Benefit Evaluation of Dengue Adult Mosquito Chemical Control and Its Application

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Abstract

In Southeast Asia, most countries use insecticide spray to kill adult mosquitoes as a major way of prevention of dengue fever. However, literature review and studies in Asia, Central and South America, and Caribbean area, have shown that the effectiveness of this method targeting adult mosquitoes for prevention of dengue fever is very limited. Effectiveness of insecticide spray is also affected by the spraying equipments, maintenance of the equipments, correct dilution of insecticides, and resistance of mosquitoes. In addition, labor and budgets required for spraying insecticide form a big burden for health authorities. Hence many countries recently have reassessed and modified methods of spraying insecticides. It has been suggested that spraying is only applied when and where appropriate, in addition to eradication of breeding source, elimination of larvae, and personal prevention. Indications for insecticide spraying include cluster infections (more than two cases within 150 meters radius in 14 days), occurring of more than two serotypes of dengue viruses, and appearance of dengue hemorrhagic fever.

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Insecticide spraying to prevent dengue fever has been used in Taiwan for more than 20 years. It is usually done immediately when suspected cases are reported. However, outbreaks of dengue fever still occur every year. Since local counties or cities apply insecticide indoors by the thermal fogging method that leads to wet floor surface, complaint and resistance of residents increase gradually. As rapid testing reagents are getting popular, it is time to reassess timing and methods of chemical spraying for prevention and control of dengue fever. Recommendations of WHO and experience of other countries can be used as a reference in our strategy for prevention of dengue fever and control of adult mosquitoes.

Keywords: *Aedes aegypti*, insecticide spraying, space spray, ultra low-volume, chemical control of adult mosquitoes

Introduction

The purpose of spraying insecticides is to eliminate adult mosquitoes that may carry virus around possible infection areas or areas where viremia cases have stayed by immediate application of insecticides in order to interrupt transmission.

However, years after application of this strategy, dengue fever still spreads after endemic cases emerge each summer, even after immediate prevention measures are taken. The government has spent huge amount of resources and labors, local health personnel are overwhelmed with work, and residents complain about or resist indoor chemical spraying.

In this article, we review the literature of chemical control of adult mosquitoes and summarize prevention measures of WHO and countries having dengue fever in order to assess effectiveness and methods of chemical control of adult mosquitoes.

Literature review

WHO consider that space spray of insecticides cannot effectively control dengue fever, as shown by the increasing incidence of dengue fever in epidemic areas after 25 years of applying space spray for dengue fever prevention [1].

Pant et al (1971) conducted ultra-low volume (ULV) spray tests in Thailand and showed that Malathion can decrease density of *Aedes aegypti* by 99%. It took two weeks for density of *A. aegypti* to recover [2]. ULV spray of Fenitrothion is more effective. Five times of spray can control *A. aegypti* population for 4-5 months [3].

Gratz (1999) reported the study on space sprays for the control of *Aedes aegypti* in South-East Asia and Western Pacific and found it is effective if the spray is done appropriate. Moreover if the ULV spray is applied sequentially [4].

Perich et al [5] also showed that in Honduras using ULV or thermal fogging to spray Lambda-cyhalothrin one minute at front doors or 15 seconds in each room can kill 97-100% of mosquitoes in mosquito nets either in open or hidden areas. The effect could last for four weeks.

Gubler (1989) studied the effects of ULV spray on wild adult mosquito population in Puerto Rico, instead of using traditional mosquito net methods. The results showed that ULV spray or thermal fogging spray of insecticides could not effectively decrease wild adult mosquito population [6].

Perich et al (1990) in Santo Domingo, Dominican Republic, sprayed insecticides in two residential areas by cars or helicopters and showed that indoor volume median diameter (VMD) was 18.7μm, within ideal effective ranges. However, average dosage of insecticides gathered by filter papers

was only 0.22ug/cm^2, lower than the expected dosage 5.0ug/cm^2.The study showed that after chemical administration, average death rate of female *A. aegypti* was higher outdoors. *A. aegypti* population was not reduced significantly, as shown by indoor net capture of mosquitoes in the morning and outdoor Ovitraps [7].

Newton and Reiter (1992) used mathematical models to simulate outbreaks of dengue fever after chemical administration that decreases different percentages of mosquitoes in the environment. The results showed that chemical administration, even multiple applications are made, could not decrease disease incidence, but could only delay onset of outbreaks. They concluded that ULV spray has little impact on disease incidence, however, effective ULV spray could delay outbreaks, decreasing the carrying capacity of the environment for mosquitoes, or better environmental factors (cooler weather) and winning time to stop disease transmission [8].

PAHO [9] thought it is hard to confirm effects of emergency prevention measures on outbreaks of dengue fever by adulticide since outcomes without ULV spray are unknown. No sufficient evidence in America supported that chemical spray could stop outbreaks of dengue fever. However, any prevention measures that could eliminate virus-carrying adult mosquitoes, even if it is shorter, could decrease chance of virus spreading at the time of chemical administration.

Then US CDC has conducted large scale ULV spray tests in Central and Southern America between 1983 and 1994. In the 13 large scale ULV spray tests in Puerto Rico, although the maximum dosage (50mL/ha) could kill more than 90% of mosquitoes in mosquito nets, only small changes could be found in *A. aegypti* population. In the 12 experiments in PAHO

collaboration laboratories, Jamaica and Venezuela, the female *A. aegypti* was decreased by 56% and male by 95%. However, population density returned to the levels before drug administration in 7-9 days. Ovitraps showed a similar trend [10].

In an outbreak of a small isolated town (8,689 people) in Puerto Rico, there was no significant control of the outbreak after 16 times of ULV spray by cars at frequencies of one time per week or every other week. The epidemiological curve after chemical spray was the same as a typical epidemiological curve [10].

Perich et al (2000) investigated the habitat behavior of *A. aegypti* in 14 areas in Panama City and sprayed Malathion by ULV. The study showed that 75.1% of adult mosquitoes stayed indoor, at least 6 meters away from streets. Since most mosquitoes stayed in bedrooms, living rooms and bath rooms, only small amounts of smaller spray particles can enter their habitats. Hence, effectiveness of outdoor chemical spray is limited [11].

In Malaysia, oviposition behavior of *A. aegypti* was studied by ovitraps around buildings in cities. The study showed that, during chemical spraying or immediate after spraying, no dead larvae of *A. aegypti* was found. Numbers of larvae were close before, during and after spray. No significant differences in average ovitrap time. The results showed that chemical spraying in natural environment could not eliminate pregnant female mosquitoes to interrupt the reproductive cycle [12].

Preventive measures in other countries

When cases of dengue fever are reported, Singapore National Environment Agency (NEA) will conduct mosquito surveillance and

elimination of breeding sources. When a cluster event happens, NEA will survey the area and start elimination of disease vectors until the outbreak is over. Indoor ULV spray and outdoor thermal fogging spray will start when high densities of mosquitoes are found or cluster dengue fever cases are reported. However, only under special circumstances when indoor spraying becomes mandatory. In areas having cluster dengue fever cases, if the case number is lower than 10, ULV spray is done around houses with cases and neighboring areas having mosquitoes. Thermal fogging spray is done for outdoor breeding sources [13].

In northern Queensland, Australia, indoor residual chemical spray is used to eliminate adult mosquitoes since effectiveness of spray by cars is limited. Indoor residual drug spray is done prior to outdoor space spray. When sporadic cases appear, larvae elimination will be strengthened in areas within 200 meter radius of houses or activity areas of the cases. Traps to eliminate adult mosquitoes will be used in areas within 100 meter radius. Indoor residual spray will also be done. When large scale outbreaks occur, disease control areas are defined according to distribution of the confirmed cases. Areas without previous surveillance or mosquito control have higher priority. Disease control measures are done against both adult mosquitoes and larvae [14].

Chemical spray is mainly done for reported cases of dengue hemorrhagic fever in Thailand. When a case of dengue hemorrhagic fever is reported, heath authorities will do space spray in areas within 100 meter radius of houses of cases by ULV spray or thermal fogging spray every 10 days for three times at least [15].

Questions and Discussion

1. Some studies suggested that particles generated by chemical spray cannot sufficiently go through door and windows to reach indoor areas to eliminate mosquitoes. However, this is highly correlated with the ways of spray. Spray equipments currently used in Taiwan are mainly back-pack ULV or shoulder-carry thermal fogger. It is required to spray indoors in each room. In order to increase effectiveness of killing, doors and windows are required to be closed and ventilation equipments are required to be turned off. Most southeastern countries are also using this indoor spray method, which is very different from WHO recommendation. The WHO recommends chemical to be sprayed near buildings/houses and requires windows and doors to be opened to allow diffusion of chemical into the rooms to kill mosquitoes.
2. Current spray strategy does not cover closed closets or storage areas. Residents usually cover food and bed sheets with plastic bags or newspapers as well. Effectiveness of chemical spray is decreased in those areas.
3. Some studies have raised questions regarding the use of mosquito net in accessing effectiveness of chemical spray. Although high death rates have been found both in indoor and outdoor experiments, it correlates poorly with responses of wild mosquito populations. Since mosquito nets are selective for particle sizes and prohibitive for normal escape behaviors, they are actually not representative. Some studies have used ovitraps to monitor wild mosquito populations. However, ovitraps are sensitive to environment and human disturbances, leading to variations.
4. Although the WHO recommends that space spray is only necessary in

epidemic areas of dengue hemorrhagic fever, in epidemic countries of dengue fever, insecticide spray is still a main prevention method. In addition to rapid killing of virus carrying adult mosquitoes to stop transmission, feelings of the general population is also taken into consideration. People would think the government is not responsive without chemical spray. During an outbreak of dengue fever in southern Taiwan in 2006, 93.2% of residents were willing to cooperate with drug spray around buildings, and only 2.1% denied. However, 82.6% of people in 2007 were resistant to drug spray (by thermal fogging due to moisture and difficulties of cleaning, as shown in a study by Taiwan CDC in 2007. Field observation also showed frequent resistance during indoor chemical administration, especially after repetitive spray in cases when multiple local cases are reported.

5. Most countries start chemical spraying right after report of cases of dengue fever. However, Thailand starts spraying only after reported cases of dengue hemorrhagic fever. In the past, the Department of Health in Taiwan requires spray to be done within 36 hours after cases are reported. Hence, health authorities usually give immediate notice of application the day when cases are reported and spray the next day. Since drugs are sprayed when suspected cases are reported, drug spray is often done when later confirmed negative cases. This strategy increases burden of labor and resources, in addition to complaints from residents.

Suggestions

1. According to the literature and related studies, it is still controversial

whether chemical spray can stop outbreaks of dengue fever. Although there are cases when spray failed to control outbreaks, in fact no countries uses spray as the only method to eliminate adult mosquitoes. Multiple measures including elimination of breeding sources and chemical control for larvae and adults are usually used. In terms of stopping adult mosquitoes from spreading viruses and decreasing risks of disease transmission, chemical spray could have an augment role in disease prevention.

2. The WHO thinks that chemical spray alone is not sufficient to control dengue fever. However, elimination of disease carrying mosquitoes can still be effective when drugs are sprayed at the right time and place and follow the right methods. Hence, spray is not totally excluded from prevention measures in most countries, although the strategies for chemical spray have been modified. For examples, due to possible drug resistance, Singapore has decreased frequency of spray and found no significant increase~~s~~ in case numbers. Hence, necessity of chemical spray for reported cases needs to be reassessed, that is, chemicals are sprayed only after the risk of transmission exist. Timing to spray should also be extended from 36 to 48 hours to allow enough time for mosquito surveillance, elimination of breeding sources, and assessment according to epidemiological data, mosquito surveillance, clinical data, and examination results. Frequency of spray should also be adjusted accordingly. Besides, indoor spray should be done by ULV to decrease complaints from residents caused by moisture. Outdoor spray may use thermal fogging method.
3. In recent years, spray is also done indoors. This strategy can improve

poor effectiveness shown by some studies and make sure that suspension particles can kill mosquitoes indoors. Care should be taken for mosquitoes hiding in closets or cabinets. Residents should be instructed to open cabinets and closets, which should be confirmed by team leaders to ensure effectiveness of chemical spray.

4. Periodical monitoring of effectiveness of chemical spray is also suggested. We found that poor effectiveness of spray is mainly caused by technical problems and dosage problems, in addition to chemical resistance of mosquitoes. Effectiveness of chemical spray varies a lot, and hence periodical nonscheduled monitoring should be done. If resistance of mosquitoes happens, other effective chemicals should be used. If technical issues are found, improvement should be done. On-the-job training can also be used to improve techniques and quality of personnel.

Conclusion

Since emergency chemical spray can reduce risk of spreading of dengue fever, spray is a necessity, but not the only option. In our future chemical spray strategy against dengue fever, necessity of chemical spray should be assessed carefully to reduce frequency of spray. Concepts and dependence of residents to chemical spray should be changed gradually. Weight of breeding source elimination and larvae prevention should be increased. Breeding source elimination through community should be the main strategy for prevention and control of dengue fever.

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