ARTICLE REVIEW

Should we bother doing dengue vector surveillance, and if so, how should we do it?

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ABSTRACT

Received 12 December 2018
Accepted 25 July 2019

There is an enduring disconnect between the routine surveillance of mosquitoes that transmit dengue viruses and control activities to limit disease spread. A great variety of methods used to collect vector surveillance data exists globally, with program design typically influenced by historical, socio-cultural and cost factors. Surveillance data can be expensive to collect, meaning that without demonstration of its usefulness in directing mosquito control it may be deprioritized or even abandoned. Given that universally prescribed surveillance methods are unlikely to be sustainable and successful, we propose that strategies be designed according to the local terroir of dengue transmission. Strategy design should consider not only costs, but the amenability of workers and the public to various methods, the utility of methods for directing control and reducing disease, and the underlying spatial structure of the vector populations locally. A process of evaluating each of these factors should precede strategy design and be part of on-going review processes. In the case that the usefulness of vector surveillance cannot be demonstrated, then it may be argued that resources could be allocated to other aspects of disease control.
Keywords Dengue - Vector surveillance - *Aedes* - Decision-making - Strategy design.

INTRODUCTION

Mosquito-borne diseases are common and widespread. In the absence of commercially-available vaccines for many diseases, mosquito control remains the most important management tool to limit disease burden. In theory, control activities should be optimized through the use of vector surveillance data to ensure they are well targeted and cost efficient. However, there is often a disconnect between surveillance and control activities; with vector surveillance rarely used to effectively trigger and target control of dengue vector mosquitoes or to prompt public warnings of heightened risk.[1,2] Surveillance data should ideally be a component of any disease management strategy, so intuitively information about vector mosquito abundance and type should be useful.

Dengue viruses are the most common arbovirus type in humans globally (around 3.9 billion at risk), and are an increasingly intractable problem throughout the tropical world.[3] Dengue transmission occurs in a variety of socio-political circumstances, affecting not only poor communities in developing nations, but relatively wealthy developed communities.[4] Dengue is very much a disease of the slum and the high-rise, and is common in urbanized tropical environments. The need to improve the sustainability and usefulness of dengue vector surveillance, the approach to which is wildly inconsistent, has already been well argued.[1,2,5] However, the most important considerations for improving vector surveillance are not well documented.

VARIABILITY IN THE APPROACH TO DENGUE VECTOR SURVEILLANCE

Such a variety of dengue transmission terroir has in part created distinct heterogeneity in approaches to vector surveillance. Methods for collecting information about vector populations (chiefly *Aedes aegypti* and *Ae. albopictus* mosquitoes) range from container surveys for the absence of larvae through to the use of traps that kill egg-laying mosquitoes.[5] This variability is understandable because of the variety of financial, historical and cultural circumstances that exist in the tropical world.

However, this variety of circumstances is insufficient justification on its own for the choice of vector surveillance strategy. Specifically, methods should be designed to optimize the utility of data they yield, as well as being cost-efficient and acceptable for health workers and the public. Further, it is important to justify strategy with evidence so that workers, managers and policy makers have sufficient 'buy-in' to it. When new staffs commence work, charged with responsibility for dengue management, they need to understand why they are doing things in a certain way, and if they desire to change it, must be able to justify this.

FACTORS FOR CONSIDERATION WHEN DESIGNING A VECTOR SURVEILLANCE STRATEGY

A dengue vector surveillance strategy will comprise a sampling method, description of the frequency and spatial arrangement of sampling, and the collation and analysis and end-use of data. There are four main factors that ideally should inform the design of such strategies (Panel6). A one-size-fits-all approach to dengue vector surveillance globally is unlikely to be widely accepted, nor successful. These factors can be assembled under four main headings: costs, perceptions of workers and the public, data usefulness for triggering control, and spatial ecology of the disease vector.

Costs

All surveillance programs are financially constrained. However, the costs incurred should be offset by the economic savings through reduced disease burden, which can be an order of magnitude greater without surveillance.[7] Further, the true costs of vector surveillance will include not only the costs of equipment (e.g. traps) and staff salaries in trap deployment, but also labor costs for collating and analyzing data. For a surveillance program to be sustainable it must be affordable, which will be influenced by the socio-cultural environment in which the program takes place. A sustainable method is able to withstand changing conditions and priorities for a surveillance program. For example, methods requiring mosquito samples to be brought back to the laboratory for rearing and/or identification might not be the best option when personnel-time and laboratory funding are stretched, such as during an epidemic. Hence other alternatives that enable on-site identification of mosquito species are feasible and can save costs in the long run.[5,8] Such methods are more likely to be retained during outbreaks, when most human resources are channeled to control operations. In short, the true costs of vector surveillance require full evaluation of equipment and labor costs and comparison of costs with alternative methods.

Perceptions of workers and the public

Engaging with key stakeholders is an important step to improve evidence-based decision making for vector surveillance. Historically, successful dengue control strategies have involved significant community participation.[9,10] Designing and implementing a method without inputs from the stakeholders, such as field workers and the public, could result in the strategy being poorly executed or even resented. In a recent study of vector control officer opinions,[11] a number of insights about the amenability of both the workers themselves and the public to particular surveillance methods were obtained, revealing the pros and cons of various methods as distinct from their performance in collecting mosquito data. Surveillance activities may be performed less attentively if a method is too labor-intensive or inconvenient, which can in turn influence the quality of surveillance data collected. Methods which generate data suitable for direct communication to participating households may also prove useful as a measure to engage residents to take affirmative action in preventing mosquito breeding. Assessing the perceptions of field workers and the public is a vital and often overlooked means of assessing the worth of vector surveillance methods.

Data usefulness for triggering control action
A method that can accurately describe the fluctuation of vector abundance throughout the year can act as a trigger for pre-emptive vector control. Such methods should be the ones that collect adult mosquitoes responsible for transmitting dengue viruses. Surveys of immature stages that assume a direct relationship between the abundance of the immature and adult vectors may not be appropriate because they are weak indicators for adult populations.[1,12] There are times when data from routine vector surveillance are incomplete or cannot be obtained. The use of proxies (non-entomological data) to predict vector abundance would be convenient in these situations. Coupled with entomological data, retrospective and forecasted meteorological data from national weather bureaus can be used to construct predictive models for elevated vector abundance.[13-15] However, developing evidence for the link between entomological indicators and transmission risk is difficult and consequently has not been done frequently.[16,17]

Spatial ecology of the disease vector
Dengue is a disease of human environments, with the production of the vectors strongly linked with human activity through the provision of breeding sites (water-filled containers) and food (blood meals). Such a dependence on humans understandably leads to non-random spatial structuring of the vector population.[18-22] This has implications for the way surveillance is conducted. Surveillance by census is rarely practical, meaning that sampling of the vector at discrete points is the only option. However, different surveillance methods (e.g. different kinds of traps, larval habitat inspection regimes etc.) may reveal different spatial patterns of the vector population that they describe.[23] Hence, knowledge of what kind of spatial information each surveillance method reveals is requisite for designing a strategy; such as how many samples need to be collected, what number of houses need to be visited, and how often. Sampling strategies can be optimized, meaning data quality can still be maintained even when costs for vector surveillance have to be reduced. Information about the spatial autocorrelation of a vector population can assure program managers that vector abundance yielded from a trap set at a property represents abundance in the surrounding area.[24,25]

Panel: Considerations for designing dengue vector surveillance strategies

1. Costs: every vector surveillance program will be limited by costs, which may be incurred through salaries and equipment purchases. Analysis of costs should include not only the cost of individual equipment items but also the time spent by staff in collecting and processing data.
2. 2. Perceptions of workers and the public: while every surveillance method will have its own quantifiable properties for data collection, it will also have a number of qualitative properties. These properties will include the perceptions of workers to each method and their willingness to conduct them properly, which will also be determined partly by the perceptions of the public.
3. Data usefulness for triggering control: in order to justify the expenditure of a vector surveillance program, its ultimate value in disease prevention must be analyzed. This might be best achieved by using such data for pre-emptive vector control strategies.[2]
4. Spatial ecology of the disease vector: the execution of surveillance method, including not only the choice of method (trap, abundance index etc.) but also the spatial arrangement of sampling effort and the frequency of sampling should be informed by initial study of the spatial structure of the vector mosquito population. Such an approach will optimize sampling effort in terms of cost-effectiveness.

RECOMMENDATIONS FOR DENGUE VECTOR SURVEILLANCE

A dengue vector surveillance strategy needs to be characterized by more than the method used to collect mosquitoes and the data. Our recommendation is that any dengue vector surveillance strategy should be explained and justified in terms of its economic sustainability, the amenability of the public and workers towards the methods employed, and the utility of the strategy for triggering control and warnings for the public. This requires a triangulation of information through qualitative and quantitative approaches, and significant leadership and commitment from those charged with vector-borne disease control.

Furthermore, strategies require regular review of these aspects. Recently, Eisen and others[2] described a 'continuous improvement model' for dengue control programs. Here we describe the aspects of dengue vector surveillance methods that should be considered when designing strategies, an approach entirely consistent with the Eisen model. The Queensland Dengue Management Plan (2015-2020)[26] is an example of periodically revised guidelines produced from such approaches, with a purpose to improve evidence-based practices in disease and vector surveillance. While we make no claims of perfection for this plan, it is one subject to iterative improvement that will hopefully in time reduce the significant disease burden caused by dengue.

We implore those in other regions to adopt a similar approach to vector surveillance strategy design and review and regularly question the usefulness of dengue vector surveillance and the resources allocated to it, as suggested in Eisen's continuous improvement model. Such interrogation of existing strategies could trigger moves to adopt new surveillance methods. We argue that if a vector surveillance program cannot be justified in terms of usefulness, then it will either be abandoned or deprioritized when resource allocation is reviewed by governments, which would be lamentable given the potential for pre-emptive control of dengue vectors before outbreaks, a process which relies on vector surveillance data.[2] Furthermore, if the efficacy of a control strategy (there are several new promising approaches available,[27,28] is to be evaluated, then sensitive, sustainable vector surveillance is required. In the case that the usefulness of vector surveillance cannot be demonstrated, then it may be argued that resources could be allocated to other aspects of disease control.

CONTRIBUTORS

CW and AA wrote the paper with input from SR. All authors are collaborators in dengue management strategy research. All authors have seen and approved the final version.

ACKNOWLEDGMENT

We are grateful for the technical assistance and advice provided by Joe Davis (QH, Cairns) and Brian Montgomery (Eliminate Dengue, Cairns). The Ministry of Higher Education Malaysia and Universiti Kebangsaan Malaysia provided financial support to AA. We thank Ming Li (University of South Australia) for comments on an earlier draft.

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