Abstract

**Purpose:** The increasing urbanisation and evolution of dengue vector offers favorable grounds for dengue. In absence of effective vaccine and therapeutic interventions, surveillance and reporting becomes mainstay for dengue management.

**Methods:** Extensive efforts integrated various components (vector, human case, laboratory, environment and virus) of dengue surveillance with existing vector-borne disease surveillance in a large municipal corporation of western India. Approximately 80% private sector was involved to enhance and expand epidemiological picture of dengue transmission. Weekly entomological surveillance for immature and mature forms of *Aedes* mosquito was performed by trained team. Standardised sentinel hospital laboratories confirmed serological diagnosis. Virus serotype surveys and environmental indices were integrated later.

**Results:** Between years 2000-2016, total 24,506 clinically suspected and 3,515 confirmed cases were tested and reported respectively. After 2006, private sector contributed 10970 (40%) suspected and 971 (30%) confirmed cases. The adult vector density emerged as significantly correlated (r=0.67) to dengue cases. Low (<1) level of larval indices; House index (HI), Container’s index (CI) and Breteau index (BI) supported dengue transmission. The virus serotype survey shows predominant DEN-2 strain. The quality controlled and detailed case information guided implementation of prevention and control measure.

**Conclusions:** Integration of dengue surveillance components with special emphasis on private sector leads to better informed program managers and healthcare providers.

**Keywords:** Dengue, Private hospital, Surveillance, Entomological, *Aedes*
spread of dengue epidemics and poses more challenges in implementing vector control measures.\textsuperscript{5,6}

Currently available global data grossly underestimates dengue particularly in an urban set up.\textsuperscript{5,8} India is experiencing a remarkable expansion of urban agglomerations like other tropical countries.\textsuperscript{5,6} In India, the dengue cases are several times more than estimates based on official reporting because a major proportion, 80\%, of disease burden is managed by private medical sector.\textsuperscript{7,10}

In the absence of drug, vaccine and effective adult vector control tools, surveillance becomes an important mainstay in dengue management. By providing correct estimates, trends and early warning signs, surveillance can predict, detect and contain dengue epidemics.\textsuperscript{6,11} Recent review of literature on dengue surveillance recommends the integration of various disease, vector and environment components\textsuperscript{12} with special emphasis on strengthening the existing surveillance system by up scaling the current surveillance methodologies, a quality assured laboratory support and an in built evaluation component.\textsuperscript{12,14} The shift in dengue serotypes and genotypes into the existing surveillance machinery also holds a huge potential.\textsuperscript{4,12,14}

In context of above background, we share the trend of dengue cases over sixteen years from 2000 to 2016 in Surat city, India. After year 2006, efforts were taken to integrate and enhance dengue surveillance strategy with epidemiological (human case), laboratory/ serological, entomological and serotyping/ virus isolation of adult mosquitoes with special efforts to motivate private sector for reporting of dengue suspected and confirmed cases backed by an approved, standardized and quality controlled laboratory support. We envisage that information obtained from epidemiologists, clinicians, entomologists and environmentalists will ensure correct quantification of dengue to plan preparedness and response activities for effective dengue control.

Study Area

Surat is a tropical city on western coastline of Gujarat, India with approximately five million populations. Due to favorable climatic conditions, rapid urbanization, dense population (13684 people per square km), migration and massive construction activities, dengue is fast reemerging as a major challenge.\textsuperscript{15} Compared to only ten cases in year 2000, recently, in year 2016 there were more than 605 confirm dengue cases in city (60 fold increase).

Materials and Methods

Study duration and variables: Surat Municipal Corporation (SMC) has a well-structured separate administrative Vector-borne Disease Control Department (VBDCCD) in addition to Health Department. Over the years, the population of city increased due to migration and expansion of city limits. The WHO and national surveillance guidelines\textsuperscript{16,20} were followed but the number of peripheral health workers (PHWs) and supervisors increased so that the whole city area could be covered fortnightly. The trend of dengue suspected serum and tested (SST) and confirmed cases (CC) was recorded over many years for Surat city but in the present communication we present the data from 2000-16. The private sector, laboratory/ serological, entomological and serotype components were added later in 2006; and integrated with environmental and human case surveillance and reporting (Figure 1).

The human case/ epidemiological surveillance involved data collection from sentinel hospital/ clinic/ physician network of both government (public) and private medical sector. Standard case definition (when a case was considered dengue): Dengue was defined as an acute febrile illness of 2-7 days duration with two or more of the following manifestations: headache, retro-orbital pain, myalgia, arthralgia, rash, hemorrhagic manifestations.\textsuperscript{16,19}

The city area has been divided in zones, wards and then areas; according to number of houses to be covered. Each area is covered by a PHWs; whereby every house in the city is visited once a fortnight by designated PHW to enquire about fever cases\textsuperscript{16} for malaria, other vector-borne diseases and mosquitogenic- water storage practices. PHWs were trained with dengue case definition to find and refer suspected cases to nearby government health centers.

These suspected dengue fever cases were screened by Medical Officers at government health centers and if required referred to tertiary care institutes for healthcare. The tertiary care institutes were government identified sentinel surveillance hospitals (SSHS) to maintain line-listing of all cases and sent the report to the respective health authorities for implementation of remedial vector control measures to interrupt the transmission.\textsuperscript{17,20} But this system could not capture information of people who took care from private health sector.

To address the magnanimous task of getting correct information about all dengue suspects and confirm cases in city, a workshop was organized by program managers and health experts with local medical doctors’ organization to sensitize the private medical practitioners about the emerging problem of dengue in the year 2006. The details of dengue case identification and management guidelines were discussed. All the city hospitals were required to report the dengue suspected and confirmed cases in the standard national guideline format.\textsuperscript{16,19,20}

Each ward office of city, collected health related data from private practitioners and hospitals every day. In addition to daily house survey, the PHWs were required to get information about suspected and confirmed dengue cases.
from private hospitals (already identified as part of dengue surveillance network) and ward offices in their respective areas (Figure 1).

Thus, a human case/ epidemiological surveillance system integrated with private clinician/ hospitals was set up in city utilizing already existing man, material and money resources.

The detailed history and blood samples of dengue suspected cases were collected (by treating physician) during febrile stage, using standard vein puncture method. The cases were diagnosed and confirmed by nationally approved and accredited laboratory surveillance at SSHs. For Serological Diagnosis all suspected cases were tested for dengue specific immunoglobulin M by using IgM antibody capture Enzyme-Linked Immunosorbent Assay (MAC-ELISA) kits through the National Institute of Virology (NIV), as per guidelines. The SSHs are linked to regional Apex Referral Laboratory (ARL) for advanced diagnosis, capacity building, quality assurance and backup support.

Entomological Surveillance: The PHWs carried out mosquito-genic (water storage practices) surveillance; intra and peri-domestic (outdoor) surveys of various types of wet containers for breeding of dengue vector. This data was processed to calculate premises’ (vector) indices for dengue-House Index (HI), Breteau Index (BI) and Container Index (CI).

Specifically trained insect collectors did resting adult mosquito collections with a suction tube (aspirator) from five specified fixed and five random sites (having confirmed dengue cases) per team every day to a total of approximately three thousand sites and 700 man hours monthly to calculate adult vector density.

Serotype survey or virus isolation: Samples of collected mosquitoes were processed at local entomological laboratory, labeled and sent for virus isolation/serotyping by immunofluorescence essay (IFA) and identification of DEN strain by RT-PCR method at NIV after year 2006 only.

Declaration for Ethical Issues: The surveillance activities performed under this study were implemented by city administration under the guidelines of NVBDCP. As per Government Regulations, national program activities are considered beneficial, hence written informed consent is not required. The data collected from people was used for implementing prevention and control measures. For research purpose, the identifiers were removed. All information was kept confidential with access by primary investigator only.

Analysis: The dengue cases were reported as suspected serum tested (SST) and confirmed cases (CCs). All data was entered and analyzed in Microsoft Excel Sheet using descriptive statistics.

The larval indices- House Index (HI)-percent of inspected houses with at least one container positive for immature forms of Aedes; Container Index (CI)- percent of water containers positive for immature forms of Aedes; and Breteau Index (BI)- number of containers positive for immature forms of Aedes per 100 inspected houses, were calculated.

The adult vector density (number of mosquitoes collected divided by man hours spent) was calculated per man hours but demonstrated as per ten man hours in this paper for allowing easy comparison with other indices in a chart/figure (Figure 3 and 4).

Tests of correlation were applied for finding association between dengue cases and vector indices and expressed as ‘r’ (the Pearson’s Correlation Coefficient). Statistically significant p value was <0.05.

Results

Between 2000-2016, total 24,506 suspected serum were tested (SST) and 3,515 confirmed dengue cases (CC) reported showing a rising trend. Between 2006-16 years, 23,535 SST and 3,258 CCs were reported; the private sector contributed to 10,970 (47%) fever cases and 971 (30%) CC. The peak of CC was seen every 3-4 years (Figure 2).

The dengue distribution of public and private sector (2010-14) showed number of suspected cases in private was almost similar to government sector but proportion of confirmed cases was lower in private hospitals. Out of the total suspected children and adult cases, the proportion of positive cases was 5.3% and 6.0% in the private sector and 22.6% and 16.6% in public sector respectively (Table 1).

In mosquito-genic surveillance larval indices stayed above 0.4 for BI; 0.3 for HI and 0.2 for CI in years 2005 to 2014. The adult vector density increased from 0.6 per ten man-hours to 1.0 per ten man-hours density after year 2008, with corresponding increase in dengue cases (Figure 3). On applying statistical tests (Figure 3), the linear density of Adult Aedes showed a significant positive correlation with dengue cases (Coefficient of co-relation ‘r’=0.54).

The mosquito density was minimum in March and maximum (three fold) post rainfall in September and October (Figure 4). This month-wise increase in dengue CCs and adult Aedes density had a positive strong correlation (‘r’= 0.8 for year 2012; ‘r’= 0.8 for year 2013; ‘r’= 0.6 for year 2014) which was statistically significant (p <0.05). This trend continued in all years but in this communication, we have presented analysis of three years 2012-2014 (r=0.67) (Figure 4).

We also analyzed the environmental indices like temperature, humidity, rainfall and rainy days to year-wise occurrence of dengue cases; and found no significant relation. The mean annual temperature for years 2000 to
2016 remained between 23.2°C to 33°C while the average relative humidity was 59% (Figure 5).

The Dengue virus serotype survey reports are positive among adult mosquitoes in years 2006-16; except 2008, 2011 and 2016 (Table 2) and demonstrate DEN-2 most prevalent in vector mosquitoes while DEN-3 and DEN-4 are also present in western parts of city.

**Discussions**

**Table 1. Distribution of dengue suspected and confirmed cases among children and adults**

| Year | Suspected cases (SST) | Confirmed/Positive cases (CC) |
|------|-----------------------|------------------------------|
|      | Children N (%) | Adult N (%) | Total | Children N (%) | Adult N (%) | Total |
| Private hospital |
| 2010 | 41 (16.53) | 207 (83.47) | 248 | 17 (25.37) | 50 (74.63) | 67 |
| 2011 | 66 (91.67) | 6 (8.33) | 72 | 4 (50.00) | 4 (50.00) | 8 |
| 2012 | 200 (17.59) | 937 (82.41) | 1137 | 8 (18.60) | 35 (81.40) | 43 |
| 2013 | 218 (17.11) | 1056 (82.89) | 1274 | 6 (15.79) | 32 (84.21) | 38 |
| 2014 | 238 (23.20) | 788 (76.80) | 1026 | 6 (9.23) | 59 (90.77) | 65 |
| Total | 763 (25.4) | 2994 (75.6) | 3757 | 41 (18.5) | 180 (81.5) | 221 |
| Government hospital |
| 2010 | 96 (7.31) | 1217 (92.69) | 1313 | 57 (15.88) | 302 (84.12) | 359 |
| 2011 | 145 (17.58) | 680 (82.42) | 825 | 21 (33.33) | 42 (66.67) | 63 |
| 2012 | 106 (10.08) | 946 (89.92) | 1052 | 27 (21.95) | 96 (78.05) | 123 |
| 2013 | 243 (18.90) | 1043 (81.10) | 1286 | 76 (27.84) | 230 (72.16) | 306 |
| 2014 | 614 (30.59) | 1393 (69.41) | 2007 | 91 (30.54) | 207 (69.46) | 298 |
| 1204 (18.6) | 5279 (81.4) | 6483 | 272 (31.0) | 877 (69.0) | 1149 |

**Figure 1.** Flow diagram showing integration of dengue surveillance, plan and response activities
Table 2. Results of virus isolation among adult Aedes mosquitoes

| Year | Male | Female | Total | Positive for dengue* | Serotype isolation |
|------|------|--------|-------|----------------------|--------------------|
| 2006 | 23   | 217    | 240   | 6                    | DEN-2              |
| 2007 | 30   | 80     | 110   | 5                    | DEN-2              |
| 2008 | 140  | 409    | 549   | 0                    | DEN-2              |
| 2009 | 212  | 750    | 962   | 10                   | DEN-2              |
| 2010 | 170  | 276    | 446   | 7                    | DEN2, DEN-3 & DEN-4|
| 2011 | 119  | 277    | 396   | 0                    | DEN-2              |
| 2012 | 265  | 693    | 958   | 2                    | DEN-2              |
| 2013 | 305  | 517    | 822   | 3                    | DEN-2              |
| 2014 | 99   | 253    | 352   | 1                    | DEN-2              |
| 2015 | 137  | 591    | 728   | 4                    | DEN-2              |
| 2016 | 149  | 816    | 965   | 0                    |                    |

*Number of female mosquitoes positive for dengue virus.

Figure 2. Stacked column and area wise chart of dengue fever and confirmed cases by public and private sector

Figure 3. Entomological indices and confirmed cases of dengue
The human case surveillance by sentinel hospitals, private doctors and government sector under supervision of Sanitary Inspectors, in their designated city areas, acted as dengue alert system in present study (Figure 1). Approximately, half of 23,525 fever cases (46%) and one-third (30%) of 3,258 dengue CCs during years 2006-2016 were contributed by the private sector (Figure 2). The dengue CCs were diagnosed by uniform standardised laboratories at SSHs. The private-public co-ordination provided a background for vector surveillance and control measures. This may be an important reason that though fever reported (SST) increased but CCs did not increase after 2009 (Figure 2). Other studies also confirm the role of private sector to understand actual dengue case estimates.\textsuperscript{13,24,25} The three-four year trend of increase in CCs (figure 2) was similar to study in Cambodia.\textsuperscript{25} Surveillance is paramount for effective dengue control, and more accurate quantification of dengue allows improved political, financial, and research prioritization and enhanced modeling.\textsuperscript{6,8,9,23} Presently, only public healthcare dengue data is utilized for risk assessment, epidemic response and program evaluation in many nations\textsuperscript{1,10,24} including India, where, almost 80% of urban and peri-urban do not utilize public health care.\textsuperscript{7,9} 

\textit{Aedes} surveillance (Figure 5) reports were consolidated area-wise, zone-wise and then year-wise. The larval indices - HI, CI and BI- stayed <1.00 between years 2005-2016. Similar findings that low levels of larval \textit{Aedes} are capable
of causing epidemics were found by Bowman et al in his systemic review on dengue vector and transmission. This suggests that once the circulation of virus exits in community (human and vector), despite vector control to below threshold levels, the viral transmission continues.

The dengue prevalence showed a significant positive strong correlation (r=0.7) and association with adult Aedes density. (Figure 3 and 4) Aedes is an aggressive multiple biter, capable of trans-ovarian transmission. Previous studies and systematic reviews consider the abundance of adult female mosquitoes as the most appropriate measure of entomologic risk for virus transmission.

The data from integrated dengue surveillance formed basis for Integrated Vector Management (IVM). The anti-larval activity was conducted throughout the year by source reduction and; applying larvicide [Temephos 50%-emulsified concentration at the dosage of 1 ppm] where container source removal was not possible. Anti-adult activities were carried out weekly in areas of confirmed dengue cases by ultralow volume space spray and thermal fogging through vehicle mounted machines using cyphenotherin and other pyrethrum extracts. Fogging was conducted during 10 to 11 AM to coincide with peak biting time of vector. Seventy-five squads, of five to seven workers each, were employed for IVM after 2006. In the absence of an effective drug or vaccine for dengue; vector control becomes critical.

In current study, early rainfall months (June and July) in years 2005-16; were followed with maximum dengue cases because humid climatic conditions increase longevity and breeding activity of dengue vector. This indicates that outbreaks might be predictable by seasonal variations (Figure 5).

The dengue serotypes reports show 38 positive out of 3528 mosquitoes tested from year 2006 to 2016 (Table 2). Despite this low positivity (0.58%) dengue cases persisted as Aedes mosquito frequently and preferentially imbibes human blood and transmit dengue virus to as many as 20 consecutive hosts, within a period of few days. The prevalence of multiple virus serotypes (Den-2, Den-3 and DEN-4) can expose city population to serious dengue illnesses due to second or combined infections. Previous research also shows that serotype changes or reintroductions are positively correlated with dengue incidence.

Though, various components of dengue surveillance were brought together in Surat city over long periods of time which guided prevention and control response of dengue; this study has some limitations. Most important being restricted resources for detailed day-wise and month-wise analysis of all data. The data was collected by a staff of more than seven hundred in five million population city; therefore, some bias could have been introduced even after regular supervision by insecticide officers, medical officers, and independent assessment by medical college teams. Large migratory population and temporary settlements made surveillance and response efforts difficult to sustain.

In conclusion, the current communication deliberates how to develop and utilize private clinician/hospital network, dengue surveillance and standardised laboratory component to enhance and expand the epidemiological picture of dengue transmission in resource-constrained settings. We also make available the dengue data over sixteen years from urban India to allow comparisons and insights internationally. The study shows way ahead that integration of dengue surveillance components leads to better informed program managers and healthcare providers to plan dengue response.

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Conflict of Interest: None

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