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Lungworms infection of domestic ruminants with particular to Ethiopia: A review

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Abstract

Lungworms are parasitic nematode roundworms of the order Strongylida that infest the lungs of vertebrates. The most common lungworms belong to one of the two superfamilies, Trichostrongyloidea or Metastrongyloidea. Of which, *Dictyocaulus* and *Protostrongylus* are causes of lungworm infection in ruminants. *D. viviparus* belongs to cattle and the common causes of *verminous pneumonia* in sheep and goats are *Dictyocaulus filaria*, *Protostrongylus rufescens* and *Muellerius capillaris*. Depending on the severity of infection, age and immunological status of the animal, the clinical sign ranges from moderate coughing with slightly increased respiratory rates to sever persistent coughing, persistent respiratory distress and failure. Diagnosis of the disease is by examination of the faeces with Baermanization to detect the L1 larvae in the laboratory, and postmortem examination of the lungs of infected animals for adult worms' isolation. Treatment of lungworm necessitates the use of appropriate Anthelmentics which are effective against lugworm infections. The effective Anthelmentics including Benzimidazoles, Levamisols and Ivermectin should be used in the treatment of the disease. The prevention and control of lung worm infection can be achieved most effectively by integration of three interrelated approaches: administration of effective Anthelmentic drugs, immunization and improved management practices.

Keywords: *Dictyocaulus*, *Protostrongylus*, *Muellerius*, Lungworm infections, Ruminants.

1. Introduction

Ethiopia has the largest livestock population in Africa. An estimate indicates that the country is a home for about 54 million cattle, 25.5 million sheep and 24.06 million goats. From the total cattle population 98.95% are local breeds and the remaining are hybrid and exotic breeds. 99.8% of the sheep and nearly all goat population of the country are local breeds [1]. Livestock production in Ethiopia contributes about 30-33% of agricultural gross domestic product (GDP) and more than 85% of the farm cash income mainly through meat, milk, eggs, wool, hides and skins [2 and 3].

Parasites pose subtle economic loss and are the major factors responsible for lowered level of production in tropical and subtropical regions particularly helminthes infection are among the most prevalent and widely distributed ones. [4] Infections with gastrointestinal and other helminthes parasites are among the most neglected areas of veterinary care in much of the developing world. However, it has been established that high prevalence of the infection with less obvious signs associated with poor production and unthriftness [5]. Among many contrasts which limit productivity in livestock populations helminthes

parasites particularly lung worms of ruminants are of major importance. The species of importance in ruminants belongs to two different families (dictycaulidae and metastrongylidae). Lung worms are widely distributed throughout the world providing nearly perfect conditions for their survival and development but are particularly common in countries with temperate climates, and in the highlands of tropical and sub-tropical countries. Dictyocaulidae and/or certain Metastrongylidae are known to exist in East Africa (Ethiopia, Kenya, and Tanzania) and South Africa. [5]. The prevalence of lungworm infection of small ruminants depends on different factors like, the climate of area, altitude, intermediate hosts and favorable ecological conditions such as rain fall, humidity, temperature, and marshy area for grazing, sheep and goat management system for the development of lungworm species [29]. Control of these parasites is, therefore, essential for releasing the potential of domestic ruminant production. For proper control to be instituted, however, diseases and their dynamics must be known. At our present state of knowledge of parasitic diseases, it is difficult and even dangerous to lay down rigid rules for their control which are applicable to all regions. For this reason a study of epidemiology of each parasitic disease should be limited to small areas. [6] The incidence of parasitic diseases, including respiratory helminthosis varies greatly from place to place depending on the relative importance of many of the factors.

The objective of this paper is to review on lungworms of domestic ruminants with particular emphasis on identification, diagnostic and control approaches.

2. Lungworms classification and identification

2.1. Major lungworm of domestic ruminants

Lungworms of domestic ruminants are nematodes that belong to the phylum nemathelminthes, commonly named as round worms. Lungworms of domestic animals are classified under the super family of trichostrongyloidea and metastrongyloidea. Generally, major lungworms of domestic ruminants are described in table 1 and 2 [7 and 8].

Table 1: Classification of lungworms of domestic ruminants

Super family	Family	Genus	Species
Trichostrongyloidea	Trichostrongylidae	Dictyocaulus	*D. viviparus* *D. filaria*
Metastrongyloidea	protostrongylidae	Protostrongylus Muellerius	*Protostrongylus rufescens* *P. hobmaier* *P. davitiani* *P. stilesi* *Muellerius capillaries*

Table 2: Host morphology and predilection site of major adult lungworms of domestic ruminants [7 and 8]

Species	Host		Morphology	Predilection
	Intermediate	Final		
D. viviparus	-	Cattle	- Male is 4-5cm long - Female is 6-10cm long - Medium and posterior lateral rays are completely fused - Spicules are 0.195-0.215mm long	Trachea and bronchi
D. filaria	-	Sheep Goat	- Male is 3-8cm long - Female is 5-8cm long - Milk white in color - Intestine shows as a dark line - Relatively large bursa	Trachea and bronchi

M. capillaries	Snails Slugs	Sheep Goat	- Male is 12-14mm long - Female is 19-23mm long - Posterior end of the male is spirally coiled - No bursa	Alveoli
Protostrongylus species	Snails	Sheep Goat	- Male is 16-28mm long - Female is 25-35mm long - Slender and reddish in color - Bursa is short - The ventral, lateral and externo-dorsal rays are present	Bronchioles

3. General morphology

Lungworms of domestic ruminants are nematodes that belongs to the phylum Nemathelminthes commonly named as round worms; classified under the super family Trichostrongyloidea and Metastrongyloidea. [10] Of which, *Dictyocaulus* and *Protostrongylus* are causes of lungworm infection in ruminants[15]. *D. viviparus* in cattle and the common causes of verminous pneumonia in sheep and goats are *Dictyocaulus filaria, Protostrongylus rufescens* and *Muellerius capillaris*. *Dictyocaulus filaria* belongs to the super family Trichostrongyloidea while the latter two belong to Metastrongyloidea, which have direct and indirect life cycles respectively. [16 and 17] Although mixed infection may occur, *D. filaria* predominates in most outbreaks [18].

Adult *Dictyocaulus* worms are slender, medium sized roundworms and up to 8 cm long as indicated in figure 1 [9]. Females are about one third longer than males. They have a whitish to grayish color [10]. As in other roundworms, the body of these worms is covered with a cuticle, which is flexible but rather tough. The worms have a tubular digestive system with two openings, the mouth and the anus [11]. They also have a nervous system but no excretory organs and no circulatory system, i.e. neither a heart nor blood vessels. The female ovaries are large and the uteri end in an opening called the vulva. Posterior end male lung worms have a copulatory bursa with two short and thick Spicules for attaching to the female during copulation. Posterior end of an adult male lung worm *Dictyocaulus filaria* has short bursa having a short, stout, dark brown Spicules “boot-shaped” [9] The eggs of *Dictyocaulus filaria* and *Dictyocaulus arnfieldi* is approximately 60x90 micrometers and that of *Dictyocaulus viviparous* approximately 35x85 micrometers. They have ovoid shape and contain a fully developed L1 Dictyocaulus larva [12].

Adult *Muellerius capillaris* are medium-sized (not longer than 3 cm) and thin worms (hence their common name hairworms),while adult *Protostrongylus rufescens* are slender, reddish to brownish color worms up to 70 mm [13 and 14].

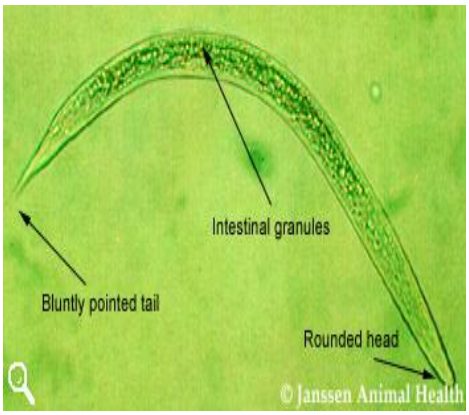

Figure 1: *Dictyocaulus filaria*, figure 2: *muellerius capillaries* lung worm of sheep and goats and figure 3: Dictyocaulus viviparus of cattle.
Source: [9]

4. Life Cycle

Lungworms of domestic ruminants have two forms of life cycle. One form is direct life cycle (Dictyocaulidae) in which the free living larvae undergo two moults after hatching and infection are by ingestion of the free L3. The other form is indirect life cycle (Protostrongylidae) whereby the first two moults usually take place in an intermediate host (snails or slugs) and infection of the final host is by ingestion of intermediate host [10].

4.1. Direct life cycle

The life cycle of Dictyocaulus species is direct. Female parasite lives in the trachea and bronchi producing embryonated eggs, which are coughed up swallowed and usually hatch still in the digestive tract. Therefore the first stage larvae (L_1) are found in fresh bovine faeces. Under favorable condition, L_1 develop to the infective third stage larvae in less than a week. Infection is by ingestion of the free third stage larvae. Then L_3 larvae penetrate the intestine and migrate via lymphatic to mesenteric lymph node, where they moult. Hence, the L_4 travel via the lymph and blood to the lung and break out of the capillaries in the alveoli about one week after infection. The final moult occurs in the bronchioles a few days later and the young then move up the bronchi and matures [7 and 8]. The prepatent period of *D. viviparus* is 3-4 weeks but the prepatent period of *D. filaria* is 5 weeks [7].

4.2. Indirect life cycle

It occurs in lungworms belonging to the family protostrongylidae. Protostrongylus and muellerius are the two important genera of lungworm in ruminants whose life cycle is indirect, requiring intermediate host. The female parasites are ovo-viviparus, the L_1 being passed in the faeces. The L_1 passed in the faeces penetrate the foot of the mollusk intermediate host and develop to L_3 in a minimum period of 2-3 weeks. Sheep are infected by ingesting the mollusks and the L_3 freed by digestion travel to the lungs by the lymphatic-vascular route, the parasitic moults occurring in the mesenteric lymph nodes and lungs [7]. The prepatent period of muellerius is 6-10 weeks and that of Protostrongylus is 5-6 weeks. The period of patency is very long, exceeding two years in all genera examined [7 and 8].

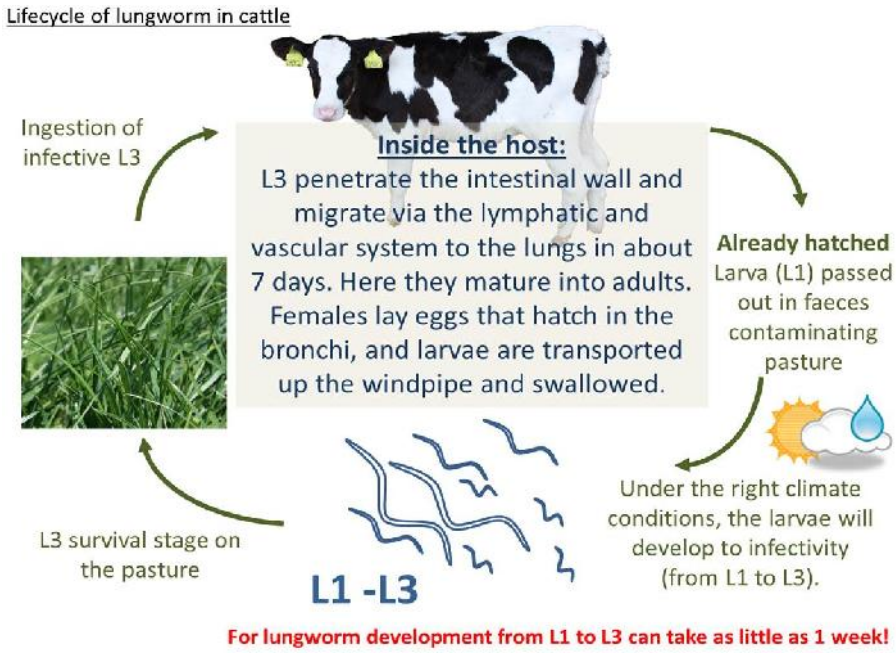

Figure 3: Life cycle of lungworm in cattle, Source: [48]

5. Epidemiology

Epidemiology depends more on pasture contamination by carrier animals. Pasture infectivity is related to rainfall which stimulates the activity of both the larvae and the mollusk [22]. Moisture is essential for the survival and development of the larvae. The larvae is active at moderate temperature of 10-21^{o}c. Larvae survive best in cool, damp surroundings especially when the environment is stabilized by the presence of long herbage of free water. Under optimum conditions the larvae can persist for over one year [19].

Lungworm parasites are host specific and common in areas of mild high rain fall and abundant grass [20 and 21]. The prevalence of infection is low in spring and summer and rises rapidly in the autumn and winter. When most clinical cases are seen, wet summers give rise to heavier burden in the following autumn and winter [21]. Over stocking, deficient feeding, previous or concurrent infections predispose to infection [22]. Sheep of all age are susceptible, but lambs of 4-6 months of age are severely affected with lungworms [23].

Generally, only young ruminants in their first grazing season are clinically affected, since on farms where the disease is endemic older animals have a strong acquired immunity. Goats appear to be more susceptible to helminthes than sheep as they appear to develop less immunity. Sheep predominantly graze; pick up more parasites so have higher acquired resistance than goats which mostly consume browse. Goats with their browsing behavior consume uncontaminated matter with parasite larvae, so being less exposed to infective larvae, and may therefore have lower acquired resistance than sheep [24].

Sex depended prevalence of lung worm in small ruminants was not reported in many studies. However, some difference had been reported in some studies. According to [25] 16.6% and 8.1% of lung worm prevalence rate in female and male respectively, and [26] also reported small ruminant lungworm prevalence rate of 48% in female and 43.2% in male in north Gondar. [27] Also found 25.44% in female and 25.09% in male sheep. In contrast to these finding, the higher prevalence was reported in males (27.23%) than female (23.75%) [28] However, there is no report that caused this difference but it may be immune suppression of female due to production and reproduction and other stress factor.

Among ovine lung worm parasites *Dictyocaulus filarial* (26%) is the most predominant lungworm species, followed by *Muellerius capillaries* (18%) and *Protostrongylus rufescens* (10%) is the least prevalent [29]. The possible reason for the predominance of *D. filaria* might be attributed to the difference in the life cycles of the parasites. *D. filaria* has a direct life cycle and requires shorter time to develop to an infective stage. After ingestion, the larvae of these parasites can be shed with feces within 5 weeks. Unlike to *D. filaria*, the transmission of *P. rufescens* and *M. capillaris* is epidemiologically complex event involving host, parasite and intermediate host. Because, *P. rufescens* has indirect life cycle that requires longer time and wet or rainy warmer season to complete their complex life cycle in the presence of suitable intermediate hosts that create favorable condition for sporadic distribution, dry or short rainy season does not favor the development of the snail intermediate hosts [30 and 29].

6. Pathogenesis

The pathogenic effect of lugworms depend on their location within the respiratory tract, the number of infective larvae ingested, the animal immune state, and on the nutritional status and age of the host [16 and 31].

The relative pathogenicity of each lungworm depends on its predilection site. *D. filaria* lives in the trachea and bronchi so aspirated eggs, larvae and debris affect a large volume of lung tissue. It is therefore the most pathogenic species. Adult *P. rufescens* are found in smaller bronchioles, so associated lesions are much smaller. *M. capillaris* is found in the lung parenchyma where it becomes encysted in fibrous nodules; lesions are therefore confined to its immediate surroundings. Consequently, this worm is generally considered as involves heavy mixed protostrongyloid infection and impair pulmonary gaseous exchange [23]. It is suggested that when the larval stages of *M. capillaris* migrated through the walls of small intestine, the resulting damage may predispose to enterotoxaemia [32]. Infection with more than one species is common and course of infection is usually chronic [22].

Sever infection with lung worm can cause vasculitis and perivasculitis with ifiltration of inflammatory cells in and around the vascular wall and thickening of inter alveolar walls and mononuclear cell infiltration due to inflammation response in lung [9].

Migrating *D. viviparous* larvae provoke little damage until they reach the lungs. Thereafter, passage of larvae up the bronchioles causes them to become blocked by mucus, eosinophils and other inflammatory cells, leading to collapse of the alveoli that they supply. Coughing and dyspnea occur if a sufficiently large volume of lung tissue is affected [33]. This is accompanied by pulmonary edema and interstitial emphysema; as no structural damage has yet occurred, treatment at this stage in the disease produces an immediate clinical response. Later however when mature parasites are in the major bronchi, eggs and fragments of worms killed by immunity are aspirated and provoke foreign body pneumonia [23].

7. Clinical signs

The clinical course of lungworm infection depends on severity of infection, age and immunological status of the animal. Signs of lungworm infection can range in many cases from moderate coughing with slightly increased respiratory rates to severe persistent coughing and respiratory distress and even failure [34]. Reduced weight gains, reduced milk yields, and weight loss accompany many infections in cattle, sheep, and goats, and patent subclinical infections can occur in all species [35].

The most common sign in sheep and goats are pyrexia, coughing, rapid shallow breathing, nasal discharge, and emaciation with retarded growth [36]. Initially, the animals experience the sign of rapid, shallow breathing which accompanied by a cough that is exacerbated by exercise. Respiratory difficulty may proceed, and heavily infected animals stand with their heads stretched forward and mouths open and drool. Lung sounds are particularly prominent at the bronchial bifurcation. Such sever pulmonary signs usually are associated with *D. filarial* (more pathogenic) in sheep while *M. capillaries* (more pathogenic in goats) can affect goats similarly [37].

8. Diagnosis

The factors that suggest lungworm infection are a history of exposure to previously grazed pasture by animals of the same species, the presence of the disease in the area and failure to respond to standard treatments to bacterial or viral pneumonia [20 and 21].

8.1. Clinical diagnosis

Pneumonic signs of Metastrongylus of sheep and goats have rarely been observed and infections are almost always inapparent, being identified only at necropsy. Depending on the numbers of *dictyocaulus* larvae ingested, animals develop acute and subacute forms of verminous pneumonia [7].

The acute form of *D. viviparus* is characterized by sever tachypnea (>80 respiration per minute, in case of moderate cases >60 respiration per minute) and dyspnea, and frequently adopt the classic "air hunger" position of mouth breathing with head and neck stretched. There is usually a deep harsh cough/squeaks and crackles over the posterior lung lobes, salivation, anorexia and sometimes mild pyrexia (40-41^{o}C). Slight nasal discharge, increased heart rate, vesicular murmur and bronchial tones are evidenced. Loud bronchial tones due to consolidation and most riles are heard over the bronchial tree [7 and 8].

In sub acute cases, animals cough intermittently particularly when exercised but in moderate cases, in which most animals are affected, there are frequent bouts of coughing at rest and frequently hyperpnoea squeaks and crackles over the posterior lung lobes are heard on auscultation. There is evidence of recent diarrhea and normal or slightly elevated temperature. The course of disease is long 3-4 weeks and auscultation findings vary widely. In general there is consolidation and bronchitis ventrally and marked emphysema dorsally. Affected animals lose weight very quickly but mortality rate is less than that of the acute form. Most animals gradually recover, although complete return to normality may take weeks or months. Many of surviving calves have severely affected lungs and may have labored breathing for several months and are very susceptible to secondary bacterial broncho pneumonia and remain stunted for long periods. So the presence of worms or larvae indicates the case to be verminous pneumonia that is pneumonia with vermin (worms) [7].

The most common signs in case of *D. filaria* are coughing unthriftness which, in endemic areas, is usually confined to young animals. In more severe cases dyspnea and tenacious nasal discharge is also present [8].

8.2. Laboratory Diagnosis

In laboratory, 25 gram of fresh faeces will be weighed from each sample for the extraction of L1 larvae using modified Baermann technique. The paste enclosed in gauze fixed on string rod and submerged in clean glass tube filled with fresh water. The whole apparatus will be left for 24 hours. The larvae leave the faeces and migrate through the gauzes and settle at the bottom of the glass. After siphoning of the supernatant, the sediment is examined under the lower power of the microscope [16 and 38].

The larval identification of small ruminant lungworm is then takes place based on their morphological characteristics. The larvae of *Protostrongylus rufescens* is confirmed by larvae found in the feces which elongate 300 to 400 micrometers with a characteristic tapering tail and a wavy outline but without dorsal spine [35 and 14], and that of *M. capillaries* (250 to 300 micrometers long) is also confirmed in the feces with its characteristic tapering and a wavy outline tail and a dorsal spine [13] and larva of *D. filaria* (550-585 µm in length) could be identified by having head with protruding knob, bluntly pointed tail and brownish intestinal granules [35 and 30].

[29] Performed microscopic examination and identification of lungworms in their study and performed identification of lungworm using its features. In accordance, they reported *D. filarial* which is slender, thread like nematodes, white in color with knob on head was occurred in the trachea, bronchi and bronchioles of sheep and goats; *M. capillaris* was occurred in the lung (bronchi, bronchioles and alveoli) of sheep and goat which is small hair like with bent tail, while the adults of *P. rufescens* were found within the bronchioles, grey reddish in color and have wavy tail.

8.2.1. The Baermann Apparatus

The Baermann technique is used to recover the larvae of roundworm from faeces, soil, or animal tissue. Warm water stimulates the larvae in a sample to move about. Once the larvae move out of the sample, they relax in the water and sink to the bottom of the container. A Baermann apparatus may be easily constructed to perform this function. It consists of a ring stand and a ring supporting a large glass funnel. The funnels stem is connected by a piece of rubber tubing to a tapered tube. The rubber tubing is camped shut with a pinch clamp. A piece of metal screen is placed in the funnel to serve as a support for the sample [39].

In Baermann technique spread to a piece of cheese cloth or a gauze square out on the support screen in the Baermann apparatus, place 5 to 15 gram of the faecal sample on the cheese cloth. Fold any excess cheese cloth over the top of the sample. The funnel is filled with water or physiologic saline at about 30°c to a level 1-3cm above the sample. Allow the apparatus to remain undisturbed overnight. Hold a glass microscope slide under the cut-off pipette and open the pinch clamp long enough to allow a large drop of fluid to fall on the slide. Apply a cover slip to the slide and examine it microscopically for the presence of larvae. Repeat examining several slides before deciding that the sample is negative. The Baermann technique is based on the active migration or movement of larvae that sink to the bottom and can be collected for identification [39].

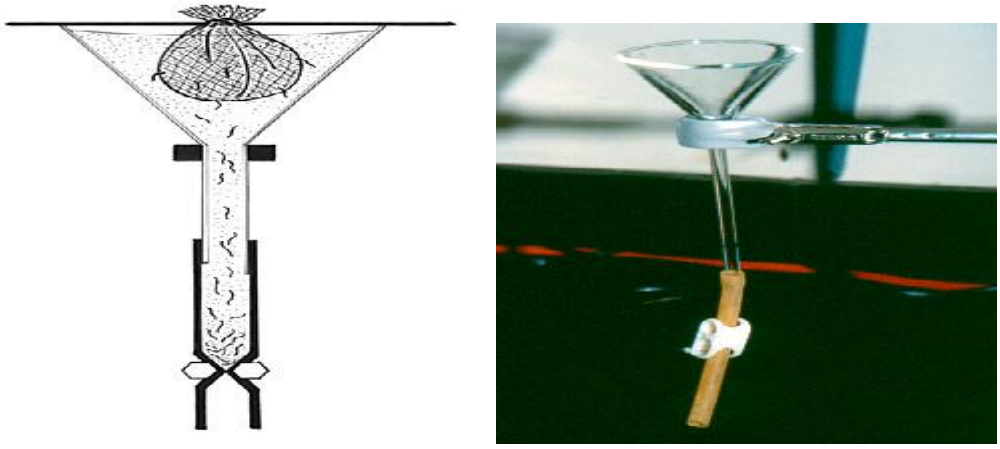

Figure 5: Baermann Apparatus Source [53]

8.3. Postmortem Examinations

Lungs from selected animals were palpated for the presence of Protostrongylidae nodule. If the nodule present they were trimmed off and worms extracted from the tissue by gentile comprising a small non-calcified nodule or part of large nodule between two glass slides and then carefully testing the worm away from the tissue. Air passages were opened starting from the trachea to the small bronchi with fine blunt pointed scissors to detect the presence of adult Dictyocaulidae [15 and 22].

At necropsy, most lesions are found in the respiratory system. With infection by *D. filaria*, the bronchi, especially those of the diaphragmatic lobes, contain tangled masses of worms mixed with frothy exudates. Atelectatic and infected lobules often surround or extend ventrally from infected bronchi. Bronchioles infected with *P. rufescens* often are closed with worms and exudates; consequently, affected lobules may be atelectatic and infected. Lungs infected with *M. capillaris* contain red, grey or green lobules 1 to 2 mm in diameter. These lesions, located in the sub-pleura of the diaphragmatic lobes, vary in consistency, number, and shape [18]. Lung nodules as a result of *M. capillaris* infection have the feeling of lead shot [41].

Grossly on the postmortem diagnosis, the lungs may reveal depressed consolidated areas and elevated emphysematous patches or dirty white to irregular nodular lesions distributed in various lobes especially in the diaphragmatic lobes. On dissection, the trachea and bronchial tree revealed copious foamy froth in which numerous slender thread-like creamy white worms may found and bunches of worms often observed in terminal bronchioles of the diaphragmatic lobes [9]. Lungs infected with *M. capillaris* contain red, grey or green lobules 1 to 2 mm in diameter [34].

8.4. Serological Diagnosis

Another method which is alternative to faecal analysis to detect parasite-specific serum antibodies by enzyme linked immune sorbent assay (ELISA) in cattle [40]. In practical terms, when investigating an avail outbreak, it is advisable to analyze faecal and serum samples collected from a group of 6-10 animals that have been showing clinical signs of disease the longest. The ELISA is the preferred option when large numbers of samples are being tested.

ELISA Test: an ELISA test can demonstrate antibodies from 5 week after the animals have been exposed and it may be useful in identifying infected animal particularly in the autumn when heavy burdens of worms do not generate and larvae in the faeces. The time needed to perform an ELISA depends on the availability of antigen-coated microtitre-plates. If such plates can be provided, the results can be obtained within 4 hours after the serum has been prepared, If not plates have to be coated with antigen for up to 16 hours. These studies have been carried out to aid diagnosis of infections in the field or to provide information on prevalence. Positive ELISA titer appears to be satisfactory indicator of recent herd exposure [51 and 52].

8.5. Laboratory examination of Sputum and Tracheal washes

Dictyocaulus species: lungworms of cattle and sheep which are usually seen in the sputum as egg containing larvae rather than free larvae in the faeces [39].

A drop of sputum or nasal discharge on a microscope slide is easily examined. Several slides should be examined, when the sputum is especially viscous, a drop of the material should be placed between two microscope slides and both slides examined microscopically. Larger quantity of fluid obtained from the respiratory tract should be concentrated by centrifugation at 1500 rpm for 5 minutes. A drop of the sediment can be placed on a slide and examined microscopically [39].

9. Treatment

Strong acquired resistance against dictyocaulosis of bovine and ovine species by natural infection is well documented fact. However, owing to the undetermined number of infective larvae that could be ingested in the field and the accompanying disease process makes it unreliable [42].

Treatment of lungworm necessitates the use of appropriate Anthelmentics which are effective against lugworm infection [43]. The effective Anthelmentics including Benzimidazoles, Levamisols or Ivermectin should be used in the treatment of the disease [10 and 31].

However, some dewormers that used to be effective against a specific parasite are no longer effective, due to the development of resistance in some worms. Therefore, just because you apply a dewormer doesn't mean you've killed the worms; you have to be sure to use the right dewormer for your specific situation. Sheep and goats have a much higher metabolism rate than cattle. Therefore, drug dosages will likely be higher than those listed for cattle [44].

10. Control and Prevention

The objective of prevention and control can be achieved most effectively by integration of three interrelated approaches of Anthelmentic drugs, immunization and improved management practice [17].

Management practice such as provision of ample nutrition increases the resistance of the host and therefore it is important for the control of Dictyocaulosis. Larvae of *Dictyocaulus* may persist and develop in swampy pastures and may serve as a source of infection; therefore, those susceptible animals should not be allowed to have access to such areas because young hosts of all kids are more susceptible to *Dictyocaulus* than adults. Animals must be placed on dry pasture and supplied with clean drinking water; moist pasture must be avoided while dry pasture is fairly safe, because the infective larvae are not very resistance to dryness. Young stock should be separated from other stock [10].

Extinction of the snail intermediate host is an additional measure important for the control of Metastrongyloidea. This technique enables to control the nude slugs and shelled snails more easily, and spreading of lime has been recommended for this purpose. The snails creep up plants in the early morning and evening and rainy weather, the animals should, therefore, not be allowed to graze at such times, particularly in the autumn when the infection most frequently occur [45].

Control of lungworm infection in first year grazing sheep and goats has been achieved by the use of prophylactic anthelmintic regimens either by strategic early season treatment or by administration of rumen bolus [10].

The best method of preventing verminous pneumonia is to immunize all young sheep and goats with lungworm vaccine [10]. Vaccine for *D. filaria* is available where this worm is a particular problem [23]. This live vaccine, consisting of larvae attenuated by irradiation, is given orally to young's aged 8 weeks or more. Two doses should be administered in order to allow a high level of immunity and to develop resistance. Vaccinated animals should be protected from challenge until two weeks after their second dose [10].

In Ethiopia the relatively best method to control and prevention is to graze young stock in advance of older stock especially in the rainy season since the susceptibility of animals varies with age and using cut and carry feeding systems can significantly limit worm infestation. Overpopulation increases the concentration of parasites and also forces animals to graze closer to the ground, and may result in consumption of a higher number of infective larvae. So it is recommended that all farmers/pastoralists in Ethiopia using the same pasture have to take control measures at the same time and deworm all newly introduced animals and keep them separate for three days before allowing them to mix with the rest of the flock [46].

In addition to this, [46] also recommended the better deworming strategy for control of sheep and goat parasite including lungworm in Ethiopia based on rainy season of different altitudes as the following:

- In highland areas, with short rains followed by long rains: Deworm all sheep and goats at the end of the rainy season when the pasture becomes dry (December) and deworm all sheep and goats at the end of the dry season before the rain starts (April).
- In lowland areas where there are two distinct rainy seasons: Deworm all sheep and goats at the end of the dry season (February) before the rains start and deworm all sheep and goats at the end of each of the rainy seasons (September and April).
- In mid-altitude areas where there is one long rainy season giving long crop growing periods: Deworm all sheep and goats after the rainy season (November) and deworm all sheep and goats before the beginning of the rains (May).

The best prevention method to reduce exposure to parasites are as follows [44]:

- Providing a clean environment beginning at birth and avoiding overcrowding of pens.
- Providing balanced nutrition is very important to keep animals healthy and help them to develop appropriate resistance to external pathogens, especially for dams before and after lambing/kidding.
- Avoid pasturing in damp areas and during early morning and evening hours, when there is Dew on the pasture.
- Rotate pastures to avoid high burdens of parasites.

The other most important to control and prevention of lung worm is vaccination. Vaccine was developed from larvae of *D. filaria.* Larvae are separated from feces by Baermann technique and cultured to L3 in water and attenuated with X-radiation or gamma-radiation and packed in a single dose containing 1000 attenuated larvae, need two dose four weeks apart, provide 97% protection [47]. Vaccine is given for 8-week-old lambs [10].

11. Lungworm infections of domestic ruminants in Ethiopia

Prevalence of domestic ruminant lung worm is different based on geographical and climatic factor of spatial area. Some studies conducted at different location in Ethiopia gave different prevalence records as indicated in table 3.

Table 3: Summary of the data of studies conducted on prevalence of lungworm infection of domestic ruminants in different areas of Ethiopia

Place	Prevalence rate (%)	Reference
In and around Bahir Dar City	18.16% 22.7%	Muluken, 2009 Asaye and Alemneh, 2015
In North and South Gondar Zones	39.6%	Tigist (2009)
Tigray (Atsbi)	21.5%	Mangistom (2008)
In North East Ethiopia	53.6%	Alemu *et al* (2006)
At Mekele Town	13.4%	Ibrahim and Degefa (2012)
In and around Jimma Town	29.04%	Fentahun *et al*., 2012
Ambo District	34.90%	Beyene *et al*., 2013

Source: [49]

Sheep of all age are susceptible, but lambs of 4-6 months of age are severely affected with lungworms [34]. The prevalence of lungworm infection in young sheep (75.6%) was reported which is significantly greater than in adult sheep (51.8%). Similarly, the prevalence rate of lungworm infection in young goat (75.6%) is significantly higher than that of the adult goat (46.4%) in Dale District, Southern Ethiopia [29]. According to, [49] who reported that young sheep were found to be infected more than adults and this might be associated with the naturally acquired immunity against infection in older animals which slowly developed due to the previous exposure and better immunity against reinfection after recovering from the disease. *M. capillaris* is prevalent worldwide and can cause severe signs in goats, although it usually less pathogenic in sheep [35]**.**

The variation in the overall prevalence rate in different areas might be due to differences in nutritional status, level of immunity, management practice of the animal, rain fall, humidity and temperature differences and season of examination on their respective study area [29]. These differences in the prevalence of lungworms of small ruminants might be associated with difference in nutritional status, level of immunity, management practice of the animal, rain fall, humidity, temperature and altitude differences [50].

Bovine parasitic bronchitis, or lungworm disease (“Hoose” or “husk”), in Ethiopia is caused by the roundworm, *D.viviparous* ages of cattle, the disease is mainly seen in calves during their first season at grass. However, lungworm disease has recently emerged as a disease of second grazing season and older animals [25]. On most organic farms, a gradual infection occurs in young animals resulting in development of a natural immunity. However, on some farms this gradual infection does not take place and large numbers of infective larvae may build up on pasture. The challenge may be sufficient to cause clinical disease in cattle which have not developed adequate immunity [42]. The increase in bovine dictyocaulosis has been attributed to several factors, including climate change, a reduction in usage of the vaccine and/or common use of anthelmintic treatments to control lungworm and gastrointestinal parasites, which preclude adequate parasite antigen exposure, depriving the animal from subsequent immunological boosting. These challenges highlight the need for extensive research efforts to better understand the epidemiology and pathophysiology of bovine dictyocaulosis, with the aim of developing improved therapeutic interventions [12]. Lungworm infection is one of the most important respiratory diseases of cattle, which is a roundworm (Nematode) parasite imilar to gut worms. However, it completes its life cycle in the lungs rather than in the gastrointestinal tract [5].

Bovine parasitic bronchitis is a sporadic and largely unpredictable disease. This is because immunity develops more quickly than is the case with many other nematode infections, but nevertheless can emain incomplete for many weeks and may wane in the absence of re-infection. In most grazing seasons, immunity will develop fast enough to protect calves against the accumulating numbers of infective larvae on the grass. The farmer may not even realize that his land is contaminated. Clinical outbreaks occur when weather patterns, management or other factors result in sudden exposure to a pasture challenge sufficient to overwhelm any immunity that has already develop [6].

12. Conclusion and Recommendations

Lungworms of domestic ruminants are very common parasitic problem in Ethiopia. Among these, *Dictyocaulus* and *Protostrongylus* are causes of lungworm infection in ruminants. Among all domestic ruminants, sheep and goats are more susceptible to lungworm infection. Female animals, young animals of less than one year of age, poorly conditioned animals, and those managed under extensive system of production are more prone to lungworm infection. The respiratory nematodes, *Dictyocaulus filaria, Muellerius capillaris* and *Protostrongylus rufescens,* are the species of lungworms most commonly affecting small ruminants. Lungworm distribution is mainly based on climate of an area, rain fall or marsh and intermediate host snail and slug, so the infection is more common during rainy season. Goats are more susceptible than sheep for lungworm because it is less infected due to its grazing behavior. Commonly, female animals, young animals of less than one year of age, poorly conditioned animals, and those managed under extensive system of production are more prone to lungworm infection. It highly damage lung, bronchi and bronchioles and mostly present clinical sign like pyrexia, coughing, rapid shallow breathing, nasal discharge, and emaciation with retarded growth, may be up to sever respiratory distress and failure. The clinical picture of the disease ranges from moderate coughing and sneezing to sever respiratory distress and failure.

Diagnosis can be done by taking history and clinical sign followed by faecal examination for presence of larvae using Bermann technique. The market available anthelmintics for treatment of lungworm are Albendazole, Ivermectin and Levamisole. Treatment is not enough for control and prevention but treatment with grazing management and its usage as prophylactic treatment before the onset of infective season is the most important method to control lungworm infection. Lungworm infection in ruminants can be prevented and controlled by integration of effective Anthelmintic drug administration, vaccination, and improvement of the management and husbandry system. Grazing young stock in advance of older stock, rotational grazing, decreasing overcrowding, separating sheep and goat stock and regular deworming before and after rainy season are best management practice to control and prevention of lungworm in Ethiopia.

Based on the above conclusion the following points are forwarded:

- Proper diagnosis and treatment should be given for sick animal.
- Awareness should be given for farmers about lung worm effect by veterinary health servants.
- Young animal should be kept separately from older animal.
- Sheep and goat should be kept separately.
- Grazing on marshy area should be avoided or cutting or feeding strategy should be followed.
- Regular deworming should be practiced before and after rainy season.
- Newly introduced animal to the flock should be dewormed.

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