Perspective

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Sustainable dengue prevention and control through a comprehensive integrated approach: the Sri Lankan perspective

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ABSTRACT

Dengue is a leading public health problem in Sri Lanka. All 26 districts and all age groups are affected, with high disease transmission; the estimated average annual incidence is 175/100 000 population. Harnessing the World Health Organization *Global strategy for dengue prevention and control, 2012–2020*, Sri Lanka has pledged in its National Strategic Framework to achieve a mortality from dengue below 0.1% and to reduce morbidity by 50% (from the average of the last 5 years) by 2020. Turning points in the country's dengue-control programme have been the restructuring and restrategizing of the core functions; this has involved establishment of a separate dengue-control unit to coordinate integrated vector management, and creation of a presidential task force. There has been great progress in disease surveillance, clinical management and vector control. Enhanced real-time surveillance for early warning allows ample preparedness for an outbreak. National guidelines with enhanced diagnostics have significantly improved clinical management of dengue, reducing the case-fatality rate to 0.2%. Proactive integrated vector management, with multisector partnership, has created a positive vector-control environment; however, sustaining this momentum is a challenge. Robust surveillance, evidence-based clinical management, sustainable vector control and effective communication are key strategies that will be implemented to achieve set targets. Improved early detection and a standardized treatment protocol with enhanced diagnostics at all medical care institutions will lead to further reduction in mortality. Making the maximum effort to minimize outbreaks through sustainable vector control in the three dimensions of risk mapping, innovation and risk modification will enable a reduction in morbidity.

Key words: dengue, dengue epidemic, dengue prevention and control strategies, sustainable integrated dengue control, Sri Lanka

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BACKGROUND

The dramatic spread of epidemic dengue in the World Health Organization (WHO) South-East Asian Region underscores the urgent need for better control and prevention of this disease across Member States of the region and Sri Lanka is no exception.[1,2] The infection was first reported in the country in the early 1960s, but it was not until the late 1980s that dengue haemorrhagic fever (DHF), the more severe form, became endemic.[3] Since 2000, the magnitude of dengue epidemics has increased and dengue viruses have started to spread from urban to semi-urban and rural settings. Since then, cases have been reported from all 26 districts and dengue has become a major public health burden.[4] All four serotypes of dengue virus circulate in the country. From 2009 to 2014, Sri Lanka experienced an exponential increase in the prevalence of dengue, with an average of 35 000 cases per year and an annual incidence of 175/100 000 population reported nationally.[5] Dengue generally affects a greater proportion of children and adolescents but has now expanded to affect young adults and adults as well. Today, however, Sri Lanka has reached the lowest-ever case-fatality rate of 0.2% (47 258 cases with 97 deaths) in 2014, from a high of 5% and 1% in 1996 and 2009 respectively, despite an increase in the proportion of DHF to 10–15%.[5,6]

The Ministry of Health, Nutrition and Indigenous Medicine of Sri Lanka has developed a sustainable dengue-prevention and control programme, through a comprehensive integrated approach aiming to reduce the morbidity and mortality due to dengue to such an extent that it will no longer be a major

public health issue by 2020. This paper presents the current epidemiological situation for dengue, and control and preventive strategies implemented through an evidence-based approach that have led to substantial capacity-building and system strengthening over the past decade. Finally, it discusses how the current strategies will be further enhanced in order to achieve a more robust sustainable reduction in both morbidity and mortality over the next 5 years.

EVIDENCE AND LESSONS LEARNT

Epidemiology

There are many contributory factors driving the emergence and transmission of dengue, related to the agent (dengue virus), human host and mosquito vector. Each of the contributory factors influences transmission of virus and operates against a background of the ecological and environmental factors in the country.[7] Improved surveillance, together with sequence data, strengthens the ability to characterize the patterns of evolution and circulation of the four dengue serotypes. Genetic changes in the virus may lead to changes in the epidemic potential: recent studies have shown that certain gene sequences can have considerable impact on pathogenicity and epidemic potential.[8,9] The emergence of epidemic DHF in Sri Lanka after 1989 led investigators to identify a clade replacement event as the critical factor.[10] More recently, the authors of this paper reported a dengue virus serotype 1, with a new strain circulating in Sri Lanka that coincided with the 2009 dengue epidemic.[11] On the other hand, individuals infected with any of the dengue virus types can have a wide spectrum of infection outcomes. While most will remain asymptomatic or develop undifferentiated fever, a lesser number will develop classical dengue fever (DF), a debilitating but self-limiting illness. A minority will develop DHF, with increased vascular permeability (plasma leakage), thrombocytopenia and haemorrhagic manifestations. Patients with DHF could gradually leak critical amounts of plasma into the interstitial (pleural and peritoneal) spaces, resulting in hypovolaemic shock, which, without early recognition and appropriate treatment, may lead to death. Hence, the more severe form of DHF is also known as dengue shock syndrome, or DSS. The acute phase of DHF/DSS begins in a similar way to that of dengue fever, with few or no clinical parameters to differentiate the two conditions early.[12] Antibody-dependent enhancment due to a secondary infection by any one of the four dengue viruses is one of the most important risk factors for severe disease.[13] Now considered to be a fully domesticated mosquito, *Aedes aegypti* is an efficient epidemic vector because it lays eggs in artificial containers and remains indoors, with easy access to humans. While *Aedes albopictus* remains a less efficient secondary vector, in recent years its importance has increased because it is rapidly expanding its range, resulting in epidemic transmission.[14]

Restructuring the prevention and control programme

In 2004, following a large epidemic with 15 463 dengue cases reported, on the request of the Ministry of Health, WHO conducted an external in-depth review of the dengue-control programme in Sri Lanka. At that time, as seen in other countries, the Ministry of Health anti-malaria campaign was leading the overall vector surveillance and control of dengue. The deliberations led to several policy decisions:

- establishment of a separate unit in the Ministry of Health to develop and implement the national dengue-prevention and control plan with an annual budget allocation;
- supplementation of passive surveillance data by a surveillance system based on sentinel sites, in order to detect early epidemics;
- standardization of clinical diagnosis and management of dengue and DHF, through regular training for all types of clinical workers, including general practitioners;
- hospitals were to be provided with necessary equipment, including microscopes and microcentrifuges, and in large hospitals, a biochemistry laboratory and haematology facility were to be made available (e.g. blood gas electrolytes and coagulogram);
- an effective laboratory-based surveillance system was identified as a priority need and it was planned to provide adequate staffing and support to develop the Medical Research Institute, Colombo, into a national reference laboratory for dengue;
- the urgent need for dedicated entomological staff both centrally and peripherally was emphasized, in order to encourage integrated vector management;
- the necessity of a multidisciplinary approach for vector control, including involvement of other government sectors, the private sector and local nongovernmental organizations, was recognized as a priority;
- it was also decided that an ongoing communication and social mobilization plan was to be established, with sound monitoring and evaluation and specific indicators to measure the actual behaviour to be changed.[15]

The National Dengue Control Unit was established in 2005, to coordinate entomological surveillance, integrated vector control and intersectoral collaboration, social mobilization and capacity-building, along with regular monitoring and evaluation of both national and subnational activities for control and prevention. Based on the growing need for intersectoral collaboration, a presidential task force was established in 2010, incorporating several related ministries such as the Ministries of Local Government, Environment, Law and Order, Defence, Education, Public Administration, Disaster Management, and Media, with the Ministry of Health maintaining the task of overall coordination.[16] The presidential task force meets regularly, with the guidance of the President and the patronage of the Minister of Health, together with relevant stakeholders, in order to arrive at important policy decisions. The multidisciplinary partnership created at the national level flows across provincial, district and divisional levels, to finally reach the communities, where acceptance of the programme has been high by all community members. The overwhelming contribution in rolling out emergency response activities, particularly during outbreaks, has boosted successful community participation, helping to create sustainable coordination mechanisms.[17]

Surveillance

In Sri Lanka, an integrated surveillance system for communicable diseases has included dengue since 1996 and has island-wide coverage through trained clinical and public health staff. National surveillance data are largely based on clinical diagnosis and therefore depend on early notification by both indoor and outdoor public and private-sector institutions. The surveillance system combines both passive and enhanced sentinel surveillance methods and largely relies on clinical diagnosis. Laboratory diagnosis is optional, but the majority of indoor patients have their diagnosis confirmed by commercial assays (rapid diagnostic test for dengue virus NS1 protein and/or enzyme-linked immunosorbent assay [ELISA] immunoglobulin M [IgM]). A recent study done in the capital, Colombo, has shown that the sensitivity of clinical diagnosis by clinicians in the country is as high as 84% concurrence with molecular and serological diagnosis.[6] This finding is similar to the reported sensitivity of 86% in Philippines in 2009–2010.[18] The Central Epidemiology Unit is leading disease surveillance, coordination of clinical management training, outbreak response and operational research activities. For disease surveillance, both online and paper-based systems function in parallel, with weekly reporting and daily updates online, where feedback reports are generated weekly and quarterly. Further, an online sentinel hospital-reporting system established more recently serves as an early-warning system for timely detection and mitigation of outbreaks.

Clinical management

Over the past few years, a number of activities have been initiated to strengthen the clinical management and prevention of dengue. Sri Lanka was proactive in developing guidelines for clinical management way back in 2005. More recently in 2010, based on advanced training on management of DHF received from the WHO collaborating centre in Bangkok, Thailand, a new set of guidelines was developed, which were further revised and updated in 2012 based on Sri Lankan experience.[19,20] National reviews conducted have revealed that these guidelines are currently being used throughout the island, ensuring standardized clinical management encompassing all levels of clinical care facilities. Further, capacity-building of laboratories in all secondary-care facilities at district level and above has ensured basic laboratory testing, including serology on demand by a practising clinician. Further, high-dependency units have been established in all major hospitals, with the necessary equipment, including portable ultrasound scanners, in order to detect plasma leak early in DHF, even before clinical and haematological evidence becomes apparent. Training of clinical staff, based on national guidelines, institutionalizing mandatory patient monitoring charts, and regular clinical and death audits were a few key activities undertaken to strengthen clinical management. The Medical Research Institute is the centre of excellence in the country for both clinical and public health laboratory diagnostics. A new dengue molecular reference laboratory was set up at the Medical Research Institute, to further explore additional information on circulating dengue virus, aiming to strengthen both clinical management and surveillance in the country.[6] National-level death audits have revealed that late admission to hospital, particularly for young adults and adults, has significantly contributed to the number of avoidable deaths due to dengue. Adaptation of clear hospital admissions criteria, based on both clinical and basic laboratory parameters (including complete blood counts after 2 days of fever), has had a tremendous impact on timely admission of patients for proper monitoring and care, thereby avoiding many deaths in the past few years.

Vector control

The practice of spraying adulticides and larvicides indiscriminately during peak monsoon seasons had demonstrated little effect in preventing outbreaks of dengue in the past.[21] However, proactive integrated vector management led by source-reduction campaigns, with the participation of diverse groups of stakeholders, based on strong real-time web-based epidemiological and entomological surveillance data on an environmental management platform, is gaining momentum, with promising results. A unique opportunity was created with the end of the long armed conflict, which allowed the release of a vital source of trained and disciplined human capital (armed forces and police personnel) who could be mobilized to augment systematic premises-inspection campaigns in localities with high case reporting.[17] Despite all these efforts, the challenges of sustainable vector-control activities should not be underestimated, particularly with respect to public participation and resource mobilization.

Economic impact

During the epidemic year 2012, the economic burden of dengue to the health sector was assessed in the heavily urbanized and populous Colombo district, where dengue reporting has been the highest in the island. It was estimated that the total cost of the dengue response for control and hospital care was US$ 3.45 million (US$ 1.50 per capita), with a per capita cost of US$ 0.42 for control activities.[22] The average cost of hospitalization ranged between US$ 216 and US$ 609 for paediatric cases and between US$ 196 and US$ 866 for adult cases, according to the disease severity and treatment setting. These results indicate that dengue poses a serious economic burden to the public health sector in Sri Lanka.[22]

Sharing experience

In 2011, Lahore, the capital of Punjab, Pakistan, experienced its first major dengue epidemic, with over 20 000 confirmed cases and 350 deaths.[23] At the invitation of the Government of Punjab, a multidisciplinary national team from Sri Lanka, comprising clinical, public health and entomology professionals, visited Lahore to assess the situation and to assist in their outbreak-management efforts.[24]

Recently, an international conference on dengue, themed "Dengue: to stem the tide" was held in Colombo. This event was organized by the Epidemiology Unit, Ministry of Health, Sri Lanka, in collaboration with the European Community's Dengue Tools project,[25] and brought together renowned international scientists, clinicians, researchers and scholars with a common interest and concern in the global dengue situation. The overall objective of the project was to develop a comprehensive early-warning and surveillance system that has predictive capability for epidemic dengue and benefits from novel tools for laboratory diagnosis and vector monitoring. At the conference, the findings of this project were disseminated among the stakeholders as part of the country's advocacy programme. This kind of academic session also provides a broader evidence-based practice for dengue prevention and control. This event was an opportunity for Sri Lankan professionals to listen to global experts on dengue, which is an important activity for any country to consider. The deliberations on improved tools for surveillance, better diagnosis and clinical management, prevention and prediction of the spread of dengue signals much hope for the future.

Research

In general, the ability to predict and explain the epidemiological and clinical presentations of dengue using currently available knowledge is as yet rather limited. To understand the effect of infection and disease both over time and by place, in an endemic setting, the present authors established a community cohort (initially among children and then whole families) living in the Colombo metropolis.[26] At enrolment, the seroprevalence of dengue among children younger than 12 years was 53.1% (by 5 and 9 years of age 51% and 70% were seropositive respectively).[27] The risk of primary infection was 14.1% per year (95% confidence interval [CI]: 12.7–15.6%), indicating that among initially seronegative children, approximately 1 in 7 experiences their first infection within 12 months.[28] Over the study period, the incidences of dengue virus infection and disease were 8.39 (95% CI: 6.56–10.53) and 3.38 (95% CI: 2.24–4.88) per 100 children per year, respectively, demonstrating high transmission in that urban population.[29] An association of high rainfall with a lag time of 6–12 weeks before the onset of an outbreak of dengue was revealed in an ongoing study conducted in an urban district.[30] This underscores the need for, and usefulness of, utilization of climate parameters in disease surveillance and preparedness in the country.

Given the heavy burden of disease occurring at young ages and the distinct strains of dengue virus circulating locally, it is important to note that, at the very least, pilot vaccination projects should be conducted in such settings, in order to make decisions about how best to introduce future dengue vaccines.

FRAMEWORK FOR ACTION

Repeated epidemics and increasing endemicity, possibly leading to more severe disease outcomes, make dengue prevention and control a challenging proposition to any lower-middle-income nation. It is imperative that available vector-control strategies use multisectoral involvement, while long-term multisectoral involvement needs substantial responsibility and accountability. Despite the awareness created, getting the community to respond on their part remains a key challenge. Although vaccine introduction has become a possibility, it will need time to make a significant contribution as a primary prevention strategy. Therefore, the health sector is expected to strive to diagnose dengue early and improve clinical management, so that the severity of disease, as well as its case-fatality can be minimized. In addition, introduction of new control and prevention interventions using an evidence-based decision-making process remains an important task of the health sector. All other stakeholders must concentrate on ways to make the necessary environmental changes from positive to negative vector breeding, and adopt new technologies on water management, waste management and building construction and maintenance. To this end, the authors believe that the WHO *Global strategy for dengue prevention and control, 2012–2020* provides a good platform to reverse the growing trend.[31] As such, in order to achieve and maintain a mortality rate below 0.1%, to bring down the current morbidity level (i.e. reported average for the past 5 years) by 50% by 2020, and to strengthen surveillance for prevention and control, Sri Lanka has reviewed its national strategic framework (see Fig. 1).[32]

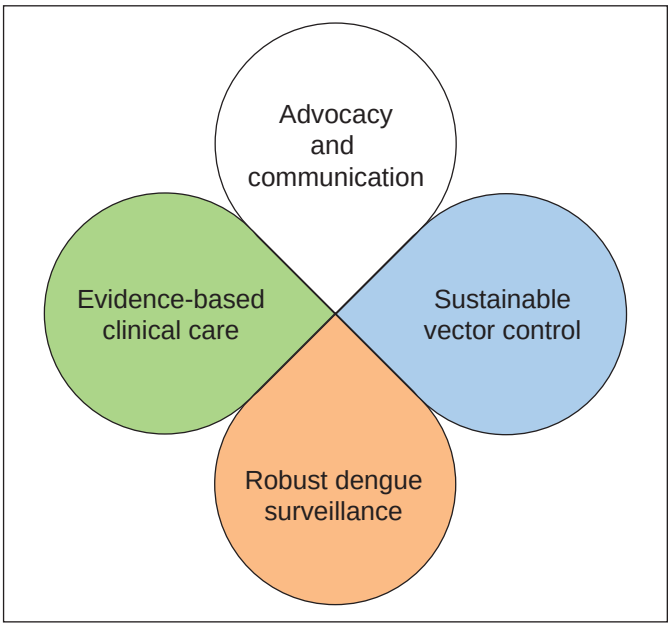

Fig. 1. Key strategies for dengue prevention and control, 2016–2020

Reducing mortality

Lowering the mortality from the current case-fatality rate of 0.2% to 0.05% is the country's top priority. Early detection and standardized management of DHF based on national guidelines have significantly contributed to lowering the mortality over the past few years. In order to minimize dengue-related deaths during the next 5 years, the health sector has to further strengthen health care and laboratory capacities for early diagnosis through enhanced fever screening and emergency care at the level of first contact. Establishment of clinical management training centres in each of the nine provinces in the country; publishing and disseminating scenario-based case-management training guides; providing hands-on training to all levels of clinical workers; and increasing the number of high-dependency units in every secondary care facility across the country, in order to minimize unnecessary referrals, are several important actions for consideration.

A pool of clinical experts will be identified who are trained and skilled to provide a 24-h helpline to all clinicians serving small institutions, including private-sector facilities. Enhancing laboratory surveillance in existing facilities at state and private-sector institutions, and improving first-contact screening through standardized use of rapid diagnostic tests, especially in non-endemic areas, will help to improve early identification, while enhancing specificity. Further, a satellite case-management system will be developed for smaller institutions and general practitioners managing non-severe and recovering dengue patients. In-depth technical investigation into all suspected dengue deaths, and continuous community awareness on early health-care seeking, will not be overlooked. Mortality- and morbidity-based national quality indicators will be agreed upon by all levels of clinical care setting, including private-sector institutions and general practitioners. Avoiding the use of unconventional treatment modalities and nonsteroidal anti-inflammatory drugs for presumptive dengue will be adopted.

Reduction of morbidity

The task of reducing dengue morbidity is equally challenging and requires adaptation of specific collaborative actions. Multiple opportunities have opened up in terms of advocacy, social mobilization and legislation, with the presidential task force providing a platform for both intra- and intersectoral collaboration. Making maximum use of the opportunity created to forecast, detect and curtail outbreaks early, an evidence-based decision-making process will be developed. For this purpose, the country will work on three dimensions: risk mapping, innovation and risk modification (see Fig. 2).

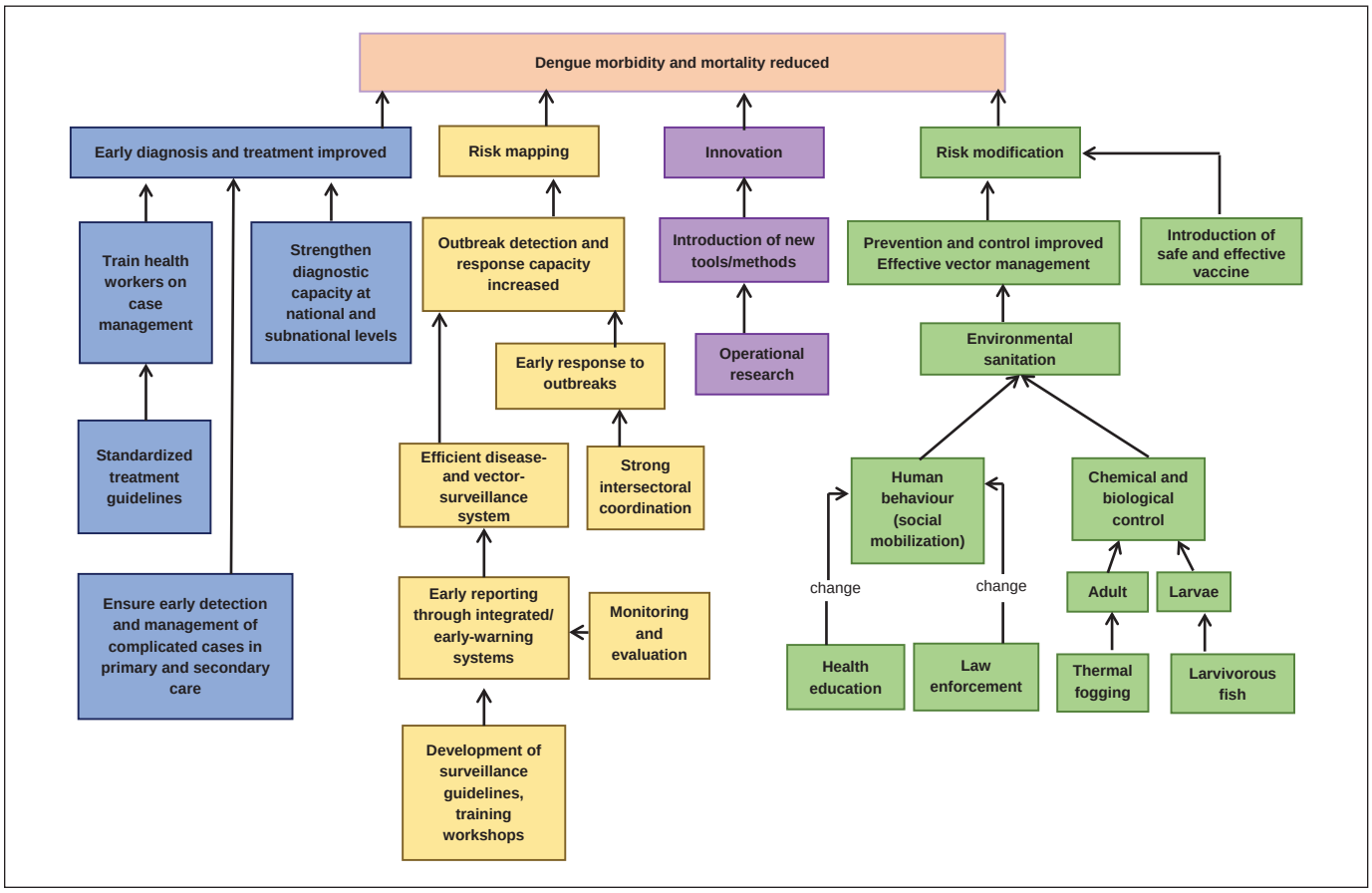

Fig. 2. Logic framework for dengue prevention and control, 2016–2020

Risk mapping

Current activities related to control and prevention are carried out based on a more general process of ranking risk as priority high-risk, high-risk and low-risk areas, decided mainly upon historical outbreaks and the number of dengue cases reported in the past few years for each geographic health division. A more scientific real-time risk-mapping system will enable better resource allocation, as well as timely interventions. Development of a composite scoring system using the rich epidemiological and entomological data available, and a divisional high-risk approach that has already been adopted, would enable identification of the smallest geographic areas for proactive interventions. To this end, a composite risk mapping for action, based on predetermined criteria, will help not only objective interventions but also indicator-based monitoring by supervisory staff. The population density of the locality; the proportion of reported dengue cases in individuals below 15 years of age (indicating high local transmission); and the premises index, indicating the abundance in vector habitats during the current year and existence of additional potential breeding sites such as construction sites, schools and bare land, would collectively give an indication of the additional risk of transmission in that particular location. This background information will help the public health fieldworkers to make quick decisions on the intensity of control measures to be exercised in such localities (outbreak clusters mitigation). In response, source-reduction activities for *Aedes* breeding, use of adult and larval mosquito-control measures, communication using public address systems, and taking legal action against repeated offenders are important considerations. To ensure effective and sustainable execution, trained and committed field inspection teams will be established in highly affected divisions, on a priority basis, by recruiting additional staff.

Innovation

Further strengthening of disease surveillance will be ensured by the introduction of modern information technology and diagnostics. These new technologies will be applied to all sentinel reporting sites and also expanded into the private-sector institutions. Satellite technological advancements for mapping climate parameters will be used to predict and monitor trends and outbreaks of the disease.

Introduction of a mosquito inspection card through young schoolchildren, as a curriculum-based activity, is expected to bring about behavioural change in families, encouraging greater community participation through regular inspection of their surroundings. By developing a mobile application for the community to report potential *Aedes* breeding habitats in their own premises, the school card system will be taken a step further. A gradual change in the community to be more socially responsible will be expected through these novel campaigns, which will be monitored regularly by both local and higher-level public health workers.

Risk modification

Urban Sri Lanka has a growing population density, with a rapid and large demand for urbanization. The process of urbanization over many decades has been largely unplanned and the urban lifestyle is frequently not environmentally friendly. Expansion of the urban lifestyle to peri-urban areas is spatially extending the risk of dengue. All these factors contribute to an abundance of breeding places for *Aedes* mosquitoes. Rapid urbanization is probably one of the main drivers of dengue, resulting in public health and built-environment professionals working more closely together than ever before to address the needs of the communities they serve. This new relationship will be further encouraged and facilitated to ensure a well-integrated approach to issues relating to the built environment.[33] Sri Lanka has passed a number of laws and regulations for prevention and control of mosquito breeding, which will be further strengthened in view of future demands. It is important to pass an act that will help to regulate the use of roof gutters for new building developments, to implement new guidelines, and to develop an efficient and effective system for maintaining existing roof gutters. Further, it is essential to exercise strict laws for maintaining construction sites free of mosquito breeding during the entire period of construction. Emerging new horizons and challenges facing Sri Lanka over the coming 5 years, with mega-cities, port cities and both public and private economic development plans, will no doubt be testified by the sustained effectiveness of the proposed approaches for dengue prevention.

CONCLUSION

The intention of this perspective is not to give an exhaustive list of strategies and activities for dengue prevention and control adopted in Sri Lanka. No doubt many nations have established multiple approaches thus far, to strengthen clinical management to reduce mortality, and vector-control interventions to minimize morbidity. However, sustaining such interventions needs meticulous planning and a holistic approach in implementation, with contributions from multiple stakeholders. Sri Lanka wishes to continue the partnership with WHO and other collaborators in the fight against dengue, utilizing both old and new interventions in the dengue-prevention and control pipeline.

In coming years, the country will pay more attention to reducing morbidity, which is a challenging task. However, with the new strategies of risk mapping, innovation and risk modification, more positive results should be expected. One would also expect that, with a reduction in morbidity, the country can focus in parallel on further improving case-management, leading to the most vital task – the reduction of mortality, where the highest public and media concerns are raised. None of the above would be achieved without two important factors: adequate funds and availability of resources, and a trained and skilled workforce. While the first is more within the political and management radar, human-resource mobility is highly dependent on individuals. It is hoped that the country will move forward with these two requirements in harmony, to achieve the goal of eradication of dengue as a public health problem in the country.

REFERENCES

1. SEARO dengue situation update, 24 September 2012. New Delhi: World Health Organization Regional Office for South-East Asia; 2012 (http://www.searo.who.int/entity/vector_borne_tropical_diseases/data/seardengueupdate.pdf, accessed 8 July 2016).
2. World Health Organization Regional Office for South-East Asia Regional Office. Dengue fact sheet (http://www.searo.who.int/entity/vector_borne_tropical_diseases/data/data_factsheet/, accessed 8 July 2016)
3. Vitarana T, Jayakura WS, Withane N. Historical account of dengue hemorrhagic fever in Sri Lanka. Dengue Bulletin. 1997;21:117–8.
4. Kanakaratne N, Wahala WM, Messer WB, Tissera HA, Shahani A, Abeysinghe N et al. Severe dengue epidemics in Sri Lanka, 2003–2006. Emerg Infect Dis. 2009;15(2):192–9.
5. Disease surveillance trends. Dengue. Colombo: Epidemiology Unit Ministry of Health; 2011 (http://www.epid.gov.lk/web/index.php?option=com_casesanddeaths&Itemid=448&lang=en, accessed 8 July 2016).
6. Tissera H, Amarasinghe A, Gunasena S, De Silva AD, Yee LW, Sessions O et al. Laboratory-enhanced dengue sentinel surveillance in Colombo District, Sri Lanka: 2012–2014. PLoS Negl Trop Dis. 2016;10(2):e0004477. doi:10.1371/journal.pntd.0004477.
7. Kyle JL, Harris E. Global spread and persistence of dengue. Annu Rev Microbiol. 2008;62:71–92. doi:10.1146/annurev.micro.62.081307.163005.
8. Lee KS, Lai YL, Lo S, Barkham T, Aw P, Ooi PL et al. Dengue virus surveillance for early warning, Singapore. Emerg Infect Dis. 2010;16:847–9. doi:10.3201/eid1605.091006.
9. Manokaran G, Finol E, Wang C, Gunaratne J, Bahl J, Ong EZ et al. Dengue subgenomic RNA binds TRIM25 to inhibit interferon expression for epidemiological fitness. Science. 2015;350:217–21. doi:10.1126/science.aab3369.
10. Messer WB, Gubler DJ, Harris E, Sivanathan K, de Silva AM. Emergence and global spread of a dengue serotype 3, subtype III virus. Emerg Infect. Dis. 2003;9:800–9.
11. Tissera HA, Ooi EE, Gubler DJ, Tan Y, Logendra B, Wahala WM et al. New dengue virus type 1 genotype in Colombo, Sri Lanka. Emerg Infect Dis. 2011;17(11):2053–5. doi:10.3201/eid1711.101893.
12. Nimmannitya S. Clinical spectrum and management of dengue haemorrhagic fever. Southeast Asian J Trop Med Public Health. 1987;18:392–7.
13. Halstead SB. Dengue. Lancet. 2007;370:1644–52.
14. Reiter P. Yellow fever and dengue: a threat to Europe? Euro Surveill. 2010:15(10):19509.
15. External in-depth review of dengue fever/dengue haemorrhagic fever control programme in Sri Lanka. New Delhi: World Health Organization Regional Office for South-East Asia; 2005.
16. The national strategic plan for dengue prevention and control in Sri Lanka 2011–2015. WER Sri Lanka. 2014;41(14):1–4.
17. HA Tissera, PC Samaraweera, NWAN Wijesekara, BDW Jayamanne, MPPU Chulasiri, WCD Botheju et al. Civil-military cooperation (CIMIC) for an emergency operation against a dengue outbreak in the western province, Sri Lanka. Dengue Bulletin. 2014;38:64–77.
18. Capeding MR, L'Azou M, Manalaysay M, Vince-Woo CR, Rivera RG, Kristy Sy A et al. Laboratory-confirmed dengue in children in three regional hospitals in the Philippines in 2009–2010. Pediatr Infect Dis J. 2015;34:1145–51. doi:10.1097/INF.0000000000000810.
19. National guidelines. Guidelines on management of dengue fever & dengue haemorrhagic fever in children and adolescents. Colombo: Epidemiology Unit Ministry of Health; 2012 (http://epid.gov.lk/web/images/pdf/Publication/gmdfca12.pdf, accessed 8 July 2016).
20. National guidelines. Guidelines on management of dengue fever & dengue haemorrhagic fever in adults. Colombo: Epidemiology Unit Ministry of Health (http://epid.gov.lk/web/images/pdf/Publication/guidelines_for_the_management_of_df_and_dhf_in_adults.pdf, accessed 8 July 2016).
21. Arunachalama N, Tana S, Espino F, Kittayapong P, Abeyewickrem W, Wai KT et al. Eco-bio-social determinants of dengue vector breeding: a multicountry study in urban and periurban Asia. Bull World Health Organ. 2010;88(3):173–84. doi:10.2471/BLT.09.067892.
22. Thalagala N, Tissera H, Palihawadana P, Amarasinghe A, Ambagahawita A, Wilder-Smith et al. Costs of dengue control activities and hospitalizations in the public health sector during an epidemic year in urban Sri Lanka. PLoS Negl Trop Dis. 2016;10(2):e0004466. doi:10.147/journal. Pntd.0004466.
23. Khan MA, Ellis EM, Tissera HA, Alvi MY, Rahman FF, Masud F et al. Emergence and diversification of dengue 2 cosmopolitan genotype in Pakistan, 2011. PLoS One. 2013;8(3):e56391. doi:10.1371/journal.pone.0056391.
24. Pakistan Voice. Sri Lankan experts fly to Pakistan to battle dengue crisis. Asian Correspondent. 15 September 2011 (https://asiancorrespondent.com/2011/09/sri-lanka-comes-to-rescue-pakistan-from-dengue-virus/ accessed 8 July 2016).
25. Wilder-Smith A, Renhorn KE, Tissera H, Abu Bakar S, Alphey L, Kittayapong P et al. Dengue Tools: innovative tools and strategies for the surveillance and control of dengue. Glob Health Action. 2012;5. doi:10.3402/gha.v5i0.17273.
26. Tissera HA, Tam CT, Amarasinghe A, De Silva AD, de Silva AM, Letsone GW et al. Surveillance of dengue in a community cohort in Metropolitan Colombo, Sri Lanka: part I methods and study population. Dengue Bulletin. 2013;37:141–59.
27. Tissera HA, De Silva AD, Abeysinghe MR, de Silva AM, Palihawadana P, Gunasena S et al. Third Vaccine Global Congress, Singapore 2009. Dengue surveillance in Colombo, Sri Lanka: baseline seroprevalence among children. Procedia Vaccinol. 2010;2(1):109–12. doi:10.1016/j.provac.2010.03.020.
28. Tam CC, Tissera H, de Silva AM, De Silva AD, Margolis HS, Amarasinge A. Estimates of dengue force of infection in children in Colombo, Sri Lanka. PLoS Negl Trop Dis. 2013;7(6):e2259. doi:10.1371/journal.pntd.0002259.
29. Tissera H, Amarasinghe A, De Silva AD, Kariyawasam P, Corbett KS, Katzelnick L et al. Burden of dengue infection and disease in a pediatric cohort in urban Sri Lanka. Am J Trop Med Hyg. 2014;91(1):132–7. doi:10.4269/ajtmh.13–0540.
30. Liyanage P, Tissera H, Sewe M, Amarasinghe A, Palihawadana P, Wilder-Smith A et al. A hierarchical analysis of the temporal and spatial influence of weather patterns on dengue in Kalutara District, Sri Lanka. J Environ Res Public Health. 2016 (in press).
31. Global strategy for dengue prevention and control 2012–2020. WHO Geneva: World Health Organization; 2012 (http://apps.who.int/iris/bitstream/10665/75303/1/9789241504034_eng.pdf, accessed 8 July 2016).
32. Sri Lanka: Strategic Framework for Dengue Prevention and Control, 2016–2020 (draft). Colombo: Ministry of Health; 2016 (in press).
33. Rao M, Prasad S, Adshead F, Tissera H. The built environment and health. Lancet. 2007;37(9593):1111–3.

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