Immediate cost of dengue to Malaysia and Thailand: An estimate

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Abstract

We have analysed the average annual cost of dengue in Malaysia during the period 2002–2007 and in Thailand between 2000 and 2005. The key cost components, estimated by combining existing data from both published and unpublished studies, consist of: (i) costs of non-fatal illness; (ii) vector (Aedes mosquitoes) control costs; and (iii) research and development (R&D) costs incurred by government institutions.

We found the immediate cost of dengue to Malaysia to be in the range of US$ 88 million to US$ 215 million (mean US$ 133 million) per annum. For Thailand, the corresponding range is US$ 56 million to US$ 264 million (mean US$ 135 million) per annum. For the period analysed, Thailand has 3.6 times more total cases of dengue, but Malaysia has a 4.6 times higher cost per case. In Malaysia, the most important parameters creating uncertainty in the immediate cost are reporting rate, hospitalization rate, and cost per ambulatory case. The corresponding parameters in Thailand are cost per ambulatory case, cost per hospitalized case, and reporting rate. Better estimates of cost per ambulatory case and reporting rate are therefore needed for both countries. Future studies should also refine the estimates of hospitalization rate in Malaysia and the cost per hospitalized case in Thailand.

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Introduction

In two previous publications we developed the RUHA framework (defined below) to incorporate disease underreporting in estimating the cost of illness from certain mosquito-borne diseases, and applied it to dengue and chikungunya in India.[1,2] This paper uses this approach to examine the immediate costs of dengue in two heavily affected countries in South-East Asia, viz., Malaysia and Thailand.

Methods

Estimating key cost parameters

Previous studies have reported dengue costs for a specific year, but we have analysed the average cost over several years to reduce the effect of year-to-year fluctuations caused by the tendency of dengue to occur in cycles.[3] Based on data availability, we have chosen the period 2002–2007 for Malaysia and 2000–2005 for Thailand. From a societal perspective, the key cost components consisted of: (i) costs of non-fatal illness (i.e. direct and indirect health-care costs due to hospitalized and ambulatory cases, both reported and unreported); (ii) vector (Aedes) control costs (i.e. inspections and enforcement, fumigation, household insecticides, private sector vector control and the government’s communication-for-behavioural-impact (COMBI) efforts); and (iii) research and development (R&D) costs incurred by government institutions. This is consistent with Haddix et al.[4] who have considered cost of illness and cost of intervention measures in their analysis.

These components were estimated by combining data from various studies (both published and unpublished) where available. If unavailable, trends/data from comparable countries in the region were used to obtain a range of values, which were then subjected to a Monte Carlo sensitivity analysis. For comparison, the impact of a major outbreak on tourism revenues[2] has been included in the epilogue. All cost estimates have been inflation-adjusted to 2008 Malaysian Ringgit (MYR) and Thai Baht (THB), and final values have been reported in US dollars, at the exchange rates for 2008 (exchange rates 3.22 MYR/US$ and 33.6 THB/US$).

Illness costs

Illness costs are determined by three inputs: (i) a “RUHA matrix” (defined below); (ii) the reported number of cases, and (iii) direct costs (e.g. medical treatment, drugs, and transportation) and indirect costs (e.g. income and value of time lost by patients/household members) of hospitalized as well as ambulatory cases. The RUHA matrix shows the shares of reported (R) and unreported (U) hospitalized (H) and ambulatory (A) cases.

Malaysia’s immediate cost of dengue is substantial and is equivalent to 3%–7% of the government’s spending on health care. According to our estimates the illness costs due to dengue are 11 times (range 5 to 28 times) the amount of government spending on Aedes vector control in Malaysia, and 13 times (range 1 to 106 times) the government’s spending on Aedes vector control in Thailand. This relationship shows that increased investment on prevention could potentially generate large offsets in illness costs. In addition to the immediate costs reported here, dengue may also adversely impact tourism and create emotional and long-term burdens on families affected by illness and deaths.

Keywords: Burden; dengue; immediate costs; Malaysia; Monte Carlo; RUHA matrix; Thailand.
We have analysed these proportions using dimensionless analysis (or ratio analysis). We have used the ‘RUHA matrix’ approach, similar to Mavalankar et al.,[1] as a useful tool for combining cost studies, filling gaps in data and making comparisons across countries.

Monte Carlo sensitivity analysis

A Monte Carlo sensitivity analysis was carried out (@Risk software version 5.0.1, Palisade Corporation, USA) to determine how uncertainties in cost parameters affect the total cost of illness (similar to Rafael et al.[5] and Mavalankar et al.[1]). Fifty-five and 50 simulations were performed (five per input) for Malaysia and Thailand respectively, each with 10 000 iterations, and the mean of the total cost was used as a tracking variable in the simulations. For each iteration, values for the parameters were independently drawn from the Beta-PERT distribution.[6] The Beta-PERT distribution is defined by minimum, most likely and maximum values which are relatively uncomplicated to estimate; it is also considered preferable to the triangular distribution (for instance, Rafael et al.[5]) because the smooth shape of the curve places less emphasis in the direction of any possible skew.

Results

RUHA matrix for Malaysia and Thailand

Table 1, panel 1a presents an initial RUHA matrix for Malaysia based on a preliminary study in a public hospital by Shepard et al.[7] Comparing patterns from neighbouring Thailand (Table 2), in which a careful population-based study was reported,[8,9] Table 1, panel 1a appears to have underestimated the UA cases because it did not account for cases treated solely in private clinics and private hospitals. The Ministry of Health, Malaysia[10] has estimated that the public sector bears 39.5% of the ambulatory care costs; so we have refined the RUHA matrix by adding 69 private sector ambulatory cases (all assumed unreported) to the 45 public sector ambulatory cases studied by Shepard et al.[7] This refined RUHA matrix for Malaysia (Table 1, panel 1b) is more similar to the one constructed for Thailand (Table 2).

Reported cases

The number of reported cases for Malaysia and Thailand for recent years are shown in Table 3. The number of reported cases in Malaysia during 2002–2007 varied from 31 545 to 50 341 (mean 37 793) per annum, and these were assumed to be mostly hospitalized cases in public sector facilities.[7] Unreported cases have been assumed to vary from year to year in proportion to reported cases. In Thailand, the number of reported cases during 2000–2005 varied substantially–from 18 617 to 139 327 (mean 68 028) per annum.

Costs per case

Both hospitalized and ambulatory cases have direct and indirect cost components, and their estimates from public sector hospitals in Malaysia[12] are shown in Table 4. As these authors have estimated the ambulatory cost from reported cases, the reporting rate of ambulatory cases has been modelled to have a medium to large correlation (following Cohen 1988[15]) with the average cost of an ambulatory case. This assumption would result in a conservative estimate of the national cost. For Thailand, the maximum, minimum and most likely values of hospitalized and ambulatory costs per case have been taken from previous reports.[9,12,16]
Table 1: RUHA matrices for Malaysia

<table>
<thead>
<tr>
<th></th>
<th>Reported</th>
<th>Unreported</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a: Preliminary (not accounting for UA cases in private facilities)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitalized</td>
<td>43%</td>
<td>21%</td>
<td>64%</td>
</tr>
<tr>
<td>Ambulatory</td>
<td>5%</td>
<td>31%</td>
<td>36%</td>
</tr>
<tr>
<td>Sum</td>
<td>48%</td>
<td>52%</td>
<td>100%</td>
</tr>
</tbody>
</table>

1b: Refined (accounting for UA cases in private facilities)*

<table>
<thead>
<tr>
<th></th>
<th>Reported</th>
<th>Unreported</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitalized</td>
<td>28%</td>
<td>13%</td>
<td>41%b</td>
</tr>
<tr>
<td>Ambulatory</td>
<td>3%</td>
<td>56%</td>
<td>59%</td>
</tr>
<tr>
<td>Sum</td>
<td>31%c</td>
<td>69%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Notes to Table 1: In Table 1a, 100% = 124 cases; bold values from studies; values not in bold are calculated; Source: Shepard et al.[7] In Table 1b, 100% = 193 cases; bold values from studies; values not in bold are calculated.

*aWe assumed the public sector’s share for ambulatory care for subsequently hospitalized patients of 39%[7] would apply to all ambulatory cases. Recognizing the uncertainty in our assumption, our simulations varied this parameter over the range of 30% to 50%. As home-care patients (who do not visit any health-care facilities) were not included, this RUHA matrix is a conservative estimate.

*bBased on Anderson et al.[8] the 25% hospitalization rate has been taken to be the most likely estimate for the share of dengue patients who are hospitalized in Thailand. Their study included home-care patients, therefore 25% was also taken to be the most likely estimate for Malaysia. 41% (obtained in the revised RUHA matrix) has been taken as the maximum estimate of the share of dengue patients hospitalized in Malaysia. The data from Malaysia reported by Lum et al.[11] Suaya et al.[12] and Shepard et al.[7] are consistent with this assumption. The corresponding hospitalization rate of 20% was used by Suaya et al.[13] for Cambodia, which was taken as the minimum for Malaysia and Thailand.

*cThe range of 7%–20% was considered by Clark et al.[9] in their study of Thailand, so this range has been used for that country, with 10% as the most likely value. The values of 10%–31% have been used as the range for Malaysia with 20% as the most likely estimate.

Table 2: RUHA matrix for Thailand*

<table>
<thead>
<tr>
<th></th>
<th>Reported</th>
<th>Unreported</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitalized</td>
<td>9%b</td>
<td>16%</td>
<td>25%cd</td>
</tr>
<tr>
<td>Ambulatory</td>
<td>1%</td>
<td>74%</td>
<td>75%</td>
</tr>
<tr>
<td>Sum</td>
<td>10%e</td>
<td>90%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Notes to Table 2: Bold values from studies; values not in bold are calculated; Sources*: Anderson et al.[8] and Clark et al.[9]. These two sources have been assumed to be consistent with each other. Garg et al.[14] have also combined percentages from these two studies.

*bRatio of hospitalized cases to reported cases has been taken as 0.9 based on preliminary data from Malaysia summarized by Shepard et al.[7]: out of 60 reported cases 54 were hospitalized.

*cSource: Anderson et al.[8]

*dA comparable hospitalization rate of 20% was used by Suaya et al.[12] for Cambodia.

*eSource: Clark et al.[9] report a range 7%–20%.
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**Table 3:** Reported dengue cases obtained from Malaysia and Thailand

<table>
<thead>
<tr>
<th>Year</th>
<th>Malaysia</th>
<th>Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>NC</td>
<td>18,617</td>
</tr>
<tr>
<td>2001</td>
<td>NC</td>
<td>139,327</td>
</tr>
<tr>
<td>2002</td>
<td>32,767</td>
<td>114,800</td>
</tr>
<tr>
<td>2003</td>
<td>31,545</td>
<td>62,767</td>
</tr>
<tr>
<td>2004</td>
<td>33,895</td>
<td>38,367</td>
</tr>
<tr>
<td>2005</td>
<td>39,654</td>
<td>34,291</td>
</tr>
<tr>
<td>2006</td>
<td>38,556</td>
<td>NC</td>
</tr>
<tr>
<td>2007</td>
<td>50,341</td>
<td>NC</td>
</tr>
</tbody>
</table>

NC: Not considered for the study as data were not available.

**Aedes control costs**

Table 5 shows the cost parameters that contribute to vector (*Aedes*) control costs. A large correlation (following Cohen[15]) was used between government expenditure on *Aedes* control (parameters in section 1.1 in Table 5) and reported annual dengue cases. Market size data did not indicate any obvious dependence between household insecticide spending and the number of reported dengue cases; hence, no correlation was used to relate these. The total market size of household insecticides has been reported by the Malaysian CropLife & Public Health Association (MCPA), and we have considered 10% of these household insecticides to be used for dengue and chikungunya control.

**Table 4:** Direct and indirect costs per case for hospitalized and ambulatory cases (US$)

<table>
<thead>
<tr>
<th>Cost component</th>
<th>Malaysia&lt;sup&gt;a&lt;/sup&gt; (most likely)</th>
<th>Malaysia&lt;sup&gt;b&lt;/sup&gt; (range)</th>
<th>Thailand&lt;sup&gt;c&lt;/sup&gt; (most likely)</th>
<th>Thailand&lt;sup&gt;d&lt;/sup&gt; (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hospitalized</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>1259</td>
<td>1101–1259</td>
<td>208</td>
<td>118–794</td>
</tr>
<tr>
<td>Indirect</td>
<td>158</td>
<td>0%–100%&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ambulatory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>174</td>
<td>139–422</td>
<td>60.5</td>
<td>22.4–341.2</td>
</tr>
<tr>
<td>Indirect</td>
<td>283</td>
<td>0%–100%&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td></td>
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</tbody>
</table>

Notes to Table 4:  
<sup>a</sup>The University Malaya Medical Centre (UMMC), collaborating with two Ministry of Health hospitals (in Ampang and Klang), found that the number of investigations and management of patients were more or less similar in all locations studied (Lucy Lum, unpublished data, 2007). The length of hospital stay was also comparable (in fact slightly shorter in UMMC), therefore, the costs per case in Table 3 would result in a conservative estimate when applied to the entire public and private sector health-care network. Our study also assumes that not all of the direct and indirect costs would apply to all the cases, leading to a conservative estimate of the cost of dengue.

<sup>b</sup>The most likely estimates of hospitalized and ambulatory costs in Thailand have been taken from Okanurak et al.[17]

<sup>c</sup>Minimum costs per case in Thailand have been calculated as the sum of private costs from Clark et al.[9] and public costs from Okanurak et al.[17] Maximum cost per hospitalised case in Thailand has been taken from Suaya et al.[12] Maximum cost per ambulatory case has been calculated based on the results of Suaya et al.[12] using the ratio of hospitalized cost to ambulatory cost. These authors have recently published their work.[18]

<sup>d</sup>This approach is similar to Anderson et al.[8] in assuming that indirect costs vary. 100% is taken as the most likely value in our simulation.

<sup>e</sup>The variation is assumed to be dependent on the reporting rate of ambulatory cases. For the most likely value used in our simulation, home-care patients are assumed to incur 0%, while others incur 100% of direct cost.

**Table 5:** Cost parameters that contribute to vector (*Aedes*) control costs.

<table>
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<tr>
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<th>Malaysia&lt;sup&gt;a&lt;/sup&gt; (most likely)</th>
<th>Malaysia&lt;sup&gt;b&lt;/sup&gt; (range)</th>
<th>Thailand&lt;sup&gt;c&lt;/sup&gt; (most likely)</th>
<th>Thailand&lt;sup&gt;d&lt;/sup&gt; (range)</th>
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The Malaysian household insecticides market size has been adjusted for relative GDP and population in order to estimate the total size of the household insecticides market in Thailand. In order to be conservative, only 7.5% of this market has been considered to be relevant for dengue.

Discussion

Immediate cost of dengue to Malaysia and Thailand

Using Monte Carlo analysis, we have estimated the mean economic cost of dengue to Malaysia as US$ 133 million (range US$ 88 million to US$ 215 million) per annum. Figure 1 shows the variation of total cost resulting from each parameter varying from minimum to maximum. The most important parameters accounting for the variation of the total cost are the reporting rate, the annual variation in reported cases, the hospitalization rate, and cost per ambulatory case. The bulk of the cost (78%) comes from illness; hence a key factor is the low reporting rate for dengue, especially for ambulatory cases.

For Thailand, the estimated mean economic cost of dengue is US$ 135 million (range US$ 56 million to US$ 264 million) per annum (Figure 2). In this case, the most important parameters accounting for the variation of the total cost are cost per ambulatory case, cost per hospitalized case, and reporting rate. The first two factors have become significant due to large differences in the estimates reported by Okanurak et al.[17]
Clark et al.\cite{9} and Suaya et al.\cite{12} – indicating the need for further studies.

Estimates of cost per ambulatory case and reporting rate need to be improved in both countries. In addition, we need better estimates of the hospitalization rate in Malaysia and the cost per hospitalized case in Thailand. Both Figure 1 and Figure 2 show the variation in the mean economic cost of dengue due to “annual variation in the number of reported cases”. This shows that policy-makers should take a longer term view of dengue when allocating funds as the number of cases fluctuate from year to year, especially in Thailand.

Comparing the RUHA matrices for Malaysia (Tables 1) with Thailand (Table 2), we recommend that future studies address the uncertainty in the number of unreported cases, especially unreported ambulatory cases, and that studies similar to Shepard et al.\cite{7} Suaya et al.\cite{12} and Kongsin et al.\cite{16} should be

\hspace{1cm}Figure 1: Sensitivity analysis of the annual cost of dengue to Malaysia (Bars show range from possible variation in each factor)
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**Figure 2:** Sensitivity analysis of the annual cost of dengue to Thailand
(Bars show range from possible variation in each factor)

Carried out to assess the variation in costs per case across the healthcare network.

Another article in this issue of the *Dengue Bulletin* also develops an estimate of the national cost of dengue in Thailand. That estimate, US$ 158 million with a standard deviation of US$ 33 million, is close to the central estimate for Thailand in this article. While both articles rely on some of the same primary data (the initial observations collected by Kongsin et al.), the merger of these data with other information and assumptions was done independently in the two articles. Despite the uncertainties, this agreement suggests that the present findings are plausible.

**Comparison between countries**

The mean number of reported cases per annum in Thailand (68 028 cases for 2000–2005) has been 1.8 times that of Malaysia (37 793 cases for 2002–2007). The reporting rates in Thailand (10%) and Malaysia (20%), given in the notes to Table 1, differ by a factor of 1 to 2. Thus, Thailand has 3.6 times as many total cases. The average cost per case in Malaysia (US$ 445.25) is higher than that of Thailand (US$ 97.38), as shown in Table 4. So Malaysia has a 4.6 times the cost per case. These two offsetting factors are the reason why the total immediate cost of dengue is comparable between these countries, with
The bulk of immediate costs in both countries due to illness – 78% in Malaysia and 76% in Thailand. The mean annual cost of dengue per capita is US$ 5.3 for Malaysia and US$ 2.0 for Thailand. This is not unexpected because the GDP per capita of Malaysia is 1.9 times that of Thailand.

The immediate cost of dengue (US$ 88 million to US$ 215 million per annum) to Malaysia is substantial and amounts to US$ 3.5 to US$ 8.5 per capita and is equivalent to 3%–7% of government spending on healthcare. The mean cost of US$ 5.3 per capita for Malaysia compares closely to the US$ 6.2 estimated by Armien et al. for Panama – an upper-middle income country like Malaysia with comparable GDP per capita (US$ 6717 for Panama, US$ 7605 for Malaysia), with similar costs per case (US$ 1256 and US$ 391 respectively for hospitalized and ambulatory cases in Panama and US$ 1259 and US$ 422 respectively for hospitalized and ambulatory cases in Malaysia), and comparable number of reported annual cases per thousand people (1.7 for Panama, 1.5 for Malaysia) for the study periods. It should be borne in mind that this paper and Armien et al. are not strictly comparable because Armien et al. did not consider several parameters such as annual variation in reported cases, variation in hospitalization rates, and spending on household insecticides. However, they did consider the economic loss due to fatal dengue which is beyond the scope of this paper.

We can also compare our estimates for Malaysia with Brazil – another upper-middle income country with comparable GDP per capita (US$ 8450), and a slightly higher number of reported annual cases (2.2 during 2002–2007) per thousand people. Brazil’s 2002 federal dengue prevention budget was reportedly BRL 1034 million, and the estimate for 2007 is at least BRL 1527 millions. These figures translate to an annual federal spending of US$ 4.3 per capita for dengue prevention in Brazil during 2002–2007. Separate state and municipal budgets for dengue prevention and illness costs are not included in this Brazilian estimate.

In Malaysia, illness costs due to dengue are typically 11 times (range 5 to 28 times) the government spending on Aedes vector control (see Table 5 and Figure 1). Similarly in Thailand, illness costs due to dengue are typically 13 times (range 1 to 106 times) the government spending on Aedes vector control (see Table 5 and Figure 2). This result shows that increased investments in prevention could potentially generate large offsets in illness costs.

**Additional considerations**

There are three additional considerations worth mentioning, but are beyond the scope of the immediate costs. First, this study has not considered chikungunya, another Aedes-borne viral infection, which has affected Malaysia with increasingly bigger outbreaks in recent years: 27 cases in 1999, 227 cases in 2006, and 4271 cases in 2008. Thailand experienced a severe ongoing outbreak with 20 541 reported cases from 23 provinces for the period 1 January 2009 to 20 May 2009. The potential threat of chikungunya can be clearly seen from the experience of Indian Ocean countries such as India which had around 1.5 million suspected cases during 2006–2008, and Réunion Island where one third of the population was affected during the 2005-2006 outbreak. Although dengue and chikungunya are virologically distinct, cases are indeed comparable from disease prevention and management perspectives, therefore policy-makers should consider their socioeconomic impact together.
Secondly, it has been shown elsewhere[2] that a 4% decline in tourists from non-endemic countries would result in a substantial loss of tourism revenue: US$ 65 million for Malaysia and US$ 363 million for Thailand. While all these potential revenue losses do not constitute economic costs, it is nevertheless striking that the impact on tourism is comparable to the total cost of illness estimated by following the traditional approach, limited strictly to economic costs. In other words, the impact on tourism revenues should not be ignored when calculating the burden of infectious diseases.

Finally, we note that the emotional and long-term burden of illness and deaths due to dengue are beyond the scope of this study, therefore we recommend reading this working paper in conjunction with studies that report impact on quality of life,[13] lost DALYs (disability adjusted life years), long-term effects of illness on education and economic growth,[28,29] per capita income,[30,31] foreign direct investment,[28,29] etc. Such long-term effects are likely to be important for chikungunya, as some cases experience persistent joint pain for several months, even years.[1,34]

We hope that our estimate of the immediate cost of dengue will trigger more refined studies on cost of illness, as well as analyses of the cost-effectiveness of vaccines and other interventions to combat these neglected tropical diseases.

Acknowledgements

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