Indian Journal of Animal Sciences **81** (7): 653–660, July 2011

Trypanosomosis of livestock in India: A review of two decades

K M L PATHAK[1] and M B CHHABRA[2]

National Research Centre on Camel, Jorbeer, Bikaner, Rajasthan 334 001 India

Received: 10 September 2010; Accepted: 25 February 2011

ABSTRACT

Trypanosomosis ranks as the most important haemoprotozoan disease impacting the livestock economy in India through widespread morbidity and mortality. Although prevalent in almost all parts of the country, data from different states showed wide variations being influenced by various epidemiological factors. During the last two decades, outbreaks as well as individual cases involving bovines, equids, camels, dogs and some wild animals have been reported. Endemicity appears to have extended to new areas. Reported clinico-haematological changes cover a vast range and vary between the host species, even as progressive emaciation, anaemia and intermittent fever appear to be more common. Diagnostic techniques have undergone major improvements due to availability of purified antigens and the developments in molecular biology with application in parasitic infections. Standardization of some tests and emergence of assays has led to more reliable epidemiological data being generated. DNA-based technologies have enabled the characterization of antigenic components of trypanosomes. Chemotherapy and availability of drugs have witnessed only limited progress. Control strategies do not seem to take into account the vector component. There is need for greater coordination among laboratory workers and field personnel to take stock of the present status and also to define the priority areas for research with the objective of minimizing the ongoing losses.

Key words: Haemoprotozoan, Mammalian parasite, Surra, Trypanosomosis, *Trypanosoma evansi*

Trypanosomosis (surra), caused by the haemo-flagellate protozoan *Trypanosoma evansi* is a major constraint on the health and productivity of domestic animals throughout the tropics and subtropics. *T. evansi* is the common and the most prevalent trypanosome of livestock in India, although isolated cases of *T. equiperdum* and *T. theileri* were also encountered (Ruprah 1985). The parasite is capable of infecting a wide host range including almost all land mammals. Humans are refractory except in rare instances of mutation of Apo L-1 protein (Lun *et al.* 2009). Transmitted mechanically through the bite of blood sucking flies, the disease condition is commonly called "Surra". It is endemic in most parts of the Indian sub-continent, and epizootics have occurred particularly in bovines with mortality rate ranging from 20 to 90%% (Gill 1991). Widespread morbidity in the form of progressive emaciation, anaemia, oedema, pyrexia, lowered weight gains, lowered milk yield, lowered work capacity and abortions, results in heavy economic losses to the livestock owners. The Office Internationale des Epizooties listed it as the list B disease among notifiable diseases of significance (OIE 2004). A classic monograph published by the ICAR (Gill 1991) provided comprehensive knowledge on trypanosomosis in Indian livestock since the discovery of *T.evansi* in 1880. However, in the two decades since its publication, a large volume of literature has come up on various aspects of this important topic. The objective of this review is to update the India-specific information and try to highlight some of the lacunae which need to be filled in by future research.

Prevalence and epidemiology: T. evansi is more common in India, where environment for the breeding of the fly vectors is most suitable (Bhatia *et al.* 2006) , or is rendered so. Accordingly, a spurt in camelid surra occurred after the advent of Indira Gandhi Canal and irrigation of vast tracts of arid land in western Rajasthan (Pathak and Khanna 1995). By the same token, the incidence in bovines was found to follow the onset of monsoon, viz. August, and extends well into the post-monsoon period in Punjab (Soodan *et al.* 1995b). Similar trend was observed in West Bengal (Ray *et al.* 1992) , Andhra (Prasad *et al.* 1997) , Jammu (Raina *et al.* 2000) , Chhatisgarh (Agrawal *et al.* 2003) and Bihar (Sinha et al. 2006). Cattle and buffaloes mostly carry an asymptomatic infection. Stress factors such as flooding, intercurrent disease (Gupta et al. 2009) , vaccination, transport (Kalra *et al.* 1994)

Present address: [1]Deputy Director General (Animal Science) (e mail: pathakkml@yahoo.co.in), ICAR, Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi 110 014.

[2]Formerly Professor and Head, 2518, Sector D-2, Vasant Kunj, New Delhi 110 070.

and malnourishment (Malik *et al.* 2000) may change an inapparent infection into clinical disease. Outbreaks of acute disease were recorded in these animals especially in the high endemicity states like Haryana and Punjab (Batra et al. 1994, Gupta *et al.* 2003, Jindal *et al.* 2005). In Bihar, the incidence of bovine trypanosomosis was fairly high in cattle, viz. 58.86% and in buffaloes at 41.14% (Sinha et al. 2006) based on the data of clinical cases recorded in various hospitals. Prevalence of a low order was reported from Andhra Pradesh, viz. 1.42% in cattle and 2.71% in buffaloes by blood smears in Guntur district (Das *et al.* 1998) and 7.28% by stained blood smears in East Godavari district (Bhaskar Rao and Hafeez 2005). In Karnakata, prevalence assessed on the basis of a proforma developed and sent to field veterinarians, was 42.12% in bovines, 39.78% in buffaloes and 2.15% in goats (Krishnappa *et al.* 2002 a). Among equines, in a field outbreak reported from Mathura (Kumar *et al.* 1994) , 100% morbidity and 66.6% mortality was recorded. An outbreak in ponies was reported from Jammu (Raina *et al.* 2000). A case report of 'surra' in a Kathiawari mare (Bharkad *et al.* 2005) came from Udgir, Maharashtra. Laha and Sasmal (2008) found high positivity (12.74%) by Giemsa's stained smears in a horse stable in eastern India and regarded it as endemic status. In camels, trypanosomiasis was found endemic in 18 districts of Rajasthan (Raisinghani and Lodha 1989). Blood samples from 240 camels from western Rajasthan examined for *T. evansi* revealed 18 (7.5%) infected by the wet-blood/Giemsa stain smears and 76 (31.66%) positive for antigen using double antibody sandwich ELISA (Pathak *et al.* 1993). The highest incidence was recorded during high rainfall favourable to the breeding of vector flies. In another investigation (Singh *et al.* 1997) , prevalence based on clinical observations was 20.37% in 530 camels in *T. evansi* endemic areas of Bikaner district of Rajasthan. In dogs, 4.68% positivity was recorded in Ludhiana (Singh *et al.* 1993) , all positives occurring during or after the rainy season. Incidence among dogs in and around Kolkata city was somewhat lesser (Chowdhury *et al.* 2005). Dogs, especially exotic breeds, are very susceptible and usually experience acute fatal disease (Dakshinkar and Bhojne 2001). Occasional case reports of native breeds also exist (Krishnamoorthy and Murali Manohar 2005). Reports of natural trypanosomiasis in goats are scarce (Bhaskar Rao and Hafeez 1999, Jana and Jana 2005) and are rare in sheep (Rao *et al.* 1987). Apparently, T. evansi infections are uncommon in goats and sheep (Gill 1991). Among wild animals, incidence in hyena in Delhi zoo and Chitals in Bhilai zoo were cited (Arora 1994). An outbreak of 'surra' in tigers at Ranthambore National Park with a fatal case report in a male tiger (Ramachandraiah *et al.* 1995) and an outbreak in circus tigers in Andhra Pradesh involving 5 adults and 4 cubs (Bhaskar Rao *et al.* 1995) were described. According to Acharjyo (2000), large cats especially tigers are more susceptible to *T. evansi* infection than other species of wild mammals. As many as 12 tigers died at Nandankanan zoo in Odisa due to trypanosomosis (Parija and Bhattacharya 2001). Trypanosomosis in a circus tigress was reported from Chittoor, Andhra Pradesh (Devasena and Shobhamani 2006). Clinical case in a jungle cat (Felis chaus) at Nagpur zoo was reported by Dakshinkar *et al.* (2002). Observations on trypanosomosis in mithun (Bos frontalis) were recorded in Asom (Rajkhowa *et al.* 2003). The high incidence in dogs and wild carnivores apparently supports the hypothesis that feeding of infected tissues can also be a possible mode of transmission (Bhatia *et al.* 2006).

Antigenic variation and characterization: Despite an effective host immune response mediated through IgM and IgG antibodies directed against their surface coat and antigens, trypanosomes are able to evade it by altering the antigenic composition of their surface glycoprotein coat. The application of DNA probes for identification and characterization of *T. evansi* strains has opened up the use of this technology for strain differences and antigenic variation. Fractionation by chromatography revealed 7 distinct fractions in *T. evansi* (camel) antigen and analysis by SDS-polyacrylamide electrophoresis (PAGE) revealed protein bands with molecular weights ranging between 14–65 KDA (Pathak *et al.* 1994). Characterization of 7 stocks of *T. evansi* sourced from buffaloes, equids and camel of different localities of north India was carried out. Polypeptide profiling of whole cell lysate (WCL) by SDS-PAGE (Singh *et al.* 1994a) and of cell membrane (CM) and flagellar preparations by SDS-PAGE and western blotting (Singh *et al.* 1995b) did not indicate antigenic variability of high degree. DNA polymorphism in *T.evansi* isolates was studied by polymerase chain reaction (PCR) by Omanwar *et al.* (2001) who hypothesized the adaptability of the organism to different hosts and geographical regions as the reason for polymorphism. Existence of genetic heterogeneity within *T.evansi* isolates derived from buffalo, dog, horse and camel revealed by polymerase chain reaction seems to confirm DNA-polymorphism hypothesis (Kundu *et al.* 2010).

Clinicopathology: Although different host species show variable pathogenicity to *T.evansi*, the most common clinical feature is progressive anaemia due mainly to haemolysis of red blood cells as well as erythrophagocytosis (Bhatia *et al.* 2006). *T. evansi* is pathogenic to most domestic and laboratory animals. The infection in horses and dogs is severe. Apart from progressive anaemia and intravascular coagulation, toxins and proteolytic enzymes liberated by the parasite (Pathak and Singh 2005), hypoglycaemia is considered to be the cause of death. Impairment of blood brain barrier and increased intracerebral immunoglobulin biosynthesis are other observations reported (Singla *et al.* 1998). Immuno-suppression due to *T.evansi* fails vaccination against bacterial and viral disease (Sarmah *et al.* 1997, Singla *et al.* 2010) and secondary/concurrent infection with other pathogens (Gupta *et al.* 2009).

Cattle and buffaloes: In bovines, the more usual form of

trypanosomosis is an asymptomatic carrier state with occasional acute/peracute infection often with death occurring without fever or pronounced symptoms. In a slower course, dullness with recumbency or staggering gait, laboured and noisy breathing, lachrymation, bellowing, profuse salivation, corneal opacity (uncommon in buffaloes), icterus, twitching of muscles often terminating in convulsions and death are observed (Palanivel *et al.* 2008). Lumbar paralysis in subclinical trypanosomosis in buffaloes was reported from Bihar (Kumar *et al*. 2009b). Parasitaemia is generally low and may not accompany fever and other typical symptoms. In chronic cases, dullness, lachrymation, progressive emaciation, intermittent fever, anaemia and oedema may occur (Muraleedharan and Srinivas 1985, Rajguru *et al.* 2000). Postmortem lesions observed include hepatosplenomegaly, congestion of lungs, liquefaction of sub-epicardial fat, serious fluid in the plural and pericardial cavities, haemorrhages and petechiae (Palanivel *et al.* 2008). Instances of *T. evansi* infection in neonatal calves suggestive of transplacental transmission are on record in cows (Kalra *et al.* 1994, Rajguru *et al.* 2000) and in buffaloes (Panduranga Rao *et al.* 2001). Chronic trypanosomosis in crossbred cattle of an organized dairy farm in Punjab was reported (Bharadwaj and Randhawa 2010). The infection was found associated with history of abortions and neonatal mortality.

Equines: Clinical and haemato-biochemical changes in clinical cases of surra in equines were eported by several workers (Jani and Jani 1993, Varshney and Gupta 1996, Laha *et al*. 2004). The main symptoms are intermittent fever, anaemia, urticarial eruptions (plaques) accompanying febrile paroxysm, oedema of the dependent parts of the body and genitalia (De and Mukherjee 2006) , petechial haemorrhages in visible mucous membranes, tachycardia, staggered gait, jugular pulsation and laboured respiration (Bharathi and Padmaja 2007). Hepatic insult (Varshney and Gupta 1996) and endocrine dysfunctions (Varshney *et al.* 1999) were also ascribed to clinical trypanosomosis in horses. Transplacental transmission in a donkey mare was reported (Pathak and Kapoor 1999). The animal was febrile but aparasitaemic. Abortion ensued and faetal blood revealed *T. evansi* positivity by mouse inoculation.

Camels: The infection in camels runs a protracted debilitating course hence named 'Tibersa'. Clinical signs include emaciation, pale mucous membrane, dry coat, intermittent fever, weakness, lachrymation, anaemia and decrease in Hb and PCV, immuno-suppression often resulting in mange as concomitant, abortion and neonatal mortality (Chhabra and Sangwan 2006). A feature special to camels may be the enlargement and suppuration of lymph glands of the inguinal region. The main histopathological observation was fatty changes locally distributed in the liver.

Dogs: The large number of case reports atleast the frequency of trypanosomosis in dogs. The recorded symptoms are fever, anorexia, anaemia, lymphadenopathy, oedema, corneal opacity (a cardinal sign, often bilateral) , glaucoma, tachycardia, muscular spasms, convulsions and nervous symptoms (Balakrishnan *et al*. 1994, Arora and Pathak 1995, Dakshinkar and Bhojne 2001, Varshney *et al.* 2003, Sood *et al.* 2004, Chowdhary *et al.* 2005, Sarvanan *et al.* 2005, Lakshmi Rani *et al.* 2007). Hepatic insult (Varshney *et al*. 1998) and jaundice (Baby *et al.* 2000) were also noted. Haemato-biochemical changes included hypoglycaemia, hypoalbuminemia, hyperglobinaemia and hyperkalemia (Sarvanan *et al.* 2005). In view of great inconsistency of clinical manifestations in dogs, a score system was devised (Varshney 2005) in a clinical study. Concurrent infections of *T.evansi* with ehrlichiosis (Balachandran *et al.* 2007) and *T. evansi* with *Hepatozoon canis* (Pazhanivel *et al.* 2008) were reported.

Other animals: In cat, the clinical signs reported were, in general, similar to those in dogs except that the oedema developed in the head, and corneal opacity was accompanied by bilateral epiphora and photophobia (Thirunavukkarasu *et al*. 2000). Jungle cat (Sahoo *et al*. 2009) had similar manifestations. Pathology of *T. evansi* in tiger was elaborated by Murali Manohar *et al*. (2003). Trypanosomosis concurrent with tuberculosis in black bucks was reported from a deer park in Punjab (Gupta *et al.* 2009).

Diagnosis: The clinical signs of Surra are not pathognomonic enough for making more than a provisional diagnosis. Demonstration and identification of trypanosomes in the blood remains the basis of a definitive diagnosis. Concentration techniques such as microhaematocrit centrifugation (MHCT) and mouse inoculation (MI) were devised to overcome the problem of scanty parasitaemia. The latter was considered the most efficient parasitological test (Choudhri *et al.* 1996, Singh *et al.* 2003). Further, it was suggested that the sensitivity of MI and MHCT was improved 10-fold through the use of buffy coat in place of whole blood. In a comparison of 6 different tests for the detection of *T.evansi* in dromedaries, Jain *et al.* (2000) found that MI (86.23%) had the highest efficacy. The limitations in terms of low sensitivity of parasitological diagnostic methods were a driving force for research into alternative techniques including immunodiagnostic, antigen detection assays and DNA-based methods (Chhabra and Sangwan 2006). In India, efficacy of capillary tube agglutination and gel diffusion (Soodan *et al.* 1995a) , card agglutination test (Chaudhri *et al.* 1996, Dhami *et al.* 1999) IFAT (Ray *et al.* 1992) , counter immuno-electrophoresis (Ghorui and Samanta 1998) and various other immunodiagnostic tests were assessed alone or comparative to various parasitological methods in different host species (Singh *et al*. 1994b, Baghel *et al*. 1996, Bhatnagar *et al.* 1997, Pathak *et al.* 1997b, Krishnappa *et al.* 2002b) with variable results. Subsequently enzyme-linked immunoassay (ELISA) and its antigen-detection variant (Singh *et al.* 1995a, Jithendran *et al.* 1997, Jain *et al.* 2000,

Singh and Choudhri 2002) were found more sensitive and specific. Jeyabal *et al.* (2003) used sandwich-ELISA for detection of circulating antigens in cattle and buffaloes and found that the technique could detect 37.8% aparasitaemic animals. Improved versions of Ab-ELISA, viz. Dot-ELISA (Shahardar *et al.* 2002) and competition-inhibition ELISA (Shahardar *et al.* 2003) gave 46.66% and 63.0% positivity, respectively in detecting antibody in camel sera from an endemic area in Rajasthan. Use of detergent-solubilized antigen (Shahardar *et al.* 2004) further raised the positivity detected to 68.8%. Antigen ELISA using monoclonal antibody (mAb) was observed as specific and mAb based latex agglutination test was developed as rapid field test to detect *T.evansi* antigens (Rayulu *et al.* 2009) in different animals in Haryana. DNA amplification technology has added a new dimension to the diagnostic approach in trypanosomosis with the application of DNA-based procedures notably polymerase chain reaction (PCR). In India, PCR was first employed (Basagoundar *et al.* 1998) for detection of *T.evansi* in infected camel blood samples. The process of DNA-extraction (Jithendran *et al.* 1998) and application for detection of *T.evansi* was further standardized (Omanwar *et al.* 1999a). Higher sensitivity of this molecular technique compared to parasitological and serological methods, based on 217 camels in Rajasthan (Singh *et al.* 2004) and in captive and wild animals (Shailaja *et al.* 2005) was also reported. Efficacy of PCR vis-à-vis prevalent diagnostic tests for 100% detection of natural *T.evansi* infection in camels was validated by Singh *et al.* (2007). The utility of PCR for sensitive and specific detection of *T.evansi* in camels, donkeys and dogs was further authenticated by later workers (Ravindran *et al*. 2008). Shahardar *et al.* (2009) targeted ribosomal DNA for detection of *T.* evansi in Indian dromedary.

Treatment and control: The main thrust of control relies on chemotherapy though this approach has its own problems such as high price and limited availability of drugs. The mainstay of chemotherapy in India are diminazene and quinapyramine and most trial reports are based on these two. Of the other two effective agents there is no assured supply of suramin, and cymelarsan has still to get commercial release. Singh and Joshi (1991) dealt with a comparative evaluation of diminazene, suramin, quinapyramine and isometamidium in buffaloes naturally infected with *T.evansi*. They found that quinapyramine (4.4 mg/kg b.wt.) and isometamidium (0.5 mg/kg b.wt) were good therapeutically but for prophylaxis, quinapyramine proved better than isometamidium. A later evaluation (Joshi and Singh 2000) of the same 4 drugs against clinical *T.evansi* in buffaloes indicated that therapeutically all the 4 drugs were effective but prophylactically these had variable efficacies, viz. quinapyramine (66.6%), suramin (66.6%), isometamidium (33.3%) and diminazene (0%). Post treatment increase in Hb, PCV and TEC values and significant increase in blood glucose, total serum protein and cholesterol was observed (Joshi and Singh 2001). Early treatment with diminazene aceturate in bovines in Haryana was found encouraging line of treatment (Batra *et al.* 1994). Quinapyramine prosalt was found as an effective chemoprophylaxis for crossbred cow calves (Choudhri *et al.* 1996) and buffalo calves (Singh *et al.* 2002). As per Sangwan *et al.* (1993) inclusion of folacin and cyanobalamin may help in faster recovery of treated animals. Clinical disease in buffaloes was successfully treated with quinapyramine prosalt (methyl sulphatechloride combination) by Raina *et al.* (2000) but according to a later study (Chand *et al.* 2008), two doses at 72 h interval were more effective in buffaloes. Subclinical cases in buffaloes also responded well to this therapy administered with appropriate supportives (Kumar *et al.* 2009b). In camels, quinapyramine pro-salt was efficacious therapeutic and prophylactic agent in natural *T. evansi* infections (Pathak *et al.* 1997a). A case of natural *T. evansi* in a goat in Andhra (Bhaskara Rao and Hafeez 1999) was successfully treated with quinapyramine chloride. De and Mukherjee (2006) reported successful management of trypanosomosis in a 2-year-old male horse with quinapyramine sulphate. Recently Muralidharan (2001) reported (2011) successful field veterinary treatment of acute surra in throughbred horses with Berenil. Treatment of clinical canine trypanosomosis with diminazene accurate was variously reported (Prakash *et al.* 1994, Krishnamoorthy and Murali Manohar 2005, Sarvanan *et al.* 2005, Lakshmi Rani *et al.* 2007). In view of possible relapse, repeat treatment or higher dose was recommended (Varshney 2005). Efficacy of quinapyramine pro-salt was validated in dogs (Chowdhury *et al.* 2006, Sonika *et al.* 2007). Supportive management of derangements in endocrines and other organ systems is also called for (Varsheny and Varshney 2006). Efficacy of quinapyramine therapy was also reported in black bucks (Gupta *et al.* 2009) and in jungle cat (Sahoo *et al.* 2009). A recent report (Kumar *et al.* 2009a) dealt with the potential use of Isometamidium hydrochloride (which has proven efficacy against African trypanosomes) in the treatment of *T. evansi* in India. There is a solitary report on immunization wherein mice administered formalin-inactivated *T.evansi* (2×10^6 count) were found protected against homologous challenge (Tewari *et al.* 2009). Control of typanosomiasis is hindered by the ability of the parasite to establish chronic infection in mammalian hosts by virtue of a highly developed mechanism of antigenic variation which enables it to escape the host immune system. Traditional knowledge regarding protection of animals from biting flies provides alternative approaches to control (Kohler-Rollefson 1994).

Future thrust: In spite of an impressive volume of published work in the last two decades resulting in better understanding of trypanosomosis in India, there is an obvious lack of in-depth studies on several aspects of the infection. Despite technological advancements, a simple, inexpensive

and reliable test for *T.evansi* detection still eludes us. Field accessibility of new technology like PCR should be explored. With limited option for vaccine development and the looming challenge of drug-resistance, new formulations of effective therapy would need to be evolved on priority. Vector management and change in husbandry practices to minimize exposure to biting flies merits attention in an integrated strategy. Planners should consider setting up of a centralized referral facility to liaise, coordinate and standardize the findings emanating from state laboratories.

REFERENCES

Acharjyo L N. 2000. Trypanosomiasis. Incidence of parasitic diseases among wild mammals and their control in Indian zoos. *Proceedings of 11*th *National Congress of Veterinary Parasitology.* Pp. 10–26. (Ed.) Panda D N. Orissa Veterinary College, Bhubaneshwar.

Agrawala R, Singh R, Kumar M and Upadhyay A K. 2003. Epidemiological features of bovine trypanosomiasis and babesiosis in Durg district of Chhatisgarh state. *Indian Veterinary Journal* **80**: 314–17.

Arora B M. 1994. *Wildlife Diseases in India*. Pp. 100–75 Periodical Experts Book Agency, New Delhi.

Arora J K and Pathak K M L. 1995. Clinico-pathologic and biochemical changes associated with *Trypanosoma evansi* infection in dogs. *Indian Journal of Animal Health* **34**: 33–38.

Baby P G, David PV, Ajith Kumar S and Jayakumar C.2000. A case of canine trypanosomosis with jaundice. *Intas Polivet* **1**: 106– 07.

Baghel A K, Manohar G S, Kumar D and Bhan A K. 1996. Comparative evaluation of various parasitological and immunodiagnostic techniques in buffalo calves experimentally infected with *Trypanosoma evansi*. *Journal of Veterinary Parasitology* **10**: 39–45.

Balachandran C, Pazhanivel N and Babulal D R. 2007. Concomitant ehrlichiosis and trypanosomosis in a dog. *Indian Veterinary Journal* **84**: 877.

Balakrishnan V S, Alex P C, Babu K M J and Surendranath M R. 1994. Canine trypanosomiasis. *Cheiron* **23**: 93–96.

Basagoudanvar S H, Rao J R, Omanwar S, Singh R K and Butchaiah G. 1998. A sensitive polymerase chain reaction for detection of *Trypanosoma evansi* in camels *(Camelus dromedarius). Journal of Parasitic Diseases* **22**: 40–45.

Batra J K, Kumar A and Kulashreshtra P. 1994. A study of 'Surra' in bovines in some parts of Haryana state. *Indian Veterinary Journal* **71**: 971–74.

Bharadwaj R K and Randhawa C S. 2010. Chronic trypanosomiasis in crossbred cattle. *Indian Veterinary Journal* **87**: 408.

Bharathi S and Padmaja K. 2007. Trypanosomiasis in equine - A case report. *Indian Journal of Veterinary Medicine* **27**:72.

Bharkad G P, Bhikane A U, Raote Y V, Markendeya N M and Khan M A. 2005. Surra in a Kathiawari mare -A case report. *Intas Polivet* **6**: 205–06.

Bhaskara Rao T and Hafeez Md. 1999. A case of trypanosomiasis in a goat. *Indian Veterinary Journal* **76**: 1004.

Bhaskara Rao T and Hafeez Md. 2005. Prevalence of trypanosomiasis in buffaloes in East Godavari district of Andhra Pradesh. *Indian Veterinary Journal* **82**: 896–97.

Bhaskara Rao T, Raju P B, Das J H and Hafeez Md. 1995. Some observations on an outbreak of surra in circus tigers. *Indian Veterinary Journal* **72**:1210–11.

Bhatia B B, Pathak K M L and Banerjee D P. 2006. *Text Book of Veterinary Parasitology.* 2nd edn. Pp. 304–315 Kalyani Publishers, Ludhiana -New Delhi.

Bhatnagar C S, Pathak K M L, Kapoor M and Yadav M P. 1997. Evaluation of various diagnostic techniques in donkeys experimentally infected with *Trypanosoma evansi*. *Indian Journal of Animal Sciences* **67 (7)**: 836–38.

Chand N, Singh H, Singh N D and Dhaliwal P S. 2008. Clinical surra and its management in buffaloes. *Indian Veterinary Journal* **85**: 987–88.

Chaudhri S S, Gupta R P and Singh V. 1996. Experimental trypanosomosis in crossbred calves: its diagnosis and chemoprophylaxis with quinapyramine prosalt. *Indian Journal of Animal Sciences* **66**: 662–65.

Chhabra M B and Sangwan A K. 2006. Parasitic diseases of camels – An update. 1. Protozoal diseases. *Journal of Camel Practice and Research* **13**: 7–14.

Chowdhury P, Biswas U, Guha C and Jana P S. 2005. Prevalence of canine trypanosomosis in and around Kolkata city. *Indian Veterinary Journal* **82**: 797–98.

Chowdhury P, Biswas U, Guha C and Jana P S and Barman D. 2006. Efficacy of diminazene aceturate and quinapyramine prosalt in experimental canine trypanosomosis. *Indian Journal of Veterinary Medicine* **26**: 106–07.

Dakshinkar N P and Bhojne G R. 2001. Refractory trypanosomiasis in a dog. *Indian Veterinary Journal* **78**: 721–22.

Dakshinkar N P, Dhoot V M, Upadhye S V, Bhojne G R, Sarode D B and Kolte S W. 2002. Trypanosomiasis in a jungle cat. *Indian Veterinary Journal* **79**: 66–67.

Das A K, Nandi N C and Mohan Kumar O R. 1998. Prevalence of bovine surra in Guntur district, Andhra Pradesh. *Indian Veterinary Journal* **75**: 526–29.

De U K and Mukherjee R. 2006. Trypanosomiasis in equine and its management – A case report. *Indian Veterinary Journal* **83**:72.

Devasena B and Shobhamani B. 2006. Trypanosomiasis in a tigress – A case report. *Intas Polivet* **7**:117.

Dhami D S, Juyal P D and Singla L D. 1999. Seroepidemiology of *Trypanosoma evansi* infection by using CATT. *Indian Veterinary Journal* **76**: 842–44.

Ghorui S K and Samanta S. 1998. Diagnosis of trypanosomiasis by counter immuno-electrophoresis. *Indian Journal of Animal Health* **37**: 59–60.

Gill B S. 1991. *Trypanosomes and trypanosomiases in Indian livestock.* Pp. 191.Indian Council of Agricultural Research, New Delhi.

Gupta M P, Kumar H and Singla L D. 2009. Trypanosomosis concurrent to tuberculosis in black bucks. *Indian Veterinary Journal* **86**: 727–28.

Gupta M P, Singla L D, Singh K B, Mohan R and Bal M S. 2003. Recrudescence of trypanosomosis following administration of dexamthasone in bovines. *Indian Veterinary Journal* **80**: 360–61.

Jain S, Pareek R, Pathak K M L and Kapoor M. 2000. Comparison of six different tests for the detection of *Trypanosoma evansi* in dromedaries. *Journal of Camel Practice and Research* **7**: 215–17.

Jana D and Jana M. 2005. Report on trypanosomiasis in a Black

Bengal buck. *Intas Polivet* **6**: 204.

Jani R G and Jani B M. 1993. Haematological and biochemical changes in clinical cases of equine surra. *Journal of Remount and Veterinary Corps* **32**: 91–94.

Jeyabal l, Chaudhri S S, Singh A and Kumar D. 2003. Detection of circulating antigens in immune complexes of *Trypanosoma evansi* infected cattle and buffaloes by ELISA. *Journal of Veterinary Parasitology* **17**: 85–88.

Jindal N, Gupta S L, Batra M and Singh R. 2005. A note on the prevalence of surra in bovines in Haryana. *Indian Veterinary Journal* **82**:1114–15.

Jithendran K P, Rao J R and Mishra A K. 1997. Evaluation of antigenic preparations for the diagnosis of experimental *Trypanosoma evansi* infection in bovine calves. *Journal of Veterinary Parasitology* **11**: 17–21.

Jithendran K P, Rao J R and Singh S D. 1998.Restriction endonuclease analysis of *Trypanosoma evansi. International Journal of Animal Sciences* **13**: 81–85.

Joshi S S and Singh B. 2000. Evaluation of therapeutic and chemoprophylactic efficacy of certain drugs against clinical surra in buffaloes. *Indian Veterinary Journal* **77**: 895–97.

Joshi S S and Singh B. 2001. Clinicopathology and biochemical alterations in clinical cases of *T.evansi* infection in buffaloes and effect of treatment thereon. *Indian Veterinary Journal* **78**: 642–44.

Kalra S, Dhaliwal P S and Juyal P D. 1994. Trypanosomiasis in a 23 - day old calf (Holstein-Friesian). *Indian Veterinary Journal* **71**: 191–92.

Kohler-Rollefson I. 1994. Ethnoveterinary practices of camel pastoralists in northern Africa and India. *Journal of Camel Practice and Research* **I**: 75–82.

Krishnamoorthy P and Murali Manohar B. 2005. A case of trypanomomiasis in a Rajapalayam dog. *Indian Journal of Animal Health* **44**: 73–74.

Krishnappa T, Muralidhara A, Sastry K N V, Renukaprasad C and Krishnappa G. 2002a. Prevalence of trypanosomiasis in domestic animals in Karnataka. *Indian Veterinary Journal.***79**: 183–84.

Krishnappa T, Muralidhara A, Sastry K N V, Renukaprasad C and Krishnappa G. 2002b. Passive haemagglutination test in the seroprevalence of *Trypanosoma evansi* infection in bovines. *Indian Veterinary Journal* **79**: 185–86.

Kumar A, Saxena S C, Sharma S D and Joshi B P. 1994. Epidemiology and therapeutic studies on a field outbreak of equine trypanosomiasis. *Indian Veterinary Journal* **71**: 74–76.

Kumar U, Jas R and Ghosh JD. 2009a. Effect of Isometamidium hydrochloride on *Trypanosoma evansi* infection in rats. *Journal of Parasitic Diseases* **33**: 36–41.

Kumar S, Kumar A and Samantaray S. 2009b. Treatment of sub-clinical cases of surra in buffaloes. *Indian Veterinary Journal* **86**: 407–08.

Kundu K, Rao J R, Tewari A K, Baidya S and Mishra A K. 2010. Existence of genetic variability among Indian isolates of *Trypanosoma evansi. Indian Journal of Animal Sciences* **80** (1): 3–6.

Laha R and Sasmal N K. 2008. Endemic status of *Trypanosoma evansi* infection in a horse stable of eastern region of India – a field investigation. *Tropical Animal Health and Production* **40**: 357–61.

Laha R, Bera A K, Panja P and Sikdar A. 2004. Clinical and haematobiochemical studies in natural trypanosomosis of equines. *Indian Journal of Animal Sciences* **74** (3) : 339–40.

Lakshmi Rani N, Suresh K, Srinivas M and Sreenu M. 2007. Canine trypanosomiasis. *Indian Veterinary Journal* **84**: 186–87.

Lun Z R, Reid S A, Lai D H and Li FJ. 2009. Atypical human trypanosomiasis: a neglected disease or just an unlucky accident? *Trends in Parasitology* **25**: 107–08.

Malik B S, Chaudhri S S and Gupta R P. 2000. Effect of different levels of nutrition on experimental bubaline trypanosomosis. *Indian Journal of Animal Sciences* **70**: 559–62.

Muraleedharan K and Srinivas P M. 1985. A report on the observation of *Trypanosoma evansi* in the aborted foetus of a cow. *Indian Veterinary Journal* **62**:16.

Muralidharan M S. 2011. Treatment of acute surra in throughbred horses. *Indian Veterinary Journal* **88**: 55–56.

Murali Manohar B, Selvaraj J, Jayathangaraj M G and Khan N. 2003. Pathology of *Trypanosoma evansi* in a tiger. *Indian Veterinary Journal* **80**: 505–07.

OIE. 2004. List of diseases by OIE classification. Office Internationale des Epizooties, Paris (Retrieved from: http://www.cie.int/).

Omanwar S, Rao J R, Basagoudanavar S H and Singh R K. 1999a. Amplification of kinetoplast DNA by polymerase chain reaction for detection of *Trypanosoma evansi. Indian Veterinary Journal* **76**: 878–81.

Omanwar S, Rao JR, Basagoudanavar SH, Singh RK and Butchaiah G. 1999b. A simple and highly sensitive method to detect *Trypanosoma evansi* by DNA amplification from crude blood samples collected on filter papers. *Journal of Veterinary Parasitology* **13**: 27–29.

Oamnwar S, Rao J R, Singh R K and Butchaiah G. 2001. DNA polymorphism in *Trypanosoma evansi* isolates defined by randomly amplified polymorphic DNA-PCR. *Veterinary Records* **148**: 244–46.

Palanivel K M, Vijayalingam T A, Nagarajan B, George K S and Ganesh T N. 2008. Pathological changes in *Trypanosoma evansi* infection in a buffalo calf. *Indian Veterinary Journal* **85**: 1005.

Panduranga Rao P, Rama Devi V, Srilatha Ch. and Kavitha K. 2001. Transplacental transmission of trypanosomes in a buffalo calf. *Indian Veterinary Journal* **78**: 849–50.

Parija S C and Bhattacharya S. 2001. Tragedy of tigers. Lessons to learn from Nandankanan episode. *Indian Journal of Medical Microbiology* **19**: 116–18.

Pathak K M L and Kapoor M. 1999. Transplacental transmission of *Trypanosoma evansi* in a donkey. *Indian Veterinary Journal* **76**: 179.

Pathak K M L and Khanna N D. 1995. Trypanosomosis in camel (C*amelus dromedarius)* with particular reference to Indian subcontinent: a review. *International Journal of Animal Sciences* **10**: 157–62.

Pathak K M L and Singh N. 2005. Animal trypanosomosis. *Intas Polivet* **6**: 194–99.

Pathak K M L, Arora J K and Kapoor M. 1993. Camel trypanosomosis in Rajasthan. India *Veterinary Parasitology* **49**: 319–23.

Pathak K M L, Arora J K, Sahai P and Kapoor M. 1994. Fractionation and characterization of somatic antigen of *Trypanosoma evansi. Indian Veterinary Journal* **71**: 218–21.

Pathak K M L, Kapoor M and Shukla R C. 1997a. Evaluation of therapeutic and prophylactic efficacy of Quinapyramine methyl sulphate-chloride in camels naturally infected with

Trypanosoma evansi. *Indian Journal of Animal Sciences* **67** (2): 132–33.

Pathak K M L, Singh Y, Meirvenne N V and Kapoor M. 1997b. Evaluation of various diagnostic techniques for *Trypanosoma evansi* infections in naturally infected camels. *Veterinary Parasitology* **69**: 49–54.

Pazhanivel N, Balachandran C and Vijayalingam T A. 2008. Concurrent *Trypanosoma evansi* and *Hepatozoon canis* infections in a dog. *Indian Veterinary Journal* **85**: 774–75.

Prakash R, Sapre V A and Prakash R. 1994. Therapeutic efficacy of diminazene aceturate in experimental *Trypanasoma* sp. infection in dogs. *Indian Veterinary Journal* **71**: 512–13.

Prasad D, Madhu Babu R and Narsinha Rao A V. 1997. Incidence of trypanosomiasis in buffaloes. *Indian Veterinary Journal* **74**: 887–88.

Raina R, Raina A K and Bhadwal M S. 2000. Outbreak of surra in buffaloes and ponies. *Indian Journal of Veterinary Medicine* **20**: 32.

Raisinghani P M and Lodha K R. 1989. Incidence of *Trypanosoma evansi* infection in camels of Rajasthan. *Indian Journal of Animal Sciences* **59** (12) : 1390–92.

Rajguru D N, Salabat Ali M, Joshi S A, Swami S B and Saleem Md. 2000. Observations on *Trypanosoma evansi* infection in neonatal calves. *Indian Veterinary Journal* **77**: 996–97.

Rajkhowa S, Bujarbaruah K M, Hazarika G C and Rajkhowa C. 2003. Observations on trypanosomiasis in Mithun. *Indian Veterinary Journal* **80**: 934–36.

Ramachandraiah K. Mohan Reddy A R, Chari P V and Padmavathi G. 1995. Treatment of trypanosomiasis in a male tiger – A case report. *Livestock Advisor* **20**: 23–24.

Rao M, Ramulu M and Bhaskara Rao P. 1987. Trypanosomiasis in a Corridale ram. *Indian Veterinary Journal* **64**: 1076.

Ravindran R, Rao J R, Mishra A K, Pathak K M L, Babu N, Satheesh C C and Rahul S. 2008. *Trypanosoma evansi* in camels, donkeys and dogs in India: comparison of PCR and light microscopy for detection – short communication. *Veterinarski Arhiv*. **78**: 89–94.

Ray D, Biswas G and Sen G P. 1992. *Trypanosoma* infection in cattle and buffalo. *Indian Journal of Animal Sciences* **62** (1): 42.

Rayulu V C, Chaudhri S S and Singh A. 2009. Evaluation of parasitological and monoclonal antibody based assays in detection of *Trypanosoma evansi* infection in animals. *Indian Journal of Animal Sciences* **79** (9): 978–81.

Ruprah N S. 1985. Trypanosomatidae *Textbook of Clinical Protozoology* pp. 49–101. Oxonian Press. New Delhi.

Sahoo N, Ray P K, Samantaray R K and Das A. 2009. Treatment of trypanosomiasis in a jungle cat. *Indian Veterinary Journal* **86**: 844–45.

Sangwan N,Chaudhri S S, Rao A R, Sangwan A K and Gupta R P. 1993. Folacin and Cyanocobalamin in relation to natural *Trypanosomia evansi* infection in buffaloes. *Tropical Animal Health and Production* **25**: 79–84.

Sarmah P C, Bhattacharyulu Y and Joshi V B. 1997. Effect of *Trypanosoma evansi* infection on the antibody response in guinea pigs vaccinated with haemorrhagic septicaemia oil adjuvant vaccine. *Journal of Veterinary Parasitology* **11**:161–64.

Sarvanan S, Mohammed Basheer A, Sundar N and Nedunchelliyan S. 2005. Trypanosomosis in a German Shepherd dog. *Indian Journal of Veterinary Medicine* **25**: 62.

Shahardar R A, Mishra A K and Rao J R. 2002. Dot ELISA for detection of antibodies against *Trypanosoma evansi* in dromedary camels. *Journal of Veterinary Parasitology* **16**: 163–64.

Shahardar R A, Rao J R and Mishra A K. 2003. Detection of antibodies against *Trypanosoma evansi* in dromedary camels by competitive inhibition enzyme linked immunosorbent assay. *Journal of Applied Animal Research* **24**: 41–48.

Shahardar R A, Rao J R and Mishra A K. 2009. Detection of *Trypanosoma evansi* in Indian dromedary camels by polymerase chain reaction to ribosomal DNA target. *Journal of Veterinary Parasitology* **23**: 974–83.

Shahardar R A, Mishra A K and Rao J R. 2004. Detection of antibodies against *Trypanosoma evansi* in dromedary camels by ELISA using solubilized antigens. *Indian Journal of Animal Sciences* **72**: 117–19.

Shailaja V, Venkatesha M D, Renukaprasad C, Jaya Kumar S R and Krishnappa G. 2005. Standardization of Polymerase Chain Reaction (PCR) for diagnosis of trypanosomosis in captive and wild animals. *Intas Polivet* **6**: 207–08.

Singh A and Chaudhri S S. 2002. Comparison of efficiency of parasitological methods with Ag-ELISA in *Trypanosoma evansi* infected crossbred calves. *Indian Journal of Animal Sciences* **72**: 197–99.

Singh B and Joshi S J. 1991. Epidemiology, clinicopathology and treatment of clinical *Trypanosoma evansi* in buffalo *(Bubalus bubalis*). *Indian Veterinary Journal*. **68**: 975–79.

Singh B, Kalra I S, Gupta M P and Nauriyal D C. 1993. *Trypanosoma evansi* infection in dogs: seasonal prevalence and chemotherapy. *Veterinary Parasitology* **50**: 137–40.

Singh N, Chaudhry SS, Gupta S L and Singh A. 2002. Chemoprophylaxis with quinapyramine prosalt against *T.evansi* in buffalo calves. *Journal of Veterinary Parasitology* **16**: 31–34.

Singh N, Pathak K M L and Kumar R. 2004. A comparative evaluation of parasitological, serological and DNA amplification methods for diagnosis of natural *Trypanosoma evansi* infection in camels. *Veterinary Parasitology* **126**: 365–73.

Singh N, Pathak K M L, Chaudhry S S and Kumar R. 2007. Cameline trypanosomosis (surra) in dromedaries of Western Rajasthan, India. *Indian Journal of Animal Sciences.* **77** (7): 718:20.

Singh N, Pathak K M L, Kumar R and Manohar G S. 2003. Observations on the validity of mouse inoculation test in the surveillance of *Trypanosoma evansi* in camel. *Journal of Camel Practice and Research* **10**: 153–55.

Singh V, Singh A and Chhabra M B. 1994a. Polypeptide profiles of whole cell lysate of *Trypanosoma evansi* stocks from northern India. *Indian Journal of Animal Sciences* **84** (1) : 14–17.

Singh V, Gahlot A K and Chhabra M B. 1994b. Evaluation of some serodiagnostic tests for *Trypanosoma evansi* infection in camels. *Journal of Camel Practice and Research*.1: 30–31.

Singh V, Chaudhry SS, Kumar S and Chhabra M B. 1995a. Polyclonal antibody-based antigen-detection immunoassay for diagnosis of *Trypanosoma evansi* in buffaloes and horses. *Veterinary Parasitology* **56**: 261–67.

Singh V, Singh A and Chhabra MB. 1995b. Polypeptide profiles and antigenic characterization of cell membrane and flagellar preparations of different stocks of *Trypanosome evansi*.

Veterinary Parasitology **56**: 269–79.

Singh Y, Pathak K M L, Verma K C, Harsh D and Kapoor M. 1997. Prevalence and diagnosis of *Trypanosoma evansi* infection in camels in Rajasthan. *Journal of Veterinary Parasitology* **11**: 133–36.

Singla L D, Juyal P D and Ahuja S P. 1998. Blood brain barrier status in experimental *Trypanosoma evansi* infected and levamisole treated cow-calves. *Indian Veterinary Journal* **75**: 109–12,

Singla L D, Juyal P D and Sharma N S. 2010. Immune responses to haemorrhagic septicaemia (HS) vaccination in *Trypanosoma evansi* infected buffalo-calves. *Tropical Animal Health and Production* **42:** 589–595.

Sinha B S, Verma S P, Mallick K P, Samantaray S, Kumar B and Kumar R P. 2006. Studies on epidemiological aspects of bovine trypanosomosis in some districts of Bihar. *Journal of Veterinary Parasitology* **20**: 69–71.

Sonika, Sharma G and Juyal P D. 2007. Trypanosomosis in a German Shepherd dog – a case report. *Journal of Veterinary Parasitology* **21**: 81–82.

Sood A C, Mohindroo J, Aulakh G S and Singla L D. 2004. Glaucoma and corneal opacity associated with trypanosomiasis in a dog. *Indian Journal of Veterinary Medicine* **24**: 119.

Soodan J S, Khahra S S and Juyal P D. 1995a. Efficacy of capillary tube agglutination test (CAT) and get diffusion (GD) test for detection of experimental T*rypanosoma evansi* infection in donkeys. *Indian Veterinary Journal* **72**: 806–10.

Soodan J S, Singh K B, Juyal P D and Khahra S S. 1995b. Incidence of *Trypanosome evansi* infection in equines in Punjab State. *Journal of Veterinary Parasitology* **9**: 133–34.

Tewari A K, Rao J R and Mishra A K. 2009. Protective potentiality of killed *Trypanosoma evansi* in mice. *Indian Veterinary Journal* **86**: 892–93.

Thirunavukkarasu P S, Sunder George R R, Nambi A P, Ramesh S and Vasu K. 2000. Trypanosomiasis in a cat – A clinical report. *Indian Veterinary Journal* **7**: 428–29.

Varshney J P. 2005. Treatment aspects of naturally occurring trypanosomosis in dogs – A clinical study. *Intas Polivet* **6**: 200–02.

Varshney J P and Gupta A K. 1996. Haematobiochemical changes in clinical trypanosomiasis with reference to liver function indices. *Centaur* **13**: 13–16.

Varshney J P and Varshney V P. 2006. Evaluation of hepatic, cardiac, thyroid and adrenal functions in dogs with chronic trypanosomosis caused by *Trypanosoma evansi*. *Intas Polivet* **7**: 88–91.

Varshney J P, Varshney V P and Dwivedi S K. 1998. Clinico-endocrinological findings in clinical trypanosomiasis in dog. *Journal of Veterinary Parasitology* **12**: 143–44.

Varshney J P, Varshney V P and Dwivedi S K. 1999. Endocrine dysfunctions in clinical trypanosomosis in horses. *Journal of Veterinary Parasitology* **13**: 33–35.

Varshney J P, Bandyopadhyay S, Ranjan R and Saghar S S. 2003. Diagnosis and treatment of *Trypanosoma evansi* associated corneal opacity in dogs. *Journal of Veterinary Parasitology* **17**: 53–55.