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LETTER TO THE EDITOR

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Simulium surveillance and control in Mahenge, Tanzania: time to think bigger and utilize drone-based remote sensing technology

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Abstract

Despite the ongoing onchocerciasis control program that has been in place in Mahenge for more than two decades using the Community Directed Treatment with Ivermectin (CDTI) strategy, the persistent transmission of onchocerciasis has been observed, proving that CDTI alone is unable to interrupt the transmission. This letter aims to highlight how drone-based remote sensing technology can be utilized for *Simulium* surveillance and control in Mahenge and suggest measures that can be employed to initiate the vector control intervention using the proposed technology in Mahenge. The drone-based technology in Mahenge could assist in the identification of *Simulium* breeding sites even in inaccessible parts of rivers and streams, mapping the microenvironmental composition, and suggesting potential control measures, including whether to apply larviciding using drones or where the ground control effort of slashing and clearing should be prioritized. Therefore, now is an opportune time to combine CDTI and *Simulium* control interventions to achieve sustainable onchocerciasis control in Mahenge.

Keywords Onchocerciasis, *Simulium*, Surveillance, Control, Drone-based technology, Mahenge

Background

Onchocerciasis, commonly known as river blindness, is an eye and skin parasitic disease caused by the filarial worm *Onchocerca volvulus* (*O. volvulus*) and transmitted by repeated bites of infected blackflies (*Simulium* species) (WHO 2022). *Onchocerca* species that infect domestic and wild animals, such as *O. lupi, O. dewittei japonica, O. cervicalis, O. jakutensis*, and *O. gutturosa*, have been reported to infect humans in 40 cases with clinical manifestations similar to those caused by *O. volvulus* (Cambra-Pellejà et al. 2020). Blackflies usually breed in fast-flowing and oxygen-rich streams and rivers hence the high prevalence of onchocerciasis in villages along or near the fast-flowing streams and rivers (WHO 2022).

Each larva of *Onchocerca* species stays as a single male or female and grows until it becomes a mature worm, which remains separated in the skin or collected together in subcutaneous fibrous nodules because of the immunological reaction of the host; females produce microfilariae, which invade the skin, travel in it, and very often reach the eye. Hence, responsible for dermatological, ophthalmological, and neurological manifestations in infected individuals (Gyasi et al. 2022). Dermatological manifestations such as skin lesions are induced with inflammatory reactions due to the dying/death of microfilariae, causing onchocercal

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dermatitis (Brattig 2004; Gyasi et al. 2022). Adult worms are responsible for causing onchocercomas (subcutaneous nodules) over bony prominences. The subcutaneous nodules are pretty benign and cause disfigurement with no pain. However, occasionally the nodule can degenerate to form an abscess, or the worms can become calcified (Murdoch et al. 2002; Gyasi et al. 2022). Ophthalmological manifestations, such as ocular lesions, develop when microfilariae invade the cornea (Gyasi et al. 2022). The inflammatory reactions in the cornea due to the dying/death of microfilariae perpetuate visual impairment and river blindness (Burnham 1998; Gyasi et al. 2022). Neurological manifestations such as nodding and nakalanga syndromes characterized by repeated head nodding attacks, epilepsy, cognitive dysfunction, neurological deterioration, retarded growth, postural development, poor muscle development, and delayed puberty have been reported in children aged 3 to 18 years in onchocerciasis endemic areas (Colebunders et al. 2021). The exact pathophysiological mechanism of how *O. volvulus* causes epilepsy is still unknown. The postulated mechanisms are microfilariae invasion of the central nervous system, an autoimmune disorder due to crossreactivity between *O. volvulus* proteins and Leiomodin-1 antibodies, and neuronal dysfunction brought by the deposition of pathogenic tau protein in the brain (Hadermann et al. 2023).

Burden of onchocerciasis and associated morbidities

It is estimated that about 198 million people in 36 countries reside in areas where onchocerciasis is prevalent, close to fast-flowing rivers and streams, placing them at risk of contracting the disease in 2017 (WHO 2022). In addition, more than 20.9 million people were onchocerciasis infected, with over 14.6 million having onchocercal dermatitis and 1.15 million people having vision loss (WHO 2022). The highest prevalence of onchocerciasis has been documented in the African region, with 99% of the infected individuals residing in 31 countries in Africa. Additionally, Yemen and Latin America (Brazil and Venezuela) have reported persistent transmission (WHO 2022). It is estimated that more than 381,000 people live with onchocerciasis associated epilepsy (OAE) and the condition is responsible for 10–13 years of life with disability (Vinkeles Melchers et al. 2018). The prevalence of OAE varies across the regions in Africa, example: in South Sudan, it ranges from 4.1 to 22.4%, Cameroon (15.6–47.6%), Democratic Republic of Congo (0.8–8.5%), Uganda (3000–6000 cases), Tanzania, (1.02–10.2% prevalence of nodding syndrome) (Idro 2018; Mmbando et al. 2018; Morin et al. 2021; Raimon et al. 2021).

Onchocerciasis control approaches

The current control of onchocerciasis is through CDTI or a combination of CDTI and vector (*Simulium*) control. Ivermectin use started in 1987, aiming at killing the microfilariae, relieving skin itching, and halting the progression to blindness (Crump and Omura 2011). However, the ivermectin does not kill the adult worms until they die naturally within their life span. Hence ivermectin must be taken yearly within 16–18 years, corresponding to the parasite's life span (Klager et al. 1993). Vector control is the oldest control strategy compared with ivermectin. Its implementation started in 1975 through aerial larviciding of fast-flowing rivers and streams, targeting the larvae stage (Garms et al. 1979). However, this control strategy faced challenges like the emergence of insecticide resistance, *Simulium* cross-border migration, and implementation costs (Kurtak et al. 1987). Recently the community-directed vector control approach involving slashes and clearing of the vegetation that serves as a substrate of *Simulium* immature stages in the fast-flowing rivers and streams was introduced (Siewe Fodjo et al. 2021).

Onchocerciasis situation in Tanzania

Tanzania is among the sub-Saharan African countries with ongoing transmission of onchocerciasis, with more than 6 million people at risk of acquiring the disease in six endemic regions (Mushi et al. 2020). The first discovered heavily infected focus for onchocerciasis in Tanzania was the Mahenge in the Morogoro region, with nodule prevalence of 95–100% in some communities and microfilariae prevalence of 60–87% (Mwaiko et al. 1990). As a result, the CDTI was established in 1997 to combat onchocerciasis and has been implemented for more than two decades (NTDCP, 2017). Despite two decades of annual CDTI, there is a persistent transmission of onchocerciasis (Mushi 2018) and an increase in the incidences of OAE (Mmbando et al. 2018), demonstrating unequivocally that an annual CDTI could not interrupt disease transmission in Mahenge. Unfortunately, there has been no attempt at *Simulium* control in the Mahenge (Häusermann 1969), contributed by its mountainous nature with hard-to-reach fast-flowing rivers and streams. Hence, there is a need to implement vector control strategies in Mahenge that will be complimented with bi-annual CDTI, which started in 2019 to accelerate the control of onchocerciasis.

How can drone-based remote sensing technology be used for *Simulium* control in Mahenge?

The drone-based remote sensing technology is a recent novel technology that can be combined with mathematical/predictive modeling for the risk assessment, incidence detection, and identification of the disease transmission hotspots for the vector-borne pathogens (Stanton et al. 2021; Carrasco-Escobar et al. 2022). The use of drone technology could play a crucial role in the successful *Simulium* surveillance and control programmes in Mahenge in the following ways;

i. The *Simulium* surveillance programs could use drones with high magnification cameras and resolution to survey the fast-flowing rivers and streams and take high-quality pictures for the *Simulium* breeding sites identification. Additionally, the drones could aid in the inspection and visualization of the immature stages of *Simulium* for planning appropriate control measures based on precisely at what part of the river or stream a particular immature *Simulium* stage can be found.
ii. The microenvironmental composition that facilitates *Simulium* breeding, survival, and growth from eggs to adults could be mapped using drone-based technologies. The mapping will predict *Simulium* abundance, species composition, distribution, diversity, and resting places that will be used to indicate type of *Simulium* control intervention (chemical control or environmental manipulation or modification) needed.
iii. The drones could be utilized for *Simulium* larval source management (LSM) through larviciding of the *Simulium* breeding habitats, which will destroy the immature stages of the *Simulium*. Commercial drones for larviciding can carry up to 30 L of the larvacide, covering a large part of the breeding habitat. LSM using eco-friendly larvacides can reduce the abundance of *Simulium* and biting rates while continuing to preserve the rivers and streams for water supply, agricultural and domestic activities.

Where should we start in terms of *Simulium* control at Mahenge?

It is an opportune time to complement bi-annual CDTI in Mahenge with *Simulium* control interventions to accelerate the onchocerciasis control fight, especially knowing drone-based technology could assist. The following should be done to start the *Simulium* surveillance and control;

i. The Neglected Tropical Diseases Control Programme should conduct operational feasibility studies to determine whether drones can access areas that are typically inaccessible, whether they can capture and process high-quality images to identify breeding sites, whether they can dispense larviciding to fast-moving rivers and streams, and whether their use will lower *Simulium* abundance, densities, and biting rates. The feasibility studies should also take into account the Mahenge community's acceptance of drone technology, the safety of drone operation, and the cost of flying drones compared to terrestrial entomological investigations.
ii. The Neglected Tropical Diseases Control Programme should create a multidisciplinary team with the required skills to carry out the *Simulium* surveillance and control using drones who will work together in the feasibility and field trial studies and future on the actual implementation. Also, the Neglected Tropical Diseases Control Programme could collaborate with the organizations such as Tanzania Flying Labs and research institutes, such as the Zanzibar Malaria Elimination Program in the country, which has been successful in mosquito control using drone-based technology.
iii. The Ministry of Health, through the Neglected Tropical Diseases Control Programme, should mobilize the resources, both human and financial, for the surveillance and control activities via the proposed technology. In addition, the mobilized team should undergo training to acquire the necessary competence and skills to carry out the control activities. The financial resources will facilitate purchasing the required drones and larvicides, training the team, and conducting feasibility studies. Economically speaking, compared to manual *Simulium* surveillance and control, the investment in this technology will be less expensive, highly accurate, and easier to access remote rivers and streams.

Conclusions

In conclusion, I would like to emphasize that given the lack of vector control in Mahenge, it is more important than ever to begin the vector control interventions. Drone-based technology could facilitate the survey by possibly identifying the *Simulium* breeding site, mapping its microenvironmental composition, and controlling it. The vector control interventions in Mahenge will be crucial to complement the ongoing bi-annual CDTI, hence hastening the onchocerciasis control.

Abbreviations

CDTI	Community directed treatment with iveremctin
LSM	Larval source management
OAE	Onchocerciasis associated epilepsy

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References
Brattig NW (2004) Pathogenesis and host responses in human onchocerciasis: impact of *Onchocerca* filariae and *Wolbachia* endobacteria. Microbes Infect 6(1):113–128. https://doi.org/10.1016/j.micinf.2003.11.003
Burnham G (1998) Onchocerciasis. Lancet 351(9112):1341–1346. https://doi.org/10.1016/S0140-6736(97)12450-3
Cambra-Pellejà M, Gandasegui J, Balaña-Fouce R, Muñoz J, Martínez-Valladares M (2020) Zoonotic implications of *Onchocerca* species on human health. Pathogens 9(9):761. https://doi.org/10.3390/pathogens9090761
Carrasco-Escobar G, Moreno M, Fornace K, Herrera-Varela M, Manrique E, Conn JE (2022) The use of drones for mosquito surveillance and control. Parasit Vectors 15(1):473. https://doi.org/10.1186/s13071-022-05580-5
Colebunders R, Njamnshi AK, Menon S, Newton CR, Hotterbeekx A, Preux PM, Hopkins A, Vaillant M, Siewe Fodjo JN (2021) *Onchocerca volvulus* and epilepsy: a comprehensive review using the Bradford Hill criteria for causation. PLoS Negl Trop Dis 15(1):e0008965. https://doi.org/10.1371/journal.pntd.0008965
Crump A, Ōmura S (2011) Ivermectin, "wonder drug" from Japan: the human use perspective. Proc Jpn Acad Ser B Phys Biol Sci 87(2):13–28. https://doi.org/10.2183/pjab.87.13
Garms R, Walsh JF, Davies JB (1979) Studies on the reinvasion of the Onchocerciasis Control Programme in the Volta River Basin by *Simulium damnosum s.l.* with emphasis on the south-western areas. Tropenmed Parasitol 30(3):345–62
Gyasi ME, Okonkwo ON, Tripathy K (2022) Onchocerciasis. Ecol Heal Dis Ethiop 367–74. Available from: https://www.ncbi.nlm.nih.gov/books/NBK559027/.
Hadermann A, Amaral LJ, Cusem GV, Siewe Fodjo JN (2023) Onchocerciasis-associated epilepsy: an update and future perspectives. Trends Parasitol 39(2):126–138. https://doi.org/10.1016/J.PT.2022.11.010
Häusermann W (1969) On the biology of *Simulium damnosum*, the main vector of onchocerciasis in the Mahenge mountains, Ulanga, Tanzania. Acta Trop 26(1):29–69
Idro R (2018) Onchocerciasis associated epilepsy and nodding syndrome research. Available from:https://dndi.org/wpcontent/uploads/2018/05/Idro_OnchocerciasisAssociatedEpilepsy_UgandaMeeting2018.pdf. Accessed 30 Nov 2022
Kurtak D, Meyer R, Ocran M, Ouédraogo M, Renaud P, Sawadogo RO, Télé B (1987) Management of insecticide resistance in control of the *Simulium damnosum* complex by the Onchocerciasis Control Programme, West Africa: potential use of negative correlation between organophosphate resistance and pyrethroid susceptibility. Med Vet Entomol 1(2):137–146. https://doi.org/10.1111/j.1365-2915.1987.tb00334.x
Mmbando BP, Suykerbuyk P, Mnacho M, Kakorozya A, Matuja W, Hendy A, Greter H, Makunde WH, Colebunders R (2018) High prevalence of epilepsy in two rural onchocerciasis endemic villages in the Mahenge area, Tanzania, after 20 years of community directed treatment with ivermectin. Infect Dis Poverty 7(1):1–13
Morin A, Guillaume M, Ngarka L, Tatah GY, Siewe Fodjo JN, Wyart G, Nokam G, Tchoumi T, Nkinin MB, Njamnshi WY, Chokote ES, Boussinesq M, Colebunders R, Chesnais CB, Gargala G, Parain D, Njamnshi AK (2021) Epilepsy in the Sanaga-Mbam valley, an onchocerciasis-endemic region in Cameroon: electroclinical and neuropsychological findings. Epilepsia Open 6(3):513–527. https://doi.org/10.1002/epi4.12510
Murdoch ME, Asuzu MC, Hagan M, Makunde WH, Ngoumou P, Ogbuagu KF, Okello D, Ozoh G, Remme J (2002) Onchocerciasis: the clinical and epidemiological burden of skin disease in Africa. Ann Trop Med Parasitol 96(3):283–296. https://doi.org/10.1179/000349802125000826
Mushi V (2018) Factors associated with persistence of onchocerciasis transmission after two decades of Community Directed Treatment with Ivermectin in Ulanga District Council. Masters Thesis
Mushi V, Kakoko D, Tarimo D (2020) Knowledge, attitudes, perceptions and acceptability of onchocerciasis control through community-directed treatment with ivermectin: implications for persistent transmission in Ulanga district, Tanzania. East Afr J Appl Health Monit Eval 4:28–35
Mwaiko GL, Mtoi RS, Mkufya AR (1990) Onchocerciasis prevalence in Tanzania. Cent Afr J Med 36(4):94–96
Neglected Tropical Diseases Control Program (2016) 5th Annual Joint Planning Meeting. Ministry of Health, Community, Development, Gender, Elderly and Children
Raimon S, Dusabimana A, Abd-Elfarag G, Okaro S, Carter JY, Newton CR, Logora MY, Colebunders R (2021) High Prevalence of epilepsy in an onchocerciasis-endemic area in Mvolo County South Sudan: a door-to-door survey. Pathogens 10(5):599. https://doi.org/10.3390/pathogens10050599
Siewe Fodjo JN, Vieri MK, Ngarka L, Njamnshi WY, Nfor LN, Mengnjo MK, Hendy A, Enyong PA, Palmer D, Basanez MG, Colebunders R, Njamnshi AK (2021) "Slash and clear" vector control for onchocerciasis elimination and epilepsy prevention: a protocol of a cluster randomised trial in Cameroonian villages. BMJ Open 11(9):e050341. https://doi.org/10.1136/bmjopen-2021-050341
Stanton MC, Kalonde P, Zembere K, Hoek Spaans R, Jones CM (2021) The application of drones for mosquito larval habitat identification in rural environments: a practical approach for malaria control? Malar J 20(1):244. https://doi.org/10.1186/s12936-021-03759-2
Vinkeles Melchers NVS, Mollenkopf S, Colebunders R, Edlinger M, Coffeng LE, Irani J, Zola T, Siewe JN, de Vlas SJ, Winkler AS, Stolk WA (2018) Burden of onchocerciasis-associated epilepsy: first estimates and research priorities. Infect Dis Poverty 7(1):101. https://doi.org/10.1186/s40249-018-0481-9
World Health Organization (2022) *Onchocerciasis*. Available at: https://www.who.int/news-room/fact-sheets/detail/onchocerciasis. Accessed 29 Nov 2022

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