidity, sensitivity, and ease of standardization. This method is rapid, as culturing of

organisms is not essential for diagnosis (Santoro et al. 2019). PCR detects the Chlamydial DNA by targeting different components of the genome. Outer membrane proteins (ompA), including omp1, omp2, and amplification of pleomorphic genes enables the detection of Chlamydia through PCR. Moreover, detection of *Chlamydia abortus* has been achieved through other components, like genes encoding 16S RNA, helicase, and 16S-rRNA. There may be some problems due to which results may be false negative or isolation cannot be achieved if the samples are taken during the pregnancy or vaginal swabs are taken after many days. At the time of abortion, sampling gives remarkable results for isolation and identification the organism. PCR-mediated recognition of *C. abortus* may not relate to fruitful isolation and culture of the bacteria from tissue samples at all times (Kalender et al. 2013).

Zoonosis

Human infections of *C. abortus* may be acquired from contaminated items of premature birth, parturition or carelessly processing laboratory cultures of the organism. Women involved in handling the livestock, especially the aborted animals, are at high risk of acquiring the infection. Besides causing generalized septicemia, the organism is capable of inducing stillbirth or abortion in pregnant women (Pospischil et al. 2002). Approximately 94% cases of animal acquired Chlamydiosis result in fetal loss and 6.3% in maternal death. Clinical signs vary from the acute febrile condition, respiratory distress, fatigue, malaise, liver, and kidney function failure to shock, disseminated intravascular coagulopathy, and death (Katsura et al. 2020). Some authors have reported "influenza-like illness", terminating in fetal death, in pregnant females. The Chlamydial organism reaches the placenta, and multiplies in the epithelial cells of the trophoblasts, which damages the placental vitality. The level of C-reactive protein is raised, along with a decrease in platelet count in the infected females (Pichon et al. 2020). In non-pregnant females, the infection is associated with the development of "pelvic inflammatory disease" (Walder et al. 2003). A recent review reported that out of 23 cases of gestational Chlamydiosis, 20 were acquired from sheep and goats (Katsura et al. 2020). A case of atypical pneumonia in a veterinary researcher has been associated with C. *abortus* (Ortega et al. 2016). Therefore, biorisk management should be adopted during the handling of culture and potentially

Prevention and Control

Management of flock

It is an important aspect to control this disease, as it causes great zoonotic and economical losses. It spreads from animal to animal; horizontal transmission occurs in a herd and also from animal to humans by direct contact with aborted fetal material. For the prevention of *C. abortus*, one should take strict measures like isolation of seropositive animals from the rest of the herd/flock. Animals with recent abortion history should be kept isolated until their uterine discharge is completely dried up (approximately in 7-10 days). The disposal of infected dead fetal membranes or bedding should be properly buried or incinerated out. The infected place or bunkers should be properly disinfected and thoroughly cleaned (Robertson et al. 2018).

The veterinarian or flock manager should use his protective equipment during handling of infected animals and materials. Health workers should not use the same PPE to handle other animals, until proper disinfection of PPE is done to reduce the risk of spreading the disease in healthy animals, as the infected animals may shed organisms (Zezekalo et al. 2020). Purchasing new animals should be from a reliable source. The introduction of newly bought animals in the flock should be done after serological testing from a trusted laboratory.

Antibiotic treatment

Seropositive animals should be isolated from rest of the herd and provided supportive treatment, such as multivitamins or minerals, to reduce the severity of the infection. Antimicrobial susceptibility tests have shown that macrolides and tetracycline (20 mg/kg) can be used for treatment (Barhoom 2015). The mode of action of anti-chlamydial antibiotics is through inhibition of the Chlamydial protein synthesis by binding to the 30S ribosomal subunit (Bommana and Polkinghorne 2019). Treatment should be given on the first onset of clinical signs (if any sign appears). Single-dose of long-acting antibiotics minimizes severity of the disease. But such antibiotic therapy does not recover the animal completely or reverse any pathological changes that had occurred. It has also been reported that routine oral administration of tetracycline (400-500 mg) fortnightly can reduce the shedding of Chlamydia in the lambing season. This also reduces degree of contamination of the environment and farms. The best way of controlling the disease is the combined use of antibiotics, vaccination, and proper herd management (Longbottom et al. 2013).

Vaccination

The control of *C. abortus* infection has been focused on the vaccination protocol to minimize the abortion rate and excretion of the organism. For *C. abortus,* both attenuated and live vaccines, having origin from different countries, are available in the market. Commercially available live attenuated vaccine, which has strain *C. abortus* (temperature-sensitive), shows good results (O'Neill et al. 2019). But it is compulsory to maintain the cold chain of vaccines for best performance against infection. It is also observed that vaccines may induce the disease and abortion (Caspe et al. 2020). The vaccine should be administered 4 weeks before mating and antibiotics should not be administered with the living vaccine. The inactivated vaccine, prepared on embryonated eggs or cell culture, is also available. Now-a-

days, scientists are focusing on preparing vaccines with different strains that would be easy to handle, cheap and safe to administer in animals.

A vaccination trial of a commercially available, inactivated vaccine at different doses revealed that there was no significant difference between the control group and the vaccinated groups after the administration. The vaccine showed favorable effects on the birth weight and weight gain in lambs during the first 30 days of their life (García-Seco et al. 2016).

Live attenuated vaccine of Chlamydial strain 1B has been seen to induce abortion in the ewes, as the same strain was isolated from the aborted fetuses and other abortion material. This study showed that 1B strain may not be properly attenuated and has a risk for induction of abortion. There should be the repetition of live vaccine after every 2-3 years and the administration of inactivated vaccine should be done annually. Now-a-days, research on the vaccine is focused to develop more effective, cheap, stable and safe vaccines, which may not cause disease in animals and have a good ability to produce sterile protective immunity.

Disinfection

Cleaning and sterilization, together with individual cleanliness (e.g., hand washing, cleaning/disinfection of footwear) are important in preventing the spread of fomites. Aborting animals with Chlamydiosis should be separated because they are the risk of infecting others. Abortion or birth products from infected animals should be removed, and the area should be cleaned and disinfected. Most strains of Chlamydia are susceptible to many available disinfectants. Chlamydia is inactivated in the presence of sodium hypochlorite, glutaraldehyde, 70% ethanol, peracetic acid, and also in the presence of Quaternary ammonia. It is resistant to some alkalis and acids. Like some bacteria, application of moist heat having a temperature of 121C° for 15 minutes and dry heat at 160-170C° for one hour can cease the biological activity of Chlamydia.

Concluding remarks: The global distribution of Chlamydial bacteria infections and its sharing at the animal-human-environment interface suggest an urgent need for interdisciplinary approach, such as One Health, to control this neglected disease. Various pathogenic species of Chlamydia are associated with zoonotic transmission to humans and adverse public health outcomes or losses. There is a dire need to circumvent drug resistance in Chlamydia and the development of protective vaccines for animals and humans. Awareness, containment, and community education would be indispensable to mitigate occupational risk and dissemination of Chlamydial pathogens at the animal-human nexus.

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