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Mosquitoes (Diptera: Culicidae) as Malaria Transmitters and Procedures for Suppression to Exposure and Spread of Vectors

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Abstract

Undoubtedly, the mosquitoes are one of the most important biting and dangerous insects in the world with the greatest detrimental impacts on humans. Mosquitoes transmit pathogens that cause some of the most terribly known human diseases, including malaria and they must feed on someone with the incidence of disease to transmit parasites to another person. Once ingested by a mosquito, malarial protozoan parasites of the genus Plasmodium undergo development within the mosquito before they are infectious to humans. When a female mosquito bites, it also injects an anticoagulant (anti-clotting chemical) into the host to keep the victim's blood flowing. As the malarial parasites enter the blood stream, they infect and destroy red blood cells of human characterized by symptoms that typically include fever, fatigue, vomiting and headaches. In severe cases it can cause yellow skin, seizures, coma or death. Owing to the variation between states in epidemiology and control programs, not a single global approach is recommended to control malaria. Methods used to prevent the spread of disease or to protect individuals in areas where malaria is endemic, include reducing the number of malaria cases and deaths through prophylactic drugs**,** mosquito eradication**,** and the prevention of mosquito bites**.** New strategies for malaria prevention and control are emphasizing integrated vector management like removing or poisoning the breeding grounds of the mosquitoes, spraying and fogging to control adult mosquito populations in the residential and commercial areas, mosquito trapping technology, mosquito nets to keep vectors away from peoples, and global support to provide tools and resources required for disease control. The findings of this study can help to establish effective and appropriate vector control measures fitting with new challenges and contributing to sustain the success of malaria control program.

Keywords

Malaria Control, Anopheles, Vector Management, Mosquito Control

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1. Introduction

Arthropods (joint legged invertebrates) present in the environment may influence human health directly in a number of ways. As far as human health is concerned, the two most important classes of arthropods are the insects (six-legged adults), and the arachnids (eight-legged adults) Sarwar, 2016 a; 2016 b). Mosquitoes are known as the most dangerous insects causing more human suffering than any other organism in the world. Additionally, mosquito bites can cause severe skin irritation through an allergic reaction of the mosquito's saliva that causes the red bump and itching on body (Sarwar, 2014 a). Mosquitoes are able to sense heat, carbon dioxide and lactic acid given off as part of breathing of human, thus they can find and detect their hosts easily. Some chemicals in human sweat and peoples wearing clothing that contrasts with the background also appear to attract mosquitoes. Mosquitoes are vectors of numerous diseases including protozoan disease, i.e., malaria resulting more than one million deaths and cases reported annually in

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the world (Sarwar, 2014 b). Mosquitoes can breed in any form of stagnant water, including ponds, marshes, floodwaters, storm drains, old tires and water in tree holes. The continued existence of malaria in an area requires a combination of high human population density, high mosquito population density, and high rates of transmission from humans to mosquitoes and from mosquitoes to humans. If any of these practices is lowered sufficiently, the parasite will sooner or later disappear from that area (Sarwar, 2015 a; 2015 b).

Preventing or reducing of malaria transmission depends entirely in controlling the mosquito vectors or interruption of human and vector contact. Disrupting a mosquito's life cycle and habitat may reduce the number of mosquitoes in and around the human's environment. Therefore, the aim of this article is to promote the strategic approach known as Integrated Vector Management (IVM) to control mosquito vectors including those of malaria.

2. Symptoms of Malaria

In the early stages, malaria symptoms are sometimes similar to those of many other infections caused by bacteria, viruses and parasites. Malaria causes symptoms that typically include fever, fatigue, vomiting and headaches. In severe cases it can cause yellow skin, seizures, coma or death (Caraballo, 2014). Malaria is usually characterized clinically by fever (usually periodic), varying degrees of anaemia and spleen enlargement, and a range of syndromes resulting from the physiological and pathological involvement of certain organs, including the brain, liver and the kidneys. Symptoms may appear in cycles and this cycle of symptoms is also one of the major signs when a person is infected with malaria. The cyclic pattern of malaria symptoms is due to the life cycle of the malaria parasites as they develop, reproduce, and are released from the red blood cells and liver cells in the human body (Sarwar, 2015 c).

3. Mosquito Vectors of Malaria

Mosquitoes are insect vectors responsible for the transmission of parasitic and viral infections to millions of peoples worldwide with substantial morbidity and mortality. An understanding of mosquito classification, distinguishing features, and the life cycle is important for disease surveillance as well as for designing and implementing effective measures for disease control and prevention. Mosquitoes belong to the class Insecta, order Diptera and family Culicidae. The two subfamilies are Anophelinae (which includes the genus Anopheles- the mosquito vector for malaria) and Culicinae (which includes the genera Aedes [Stegomyia], Culex, Mansonia and Haemagogus that are the mosquito vectors for arboviruses and some filariases). Each subfamily has hundreds of species within it, although only a few dozen bite humans and therefore are capable of serving as disease vectors (White, 2002). There are about 3,500 mosquito species and those that transmit malaria all belong to a sub-set called the Anopheles. Approximately 40 Anopheles species are able to transmit malaria well enough to cause significant human illness and death. Some species are biologically unable to carry human malaria parasites, while others are readily infected and produce large numbers of sporozoites (the parasite stage that is infective to humans). About 460 species of Anopheles are recognized, while over 100 can transmit human malaria, and only 30-40 commonly transmit parasites of the genus Plasmodium, which cause malaria in humans in endemic areas (Steven, 2010). Different Anopheles species may differ in selected behaviour traits, with important consequences on their abilities as malaria vectors. In some species the females prefer to get their blood meals from humans (anthropophilic) while in others they prefer animals (zoophilic). Some species prefer to bite indoors (endophagic), and others prefer outdoor biting (exophagic). All other factors being equal, the anthropophilic, endophagic species have more frequent contacts with humans and thus are more effective malaria vectors (Pates and Curtis, 2005).

Mosquito vectors of malaria found in Pakistan are chiefly included *A. culicifacies* and *A. stephensi* (Naz et al., 2013). Understanding the biology and behaviour of Anopheles mosquitoes can help to understand how malaria is transmitted, and can aid in designing appropriate control strategies. The mosquitoes are holometabolous insects and therefore grow through an egg, larva, pupa and adult stage (Clements, 1992). Adults have delicate legs, a long proboscis and one pair of transparent wings. Female mosquitoes are usually larger than males. Females have fine threadlike antennae with few hairs, whereas males have bushy antennae. The larvae or wigglers and pupae or tumblers are aquatic (live in water). The adults are free flying and they hide in vegetation near water or in cool and damp places. The full life cycle usually takes about 14 days, but the duration varies with temperature and species. Outside of tropical climates, most mosquito species overwinter as eggs, although some overwinter as larvae or adults (Iqbal et al., 2013).

4. Species of Protozoan of the Genus Plasmodium

Malaria is caused by protozoan parasites of the genus Plasmodium which are single-celled organisms that cannot survive outside of their host. There are five species of protozoan parasites of the genus Plasmodium that have been known to cause human malaria.

i. *Plasmodium falciparum*: It is responsible for the majority of malaria deaths globally and is the most prevalent species. The remaining species are not typically as life threatening as *P. falciparum*.

ii. *Plasmodium vivax*: It is the second most significant species and is prevalent in Southeast Asia. *P. vivax* and *P. ovale* have the added complication of a dormant liver stage, which can be reactivated in the absence of a mosquito bite, leading to clinical symptoms.

iii. *Plasmodium ovale* and *Plasmodium malariae*: These species represent only a small percentage of infections.

iv. *Plasmodium knowlesi*: This fifth species is a kind that infects primates and has led to human malaria, but the exact mode of its transmission remains unclear.

The infection from *P. falciparum* is similar to infection from *P. vivax*, *P. malariae* and *P. ovale*. Incident of symptoms may occur at every 48 hours if a person is infected with *P. vivax* or *P. ovale*, and every 72 hours if infected with *P. malariae* and *P. falciparum.* Infection with the *P. falciparum* parasite is usually more serious and may become life threatening. For the effective transmitting of malaria between peoples, a mosquito species needs to have a number of characteristics including:- abundance (the species needs to exist in numbers high enough to ensure individuals encounter of an infectious human to pick up the malaria parasite), longevity (individual mosquitoes need to survive long enough after feeding on infected blood to allow the parasite to develop and travel to the mosquito's salivary glands that is ready to infect the next person by biting), capacity (each mosquito needs to be able to carry enough malaria parasites in the salivary glands to ensure the parasite is transmitted to the next human) and contact with humans (the species needs to prefer to feed on humans rather than other animals, and be able to survive and breed in places close to homes, and be able to find peoples usually by entering their houses). In rare cases malaria parasites can also be transmitted from one person to another without requiring passage through a mosquito such as from mother to child in congenital malaria, through transfusion, organ transplantation and shared needles (Nadjm and Behrens, 2012).

5. Control of Malaria and Its Transmission

Defeating of malaria requires a comprehensive approach, finding out ways for both prevention and treatment are needed, and no one tool alone can defeat the parasite. Prevention of malaria in many countries has been heavily dependent on anti-malarial drugs and residual insecticides. Malaria control in many countries is a continue process consisting of two main stages with different complementary objectives:-

i. *Scale-up for impact*: In this stage, the goal is to rapidly reach universal coverage for all populations at risk with locally appropriate malaria control interventions, supported by strengthened health systems.

ii. *Sustained control*: In this stage, the goal is to maintain universal coverage with interventions by continued strengthening of health systems until universal coverage is made irrelevant by elimination or until field research suggests that it can be reduced without risk of resurgence of malaria.

The proper management of malaria cases and population movement is, therefore, important to prevent outbreaks and the reintroduction of malaria. Factors affecting a mosquito's facility to transmit malaria include its innate susceptibility to Plasmodium, its host choice and its longevity. Factors that should be taken into consideration when designing a control program include the susceptibility of malaria vectors to insecticides and the preferred feeding and resting location of adult mosquitoes (Shigeto et al., 2007). Clearly, the cost of preventing malaria is much less than treating the disease, in the long run, however, eradication of mosquitoes is not an easy task. For effective prevention of malaria, some conditions should be met, such as conducive conditions in the country, data collection about the disease, targeted technical approaches to the problem, very active and committed leadership, total governmental support, sufficient monetary resources, community involvement, and skilled technicians from different fields as well as an adequate implementation strategy (Mutero et al., 1998). There is increasing realization that no single intervention is likely to halt malaria and a multipronged approach is needed including vector control. A variety of effective vector control measures are currently available as mentioned under:-

5.1. Protection from Mosquito Bites

The mosquitoes can bite anytime during day or night particularly feed just after sunset or late in the night, so, the importance of self-protection for local inhabitants and visiting travellers in risk areas has become more and more emphasized in recent years. A sensible precaution to prevent attack of vector is to avoid areas that are known to have high biting mosquito's activity. For avoidance from mosquito bites, dense vegetation near the breeding sites should be avoided, densely shaded areas near these habitats should be evade, choose localities of the water body which have steep margins or little marginal emergent vegetation, and check nearby potential artificial sources of mosquitoes. Wear light-colored clothing, a long-sleeved shirt, long pants and a hat to go outside when mosquitoes are most active. Insect proof clothing like, head nets, gloves and boots can protect parts of the body, which are not covered by other clothing. The best method of avoiding vector attack at night is to stay inside insect-screened houses; screens should be of the correct mesh, fit tightly and be in good repair (Sarwar, 2014 c).

Relief from biting vector attack may be obtained by applying of repellents to the skin and clothing. Repellents with the chemical diethyl-toluamide or picaridin give good protection, so, choose a repellent that contains approved ingredients. However, the repellents must be supplementary to protective clothing and should not be regarded as substitutes. Insecticide impregnated mosquito coils offer good protection in relatively wind protected areas, while candle powered mosquito lanterns or gas powered repellent dispensers offer excellent protection. The use of yellow or even better red incandescent bulbs or fluorescent tubes rather than white light can reduce the attractiveness of lights to insects. Electric insect insectocutors and other traps or killing devices utilizing an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect peoples. The most popular method of self-protection against mosquitoes is mosquito nets followed by mosquito (pyrethrum-based) coils. Other methods include insecticidal sprays and smoke from plants traditionally associated with mosquito repellence (Sarwar and Salman, 2015).

Experiments are used to measure the impact of several techniques for self-protection from malaria vectors. All the strategies have shown to offer a great degree of protection and their use should be encouraged. An electric fan, pyrethrum coils, untreated curtains, pyrethroid-vaporizing mats and permethrin-impregnated curtains have reduced the total catches of blood-fed *A. stephensi* by 27%, 36%, 47%, 56% and 65%, respectively. The most marked effect of all the interventions is in reducing the numbers of mosquitoes entering the residence, although all the techniques, except for the untreated curtain, also reduced the proportion of mosquitoes. Although the trends seen are similar for both Anopheline (*A. stephensi*) and Culicine mosquitoes, they are more pronounced in the Culicines. Impregnated curtains seem especially promising to offer a great degree of protection. Pyrethroid-impregnated bed nets have been widely promoted and contain the advantage of providing protection when peoples sleep outside during the summer. Peoples should be encouraged to use their bed nets as impregnated curtains rather than putting them into storage (Hewitt et al., 1996). Get rid of as much standing water as seen around home and property. Drain water from flower pots, wading pools, old tires and so on. Usually, change water in birdbaths and pet bowls twice a week (Sarwar, 2015 d).

5.2. Malaria Vector Control

Malaria vector control is a fundamental element of the existing global strategy to fight against malaria. If mosquitoes have entered a screened area or house or premises they can be knocked down with hand held pyrethrin aerosols. Automatic aerosol dispensers for repelling or killing of adult mosquitoes can be used in both outdoor and indoor models. Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are permethrin, deltamethrin, bifenthrin or alpha-cypermethrin sprayed on or around screens may give protection against mosquitoes, but care is needed as some insecticides affect screens (Sarwar, 2015 e).

Space spraying or fogging, which is produced by rapidly heating the liquid chemical to form very fine droplets that resembles smoke or fog, is the process of application of a pesticide during emergency situations for halting epidemics or rapidly reducing adult mosquito populations resulting in decrease of malaria transmission. Space spraying must coincide with the peak activity of adult mosquitoes, because resting mosquitoes are often found in areas that are out of reach to the applied insecticides (e.g., under leaves, in small crevices). The best moment to kill adult mosquitoes by fogging is at dusk, when they are most active in forming swarms. However, spraying strategy is threatened by development of insecticide resistance. Efforts to develop alternative tools to complement or even replace insecticide-based vector-control strategies must continue (Sarwar, 2015 f).

A variety of novel genetic approaches to vector control are under active development and considerable progress has been made in recent years towards this goal.. Research targeting on the mosquito has been greatly facilitated by huge investment in molecular resources, including the provision of numerous full-genome sequences (Jacobs-Lorena, 2003). Genetic strategies for controlling of parasites transmission based on engineering pathogen resistance in disease transmitting mosquitoes are being tested in a number of animal models. A key component is the effector molecule and the efficiency with which it reduces parasite transmission (Sarwar, 2014 d). In the mosquito, Plasmodium undergoes a complex series of developmental events that includes transformation into several distinct morphological forms and the crossing of two different epithelia-midgut and salivary gland. Circumstantial evidence suggests that crossing of the epithelia requires specific interactions between Plasmodium and epithelial surface molecules. By use of a phage display library, it has been identified a small peptide-SM1 that binds to the surfaces of the mosquito midgut and salivary glands. Transgenic *A. stephensi* mosquitoes expressing a SM1 tetramer from a blood-inducible and gut-specific promoter are substantially impaired in their ability to sustain parasite development and transmission. A second effector gene, phospholipase A2, also impairs parasite transmission in transgenic mosquitoes (Charles and Godfray, 2013; Sarwar, 2016 c; 2016 d). These findings have important implications for the development of new strategies for malaria control. Particular attention is required to ensure that interventions should reach to the most vulnerable populations, and that gender, socio-economic status or geographic location are not barriers to access vector's control.

6. Conclusion

There are three main mosquito genera, Anopheles, Aedes and Culex, which transmit malaria, dengue and lymphatic filariasis, respectively. Vector control is an essential and promising strategy as component of malaria prevention. Current article deals with the species of mosquitoes control capable of transmitting malaria parasites. Control strategies or methods now have arisen, are mainly based on two approaches, first is the replacement of a vector population by disease-refractory mosquitoes and secondly the release of mosquitoes carrying a lethal gene to suppress target populations. The first approach is self-sustaining, and only one or a few releases are needed for the exogenous gene to increase its frequency and be fixed in the target population (inoculative releases). The second strategy is self-limiting, since repeated releases are necessary to keep the lethal gene acting in the target population (inundative releases). Paratransgenesis is based on the use of symbiotic bacteria to express effector molecules inside the target vector. The symbiotic bacteria are genetically modified to express effector molecules and then reintroduced into the mosquito, where they produce the desired effect. Through the application of the malaria vector's control principles, investigators attempt to determine the presence, abundance and ecology of the vector; to identify reservoirs of infection; to evaluate modes of transmission and the ways in which they are influenced by the environment; and to implement disease control and prevention measures. New strategies, therefore, have to be created to replace the use of insecticides. These include Integrated Pest Management (IPM), in which insecticides should be used only as a last resort in malaria epidemics. The IPM guidelines are primarily based on environmental planning, public awareness and biological control, and seek to control the mosquito population more efficiently while preserving the environment from contamination. The two core measures, broadly applicable for malaria vector control are long-lasting insecticidal nets and indoor residual spraying. For effective malaria control and elimination, it is critical that sufficient nets are available to protect all community members from malaria. The insecticide is sprayed on indoor walls and ceilings where malaria vectors are likely to rest after biting. Hence, all of these factors are needed to be taken into account for malaria vector control program.

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