



Review Article

Trypanosomiasis: Recent advances in strategies for control

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Abstract

Trypanosomiasis is numbered among the list of seventeen transmissible diseases and is associated with poor socio-economic status. Trypanosomiasis is referred to as a neglected tropical disease (NTDs) by the World Health Organization, due to its limited diagnostic and treatment development, with yet poor control measures. Three diseases of parasitic origin emanate due to genetically connected protozoa, trypanosomatid and kinetoplastida. They are the basis of many public health challenges in the less developed world and include American Trypanosomiasis (Chagas disease), Human African Trypanosomiasis and Leishmaniasis. This review emphasizes Trypanosomiasis in general, the lifecycle, biochemistry of parasite infection, disease treatment and management. Prevention options, the biochemistry of drug resistance and novel treatment of disease are among subjects considered.

Introduction

Trypanosomiasis is a compound name for diseases caused by trypanosome [1]. The two categories of trypanosomiasis are Human African Trypanosomiasis (HAT); otherwise known as sleeping sickness and Chagas disease. HAT/sleeping sickness is common in several locations of Sub-Saharan Africa (SSA) and is due to organism invasion by any of the two parasites; *Trypanosoma brucei rhodesiense* or *Trypanosoma brucei gambiense*. Tsetse fly serves as its vector [2].

Humans are the major host for *T. b. gambiense*, similarly, cattle or wild bovids are vectors for *T.b. rhodesiense*. Animal to human, animal to animal, and human to human transmission is significant of *T. b. rhodesiense* [3,4]. Transmission differs based on vector density and stinging behavior [2]. When left untreated, the HAT can be deadly. The toll of the disease is majorly on countryside populations in the SSA.

American trypanosomiasis otherwise called Chagas disease just as HAT is transmitted via animal-to-animal (zoonotic)

mechanism, its trigger is the protozoan *Trypanosoma cruzi* [5], which is prevalent in Latin America [5,6].

Epidemiology

According to Siqueira *et al.*, [6], WHO ranked trypanosomiasis among the list of 17 neglected tropical diseases amidst leprosy, leishmaniasis, malaria, and tuberculosis. The disease is most predominant in low-income populations and therefore do not attract the interest of pharmaceutical companies. For this reason, advancement in therapies is seriously hampered [1]. Human schistosomiasis, is a great concern in public health taking its bang on over 200 million people in more than 70 countries. More than 800 million people stand at risk of being contaminated with the parasite illness. Even though death rates are difficult to ascertain, the disease has been predicted to cause 280,000 per annum and is likely to constitute more harm to the host [7]. The early 20th century witnessed a distressing outbreak of HAT in Uganda, the Democratic Republic of the Congo, Cameroon, and other western African countries probably due to environmental disturbances and compulsory movement of populace embraced by colonialism. Transitions

in land use and climate extremely diminished parasite vector in areas thought to be endemic [4]. *T. cruzi*, the vector for Chagas disease [8] is first released via the countryside to the metropolitan areas of Latin America and to other areas of the world. 18 million individuals suffer from Chagas disease in Mexico, Central America and Latin America. Majorly, awareness of this ailment is poor among the victim predisposed populations; however, if the disease condition is untreated, infection perseveres for a long time and can inevitably pose a serious threat to the victim's survival [9].

The Life cycle of trypanosome

Trypanosome feeds on blood and hence its transmission from one animal to the other. In *trypanosoma brucei*, Tsetse fly injects *T. brucei* into the bloodstream by stinging; *T. brucei* multiplies by binary fission in human fluids such as blood and cerebrospinal fluid. After the multiplication of *T. brucei* in human, tsetse fly bites once again and ingest *T. brucei* contaminated blood meal, it then multiplies more in the midgut of the tsetse fly. Consequently, it transforms into an infectious stage that enters in the midgut of the salivary gland and produces more parasite, which will infect its animal host. The life cycle of *Trypanosoma brucei* is simply illustrated below. Figures 1,2.

Biochemistry of Infection

The sequence of events leading to the survival of trypanosomes contrast significantly between various African trypanosome species, however a better understanding has been made using *T. brucei*. This has led to better improvement in this area. In the advent of the 1980s, research centered on laboratory adjusted circulatory system structure lines, termed monomorphs, and long haul refined procyclic structures [10]. Be that as it may, in 1990 Ziegelbauer and associates revealed that the differentiation of circulatory system work side by side with procyclic structures utilizing pleomorphic parasites (for example those fit for creating transmissible stumpy structures,

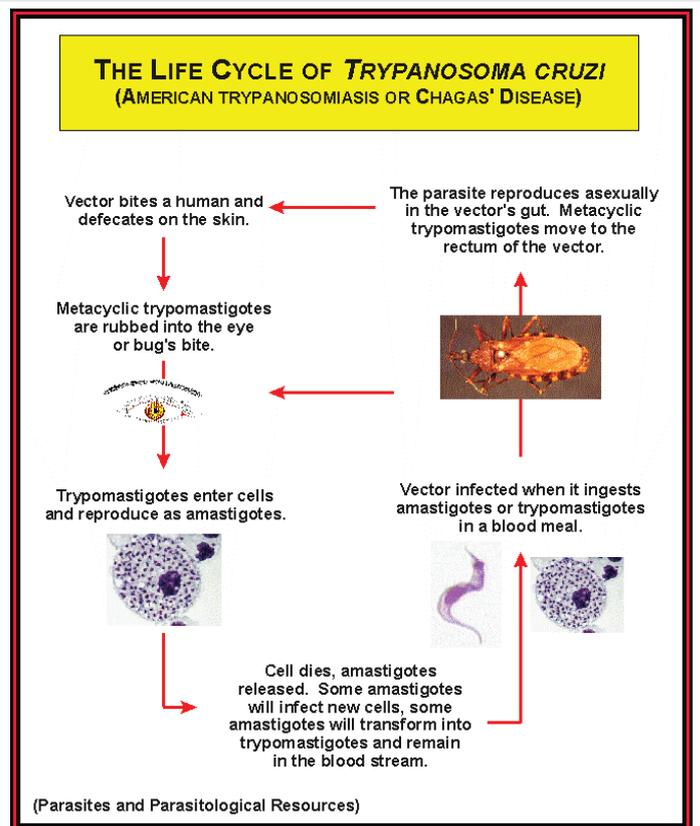


Figure 2: Life cycle of *Trypanosoma Cruzi*.

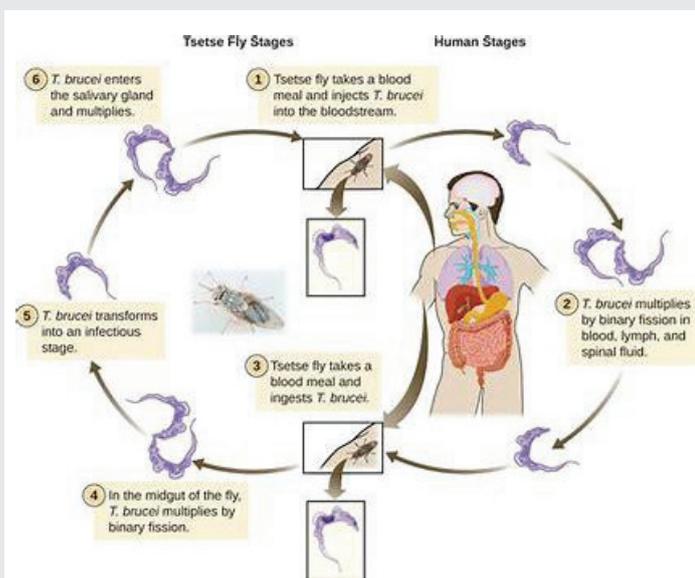


Figure 1: Life cycle of trypanosome (*T. brucei*). www.cdc.com.

an attribute decreased in laboratory attuned monomorphic lines) invigorated by the separation triggers citrate and cis-aconitate. This empowered the tractable dismemberment, *in vitro*, of developmental occasions as parasites separated from arrested bloodstream short structures. These structures gather at the pinnacle of standard parasitaemic waves in rat contaminations resulting in structures that are procyclic. Early studies established that short structures were consistently stopped at G1 checkpoint and re-emergence cell cycle that separates in a matter of hours *in vitro*, with separation skill proposed to be linked to cell cycle capture in G1/Go. Not long after separation the parasites express unique isoforms of this procyclic structure surface coat, and further changes to epimastigote after a disordered division. The mechanism of the physiological trigger for the different formative occasions during the life cycle stays cloudy as a rule; however, the production of small structures is by all accounts invigorated by a parasite-derived signal identified as short enlistment factor [11]. Whatever the specific atomic trigger, there are various constituents of the signaling response pathway that must be available before differentiation into slumpy structures from slender forms. When produced, short forms can enter into the tsetse fly via the expression of a family of proteins known as PADs (protein arginine deaminases). These proteins are responsible for the transference of the citrate/cis-aconitate signal, of which they are hypersensitive at low temperatures. Signaling continues after entrance into the tsetse fly and is facilitated by a phosphatase-signaling cascade, which transferred to the glycosomes. Subsequently, an event evident in hypoxia and/or glycerol contact *in vitro* occurs, procyclin



structures multiply until amastigotes are formed via passage through the salivary glands after an asymmetric division [12]. Then epi-amastigotes multiply as they are attached to the salivary gland wall. Specific cell proteins are conserved during the meiotic cell division cycle and appearance of fused cells after dual infection of tsetse flies with parasites expressing either red or green marker proteins are obvious generating yellow cells. In the end, metacyclic forms are produced, though arrested in division re-expresses the VSG in preparation to re-infect the mammalian hosts [11]. This shows the ability of single protein expression changes to drive multifaceted development events [10].

Diagnosis of trypanosomiasis

Medical symbols and pointers of human African trypanosomiasis are unclear and may be easily misplaced for other diseases; for this reason, they are therefore not enough for proper diagnosis [13]. Diagnosis is mainly by showing that patients are infested through serology and molecular methods using stool, urine blood and other body fluids in some cases [6]. Dependable serodiagnosis tests exist just for *T brucei gambiense* disease, and depend on the discovery of explicit antibodies. The card agglutination test for trypanosomiasis (CATT), 62 grew right around 40 years prior, has immensely helped in the control of infection due to *T brucei*. CATT is performed by using blood samples obtained from a finger prick, plasma, or serum, after which agglutination response is scored outwardly in 5 minutes. It is especially appropriate for the screening of susceptible populaces by versatile groups.

Imaging can also serve as another diagnostic tool for the parasite; ultrasound, computed tomography, and magnetic resonance, are crucial in assessing both the disease condition and its dire effects and complications in target organs [14]. Serological diagnosis indicative of schistosomiasis is connected to hypereosinophilia, approximately three weeks past the onset of the symptomatology [15]. Hypereosinophilia is characteristic of infection; however, there is a belated onset of eosinophilia in comparison to the outward show of symptoms [14].

Treatment strategies

Praziquantel (PZQ) was the initial remedy used for the treatment of schistosomiasis according to WHO approval. This is due to its effectiveness and degree of drug tolerance in the affected population. Due to its indispensability in the fight against the disease, research is being directed on the refinement of characteristics such as increased solubility, or the search for a new drug delivery system for anticipated better results [6,10].

Universally, this approach aims to circumvent parasite drug resistance, rapid systemic circulation after ingestion, and wide-ranging first-pass metabolism [16]. Four major drugs that are currently permitted for HAT treatment are suramin, pentamidine, melarsoprol, and eflornithine [3,4]. Combination therapy involving nifurtimox-eflornithine (NECT), though not approved in all HAT affected countries, has been on the WHO list of essential medicines since 2009. Suramin is efficient for

stage 1 HAT infection but is ineffective for stage 2 infection due to its ability to cross the blood brain barrier. The intravenous route of administration is used for suramin and patients require protracted hospital admission. Although indication of synergism exists for eflornithine, nifurtimox, and melarsoprol with suramin, combined is yet to be recognized. Pentamidine (discovered in 1937) can attack nucleotides and compromise mitochondrial genetic makeup. Pentamidine has been useful in stage 1 HAT remedy since 1940 but suramin iv is a better alternative. Pentamidine is ineffectual regarding stage 2 HAT. The accepted dose of pentamidine is calculated to be 4 mg/kg/day which must be made available intramuscularly (IM) or intravenously (IV), between 7–10 days. Powdered formulation of pentamidine is available but if it is in solution, it must be used before the expiration of 24 hours. Melarsoprol (discovered in 1949) is active and potent against the 2 stages of g-HAT (Gambia Human African Trypanosomiasis) and r-HAT (rhodonsie Human African Trypanosomiasis). In the meantime, there are harmless alternative medications for stage 1 HAT. Melarsoprol use is constrained to stage 2 ailment; the lone treatment aimed at stage 2 r-HAT. Drug resistance by the parasite is an issue of concern in melarsoprol use in about 10–30% of patients treated with melarsoprol. A daily intravenous dosage of 1.2 mg/kg which can be raised to 3.6 mg/kg for 3–4 days tracked by a 7-day treatment interruption, repetitive two / three times intravenously (Baker & Welburn, 2018). In recent times, short-term treatment of 2.2 mg/kg/day IV for 10 successive days is approved. Melarsoprol exhibits lethality, besides undesirable reactions which are common (5–10% of patients show a reactive encephalopathy that is lethal in fifty percent of cases handled, it is therefore paramount that patients must be admitted into the hospital to enable close checks. Eflornithine (a-DFMO) came into the limelight in the 1970s when it was used for cancer chemotherapy. It was also observed that eflornithine exhibited Trypan static action, and hence its approval for stage 2 g-HAT treatment in 1990. Eflornithine exhibits its therapeutic effect by inhibiting trypanosome ornithine decarboxylase (ODC) in *T. b. gambiense* [13]. Because of the undesirable effects of prevailing chemotherapeutic agents used in the treatment of trypanosomiasis, accordingly, novel treatment systems are desperately required. In this unique circumstance, therapeutic plants may offer appealing choices for a formative regimen [17]. Undoubtedly, there is an abundance of writing giving an account of therapeutic plants and their segregated regular items and how they act against trypanosomes *in vitro* and *in vivo* [17].

Novel drug discovery

The last 25 years have witnessed a burst in investigations towards developing therapies for African trypanosomiasis, although research in this area is yet to yield promising results; many new drugs have been encountered in the process that has assisted a great deal in the treatment and cure for trypanosomiasis. In 1990, eflornithine was the first to be licensed for the treatment of *T. b. gambiense*, and succeeded by NECT (nifurtimox eflornithine combination therapy; flung in 2009) which has been successful in its usage. NECT reduces the treatment time from 14 to 10 days and provides a 75% reduction of intravenous dosage making it cost-effective [3,4].



Research has been geared towards developing inhibitors for novel targets recognized to be crucial to the parasite survival in the host organism. Using target-based approaches N-myristoyl transferase has been identified as possibly appropriate for the exploration of therapeutic inhibition. Other targets molecular or *in vitro* inhibition tests have proven unreliable most times. As a result, the focus has shifted from molecular targets to phenotypic screening to recognize cell permeable inhibitors that possess a good therapeutic index (toxic to parasites but not harmful to host cells). A partnership among pharmaceuticals and institutions of higher learning that encourages access to high scientific and industrial equipment including expertise is encouraged as a quest for better treatment. One of the most encouraging outcomes of phenotypic screening is the development of drugs administered through the mouth, for example, fexinidazole, which was undergoing phase III clinical trials and oxaborole SCYX-7158 on phase I clinical trials [18]. These efforts raise hopes that effective new therapies will be delivered for human African trypanosomiasis, although drug development is extremely on the high side even though trypanosomiasis therapy proposes no profitable return.

Low bioavailability and water solubility have limited many oral drugs in usage, for instance, praziquantel, however various technologies such as nanotechnology have also been put in place to outwit this circumstance [7]. Nanotechnology can prevent toxic drugs from serving as potential toxicants to host organisms by using complicated structures that can carry drugs in such a manner that only the pathogen is harmed preserving the host cell from therapeutic toxicity. This is known as selective toxicity. Approaches involving nanotechnology are probable able to associate therapeutic profits of drugs to provide aid for diseased individuals [19]. There are concerns about the use of chemotherapy treatment option, in context; medicinal plants are better options, particularly for developing countries, in the quest for new therapies against trypanosomiasis. In a study using *Indigofera* as a plant therapeutic agent, the number of trypanosomes is lowered. The protective ability of the plant extract is attributed to saponins, flavonoids, quinines and coumarins, which are bioactive ingredients of *Indigofera* [17].

Biochemistry of drug resistance

Drug resistance is a property of a pathogen that makes a drug or group of drugs less effective or ineffective. When there is a mutation in the genome of *T. brucei gambiense*, it leads to resistance to melarsoprol and pentamidine. As a matter of emphasis, melarsoprol resistance remains a source of great concern. With the rise of failure rates at the turn of the century in most human African Trypanosomiasis, the challenge was alleviated when NECT came on board. NECT makes use of combination therapy of two drugs with diverse pharmacodynamics and pharmacokinetics bringing about largely, the probability of parasite resistance [4]. Because few drugs are available for the management of shistosomiasis, resistance poses a serious challenge. For example, cross-resistance is observed between ISM and diminazene. Cross-resistance to ethidium bromide has also been observed in ISM resistance.

Resistance to drugs used in the treatment of trypanosomiasis has always been believed to have been caused by gene mutations in the TbAT1/P2 transporter and the High-Affinity Pentamidine transporter genes responsible for diminazene transport [20]. In the light of *T. congolense* resistance to trypanocides it is becoming more evident that disparities exist between *T. brucei* and *T. Congolense* in terms of drug transporter as *T. Congolense* do not have an equivalent of TbAT1/P2 [21,22]. Under dosing is a technique used in selecting resistant trypanosomes in African animals in the field. The increase in resistance as observed in drugs used in the treatment of trypanosomiasis and the slim chances of a possible vaccine development has warranted the search for plants with trypanocidal prospects [23].

Management strategies

There are two major stages of clinical presentation of the HAT: firstly (hemolymphatic) and secondly (meningoencephalitis) presentation. In the most important stage, a chancre can be created at the point of immunization driven by an elevated parasite. Identification of the meiotic life cycle stage of *Trypanosoma* in the blood and lymphatic frameworks reveals side effects including irregular fever, lymphadenopathy, pruritus and specific profound agony vibrations. There is also an expression of slight neurological and hormone-related unsettling influences which are further indications of sensory system inclusion and, together with an extreme cerebral pain, this is a sign of transition to the second stage of the ailment [6,15].

Subsequently, sleep disorderliness affect circadian rhythms. Other indications are cerebral pain and neuropsychiatric aggravations [3,4]. There should be urgent evacuation logistics since trypanosomiasis requires imperative treatment. This will solve the problem of delayed treatment often experienced in trypanosomiasis management, as the disease is often multisystem and progressive. Patients are frequently extremely ill, therefore, proper diagnosis must be put in place to avoid tagging trypanosomiasis as viral hemorrhagic fevers (VHFs) which is one of the symptoms of trypanosomiasis. Health insurance companies should be able to cooperate in a timely response to the needs of patients when confirmed with the disease. Delayed diagnosis is to be carefully avoided particularly in endemic environments. Clinicians should always remember that suramin and melarsoprol are capable of exhibiting toxicity; therefore, administration of drugs should be done carefully. The side effects and dosage regimens should always be taken into consideration to avoid encountering complications during management. Multi-organ involvement is normal for patients with intense trypanosomiasis, as pointed out by Büscher *et al.* [4]. They therefore need in-depth levels of clinical care; intermittently this may include hemodialysis and automatic aeration in order for them to survive [2,5,24]. The use of intensive care units has helped in managing trypanosomiasis in Johannesburg but these amenities may not be readily available in most endemic areas. Familiar complications include myocarditis, fluid overload (which may bring about acute respiratory problems), thrombocytopenia,



disseminated intravascular coagulopathy, bleeding, hepatic and renal failure, which may all show up before CNS assault should be given closer attention and treated correctly.

Prevention strategies

Generally, HAT can be prevented by reducing stings from tsetse flies, carrying out earlier diagnosis and immediate treatment for patients diagnosed with the disease. Individuals can also protect selves although bites may penetrate clothing that is not heavy enough. Insect repellants are not quite common in endemic areas. At the neighborhood level, vector control can be achieved by screen and treatment plans, this has to do with the identification of human cases. Another way by which control of tsetse fly populations can be accomplished is via successive mid-air insect repellent spraying to target adult vector. This should be done during the developmental stage of tsetse flies from pupal stages in the ground, the use of insecticides as traps may be of immense help when treating cattle [25].

Monitoring systems that take surveillance should present discovery, investigation and disruption of subsequent transmission as a major drive and purpose of its existence alongside with disease prevention of tsetse bites. Having an effective management system will help disease managers to pinpoint risky areas, prevalent population and pattern of infection in animals and human that needs intervention and control measures where essential. For instance, monitoring of *Schistosoma* in Japan has been continuous, meanwhile animal to human disease transmission persisted extensively even when the disease was declared to have been eradicated in humans in Japan in the year 1996 [8]. This can be achieved using chemicals such as tablets and liquids preparations. Baits such as metaldehyde and methiocarb tablets, granular, and liquid preparations. Ingestion of metaldehyde baits is poisonous resulting in desiccation and the consequent demise of organisms. Similarly, carbamate, methiocarb disrupts the central nervous system, preventing acetylcholinesterase, instigating of animal death [26]. Since the neglected tropical disease is a public health problem bringing about several deaths, WHO recommends the use of chemicals for prevention as well as improved access to uninfected drinking water, hygienic environment education [7]. In Nigeria, Tsetse Eradication Campaign started in 1955 by the use of insecticides that act for a very long time in the northeastern part of the country. These activities were later extended to the Eastern and Western parts of the country. The Biological Control of Tsetse (BICOT) project, which began in VOM, Nigeria, was in operation between 1979 and 1987 and Nasarawa State was its target state [27].

Conclusion

Trypanosomiasis is a neglected tropical disease according to the World Health Organisation. Socio-economically deprived communities observed in Sub-Saharan Africa and other parts of the world are at-risk populations. Human African Trypanosomiasis is caused by *Trypanosoma brucei rhodesiense* or *Trypanosoma brucei gambiense* while *Trypanosoma cruzi* is caused by Chagas disease. Man is the major target of trypanosomiasis, although tsetse fly serves as an intermediary host. Though

the clinical signs of trypanosomiasis are unclear, the disease can be diagnosed and as well treated. Drugs such as suramin, pentamidine, praziquantel, eflornithine etc., have been used in the treatment of trypanosomiasis. Novel drug research has been geared towards developing inhibitors for novel targets recognized to be crucial to the parasite survival in the host organism. Plants bioactive substances can serve as better options in trypanosome therapy as it exploits the negative effects experienced by patients using chemotherapeutic agents and parasitic drug resistance flaws of chemically originated drugs.

References

- Gambino D, Otero L (2018) Design of prospective antiparasitic metal-based compounds including selected organometallic cores. *Inorganica Chimica Acta* 472: 58-75. [Link: https://bit.ly/2UfDG8K](https://bit.ly/2UfDG8K)
- Keating J, Yukich JO, Sutherland CS, Woods G, Tediosi F (2015) Human African trypanosomiasis prevention, treatment and control costs: a systematic review. *Acta Trop* 150: 4-13. [Link: https://bit.ly/2zXv0Nm](https://bit.ly/2zXv0Nm)
- Brun R, Blum J, Chappuis F, Burri C (2010) Human African Trypanosomiasis. *The Lancet* 375: 8-159. [Link: https://bit.ly/2MA5Uqq](https://bit.ly/2MA5Uqq)
- Büscher P, Cecchi G, Jamonneau V, Priotto G (2017) Human African trypanosomiasis. *The Lancet* 390: 2397-2409. [Link: https://bit.ly/3cBNuQz](https://bit.ly/3cBNuQz)
- Bonilla MC, Castro-Vasquez RM, Herrero-Acosta MV, Urbina-Villalobos A, Dolz G (2019) Canine trypanosomiasis in an endemic Costa Rican community: Demonstration of the active infection cycle. *Vet Parasitol Reg Stud Reports* 17: 100307. [Link: https://bit.ly/3dCRced](https://bit.ly/3dCRced)
- Siqueira LDP, Fontes DAF, Aguilera CSB, Timoteo TRR, Angelos MA, et al. (2017) Schistosomiasis: Drugs used and treatment strategies. *Acta Trop* 176: 179-187. [Link: https://bit.ly/377WlIt](https://bit.ly/377WlIt)
- Tomiotto-Pellissier F, Miranda-Sapla MM, Machado LF, Bortoleti B, Sald CS, et al. (2017) Nanotechnology as a potential therapeutic alternative for schistosomiasis. *Acta Trop* 174: 64-71. [Link: https://bit.ly/2UgNvmH](https://bit.ly/2UgNvmH)
- Gorchakov R, Trosclair LP, Wozniak EJ, Fera PT, Garcia MN, et al. (2016) *Trypanosoma cruzi* infection prevalence and blood meal analysis in triatomine vectors of Chagas disease from rural peridomestic locations in Texas, 2013–2014. *J Med Entomol* 53: 911-918. [Link: https://bit.ly/2XGOyI5](https://bit.ly/2XGOyI5)
- Nass J, Efferth T (2018) The activity of *Artemisia* spp. and their constituents against Trypanosomiasis. *Phytomedicine* 47: 184-191. [Link: https://bit.ly/3cAJQXi](https://bit.ly/3cAJQXi)
- Matthews KR (2015) 25 years of African trypanosome research: From description to molecular dissection and new drug discovery. *Mol Biochem Parasitol* 200: 30-40. [Link: https://bit.ly/3cDwFVs](https://bit.ly/3cDwFVs)
- Van Xong H, Vanhamme L, Chamekh M, Chimfwembe CE, Van Den Abbeele J, et al. (1998) A VSG expression site-associated gene confers resistance to human serum in *Trypanosoma rhodesiense*. *Cell* 95: 839-846. [Link: https://bit.ly/2Bw90t4](https://bit.ly/2Bw90t4)
- Siegel TN, Hekstra DR, Wang X, Dewell S, Cross GAM (2010) Genome-wide analysis of mRNA abundance in two life-cycle stages of *Trypanosoma brucei* and identification of splicing and polyadenylation sites. *Nucleic Acids Research* 38: 4946-4957. [Link: https://bit.ly/2Ud4syw](https://bit.ly/2Ud4syw)
- Baker CH, Welburn SC (2018) The Long Wait for a New Drug for Human African Trypanosomiasis. *Trends Parasitol* 34: 818-827. [Link: https://bit.ly/3eSHkWy](https://bit.ly/3eSHkWy)
- Jauréguiberry S, Paris L, Caumes E (2010) Acute schistosomiasis, a diagnostic and therapeutic challenge. *Clinical Microbiology and Infection* 16: 225-231. [Link: https://bit.ly/2UdqYql](https://bit.ly/2UdqYql)



15. Standley CJ, Carlin EP, Sorrell EM, Barry AM, Bile E, et al. (2019) Assessing health systems in Guinea for prevention and control of priority zoonotic diseases: A One Health approach. *One Health* 7: 100093. [Link: https://bit.ly/308ZFlo](https://bit.ly/308ZFlo)
16. Katz N (1998) Schistosomiasis control in Brazil. *Memórias do Instituto Oswaldo Cruz* 93: 33-35. [Link: https://bit.ly/2BvgBbl](https://bit.ly/2BvgBbl)
17. Dkhil MA, Hafiz TA, Thagfan FA, Al-Shaebi EM, Mubarak MA, et al. (2019) *Indigofera oblongifolia* protects against trypanosomiasis-induced spleen injury. *J Infect Public Health* 12: 660-665. [Link: https://bit.ly/30fBnpY](https://bit.ly/30fBnpY)
18. Nare B, Wring S, Bacchi C, Beaudet B, Bowling T, Eet al. (2010) Discovery of novel orally bioavailable oxaborole 6-carboxamides that demonstrate cure in a murine model of late-stage central nervous system African trypanosomiasis. *Antimicrobial agents and chemotherapy* 54: 4379-4388. [Link: https://bit.ly/2XDpHvt](https://bit.ly/2XDpHvt)
19. Kolenyak-Santos F, Garner C, de Oliveira RN, De Souza A, Chorilli C, et al. (2014) Nanostructured lipid carriers as a strategy to improve the in vitro schistosomiasis activity of praziquantel. *J Nanosci Nanotechnol* 14: 1-12. [Link: https://bit.ly/2MxwG2q](https://bit.ly/2MxwG2q)
20. Tewelde N, Abebe G, Eisler M, McDermott J, Greiner M, et al. (2004) Application of field methods to assess isometamidium resistance of trypanosomes in cattle in western Ethiopia. *Acta Tropica* 90: 163-170. [Link: https://bit.ly/2XDpGaT](https://bit.ly/2XDpGaT)
21. Delespaux V, de Koning HP (2007) Drugs and drug resistance in African trypanosomiasis. *Drug Resistance Updates* 10: 30-50. [Link: https://bit.ly/3743Hge](https://bit.ly/3743Hge)
22. Delespaux V, Dinka H, Masumu J, Van den Bossche P, Geerts S (2008) Five-fold increase in *Trypanosoma congolense* isolates resistant to diminazene aceturate over a seven-year period in Eastern Zambia. *Drug Resistance Updates* 11: 205-209. [Link: https://bit.ly/30an0Dj](https://bit.ly/30an0Dj)
23. Isaac C, Ohiolei JA, Ebhodaghe F, Igbinosa IB, Eze AA (2017) Animal African Trypanosomiasis in Nigeria: A long way from elimination/eradication. *Acta Trop* 176: 323-331. [Link: https://bit.ly/2UfnKmN](https://bit.ly/2UfnKmN)
24. Freaun J, Sieling W, Pahad H, Shoul E, Blumberg L (2018) Clinical management of East African trypanosomiasis in South Africa: Lessons learned. *Int J Infect Dis* 75: 101-108. [Link: https://bit.ly/2XFkQdf](https://bit.ly/2XFkQdf)
25. Welburn SC, Molyneux DH, Maudlin I (2016) Beyond Tsetse—Implications for Research and Control of Human African Trypanosomiasis Epidemics. *Trends Parasitol* 32: 230-241. [Link: https://bit.ly/2Y3oWe0](https://bit.ly/2Y3oWe0)
26. Useh MF (2012) Control of Shistosomiasis. Rokni MB. *Shistosomiasis. Croatia: Rijeka* 73-102. [Link: https://bit.ly/3dCSCp3](https://bit.ly/3dCSCp3)
27. Odeniran PO, Ademola IO, Macleod ET, Welburn SC (2018) Bovine and small ruminant African animal trypanosomiasis in Nigeria - A review. *Vet Parasitol Reg Stud Reports* 13: 5-13. [Link: https://bit.ly/3czHOGV](https://bit.ly/3czHOGV)
28. Timothy K, Sarah S, Markus E (2018) Beyond Blood: African Trypanosomes on the Move. *Trends Parasitol* 34: 1056-1067. [Link: https://bit.ly/374ZAK5](https://bit.ly/374ZAK5)

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