Small Ruminant Lentivirus: A practical approach

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Abstract

Small ruminant lentivirus (SRLV) is a group of viruses of the *Retroviridae* family, shared between caprine, ovine and wild ruminants. It is responsible for a systemic infection that can affect the lungs, central nervous system, mammary gland and joints, causing chronic, insidious, and progressive diseases, seriously affecting animal health. Concurrently, it is associated with a decrease in milk production, leading to malnutrition of lambs and goat kids and to the premature slaughter of adult animals, causing substantial economic losses. This review aims to gather the latest information regarding lentivirus in small ruminants in the clinical practice, their economic importance, and diagnostic and prevention methods. Diagnosis is based on clinical, analytical, and post-mortem findings. The feasibility of imaging diagnosis is also highlighted. Preventive measures and management interventions, including the culling or segregation of positive animals, are effective options to control or even eradicate this disease. SRLV prevention strategies must be applied continuously to progressively eradicate infection.

Key words: *small ruminants lentiviruses; seroprevalence; risk factors; interstitial pneumonia; mastitis; encephalitis; arthritis*

Introduction

Small ruminant lentivirus (SRLV) is a group of phylogenetically co-related viruses (family *Retroviridae*, Genus *Lentivirus*) transmitted among caprine, ovine and wild ruminants. Maedi-Visna and Caprine Arthritis-Encephalitis (CAE) have been used traditionally to describe the most frequent clinical syndromes inflicted by this virus in sheep and caprine species, respectively. Nowadays, SRLV is widely used to describe different clinical signs developed by each species. Formerly, infection was distinguished by species, although subsequent research has shown that SRLV cross-transmission is viable between sheep and goats, infecting and inducing multisystemic

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organ damage in both species (Cirone et al., 2019). Seroprevalence studies have shown that SRLV is present worldwide (Lago et al., 2012) though the data vary between regions, countries and continents. Studies in Europe have shown a herd seroprevalence of 17 to 100% and and an individual seroprevalence of 9 to 81.5% (Alba et al., 2008; Gufler et al., 2008; Pérez et al., 2010; Michiels et al., 2018; Cirone et al., 2019; Ferreira et al., 2022). In contrast, South and Central America and Africa show lower herd seroprevalence values of 18.87% and 7.69%, respectively. Asia showed higher values with 65.99% and North America showed an average of 48.58% (de Miguel et al., 2021).

SRLV causes systemic infection in ovine and caprine species, which may affect the lungs, central nervous system (CNS), mammary glands, and joints (Minguijón et al., 2015). These infections cause chronic, insidious, and progressive diseases, seriously affecting animal health and well-being (Michiels et al., 2018). Associated respiratory distress and neurological syndromes may evolve to cachexia and death. This syndrome is commonly referred to as wasting disorder with a chronic and insidious course ("thin ewe/goat syndrome"). Joint and chronic mammary infections may lead to disability with different grades of mobility impairment (mostly seen in goats) (Minguijón et al., 2015). There is currently no therapeutic treatment or commercial vaccines available for the prevention and control of SRLV infection (OIE, 2017).

Vertical transmission occurs through infected milk and colostrum ingested by young animals. Although some studies emphasise subsequent horizontal transmission among lambs (Álvarez et al., 2005), horizontal transmission occurs essentially due to airborne particles spread through the air exhaled by infected animals, and is one of the main transmission routes in intensive sheep production systems. SRLV transmission can also occur via milking equipment, mainly in goats (Junkuszew et al., 2016), or via semen, by natural mating or artificial insemination (Souza et al., 2013).

Diagnosis is based on clinical, analytical, and post-mortem assessment. However, most animals are asymptomatic and clinical signs may only develop years after infection (Barquero et al., 2013). Laboratory methods are essential and may include serological (agar gel immunodiffusion and ELISA) and molecular techniques (PCR and RT-PCR) (Reina et al., 2009).

Regarding economic losses, SRLV infection in small ruminant production is highly significant (Peterhans et al., 2004). Nevertheless, limited data are available and do not take into account all the consequences and losses associated with the production systems in questions (Leitner et al., 2010). SRLV infection can cause a decrease in milk production, a consequent increase in neonatal mortality and lower offspring growth (Greenwood, 1995). Additionally, this disease seems to affect milk quality standards and consequently cheese production (Kaba et al., 2012). Premature slaughter of sick or infected adult animals, higher sensitivity to other pathologies, costs of diagnosis, control and commercial barriers should also be considered as important losses (Keen et al., 1997; Reina et al., 2009).

This paper briefly describes the SRLV diagnostic methods based on clinical signs, pathological findings, and molecular diagnosis. The role of diagnostic imaging is also addressed. Epidemiological aspects and its importance to establish timely measures of control and/or prevention in herds are also encouraged to avoid higher economic losses.

Diagnostic methods

Clinical Diagnosis

SRLV infection is usually persistent and asymptomatic. The clinical form can cause a chronic and multisystemic disease, with clinical symptoms associated with the main target organs: lungs, joints, mammary glands and CNS. Severe cases can lead to wasting condition and death (Callado et al., 2001). Only about one third of infected animals develop symptomatic disease and clinical signs usually appear several months (or even years) after infection (Patel et al., 2012). Clinical syndromes depend on the tropism of the SRLV strain, affected species and breed/animal genetics. Usually only one of the target organs is affected, although visible histological lesions can be seen in several organs (Patel et al., 2012). Immunodeficiency and immunosuppression are not characteristics of this disease (de Andrés et al., 2005; Blacklaws, 2012).

The progressive wasting condition is mainly the result of respiratory or neurological syndromes. In the absence of concomitant infections, it occurs without fever or changes in appetite. Joints and mammary glands are not usually associated with poor condition and chronic emaciation. However, they contribute equally to low income and reduced profitability of animal production. Fever, purulent nasal discharge, depression, and death from associated secondary infections may occur (Blacklaws et al., 2004; Luján et al., 2019).

Respiratory syndrome mainly affects growing and adult animals (older than 2 years) (Luján et al., 2019) with the clinical phase lasting 3 to 6 months. Dyspnoea on exertion is initially observed and may progress to dyspnoea at rest in later stages. Progressive respiratory failure leads to physical activity limitations that restrict the animal's ability to obtain food, walk long distances, and follow the flock (Christodoulopoulos, 2006).

In advanced stages (Figures 1A and 1B), respiratory distress, open-mouth breathing, dry cough or no cough and an abdominal respiratory pattern are seen. There is no production of secretions or fluid in lungs unless secondary infections or comorbidities (e.g., ovine pulmonary adenocarcinoma) occurs. Then pulmonary auscultation can be useless or gives little clinical information in the diagnosis approach. Associated progressive weight loss occurs mostly in animals of 2-3 years. Pulmonary presentation is most frequent as a severe form in sheep, while only

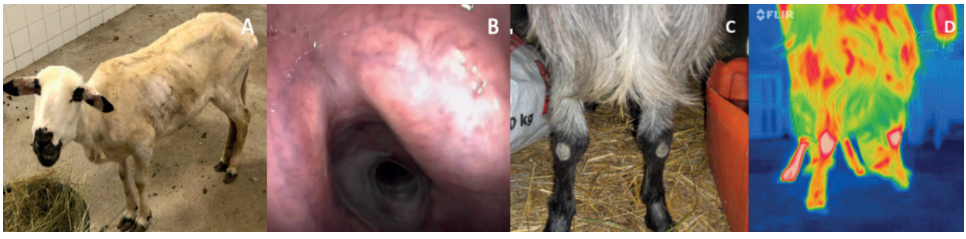

Figure 1. (A) Sheep respiratory syndrome associated with SRLV infection: progressive weight loss with normal appetite and afebrile dyspnoea without productive sounds. (B) In later stages, this syndrome can cause severe respiratory distress (marked oedema of the glottis associated with intense respiratory effort). (C) Arthritic form in goats: carpal joint distention; decreased range of motion and stiff gait related to pain; (D) synovial capsule thickening and oedema in the affected joints (evident in infrared thermal imaging).

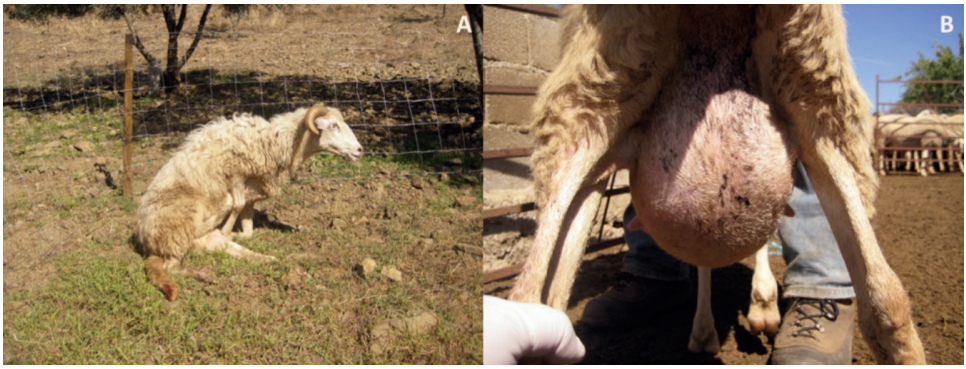

Figure 2. Nervous form: hindlimb weakness and progressive paralysis (A); mammary form: udder enlargement with severe and diffuse udder hardening, without milk production /inflammatory exudates (B).

rarely diagnosed as mild in goats (Callado et al., 2001). The arthritic form begins with oedema, synovial membrane and joint capsule congestion, leading to swelling of structures and joints. On clinical examination, it is possible to observe a bilateral increase in joint consistency and size, and consequent lameness (Gomez-Lucia et al., 2018). The most frequently affected joint is the carpal joint, though others can be affected, even at the same time. Animals present chronic arthritis that progresses over time (de Martino et al., 2016). Animals present a decreased range of motion and constant pain associated with persistent weight loss (Blacklaws, 2012; Wolf, 2021). The arthritic form is more common in adult goats (de Martino et al., 2016) (Figures 1C and 1D) than in sheep, where it is frequently a complication of the respiratory presentation. First symptoms may occur as early as 8 months old (Callado et al., 2001) and are more common after 2 years old (Blacklaws, 2012). If the animal is unresponsive to treatment and palliative care may not be enough, euthanasia may be indicated (de Andrés et al., 2005).

If the virus affects the CNS, clinical signs are usually ataxia, hindlimb weakness, paresis and chronic progressive paralysis (Figure 2A). Even when weight loss/cachexia occurs, animals are alert, eating and afebrile. A "brain form" has also been observed, with a slight head tilt and circle toward the affected side due to lesions in the lateral ventricles (Wolf, 2021). Blindness and facial twitching may be seen occasionally. Neurological disease is more common in goats than sheep. Clinical signs are similar in both species, though head tilt and circling are seen in an earlier stage in goats (Callan and Van Metre, 2004). Neurological syndrome occurs mainly in kids (2–6 months), but it has also been described in intensively raised Assaf lambs. In animals aged 2–6 months, it presents as a rapidly progressive clinical course (Benavides et al., 2007). In adult goats, there are some reports of this syndrome associated with the articular form, though this is seldom associated with clinical respiratory presentation in adult sheep (Wolf, 2021).

Occasionally, respiratory or arthritic forms are associated with chronic indurative mastitis. A mastitis form as a single lesion occurs rarely (Luján et al., 2019). SRLV mastitis could be subclinical and at most diagnosed by a histopatholog-

ical exam. Clinically, the acute form is seen early in lactogenesis in primiparous goats, with non-oedematous hardening of the organ and low to no milk production. In the chronic form, adult goats present a progressive atrophy of the mammary parenchyma, becoming swollen and hard on palpation. Atrophy can be more pronounced in one of the mammary halves, resulting in asymmetrical udders (Chartier, 2018). In ewes (Figure 2B), the chronic form sets during lactation and is characterised by a symmetrically enlarged though painless "hard udder" on palpation (Luján et al., 2019). In all clinical forms, there is persistent hypertrophy of the retro mammary lymph nodes and normal-looking appearance of milk. However, there is a gradual decrease in milk production, with agalactia occurring in severe cases (Chartier, 2018). It is also associated with a higher predisposition to secondary mammary gland infections, high somatic cell count and early culling of sheep and dairy goats. Nevertheless, the effect on milk quality is controversial and difficult to determine (Benavides et al., 2013; Gayo et al., 2019).

No susceptibility to infection related to sex and age of the animal was found, although lambs and kids born of infected mothers had a higher chance of being infected (Dawson, 1980). There is evidence that some breeds are more susceptible to SRLV infection (Gates et al., 1978). Many risk factors have been identified in SRLV transmission at the farm level (Gomez-Lucia et al., 2018). A higher prevalence is found in intensive than in extensive farming systems. The infective potential of the virus is increased with animal crowding, although it potentially could be mitigated with good management practices and adequate control plans. Wild animals may have an essential role in the epidemiology of SRLV infection (Olech et al., 2020). This is particularly important in extensive sheep and goat production and traditional pastoralism.

SRLV infection is usually detected late due to the silent course of the disease. Further, infected animals, as potential viral transmission reservoirs, only develop clinical signs months or even years after primoinfection (Luján et al., 2019). Although presumptive clinical diagnosis can sometimes be established based on clinical syndromes (Greenwood, 1995), laboratory testing is essential to establish an prompt SRLV diagnosis and for epidemiological research (Minguijón et al., 2015). In general, infections are efficiently detected by serological methods and molecular techniques complemented with a pathological diagnosis (Czopowicz et al., 2017), that should be used by a veterinary surgeon to support clinical diagnosis.

Ancillary Tests

An accurate clinical examination of affected individuals and of the flock provides important data to establish the suspicion of SRLV infection. However, clinical signs may be insidious and non-specific, delaying early diagnosis. Therefore, prompt laboratory diagnosis becomes essential to prevent and control the spread of the virus (Reina et al., 2009; de Andrés et al., 2013).

Although there is no ideal diagnostic method (de Andrés et al., 2005) serological techniques are commonly used to detect the presence of antibodies against the virus in the flock. Due to a greater stability of serum antibody levels, these tests have been an excellent diagnostic tool (Nowicka et al., 2014).

Biological and pathological characteristics of SRLV are a challenge to the best choice of techniques for early and accurate diagnosis (Kalogianni et al., 2021). As a chronic lifelong infection, it is only necessary to detect specific antibodies

to establish that a particular animal is positive for SRLV (Luján et al., 2019). An important issue is genetic variability, such as recombinations, mutations, and transmission among different species. In addition to the intermittent production of epitope-specific antibodies, the late seroconversion characterises the sheep and goat humoral immune response to SRLV. The need to develop highly sensitive and specific diagnostic protocols to be easily used and distributed worldwide remains a goal for the future (Kalogianni et al., 2021).

Agar gel immunodiffusion (AGID) and enzyme-linked immunosorbent assay (ELISA) are commonly used for serological diagnosis. The World Organization for Animal Health (OIE) advocates their use to assess infection prevalence and epidemiological surveillance, as well as for early diagnosis/serological screening before animal trade (OIE, 2017).

Commercial ELISA assays are now more commonly used due since they have a higher sensitivity than AGID techniques. AGID assays are usually used as confirmation tests for positive cases due to their high specificity (Kalogianni et al., 2021).

ELISA tests also have the advantage of being inexpensive, easy to use and have satisfactory specificity, allowing their use as a large-scale screening technique or for individual examination (Carrozza et al., 2009). These tests have either a whole virus or recombinant envelope, transmembrane and core proteins as antigens (de Andrés et al., 2005; Nowicka et al., 2014). More recently, envelope encoded surface glycoproteins (e.g., SU5 immunodominant epitopes) have been used in serological diagnosis (Olech et al., 2018). The use of specific peptides in ELISA tests allows genotype-specific diagnosis of SRLV infection. A combination of different peptides in the same ELISA test allows for the possibility to broaden the specificity and facilitates the detection of different SRLV strains (Sanjosé, 2015).

Slow viral seroconversion after infection determines that recent infections may not be detected. False-negative results can also occur due to the multiple antigens and antibodies used in these assays (Pérez et al., 2010). Some studies highlight that antibody levels decline after seroconversion, and antibody response may be intermittent. In addition, total circulating antibodies decrease in the peripartum period (Czopowicz et al., 2017). The absence or reduction of antibodies may constitute a major limiting factor in SRLV diagnosis effort (de Andrés et al., 2005). A practical advantage of ELISA methods is the possibility to test different biological samples, such as serum and blood plasma, as well as milk, maintaining reasonable sensitivity and specificity (Barquero et al., 2011; Potărniche et al., 2021). Without needing veterinary support and with lower operating costs, using milk samples for antibody detection has some advantages over blood (Mazzei et al., 2005).

Radioimmunoprecipitation, radioimmunoassay and western blot may be considered as a reference to serological tests. Although these assays have high sensitivity and specificity, they are not suitable to be used in control and eradication programmes, which are comprehensive action programmes. Owing to the need for specialised laboratories and professionals, high associated costs, time-consuming and complex techniques, they are used mainly as confirmation methods (Kalogianni et al., 2021).

Several polymerase chain reaction (PCR) protocols are available worldwide, although the instability of the SRLV genome makes the use of the same primers in different geographic regions less reliable (Barquero et al., 2013). PCR techniques allow for the diagnosis of infected animals

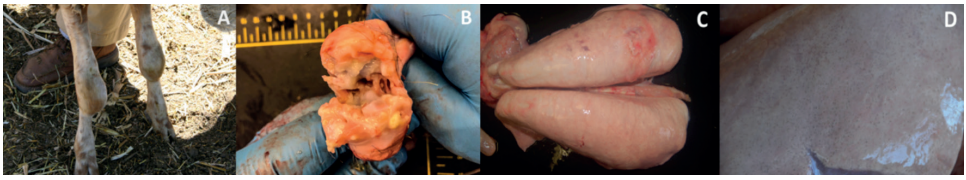

Figure 3. Macroscopic features of small ruminant lentivirus (SRLV) infection: arthritic form with bilateral enlargement of the carpal joints (A); thickening and proliferation of the joint capsule and synovial membrane (B); respiratory form with interstitial pneumonia (C), characteristic grey-yellow lung discolouration and multifocal subpleural stippling (D).

even before seroconversion, and it may also be possible quantifying viral DNA or genotyping (Leginagoikoa et al., 2009). However, due to decrease of viral load after the seroconversion period, PCR assays are less sensitive than ELISA assays. Proviral DNA detection of SRLV appears more effective in mononuclear cells of peripheral blood (Reina et al., 2009). Despite the less sensitive and reliable results, it may be detected in other tissues and biological fluids such as colostrum and milk, lung tissue, carpal synovial membranes, or semen (Ramírez et al., 2009; Herrmann-Hoesing, 2010). Thus, PCR assays should not be used as single diagnosis techniques (Barquero et al., 2013).

Diagnosis of SRLV infection must take advantage of serological and PCR techniques (de Andrés et al., 2005). In the same flock, there may be animals in different stages of the infection. Concordant testing results in both techniques guarantee a higher reliability of healthy animal status. In these situations, quarantine can be imposed with subsequent re-analysis. The cost-benefit must always be evaluated in advance (Czopowicz et al., 2017).

Pathological Diagnosis

SRLV is characterised by lymphoproliferative lesions that develop gradually in target tissues. Viral replication occurs in monocytes as they leave the blood or bone marrow and mature in target tissues. Although infection causes a humoral and cell-mediated response, these do not confer immunity. This disease is characterised as immunopathologic since the host immune system reacts to viral antigens (especially surface glycoproteins) (de Martino et al., 2016).

Anatomohistopathological presentations of SRLV infection have been classified into four forms: arthritic, respiratory, mammary and nervous (de Martino et al., 2016) (Figure 3).

The arthritic form of macroscopic and microscopic lesions are typical of degenerative and inflammatory disorders that can be observed in the periarticular connective tissues, synovial bursae, tendons and tendon sheaths. The affected joint capsule and adjacent soft tissue become progressively mineralised. An enlarged joint with synovial capsule thickening, fibrosis (Figures 3A and 3B), cartilage erosion, oedema, bony exostoses form, and joint(s) collapse with eventual ankylosis is seen (Callado et al., 2001; de Martino et al., 2016). Microscopically, it is possible to observe papillary synoviocyte proliferation with synovial membrane thickening, multifocal mononuclear inflammatory infiltrate (mostly characterised by lymphocytes but also plasma cells and macrophages), diffuse fibrosis, dystrophic calcification and cartilaginous and/or osseous metaplasia, clusters of plasma cells and binucleated or multinucleated

syncytia in the connective tissue of the proliferated synovial membrane, nonamyloid hyaline in the subsynovial connective tissue, degeneration of arterial tunica media and presence of thrombi within blood vessels and tissue necrosis (Pérez et al., 2015; Pinczowski et al., 2017).

In pulmonary presentation, lesions are characterised macroscopically by enlarged and firm lungs (Figure 3C) that may show rib impressions, general greyish discolouration of the pulmonary parenchyma, and the pleural surface can focally or diffusely present grey dots (up to 1 mm in diameter) (Figure 3D) and enlarged mediastinal lymph nodes. These lesions are compatible with interstitial and bronchointerstitial pneumonia and chronic lymphadenitis. Microscopically, lesions are characterised by thickening of the alveolar wall by lymphocytes and macrophages, lymphoid nodule proliferation, increased smooth muscle and fibrous connective tissue, peribronchial and perivascular accumulations of mononuclear cells (Pérez et al., 2015; Luján et al., 2019) (Figure 4). Bacterial pneumonia is a very common consequence of a primary SRLV infection (Wolf, 2021). SRLV infection can also coexist with ovine pulmonary adenocarcinoma (Quintas et al., 2021).

The affected mammary glands histologically show an increase in smooth muscle and fibrous connective tissue; lymphoid follicle proliferation adjacent to ductulus; lymphocytic, mononuclear, and plasma cell infiltrates in the mammary parenchyma; and a net loss of milk-secreting alveoli (Wolf, 2021).

In the neurological form, the primary lesion in the brain or medullae is a non-suppurative encephalitis, predominantly periventricular and paraventricular, accompanied by demyelination. Mononuclear infiltration of the choroid plexus may be seen that results in the development of ectopic lymphoid follicles. There are three patterns of infiltrating distribution that can be observed: (a) a vascular pattern, where mononuclear cells are arranged around blood vessels forming a perivascular cuff, (b) an infiltrative pattern, where a non-purulent infiltration of the neuroparenchyma accompanying perivascular cuffing, and (c) a malacic pattern, where demyelination is the main feature (Minguijón et al., 2015).

Imaging Diagnosis

Although not regularly practised, ultrasound examination can be a useful tool for the diagnosis of SRLV lesions at the farm level (Castells et al., 2019). Diagnosis may not be easy in the early stages of the disease, but the progression of chronic interstitial pneumonia shows an evident increase in echogenicity due to the consolidated parenchyma (Figure 5A). Chronic indurative mastitis is characterised by a high and homogeneous echogenicity in

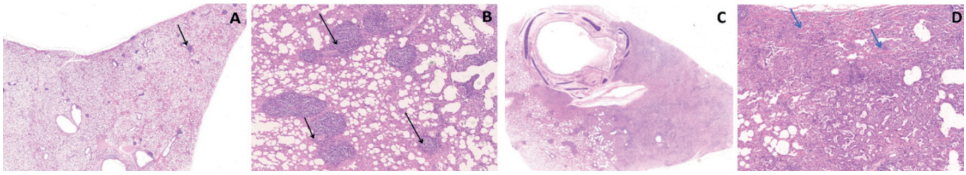

Figure 4. Microscopic features of small ruminant lentivirus (SRLV) infection in sheep. The lungs present peribronchiolar lymphoid follicular hyperplasia – black arrow (A: H&E 40x; B: H&E 100x), interstitial pneumonia with interstitial mononuclear inflammatory infiltrate, fibrosis, and increased smooth muscle – blue arrow (C: H&E 40x; D: H&E 100x).

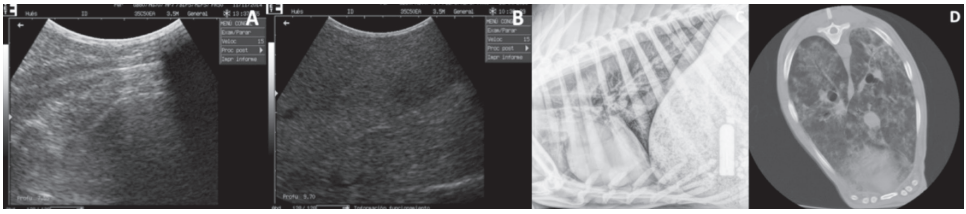

Figure 5. Diagnostic imaging in SRLV: (A) high and homogeneous echogenicity in the pulmonary parenchyma and (B) udder ultrasound examination. (C) Lateral thorax X-ray of a ram with an interstitial pattern; and (D) CT-thorax scan of a sheep with high opacity associated with interstitial pneumonia (axial plane).

the mammary parenchyma (Breuer et al., 2022) (Figure 5B).

Despite the limitations associated with health, safety regulations and associated costs, the use of ionising radiation (e.g., X-rays and computed tomography (CT)) is useful in understanding the pathological processes of SRLV infection, mainly at the respiratory level. In advanced stages, X-rays show a widely distributed unstructured diffused interstitial pattern, with airspace opacification in lungs (Figure 5C). Thoracic-CT scan enables the minute visualisation of this uniform increment of radiopacity in several planes (Figure 5D).

Changes detected by all these non-invasive methods are not pathognomonic for an SRLV infection and require integration of the clinical examination and laboratory test results for an accurate diagnosis. Furthermore, other lesions associated with pneumonia from secondary infections or concomitant illnesses can mask the lesions described above.

Control and Prevention

Actions to prevent SRLV may reduce monetary losses and increase animal welfare and productive parameters (Kalogianni et al., 2021). Control programmes remain the only effective approach for avoiding infection. Implementing this programme in sheep and goats flocks must be based on an early and accurate diagnosis since there is no effective treatment or immunisation strategy for these infections (Reina et al., 2013). An individual approach in each farm, including suitable preventive measures and management interventions, seems reasonable to achieve this goal. Recurrent serological testing with accessible diagnostic and isolation tests, removing seropositive animals, artificial lactation, and strengthening hygiene and biosecurity protocols are conventional control measures (Kalogianni et al., 2020. A significant constraint in the control of SRLV is the lack of effective protocols for a prompt and definitive diagnosis of infected animals, employing appropriate, universally accepted serological and molecular techniques (Kalogianni et al., 2021).

SRLV general control steps leading to eradication are: i. determining prevalence through investigation and data analysis; ii. reducing high seroprevalence to low seroprevalence, thus decreasing the overall prevalence of the disease; iii. reducing the low seroprevalence to negative serology, thus eradicating the disease; iv. consolidating the serologically negative status and eradicating the virus. Determining disease prevalence should be the initial action in any eradication scheme. Thereafter, the goal should be to decrease

seroprevalence and ultimately eradicate infection (Peterhans et al., 2004). In high seroprevalence flocks, the most efficient practice is the periodical slaughter of adult and less productive seropositive animals and their replacement solely by seronegative breeders (Reina et al., 2009). All animals showing clinical disease should periodically removed and slaughtered or at least isolated from other animals (Pittavino et al., 2014).

Control programmes should include measures such as avoidance of equipment sharing and quarantine measures for animals prior to their introduction to SRLV-free farms. Contact with wild fauna should also be monitored as SRLV can infect certain species of wild ruminants, such as wild goats (*Oreamnos americanus*) (Minguijón et al., 2015). Colostrum management is also an important control measure. It involves supplying colostrum from seronegative small ruminants, commercial milk substitutes, or even heat-treated colostrum (Polledo et al., 2013). Artificial feeding must be carried out in a clean area and separate from adult animals (Kalogianni et al., 2020). This is a time-consuming and expensive measure with limited benefits in moderate to high seroprevalence flocks if contact with other animals on the farm is not avoided until adulthood. Some control programmes focus on culling seropositive animals with their progeny, and a total replacement with uninfected animals (Pérez et al., 2010). This is an effective measure; however, culling leads to the loss of genetically interesting lines or animals. Limited sensitivity of serological tests associated with subclinical infections or even a lack of interest among farmers are other important issues. They are, however, useful measures in flocks with low to moderate seroprevalence (Berriatua et al., 2002).

Another strategy is the selective culling of animals with suggestive clinical signs or seropositive animals. This strategy can be applied in areas with moderate to low seroprevalence (Pérez et al., 2013) or on farms with low animal density. This selective measure does not enable rapid results in disease control, although it may contribute to a reduction of seroprevalence in flocks (Reina et al., 2009). However, in herds with very low prevalence, it may be effective to cull all seropositive animals in a test-and-slaughter strategy (Pittavino et al., 2014).

Control programmes implemented in different countries must consider the national and regional specificities and aim to maintain the genetic heritage of sheep and goat breeds. Isolating newborn animals allows for the conservation of genetic material. These animals should be isolated from their mothers immediately after birth or be delivered by C-section (Nuotio, 2006). They must be raised separately without any contact with adult animals (Blacklaws et al., 2004). These newborn animals should be fed with uninfected colostrum (from small ruminants or cattle) and/or artificial milk (Reina et al., 2009; Pérez et al., 2013).

Farm owners may be advised to keep seropositive and seronegative animals permanently separate into two different flocks. Although considered very effective, this a very difficult, expensive, and laborious control measure that requires adequate livestock facilities and human resources. Physical separation of at least two meters is required if complete separation is not feasible. This strategy is valuable and effective in flocks with moderate to high seroprevalence. The major advantage is the maintenance of animal genetic potential (Pérez et al., 2013). Another potentially effective measure is to keep replacement animals, after weaning, in separate housing to avoid horizontal

transmission that occurs through contact with adult animals. Imported animals must be placed in quarantine until laboratory methods determine their health status. There are several reliable forms of replacement, such as selecting seronegative progeny or purchasing SRLV-free animals, on certified-free herds. Although this strategy is effective, it can often be difficult to find animals originating from herds certified as free of infection. Serological monitoring should be performed periodically (Berriatua et al., 2002).

Regular cleaning and disinfection of facilities and equipment with suitable disinfectants is essential for any prevention and control strategy. In addition to cleaning and disinfecting the floor, walls, bed, milking machines, feeders and drinkers, it is also essential to use disposable needles or sterilise metallic needles before reuse, as iatrogenic transmission is possible. Likewise, all medical equipment must be sterilised after use. SRLV-free animals should be milked first to avoid cross infection. Another useful strategy is the reduction of animal density and ensuring adequate ventilation (Reina et al., 2009).

When SRLV infection is suspected in a flock, restrictive biosecurity measures must be immediately applied. During this period moving animals outside the facilities, except for slaughter, should be prohibited. The movement of products derived from sheep to other farms must be under veterinary control (Nuotio, 2006).

When the health status of the herds is unknown, grazing on common pastures and sharing equipment should be avoided (Reina et al., 2009). One study suggests that lentivirus transmission was negligible during the grazing period, suggesting that all infections occurred within the housing period. This research also suggests that extensive grazing systems could be included as a control measure in countries where lentiviruses are a problem (Illius et al., 2020).

Although venereal transmission is not considered important, in genetic selection programmes, only males from certified and free farms should be used as semen donors for artificial insemination (Cortez-Romero et al., 2013). Investment in animal breeding focused on the selection of resistant genotypes could prove to be a successful strategy (Gomez-Lucia et al., 2018). Although this strategy can be useful, it can have undesirable consequences such as susceptibility to other diseases, a negative impact on production traits, or even the selection of resistant viral strains (Larruskain and Jugo, 2013).

The possible lack of cooperation by farmers might be one of many obstacles to the successful accomplishment of eradication programmes (Peterhans et al., 2004; Pérez et al., 2013). Also, the epidemiological characteristics of the disease (virulence, transmission, seroconversion, seroprevalence at the flock level, etc.), the genetic variability of viral lineages and the herd health management system could be very distinct from flock to flock. Any eradication programme needs to be amended and enhanced individually according to these factors.

Conclusion and future perspectives

After the successful eradication of the infection in Iceland (Peterhans et al., 2004), similar control programmes were applied in other countries with relative success (Reina et al., 2009). The decrease in SRLV prevalence decreases the incidence of clinical infection and avoids direct production losses, improves animal welfare, reduces slaughter and eliminates unnecessary veterinary costs. The main

challenge in control programs is the development of cheap diagnostic tools with high sensitivity, specificity and precision (Kalogianni et al., 2021). Strengthened research in the identification of genetic markers for resistance/susceptibility to SRLV infection allows for the selection of genetically resistant animals (Larruskain and Jugo, 2013). Prevention and control strategies must be designed carefully and once infection are detected, estimating the prevalence and understanding the management risk factors are essential to effectively control the transmission of the virus (Reina et al., 2009). SRLV control programmes are expensive and a cost-benefit analysis should always be carried out, though once implemented they must be applied continuously.

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Lentivirus malih preživača: praktični pristup

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Lentivirus malih preživača (LVMP) je skupina virusa iz obitelji *Retroviridae*, koji pogađaju koze, ovce i divlje preživače, a odgovorni su za sistemske infekcije, koje mogu utjecati na: pluća, središnji živčani sustav, mliječnu žlijezdu i zglobove. Ova infekcija može prouzročiti kronične, neprimjetne i progresivne bolesti koje utječu na zdravlje životinja. Istovremeno, povezane su sa smanjenjem proizvodnje mlijeka, što dovodi do pothranjenosti janjadi i kozlića, kao i preranog klanja odraslih životinja, prouzročeći znatne ekonomske gubitke. Ovaj je pregledni članak imao za cilj prikupiti najnovije informacije u svezi lentivirusa u malih preživača u kliničkoj praksi, njihove ekonomske važnosti i metoda dijagnoze i prevencije. Dijagnoza se temelji na kliničkim, analitičkim i obdukcijskim nalazima; naglašena je i mogućnost dijagnoze oslikavanjem. Preventivne mjere i intervencije za upravljanje, uključujući usmrćivanje ili segregaciju pozitivnih životinja, najučinkovitiji je izbor za kontrolu pa čak i nestanak ove bolesti. Strategije prevencije LVMP potrebno je stalno primjenjivati za progresivno nestajanje infekcije.

Ključne riječi: *lentivirusi, mali preživači, seroprevalencija, faktori rizika, intersticijska pneumonija, mastitis, encefalitis, artritis*