Contemporary Issues in Vector Management

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Abstract:

Vector Borne Diseases represents a major public health challenge in tropical countries where poverty and vector favourable climate are the vexatious factors. These diseases are major contributors to the total global burden of disease and a significant impediment to socio economic development in resource poor countries. There are copious approaches for vector control but despite of enormous efforts the vector control strategies are getting skimpy each passing day because of emerging insecticide resistance. International organizations and government are enormously implementing public health improvement strategies but implementation of these strategies will require effective public health regulation and legislations. To meet the need of vector control and to ensure sustainability of control efforts vector control programs should strengthen their capacity to use data for decision making with respect to evaluation of current vector control programmes. This review provides an overview of all current strategies and approaches being applied for the vector control along with their failures at local and global levels. This review evidences the insecticide resistance among various vectors. It also emphasise on how these programs should be implemented and provides recommendations for further vector control development.

Keywords: Vector Control Strategies; Integrated Vector Management; Insecticide resistance.

Introduction:

Vector-Borne Diseases are illness caused by pathogens and parasites in human populations. 17% of the illness and disability suffered worldwide is due to Vector Borne Diseases, with more than half the world's population currently estimated to be at risk of these diseases [1] . The poorest segment of society and least developed countries are most affected. This is a major public health problem, particularly in tropical and sub tropical regions and places where access to safe drinking water and sanitation system is a challenge [2]. Globally, billions of people are at risk from viruses and bacteria transmitted by mosquitoes, ticks, fleas and other vectors (eg. *O. Tsutusgamushi* transmitted by mites) [3]. The risk of acquiring Vector Borne Diseases increase with increasing land use. Global trade and travel also facilitated the emergence of Vector Borne Diseases [4]. Vector borne diseases are heaviest toll on poorest people. It thrives in conditions of poverty making half a billion people sick and causing thousands of deaths each year. Evidence shows that Vector Borne Diseases have intensified their severity due to climate and environmental change and globalization [5]. The aim of vector control strategies is to prevent transmission of pathogens by controlling mosquito vectors and impede human vector contact. A number of vector control strategies are been adopted and many have been proved successful in disease eradication. In context for complete eradication all the strategies must be implemented with an integrated approach [6]. Some of the major approaches are: i) **Environmental management :** it includes prevention and reduction of vector propagation and human vector contact by destruction, alteration, disposal or recycling of containers and natural larval habitats which produce greatest number of adult mosquitoes [7] [8]. Reduction of vector habitats and breeding sites [8], Solid waste management [9] and modifications of manmade breeding sites[8] such as outdoor sinks, gutters etc are major approaches to control breeding of mosquitoes. They also avail regular recycling of solid wastes which are non biodegradable. Improving house designs also reduce entry of mosquitoes which reduces breeding of mosquitoes near human dwelling thus, reducing the risk of Vector Borne Diseases [10]. ii) **Biological Control :** Bio control measures exploit the innate behaviour of any living creature in order to limit the population size of any targeted vector species. Such natural enemies of mosquitoes include predators eg. Dragonflies [12], frogs [13] ciconiiform birds [14], mosquito fish'[11] [15] that feed on mosquitoes or mosquito larvae ; parasatoids eg. *Ascogregarina culicis* [11] that lives as parasite inside host mosquito before destroying it [8]; and pathogens eg. spores of entomopathogenic fungi (such as *Beauveria* *bassiana* and *Metarhizium anisopliae*), which affect larval and adult stages of mosquitoes [17]; Csp_P, a bacterium of the genus *Chromobacterium* that resides in the mosquito midgut and reduces survival of adults as well as larvae [18]; and *Bacillus thuringenesis* H-14 (Bti), mosquito larvicide that is commercially available under a number of trade names [19]. It checks reproduction and disable the vectors by killing them [16] [11]. iii) **Chemical Control:** These possess insecticidal properties in order to reduce mosquitoes population with in a local environment**.** These are larvicides which are directly applied to water to control larvae, adulticides used in wide area fogging and spraying to combat adult mosquitoes and synergists which are not toxic but increases efficiency of other administered chemical**s** [18**]**. Examples of chemical insecticides that have been deployed worldwide include organophosphates (e.g. Fenitrothion, Fenthione Malathione) and pyrethroids (e.g. Cypermethrin, Deltamethrin, Permethrin) [20] . iv) **Genetic Control:** It aims to suppress target population or introduces a harm reducing trait. Several methods are under development and the first field trials are showing promising progress. Examples include Genetically Modified Mosquitoes or introduction of *Wolbachia* that inhibit mosquito reproduction. These have potential to control *Aedes* transmitted diseases [21]. Other studies have succeeded in modifying mosquitoes so that they can no longer transmit dengue parasites [22]. There many other strategies like Outdoor and Indoor Spaying [23], Other Insect Repellents [24],Insecticides of Natural origin [25], Insecticide Treated Clothing [26], Expanded Polystyrene (EPS) Beads [27] aims for mosquito elimination and many more under development for elimaination and eradication of Vector Borne Diseases.

The Concept of Integrated Vector Management for Fighting Vector Borne Diseases:

Integrated Vector Management (IVM) goes beyond traditional control programs. It is a rational decision making process for the optimal use of resources for vector control. In the year 2004 the WHO promoted first time the aim of making vector control more efficient, cost effective, ecologically sound and sustainable. According to the WHO, planning and implementation of vector control involves analyzing the local determinants of disease, assessing requirements and resources and designing locally appropriate implementation strategies at national level [28]. IVM is an integrated approach that promotes collaboration within health and non health sectors. Advocacy, Social mobilization, legislation, evidence based decision making and capacity building are its main key elements [9]. IVM provides rational decision making process for optimum use of resources for vector control. In 2004 , the global strategy for IVM was prepared approaching broad principles that are applicable to all Vector Borne Diseases [29]. This strategy was designed for effective control along with health and socio economic development. To combat neglected tropical diseases IVM was implemented along with capacity building [30]. IVM relies on understanding of how environmental factors affect distribution and densities of vectors and how effectively it controls vector human contact [31]. Programmes seeking to implement IVM must appreciate that effective IVM requires the establishment of principles, decision-making criteria and procedures, together with time frames and target [31]. These principles should be incorporated into national health policies and are supposed to be supported by legislation and regulation for better results. IVM is advancement to traditional approaches for vector control in terms of collaboration with local communities, other stakeholders e.g. Agriculture ministries, Environment committees and water work committees. Public health regulatory and legislative frameworks if regulated properly support the evolution of vector control.

Emerging Insecticide Resistance and its Resistance Mechanism in Certain Species:

Insecticide resistance is an emerging problem and biggest hindrance in vector control. Despite of so many vector control strategies vectors still find a way out to move on and resist all threats. Recently, WHO global report on insecticide in malaria vectors: 2010-2016 showed that resistance to all four commonly used insecticides classes: Pyrethroids, Organochlorines, carbamates and organophosphates occurred cross WHO regions of Africa, The Americas, South East Asia , The Mediterranean and The western pacific [32]. As of 1992, the list of insecticide resistant vector species included 56 Anopheline and 39 Culicine mosquitoes Apart from mosquitoes resistance is also shown in Body lice, Bedbugs, Triatomids, eight species of Fleas, and nine species of Ticks [33]. Insecticide resistance is viewed as an extremely threat to crop protection and vector control. In 1984, The Insecticide Resistance Section Committee (IRAC) was formed to prevent the resistance development. In 2006, IRAC strengthened its public activities by setting up a new IRAC Public Health Team. The main aim of this prospective is to describe the key issues, namely how resistance emerges, what chemical classes of insecticide are used, which resistance mechanisms are involved and what is done to monitor resistance [34].
DDT (Dichlorodiphenyltrichloroethane) was introduced in 1946. The first resistance developed in *Aedes tritaeniorhyncus* and *Aedes solicitous* and since then over 100 mosquitoes developed resistance among which

50 were Anophelines [35]. Insecticide resistance is one of the main reasons for emergence of Vector Borne Diseases [36], and if disease does not emerge the vector control is influenced for the sure 24. Apart from insecticide resistance the disease emergence is also affected by vaccine availability and cost [36], [37]. The resistance became apparent during 1993 where nine mid western states were continuously transmitting arboviral disease after flooding during continuous insecticidal use [38].

In Puerto Rico, Dominican Republic, Cuba,French Guiana and Colombia resistant development of *Aedes aegypti* to insecticides such as temephos and pyrethroids is also seen [39].

Major four classes of chemical insecticides are used in vector control : Organochlorines, Organophosphates, Carbamates and pyrethroids. Apart from these Biopesticide (eg. *Bacillus thuringenesis* and *Bacillus sphaericus*) and Insect Growth Regulators such as methoprene which is juvenile hormone mimic are also used widely [40]. Bio pesticides and Hormone mimic insecticides resistance is limited as their use is also limited [41]–[43].

Most of the insecticides developed and used are neurotoxic. They have three major target sites:

i) Acetyl cholinesterase which hydrolysis neurotransmitter acetylcholine
ii) Gamma Amino Butyric Acid (GABA) receptors increases Chlorine ion neurotransmission during nerve responses
iii) Sodium channels responsible for raising action potential during nerve impulse

Some underlying mechanism are been identified but their complete understanding is missing [44]–[46]. Till date four types of resistance mechanisms against the chemical insecticides mentioned above have been described: metabolic resistance, target site resistance, penetration resistance, and behavioural resistance. Metabolic and target site resistance are investigated at molecular and genetic levels [46]. Metabolic resistance is due to overproduction of specified enzymes that are responsible for sequestration, metabolism or detoxification of insecticide [16], [35], [47], [48]. Three main groups of enzymes have been identified :

i) Carboxylesterases which is efficient against organophosphate and carbamate insecticides
ii) Glutathione-S-transferases (GSTs) which are effeicient against organophosphastes, organochlorine and pyrethroid insecticides.
iii) Cytochrome P450-dependent monoxygenases efficient against most insecticides types in conjunction with other enzymes.

The overproduction of these enzymes is achieved by gene amplification [16] and increasing the gene expression through mutations in the promoter or regulator [49]. In addition malathion resistance is associated with qualitative change in enzyme carboxylesteras. A few amino acids substitution can increase rate of hydrolysis of the enzyme [48] . The target site resistance is achieved by point mutations that render the actual targets of an insecticide less sensitive to the active ingredient [46] [50] . The acetyl cholinesterase is the target of organophosphorous and carbamate insecticides, the GABA receptors are the main targets of cyclodiene (organochlorine) insecticides, and the sodium channels are the targets of pyrethroid and organochlorine insecticides. Mutations in all three of these can confer resistance [46].

Vector control Regulations and drawbacks:

On 2016, June World Health Organisation launched a fast tracked effort to develop global plan to boost vector control. On the assembly day in 2017, 132 member countries participated in this approach. Recently, WHO has provided policies to strengthen the integration with existing National Health Policies and relevant disease specific program. This has been published in Handbook for national quality policy and strategy [51].

In 2005, International Health Regulations (IHR) adopted by 58th World Health Assembly obliged countries to take routine and specific actions to build resilience against epidemic prone diseases with an special focus on dengue [52].

However, the approaches of vector control fail because of municipal ignorance. For larval control strategy municipal and government collaboration implemented many acts. The major act was "Abate larvicide, regular house inspection and enforcement of the Destruction of Disease Bearing Insects Act, 1975" [53]. According to this act providing breeding sites for mosquitoes in houses or in nearby vicinity is punishable but due to municipal ignorance this act is not carried strictly at public level .The vector control tools and approaches appropriate to epidemiological and entomological contexts needed to be scaled up. There are no community based approaches for vector control actions and this point is always considered as granted. In major disease prone areas the non health and health sectors coordination is lacking. Many areas still have garbage dumped near houses which provide site for mosquitoes breeding.

Vector control is a vital component of disease control however, in 2017 the coverage of insecticide treated nets in region reached just 50% and protection from indoor residual spraying declined from a peak of 5% in 2010 to 3% in 2017.

According to WHO vector control response 2017-2030 the mortility due to vector borne diseases are to be reduced by 30%,50% and 75% in 2020,2025 and 2030 respectively relative to 2016. In present scenario 80% of the world's population is at risk of one or more vector borne disease and over 700 000 deaths are caused by vector borne diseases annually. The case incidence due to vector borne diseases are planned to reduce by at least 25%, 45% and 60% in 2020,2025 and 2030 respectively relative to 2016.

The administration of insecticide is always considered at emergency which is not a proper approach to vector control. The Vector control can only be achieved by regulatory use of insecticide. Post season and pre season vector surveillance and data collection is noticeable act. Data driven planning and sorting is not done properly according to vector and their disease transmission capacity. Most data's are given after disease outbreak. Most of the affected states had no public health entomologic or vector control resources, and none had susceptibility data . As a result of these findings, a resistance surveillance laboratory was established at the Centres for Disease Control and Prevention (CDC), Atlanta, Georgia. Data collected by this laboratory in the last 3 years confirm that states vary enormously in their resources to deal with insecticide resistance. In 1998, 26 states actively participated in Emerging Infectious Disease insecticide Resistance surveillance project. Which provided an update on resistance of disease vectors to insecticides, used specific instances of emerging resistance to illustrate this complex, worldwide problem, and offer strategic priorities for combating it [43].

In 2012, Global Plan For Insecticide Resistance Management (GPIRM) was prepared for malaria control , which is recently reviewed by Abraham P et al, 2015 that WHO should establish capacities for effective insecticide resistance. There is a huge gap by global communities in addressing the insecticide resistance threat [54].

Apart from problem in vector control there are failures in strategies as well. Some reasons for the slow uptake of integrated vector control include: A lack of capacity building, poorly defined roles for advocacy and legislative activities, and a general lack of inter sectoral linkage within the health sector. Similar to traditional vector control approaches IVM relies on environmental factors that influence distribution and densities of different vector species. It also depends on how effectively control measures reduce vector human contact, vector survival and the overall pathogen transmission intensity.

In any of the vector control strategies if any single point is lacking then the complete strategy fails. For a complete growth and development an integrated approach is crucial.

DISCUSSION:

Vector control programs have come across in a few countries in 1960's but only reached regional scale in 1990's. Vector control programs have proved to be effective in suppressing many vector species in geographically defined endemic regions. Once the goal is achieved vector elimination programs put very little emphasis on vector surveillance. Regular or seasonal surveillance of areas near forest is important to monitor emergence of mosquitoes through their sylvatic cycle [4]. The only reason for spread of Zika Virus and Chikungunya virus is lack of surveillance due to which these cycles remained active in *Aedes* sylvatic life cycle and is believed to spread from Africa to various parts of Asia [55]. The vector elimination and control depends on the quantity and quality of human and financial resources. Affected areas require a long term commitment for vector control and affected communities must endorse it. Similarly on global scale there is a need of advanced research to identify and evaluate new tools for vector control that can be integrated with existing biomedical strategies within a nation. There is a strong need to build a core team of entomologists in each country. In addition the stature of such people needs to be upgraded and a clear career ladder should be there to motivate them. They should be referred as vector scientists.

The insecticide resistance is increasing rapidly. However, the resistance frequency depends on the volume and frequency of insecticide administration against vector. The practice of continuous using the insecticide until it becomes a limiting factor is majorly responsible for continuous development of resistance. Newer classes of insecticides have been developed but their higher developing and registering cost inhibited them from entering public health vector control while their agricultural approach is remarkable. A detailed knowledge over insect genome and regulation of insecticide resistance mechanism can make resistance strategy management feasible [43] . As the most commonly used pesticide in agriculture and Indoor Residual Spraying are pyrethroids, Organophosphates and Organochlorines and for the treatment of LLIN's (Long Lasting Insecticidal Nets) are pyrethroids , cross resistance is common between pyrethroids and DDT [11] . The present situation also demands vigorous research for development of more appropriate insecticides for Vector Control.

CONCLUSION:

Mosquitoes are responsible for major Vector Borne Diseases and the insecticide resistance is major challenge for Vector control. Before adopting any new insecticide the vector susceptibility should be assessed. In future the over use of pyrethroid pesticide would create another public health problem. As there is a continuous inherent capacity for change there would be differences in capacity to respond.

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