ZEUGMA BIOLOGICAL SCIENCE
ZEUGMA BIOLOGICAL SCIENCE
2022
v:3 n:2 p:12-31

Review on Trypanosomiasis and their prevalence in ruminants

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Abstract

Trypanosoma is a protozoan infection that has the potential to harm both humans and animals in practically every corner of the world. Cattle, buffaloes, sheep, and goats, including members of the family Camelidae, are among the ruminants that may be infected with the pathogen. The economic impact of this condition in various countries throughout the world was evaluated in this review research, which ran from 2018 to 2022. Iran, Syria, Iraq, Eastern Thailand, Nicaragua, Central Africa, Nigeria, Uganda, Indonesia, Philippines, Ecuador, Brazil, and Saudi Arabia were among the countries where the disease was studied in depth. In Pakistan, it is dire need to investigate it in wide range. In addition to the differences in diagnostic procedures, including blood smears, buffy coat smears, giemsa stained, serological testing, hematocrit centrifugation, and molecular analysis, PCR are used in these countries, the prevalence of trypanosoma is also different in each of these countries. In the United States, the prevalence of trypanosoma is the same as it is in other countries. In the current research, an investigation on the distribution and prevalence of trypanosoma infection in various countries was carried out using information from previously published research. The published literature from 2000 to 2022 was gathered using Google Scholar and PubMed. A total of 16 papers were published between 2018 and 2022 that looked at the frequency and distribution of trypnosoma infection around the world. According to published data, camel trypanosomiasis is more common in Saudi Arabia than in other countries, and PCR is used to diagnose the disease in approximately 85 percent of clinical and non-clinical cases. As a result, accurate diagnostic tests should be used to initiate or maintain quick medication or management of the condition, since failure to do so in the early stages may result in high mortality.

Introduction

Trypanosomes are haemoprotozoans members of the trypanosoma genus, tryanosomatidae family, kinetoplastida order, and sarcomastigophora phylum. trypanosoma species and subspecies infect many hosts, including animals and people, and cause widespread disease. A

trypanosoma is an organism derived from trypano, which means "borer," and Soma, which means the body (Shah & Khan, 2019). Tsetse fly species are known to spread Trypanosomes. The relative relevance of their transmission, on the other hand, is determined by the intensity of their connections with vulnerable hosts.

For this reason, the survival of livestock and small ruminants, as well as horses, in the Gambia is jeopardised as long as these insects are allowed to persist in the country. Tsetse fly (Kuye,2020). Trypanosomiasis is associated with anaemia, which is the most common clinical sign. The signs of an infection in animals include high fever, reduced hunger, anorexia, sharp fall in milk production, lymph nodes enlarged, and an overall decline in health. The presence of jaundice with hemoglobinuria is unusual. It is also possible that trypanosomiasis is causing milk production to have reduced output fecundity has been decreased in animals. In contrast, mortality has increased (De Gier, Cecchi, Paone, Dede, & Zhao, 2020). Pathogenic trypanosomes that infect and kill domestic animals constitute a significant source of illness and mortality in these species. These viruses are a significant impediment to economic development in Africa. Their detrimental influence on the economies of South America and Asia is becoming more pronounced (Wilkowsky, 2018).

The disease has a significant economic impact in India; however, it is impossible to estimate the financial losses due to a lack of precise epidemiological statistics and an inability to collect sufficient data. More than half of the world's cattle, hundred million buffaloes, and twelve million camels are at risk of extinction because of this epidemic. It is responsible for 30% of morbidity and 3% of death in the population of the United States. However, the economic losses produced by surra in Asia may be more significant than those caused by African trypanosomes; in terms of the cost of meat and dairy products, it is estimated that they will cost 1.3 billion US$ (Kristjanson, Swallow, Rowlands, Kruska, & De Leeuw, 1999).

Trypanosoma affects significant number of domestic and wild animals around the world, including mules, horses, donkeys, camels, buffalo, sheep and a herd of goats, cows, pigs, dogs, elephants, deer, foxes, tigers, and jackals, and causes a persistently high but intermittent temperature, anemia, weight loss, edema-affected regions, anxious symptoms, and abortion among other symptoms. Animal and poultry producers suffer huge losses as a result of it. World Health Organization (WHO) states that animal trypanosomiasis is currently a permanent constraint on cattle productivity across Asia, Africa, and Latin America. According to the World Health Organization, the disease's geographic spread is still in flux (Desquesnes *et al*., 2013).

Trypanosomiasis

The members of the genus trypanosoma are the causal agents' African human trypanosomiasis (also known as African sleeping sickness) and American trypanosomiasis (also known as Chagas' illness). Insects transmit Blood-borne diseases (Barrett et al., 2003). It is a vector-borne disease spread mainly through blood-sucking insects for example tabanus, haematopota, atylotus, chrysops, stomoxys, and heamatobia (Otto *et al.,* 2010).

Trypanosoma vivax, Trypanosoma congolense, *T. brucei*, *T. simiae*, and *Trypanosoma evansi* are the most prevalent pathogenic trypanosome species. Cattle have the highest prevalence of the first three. *T. congolense* is the most commonly seen parasitic trypanosome in cattle (Algehani, Jaber, Khan, & Alsulami, 2021). The transmission of African animal trypanosomiasis is carried out by various trypanosome species (AAT), including trypanosoma congolense, *T. vivax*, *T. Godfrey*, *T. simiae*, and *T. brucei*. subspecies are responsible for

transmitting African human trypanosomiasis (Isaac *et al.,* 2016) also include trypanosome species spread mainly through biting vectors such as tsetse flies (Rahman, Goreish, Yagi, Rajab, & Gasmir, 2008).

Animal trypanosomiasis is an endemic disease in tropical regions of Asia, Africa, and South America, and it may cause both human and animal disease (Aregawi, Agga, Abdi, & Büscher, 2019). One of the biggest obstacles establishing animal husbandry and breeding and livestock-related businesses in Africa is a lack of available land for grazing. In addition, in tropical Africa, it harms mixed farming, human health, and livelihood. Tsetse flies are Africa's most prevalent vector of the illness. The chronic illness is characterized by a depressed mood, fitful fever, anorexia, anemia, diarrhea with a bloody tinge, and adenopathy, associated with petechiae on the mucosa. If left untreated, it may result in abortion and death (Maichomo, Orenge, & Gamba, 2021). Animal trypanosomes may be found in ruminants, camels, equines, pigs, and carnivores, among other animals. In addition to decreasing livestock output, the illness harms livestock producers' wealth and the overall community's nutritional status (Holt, Selby, Mumba, Napier, & Guitian, 2016).

The parasite Trypanosoma evansi causes trypanosomiasis, which is endemic in the majority of tropical areas, including Africa, Latin America, and Asia. The principal targets of *T. evansi* illness are camels and horses, which are conveyed mechanically by biting flies and other vectors. This illness has also impacted other animal species, including goats, sheep, cattle, donkeys, and buffaloes (Al-Abedi, Spray, Hussein, & Gharban, 2018). Surra also known as "Mal de caderas" is a trypanosomal infection caused by the *Trypanosoma evansi* parasite that affects both domestic and wild animals, causing extensive disease and death. It is the most prevalent trypanosomal disease of domestic and wild animals. The parasite is mechanically disseminated by biting flies and is present in a broad variety of geographical places across the globe (Monzón, Mancebo, & Roux, 1990; Truc *et al.,* 2013).

The parasite *T. congolense* lives inside the body's blood vessels. The *T. brucei* travel outside and invade other parts of the body. The virulence mechanisms, host-pathogen connections, and bodily consequences of the two species are all highly different. It can be grown in vitro for *T. congolense*, but it can't be done for *T. brucei*, which can't be done that way (Gray, Ross, Taylor, & Luckins, 1984; Gray, Ross, Taylor, Tetley, & Luckins, 1985).

Worldwide distribution

Survivors of Surra are found in tropical and subtropical parts of Northern Africa, Southeast Asia, Central and South America, and the Caribbean. Surra, and the causative agent *T. evansi*, are also found in tropical and subtropical regions of Central and South America (Raina, Kumar, Sridhar, & Singh, 1985). *Trypanosoma evansi* is a salivation trypanosome that is extensively spread in Southern America, Africa, and Asia, among other places (Aregawi *et al.,* 2019). In camels from northern Kenya, epizootic diseases have been found. A further result of this study is that the same infections were present in camel keds obtained from the same studied animals. These flies may be helpful in the xenodiagnosis of haemopathogens that are circulating among camels (Kidambasi, Masiga, Villinger, Carrington, & Bargul, 2020).

In contrast to other geographical places, it seems that the medical and economic consequences of *T. evansi* are pretty varied. It mainly affects camels and horses in Africa. It is typically regarded as a moderate or minor infection in cattle in the rest of the world. Horses, dogs, and buffalo (Bubalus bubalis) are the most frequently affected; animals in Latin America; nevertheless, it is also regarded as a weak or inconsequential infection in cattle. In Asia, on the

other hand, it influences water buffalo, horses, and pigs and cattle (Holland *et al*., 2005; D Tuntasuvan & Luckins, 1998; Darunee Tuntasuvan, Sarataphan, & Nishikawa, 1997).

According to researcher Hasan *T. evansi*, the virus is quite uncommon in Pakistan's Punjab region (Hasan *et al*., 2006). According to research conducted in the country by Mauritania, camel trypanosomiasis was projected to be widespread in the country, particularly in forested regions near streams. The greatest rise in frequency was seen in the animals between the ages of five and 10 years (Dia, Diop, Aminetou, Jacquiet, and Thiam, 1997).

According to Van Vinh Chau, the first reported *T. evansi* in Vietnam occurred in 1997. The patient had previously been healthy. According to him, a raw flesh wound that happened during the meat-processing technique was the cause of the disease (Zambrano Salazar, 2021).

Life cycle and vector

A large number of hematophagous flies are carriers of the trypanosomes parasite, present in several hosts' internal and extracellular fluids. Hematophagous insects are responsible for its mechanical transmission (Luckins & Dwinger, 2004).

Table-1 Prevalence of Trypanosome in ruminants.

Researcher	The year	Country	Sample	Total of Sample	Type of Species	Method for analysis	Percentage
Asghari	2022	Iran	*Camelus dromedarius*	134	*T. vivax* *T. evansi*	Blood microscopy and PCR analysis	Blood microscopy showed 2.98% While PCR analysis showed 30.6%
Gomes	2021	Brazil	Bovine	623	*T. vivax*	Giemsa stained blood smears, PCR molecular analysis	Blood smear 0.3% PCR analysis 18.9%
Elobaid	2021	Saudi Arabia	*Camelus dromedarius*	454	*T. evansi*	wet and thick smear film PCR- ITS1 and RoTat	wet and thick smear film 3.1% and 3.5% PCR- ITS1 and RoTat 19%
Chávez-Larrea	2021	Ecuador	Cattle	20	*T. vivax*	PCR- viCatL and DTO155	PCR- viCatL and DTO155 15%
Bahrami	2021	Iran	*Camelus dromedarius*	167	*T. evansi*	Blood smear examination PCR molecular analysis	Blood smear examination 6% PCR molecular analysis 8.4%
Setiawan	2021	Indonesia	Cattle	100	*T. evansi*	microscopic observation PCR- ITS2	microscopic observation 1% PCR- ITS2 3%
Kizza	2021	Uganda	Cattle	460	*T. vivax* *T. congolense* *T.evansi*	ITS-PCR assay	*T. vivax*+ *T.congolense* =20.4% *T.evansi* 10.2%
Oyewusi	2019	Nigeria	Sheep	243	*T. vivax* *T. congolense (Savannah)* *T. congolense* (forest) *T. congolense* (Kilifi) *T.brucei brucei*	HCT method PCR analysis by primers	HCT method found no positive PCR analysis by specific primers shows the following results. *T. vivax* 23.05% *T. congolense (Savannah)* 13.38% *T. congolense (Forest)* 7.82% *T. congolense (Kilifi)* 0% *T. brucei brucei* 4.53%

Researcher	The year	Country	Sample	Total of Sample	Type of Species	Method for analysis	Percentage
Maganga	2020	Central Africa	Sheep goats	146 sheep 140 goats=286 total	*Trypanosoma spp.*	PCR-IST1, IST2, ITS3, and ITS4 analysis	By PCR-IST1, IST2, ITS3, and ITS4 in goats *T.vivax* 2.14%,*T. simiae* 5.71%,*T. simiae tsavo* 5%,*T. theileri* 0%,*T. brucei* 0.71%,*T. congolense* 0.71% In sheep *T.vivax* 0%, *T. simiae* 18.49%, *T. simiae* 0%, *T. theileri* 1.37%, *T. brucei* 0%, *T. congolense* 0%
Megasari	2020	Syria	Cattle	207	*T. evansi*	RoTat1.2-PCR amplified ITS1 region	RoTat1.2-PCR amplified ITS1 region shows 13% positive
Shaeel	2020	Iraq	Cattle	150	*Trypanosoma spp.*	Microscopy examination PCR assay	Microscopy examination 5% PCR assay 14%
Metwally	2021	Saudi Arabia	Camelus dromedarius	400	*T. evansi*	Thin blood smears microscopy ITS-1 and ITS-2 PCR assay	Thin blood smears microscopy shows 0% ITS-1 and ITS-2 PCR assay showed 85.5%
Panja	2019	Eastern Thailand	Buffaloes	153	*T. evansi*	PCR assay analysis	PCR assay analysis shows 21.92%
Bonilla	2021	Nicaragua	Sheep	30	*T.vivax*	Blood smears microscopy PCR analysis	Blood smears microscopy shows 73.3% PCR analysis 36.7%
Mirshekar	2019	Iran	Iranian dromedary camel	370	*T.evansi*	Micro-hematocrit centrifugation technique and PCR analysis	Micro-hematocrit centrifugation technique 11.89% PCR analysis 31.5%
Elata	2020	Philippines	Goat	251	*T. evansi*	PCR- TS1	PCR- TS1 33.9%

Trypanosomes have complicated life cycles that comprise both proliferative and differentiation cell divisions in nature. The parasite's capacity to organise its cell cycle in order to accomplish these several divisions is important for infecting both the host and the vector (Wheeler, Gull, & Sunter, 2019).After reaching high concentrations slender stage cells circulate in the blood of the mammalian host transform into stumpy stage cells, which have entered the cell cycle and cannot reproduce. It is considered that the stumpy stage is the only capable of successful vector transmission. It performs two crucial functions: first, it regulates the parasite load in the host, and second, it serves as a transitional step among the parasite burden and the host (Schuster *et al.,* 2021).

If exposed to the environment, it may move through the circulatory system's spectrum of body fluids, including the lymphatic system and cerebrospinal fluid, as well as the placenta. Parasites migrate from liquids to organs, with the most common parasite disorders affecting the brain and central nervous system (CNS). However, as soon as the tsetse fly consumes blood, parasites in trypomastigote form begin to travel to the insect vector's midgut, where the processes occurring inside the vector may be seen for the first time. Following the entry into the midgut, trypomastigote forms continue to increase and migrate down the esophagus and hypopharynx, finally reaching the salivary gland. Certain strains of these bacteria are contagious, whereas others are not. They can grow and convert into highly pathogenic metacyclic forms (Sharma *et*

al., 2009).

Contaminated blood is briefly kept in the crop, which acts as a storage site and allows the tsetse to absorb more blood each meal, or it is transferred directly to the midgut. Trypanosomes move to the proliferative procyclic stage after passing through the midgut. Once implanted in the midgut, parasites must migrate through the peritrophic matrix. This protective sleeve divides the bloodmeal from the midgut tissue that surrounds it. Parasites are thought to do so by swimming up the endotrophic space to the proventriculus, the site of peritrophic matrix development, from whence they may enter the ectotrophic area (Rose *et al.,* 2020).

Symptoms

The animals infected with Nagana and Surra display clinical symptoms such as sporadic fever, anemia, lymphadenopathy, wasting, loss of condition, pallor (pallor of the skin), abortion, lacrimation (milking), weakness, and lethargy. They lag behind the rest of the herd. Diseases are prevalent on a global scale. It is possible to have an acute, subacute, or chronic (Namangala & Odongo, 2014). Numerous studies have shown that trypanosoma damages cells and affects various physiological organs. Additionally, the parasite alters the chemical composition of the buffaloes' blood, increasing their bodies' oxidative stress (Pandey *et al.,* 2015; Hussain *et al.,* 2018).

Some ruminants, such as cows, buffaloes, sheep, and goats, can die from *T. vivax* infection because of the high fever and anemia caused by the sickness, leading to death (Gonzatti *et al*., 2014). Animals exposed to high fevers and induced anemia due to *T. vivax* are at risk of contracting a severe and usually fatal sickness. Ruminants such as cattle, buffaloes, sheep, and goats are particularly vulnerable (Gonzatti, Gonzál ez-Baradat, Aso, & Reyna-Bello, 2014).

Acute anorexia with increased body temperature and severe generalized edema is the most prevalent clinical signs of ill camels. Additionally, the chronic form of trypanosoma infection manifests in noticeable muscle atrophy, an undulant fever, pale mucous membranes, gradually decreasing body weight, and ascites, among other symptoms, are more common. In certain situations, diseased dromedaries emit a characteristic odor of urine ketones, which may be identified by their smell (Constable *et al.,* 2017).

The symptoms of *T. evansi* infection are severe and sometimes fatal, mainly when the sickness is in its late stages. The severity of the illness may vary from chronic to potentially lethal. Eventually, it results in progressive weakness, depletion, lymph node enlargement, and death (Saleh *et al.,* 2009; Herrera *et al.,* 2002).

According to Eyob, E., and Matias, microscopic examination of trypanosomiasis is a dangerous disease that can spread to a wide range of domestic and wild animals, as well as humans, and it can be tough to treat. The spleen, liver, heart, lungs, brain, and kidneys are all affected by *T. evansi* infection, as are many other vital parts of the body. *Trypanosoma evansi* is a disease that affects many camel species, causing much money to be lost because of the high cost of medicine, high death rates, weight loss, and decreased animal production caused by the disease (Eyob & Matios, 2013). Antioxidant enzymes were more elevated in camels naturally infected with *T. evansi* than in those not infected with the virus. When the mean values of the positive group were compared to the mean values of the opposing group, there was a significant difference (G6PDH and G.R.). It did not change BUN levels, serum creatinine, or total protein. However, the A/G ratio did change because of this. There was a lot of hypoalbuminemia and hyperglobulinemia in the blood. Damage to the liver may be why there is not enough albumin

and much globulin in the blood (Ahmad, Butt, Muhammad, Athar, & Khan, 2004; Chaudhary & Iqbal, 2000).

However, the liver function tests revealed a significant rise in the lactate dehydrogenase enzyme (LDH) activity and globulin levels, total and indirect bilirubin. In contrast, a substantial decrease in the movement of the alkaline phosphatase enzyme was seen (Baldissera et al., 2017).

Trypanosome infection increased the WBC count in the orally and intraperitoneally treated groups to 4.3 109 WBC/mm3 and 6.7 109 WBC/mm3, respectively (P 0.050). Similarly, the percentage of lymphocytes in the infected group was lowered relative to the non-infected group. Still, it rose in the treated groups (P 0.050). RBC count and hemoglobin content were significantly lower (P 0.050) in the untreated infected group than in the non-infected group. However, both were greatly improved after LSSE treatment. The hematocrit (HCT) was markedly lower in the untreated infected group than in the control group (P 0.050). After therapy, it returned to near-normal levels. AST and ALT levels were significantly higher in the untreated infected group than in the uninfected control group (P 0.050). However, LSSE treatment restored AST and ALT to near-normal levels (Al-Otaibi, Al-Quraishy, Al-Malki, & Abdel-Baki, 2019).

This investigation focused on several clinical indications, including rectal temperature, feed intake, overall body condition, and weakness and dullness. Rough hair coat, expansion of peripheral lymph nodes, runny nose, and quick pulse are examined (Scholar, 2021).

The findings of Amin's study revealed that *T. evansi* infection in bulls, which included the negative influence of *T. evansi* on the reproductive system of the animals, was connected mainly with histological changes in the animals' testicular tissue. The purpose of this study was to assess the changes in reproductive testicular parameters and the incidence of reproductive failure in dromedary bulls during the breeding season. Infected Camelus dromedarius were studied using a variety of diagnostic methods after infection with *T. evansi*, including examination of oxidative stress, testicular lesions, semen features, hormone levels, and hematological and biochemical parameters, among other things (Amin, Noseer, Fouad, Ali, & Mahmoud, 2020).

The lungs and other organs, including the liver, intestinal tract, kidneys (including testicles), bone marrow (including cerebellum), brain (including cerebellum), and testicles, had interstitial tissues filled with immune cells from other bodies (including bone marrow). There were also trypanosomes in the lungs and other parts of the body. Also, B- and T-cell responses were found in the lymphatic system. However, the findings showed that the lymph nodes, spleen, and bone marrow were immune-suppressed (Dargantes, Campbell, Copeman, & Reid, 2005).

Hypoglycemia may occur as a result of trypanosoma infections. Trypanosomes have been shown to cause a decline in blood glucose levels at periods of high parasitemia, presumably as a result of utilizing glucose for metabolic activity (Gutiérrez Cabrera, Corbera Sánchez, Juste de Santa Ana, Doreste, & Morales Fariña, 2006)(Silva, Sequeira, Santos, & Tiago, 2013).

Another possibility for the leukopenia seen at the beginning of the infection is that leukocytes are undergoing apoptosis, as shown in rats infected with *T. brucei* (Happi, Milner Jr, & Antia, 2012). Previous studies have indicated that erythrocytes can shield neutrophils from apoptosis via glutathione and catalase metabolism, contributing to the neutrophilic decline. However, for this to be confirmed, an additional study must be done in this area(Aoshiba, Nakajima, Yasui,

Tamaoki, & Nagai, 1999). According to this research, the number of eosinophils in the blood of cattle exposed to *T. vivax* had decreased, which is consistent with earlier findings (Dagnachew et al., 2015).

As reported here, brain tissue from infected subgroups of mice was shown to have vacuolar degeneration and a moderate mononuclear cellular infiltration in the cerebellum. When *T. evansi* infected Swiss albino mice, the alterations in their brain tissue were identical to those seen in the brain of infected Swiss albino mice (Bal et al., 2012). In addition to being more sensitive, DNA-based approaches benefit from detecting trypanosomes down to the subspecies level. They can also tell if there are mixed infections (Isaac et al., 2016).

T. evansi has been associated with neurologic symptoms in horses, cattle, deer, and buffaloes during the final phase of natural infection, although there has been little research into this in horses (Seiler, Omar, & Jackson, 1981; D Tuntasuvan et al., 2000; Darunee Tuntasuvan, Sarataphan, & Nishikawa, 1997).

Diagnosis

Due to the absence of clinical signs in camels, numerous approaches with varying sensitivity and specificity may be used to diagnose human trypanosoma infection. For the identification of *Trypanosoma spp*., standard detection approaches such as microscopic examination of fresh or stained blood smears are used. However, they may lack the sensitivity and specificity necessary to identify certain parasites (Salim et al., 2011).

Trypanosoma may be identified in the blood using a light microscope at a magnification of 40X. A microscopic examination of blood samples stained with Giemsa staining may be undertaken later in the procedure (Mafie et al., 2018).

Microscopy is essential in diagnosing HAT since it detects motile trypanosomes and fixes and stained organisms in the bloodstream. Microscopy of spinal fluid must be done after a HAT diagnosis is made to see if the patient has reached the neurological stage of the illness, which is very important in deciding what kind of treatment the patient needs (Brun, Blum, Chappuis, & Burri, 2010).

In the last few years, Carl Zeiss and FIND have made an LED microscope that is so bright that it can be used for both fluorescence and bright field microscopy, called the Primo Star iLED. Acridine orange-based fluorescence microscopy and traditional Giemsa stain microscopy were compared in this investigation to see whether a parasite concentration and RBC lysis step may improve the method's sensitivity in detecting trypanosomes in the blood (Biéler et al., 2012).

Historically, *Trypanosoma spp*. was recognized using standard trypanosome detection methods, such as microscopic examination of fresh or stained blood smears (microscopy). Regrettably, this technique lacks the necessary sensitivity and specificity. The World Organization for Animal Health (OIE) has approved the card agglutination test for *T. evansi* as a rapid diagnostic test. For the identification of trypanosomosis in camels, serological tests have been designed and evaluated. Antibodies are detected using the CATT T.evansi and other assays (Songa & Hamers, 1988).

To conduct the formol gel test (FGT), one milliliter of serum was mixed well with two drops of robust formalin solution (which contained 37 percent formaldehyde). When the serum started to coagulate immediately and turned opaque, positive findings were proclaimed (Jacobson,

2004).

Additionally, the antigen preparation utilized in the enzyme-linked immune sorbent test has been used to identify (ELISA). ELISA each trypanosome isolate was tested in triplicate using an ELISA plate under similar conditions. Two weeks before the infection, negative serum samples from each sample were collected and used as controls. Specimens were collected on days 1, 2, 10, 18, 24, 30, 39, 47, and 61 of the experimental infection. Sensitized plates containing 20 g of antigen per well were washed five times with washing buffer (W.B.) and blocked for an hour at 37°C with 200 l/well of 5% skim milk in PBS. Before adding 100 l/well of each serum diluted 1:200 in W.B., the plates were washed five times with W.B. Each ELISA plate was pre-inoculated with positive and negative control sera. After an hour of incubation at 37°C, the dishes were washed five times with W.B., and 100 conjugate rabbit peroxidase-conjugated anti-(any sample) IgG Pierce were added. The Immunocore antibody was diluted at 1:5000 in W.B. and incubated for 60 minutes at 37°C. Following incubation, the plates were washed three times, and 100 l of the substrate solution, ABTS 2% H2O, was added and incubated for 45 minutes at 37 °C. Photometrically, absorbance was determined at 405nm using an ELISA reader (Parra-Gimenez & Reyna-Bello, 2019).

Many molecular diagnostic methods have been used to diagnose camel trypanosomiasis, including conventional and real-time polymerase chain reaction (PCR) tests. They are more sensitive than other methods and have the benefit of being able to categorize parasites at the subspecies level, which is not achievable with other systems(Barghash, Abou El-Naga, El-Sherbeny, & Darwish, 2014; Elhaig, Youssef, & El-Gayar, 2013)

Molecular analysis targeting the internal transcribed spacer 1 (ITS1) region has been used in epidemiological research because it enables the identification of many different trypanosome species using a single polymerase chain reaction (PCR (Salim, Bakheit, Kamau, Nakamura, & Sugimoto, 2011). The use of molecular technologies, such as the typical polymerase chain reaction (PCR), is beneficial for sampling big animals during field research initiatives (Behour, Aboelhadid, & Mousa, 2015). The unique molecular identification and characterization of each sample are dependent on special primers for each species used. In the past, the primers for amplifying the internal transcribed spacer (ITS1) in DNA is a sequence that is transcribed during the transcription process (ITS1CF and ITS1BR) were designed to do so (Constantine *et al.,* 2007).

Prevention

In the fight against AAT and the tsetse fly vector cycle, a number of different strategies have been used. It has been decided to adopt vector control measures as well as the diagnosis and treatment of animals afflicted with AAT. Trypanocides such as isometamidium chloride (ISM), diminazene acetonate (DA), and ethidium bromide are the only three presently available trypanocides that may be used to treat or prevent the spread of trypanosomes (Barrett, Coombs, & Mottram, 2004). Mechanical transmissions do not just cause the spread of trypanosomosis in the environment through vectors. Animal mobility also helps spread the disease (Holmes, 2013).

Current and future attempts to successfully eradicate AAT and its vectors in Sudan will need reliable information on the disease's geographic spread. Although epidemiological research has been conducted throughout the years, the prevalence of tsetse and AAT has not been geo-referenced or harmonized. Planning, implementing, and monitoring field engagement needs this kind of data. An project to map the prevalence of Tsetse and trypanosoma infections in

Sudan has been launched by Sudan's VRI (Vector Research Institute). The FAO's technical assistance includes the Atlas of Tsetse and AAT, according to this study (Cecchi et al., 2014; Cecchi, Paone, Herrero, Vreysen, & Mattioli, 2015). The African trypanosomosis programme's tsetse and tsetse Atlas is part of that programme (PAAT).

Vaccination and treatment

Currently, there are four main medicines that are used to treat HAT. These are suramin, pentamidine, melarsoprol, eflornithine (difluoro-methyl ornithine, or DFMO), and nifurtimox (Fairlamb, 2003).Most of these medications were developed in the first part of the twentieth century. Since 1981, no new medicine for human use has been licensed. A drug named DB 289, a dimidine derivative, has just completed its second clinical study (Legros *et al.,* 2002). Treatment for the early stages of rhodesiense and gambiense disorders is accomplished by the use of suramin and pentamidine. There is just one medicine that can be used to treat both forms of HAT in its late stages: arsenical melarsoprol. Individuals who take treatment may absorb it into their brains (Legros *et al.,* 2002). Nifurtimox may be taken orally for up to two months, whereas DFMO is administered intravenously for five weeks. However, the DFMO is not widely used, and it is considered too costly for most people to use daily. Also, DMFO is exclusively effective against *T. b. gambiense*, thus use it just against this infection (Burri & Brun, 2003).

Trypanosomiasis medicines are already available, but they have considerable side effects, and the parasite is becoming more resistant to the pharmaceuticals being used to treat it (Kizza *et al.,* 2021). However, diminazene aceturate is potentially dangerous to the host when treating T. evansi infection in domestic animals. (Do Carmo *et al.,* 2015).

To fight trypanosomiasis, it is crucial to keep researching new, safe treatments (Adeyemi et al., 2018). Indigofera oblongifolia was given to sick mice, and the parasite count in their blood was substantially lower than in control blood samples. Active compounds such as phenol, quinines, saponins, and coumarin have been shown to protect the body (Nassef, El-Melegy, Beshay, Al-Sharaky, & Al-Attar, 2018). Despite the use of well-known anti-trypanosome medications including Nagano, Cymelarsan, and Antrycide, most blood samples confirmed positive for Trypanosoma evansi failed to react to either of the two regimens (Shahjahan, Vani, & Devi, 2005).

The incidence of sickness increases at an alarming rate, reaching epidemic proportions. With the lack of a viable mammalian vaccination and a scarcity of affordable and effective drugs, illness management has become more problematic (Aksoy, 2003).

The availability of accurate and sensitive diagnostic instruments for controlling *T. evansi* infection is an absolute need. DNA-based PCR detection methods, on the other hand, satisfy all of these requirements (Li *et al*., 2020).

It is thought about if regular doses of medicine don't work. This is called drug resistance. When treatment doesn't work, it may be because of things other than parasite resistance to medications. Having parasites in animals that have been treated might mean they have a new infection, not a recurrence, in places where they are at risk (Rowlands *et al*., 2001). They don't know why the animal isn't healthy enough, how to use the medicine (like complicated treatment or long breaks between treatments), or the animal doesn't get enough of the drug. In this case, low-quality medicines could be to blame. Either because they were stored incorrectly or because they used counterfeit products, this could be the reason (Sutcliffe *et al.,* 2014).

As little as 0.5 and 0.25 mg/kg of body weight were used to treat mice that had been infected with the *T. evansi*. Six compounds were used. Besides that, they were better than the most common medications, such as suramin, diminazene, and quinapyramine. The three diamidine compounds, D.B. 75, DB 867, and DB 1192, met all of the criteria for being chosen. They could be used as preclinical candidates to fight off *T. evansi* infection (Gillingwater *et al*., 2009).

T. congolense and *T. brucei* isolates were tested in vivo, and the results revealed that the single-dose mouse test is still the gold standard for quickly identifying single or multiple resistance.Although the test does not quantify the number of parasites eliminated, it does give a means of determining if parasites react to dosages of the treatment used in veterinary medicine. There are methods for optimizing drug sensitivity studies that do not need microscopy. For instance, PCR methods may be used instead of microscopy to detect trypanosomes in the blood (Tran *et al.,* 2014).

The maximal dose evaluated in this experiment was hundred percent effective against *T. evansi*. On the other hand, Cordycepin was not curative in vivo when administered alone; instead, it lengthened the animals' lives when given therapy. Due to the rapid deamination of Cordycepin (3′-deoxyadenosine) to 3′-deoxyinosine, the trypanosomal enzymes inosine and deoxyinosine hydrolases may inactivate and destroy Cordycepin (Rottenberg *et al.,* 2005).

Drug resistance may emerge as a consequence of the abuse of trypanocidal drugs. Many reports of drug resistance to pharmaceuticals such as isometamidium chloride and diminazene aceturate have been produced in the context of these therapies (Nuryady, Widayanti, Nurcahyo, & Fadjrinatha, 2019).

Discussion

There have been fifteen articles examining the frequency and distribution of trypanosomiasis in animals worldwide. This review summarized sixteen reports to ascertain the present state of trypanosomiasis and its spread rates in a variety of countries worldwide, including Iran, Syria, Iraq, Eastern Thailand, Nicaragua, Central Africa, Nigeria, Uganda, Indonesia, the Philippines, Ecuador, Brazil, and Saudi Arabia. The current research attributes variations in the prevalence and spread of *Trypanosoma evansi* among countries to geographic location, animal management techniques, seasons, and the animals' breed, sex, and age. Certain nations seem to be more concerned with infection-control strategies with a low infection rate. A PCR experiment demonstrated that the parasite was responsible for 85.5% of trypanosomiasis infections in Saudi Arabian camels. Saudi Arabia's camel population has expanded dramatically in recent years (Faye, 2015), in 2017, there were over 500,000 camels in the Riyadh area, representing tremendous growth (FAOSTAT, 2019). The prevalence numbers for each species vary significantly among nations, depending on the diagnostic technique employed and the geographic region covered by reports. Camels had the highest estimated prevalence values of any species. Cattle, buffaloes, goats, sheep, and sheep were the following animals on the list.

A substantial source of revenue and food for many people who live in many regions of the globe, camels are an essential source of money and food. *Trypanosoma evansi* infections are less prevalent in camel markets in locations where people are better knowledgeable of how to feed and care for their camels, administer medications, and how vital it is for camel owners to sell their camels for a reasonable price. Sheep and goat infections are often regarded as moderate or non-threatening. A superficial corneal ulcer and retinochoroiditis were seen in goats that had been artificially infected, although there were no visual impairments (Morales *et al.,* 2006). Surra was detected in both acute and chronic manifestations in the camel. It has

called a critical case when severe fever, anemia, infirmity, and death. If they are sick for a long time, they are more likely to have chronic issues. The condition is devastating and has three-year duration. It includes the physical manifestations of disease like intermittent fever, dullness, progressive weakness, loss of appetite, and edema in the central parts. Young animals are more likely to get sick, but the disease affects animals of all ages. Camels may have lymph glands that grow and become infected in the inguinal region. *Trypanosoma evansi* also caused dromedary camels in the Canary Islands to have abortions and die at a high rate as babies (Gutierrez *et al.,* 2005).

According to different researches, Surra was discovered in Pakistan. Tehseen *et al*. (2015) assessed *T. evansi* infection in camels in Pakistan's Cholistan Desert using parasitological, serological, and molecular techniques. Their results were published in Parasitology, Serology, and Molecular Research. Abbasi *et al.* (2014) conducted comparative research. Immunodiagnosis is the only successful approach in field circumstances, particularly in RDT (Rapid Diagnostic Test) environments. However, there is no antigen capture test available that can be used to detect active infections, which is a severe drawback. The use of whole trypanosome lysates as antigens in the currently used ELISA-based antibody detection techniques has been limited, resulting in the problem of antigen standardization. The few articles that employed a unique recombinant protein as an antigen to address standardization problems were often found to be inadequately sensitive (Desquesnes *et al.,* 2009).

This review discovered that *Trypanosoma evansi* infections are frequent in numerous nations on a broad scale. Despite this, there is very little understanding of how animals and people acquire it. *Trypanosoma evansi* spreads to many animals through the bites of flies. Different species can cause a wide range of diseases that can significantly impact animals' health and the economy.

Take note of the study's flaws, including reporting bias and other issues. It could not conduct a statistical review of publication bias due to the lack of variance in diagnostic test categories, geographic location, breed of animals collected, and study era.

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