Research article

**Measles transmission following the tsunami in a population with a high one-dose vaccination coverage, Tamil Nadu, India 2004–2005**

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**Abstract**

**Background:** On 26 December 2004, a tsunami struck the coast of the state of Tamil Nadu, India, where one-dose measles coverage exceeded 95%. On 29 December, supplemental measles immunization activities targeted children 6 to 60 months of age in affected villages. On 30 December, Cuddalore, a tsunami-affected district in Tamil Nadu reported a cluster of measles cases. We investigated this cluster to estimate the magnitude of the problem and to propose recommendations for control.

**Methods:** We received notification of WHO-defined measles cases through stimulated passive surveillance. We collected information regarding date of onset, age, sex, vaccination status and residence. We collected samples for IgM antibodies and genotype studies. We modeled the accumulation of susceptible individuals over the time on the basis of vaccination coverage, vaccine efficacy and birth rate.

**Results:** We identified 101 measles cases and detected IgM antibodies against measles virus in eight of 11 sera. Cases were reported from tsunami-affected (n = 71) and unaffected villages (n = 30) with attack rates of 1.3 and 1.7 per 1000, respectively. 42% of cases in tsunami-affected villages had an onset date within 14 days of the tsunami. The median ages of case-patients in tsunami-affected and un-affected areas were 54 months and 60 months respectively (p = 0.471). 36% of cases from tsunami-affected areas were above 60 months of age. Phylogenetic analyses indicated that the sequences of virus belonged to genotype D8 that circulated in Tamil Nadu.

**Conclusion:** Measles virus circulated in Cuddalore district following the tsunami, although there was no association between the two events. Transmission despite high one-dose vaccination coverage pointed to the limitations of this vaccination strategy. A second opportunity for measles immunization may help reducing measles mortality and morbidity in such areas. Children from 6 month to 14 years of age must be targeted for supplemental immunization during complex emergencies.
Background
Measles remains an important cause of childhood mortality, especially in developing countries. In 2000, measles killed 770,000 children worldwide, accounting for nearly half of vaccine preventable deaths [1]. Failure to deliver at least one dose of measles vaccine to all infants remains the primary reason for high measles mortality and morbidity in developing countries [2]. Measles vaccination coverage among infants in Southeast Asia and Africa is still low, ranging between 54–55% in 1999 to 65–67% in 2003 [3]. However, Sri Lanka [4], Latin America [5], Romania [6] and South Korea [7], experienced outbreaks of measles in spite of sustained high coverage with single-dose vaccination strategy. Thus, the 2001–2005 WHO/UNICEF strategic plan for measles mortality reduction and regional elimination recommended achieving high routine vaccination coverage (>90%) in every district and ensuring that all children receive a second opportunity for measles immunization [2].

Population movement and high population densities facilitate transmission of the measles virus. Thus, outbreaks of measles are common among refugees and displaced populations [8-11]. Poor nutritional status, also common in these settings, has been associated with an increased risk of death following measles [11,12]. As a result, measles outbreaks are a major killer during complex emergencies. Immunization of children against measles is considered a highly cost-effective priority among displaced populations housed in camps [13]. WHO and UNICEF recommend vaccinating all children from six months through 4 years must be vaccinated, while vaccine availability, funding, human resources and local measles epidemiology may influence the choice of the age groups covered [14].

On 26 December 2004, a tsunami struck the coast of the state of Tamil Nadu, India, affecting more than 896,000 individuals and resulting in 7,983 deaths [15]. Affected individuals were provided with shelter in temporary camps. On 28 December 2004, the Field Epidemiology Training Programme of the National Institute of Epidemiology, Chennai, Tamil Nadu, sent three teams to the districts of Cuddalore, Nagapatinam and Kanyakumari that had been affected by the tsunami to assist district health authorities in (1) stimulating the routine surveillance system so that it would meet the needs of the emergency and (2) responding to outbreaks. On 29 December 2004, health authorities initiated supplemental measles immunization targeting children aged six to 60 months in all tsunami-affected villages in Tamil Nadu. On 30 December 2004, the emergency surveillance system set-up by the Indian Field Epidemiology Training Programme detected a cluster of measles in one of the relief camps in the district of Cuddalore. The estimated measles vaccine coverage exceeded 95% since 1988 in Tamil Nadu. (Director of Public Health, Govt. of Tamil Nadu, unpublished data). We investigated this cluster to estimate the magnitude of the problem and to propose recommendations for control.

Methods
Descriptive epidemiology
We defined a case of measles as per WHO guidelines as the occurrence of fever with maculo-papular rash and at least one of the following: cough, coryza or conjunctivitis in a resident of the Cuddalore district from 26 December 2004 [16]. We received notification of measles cases through the routine passive surveillance system that we stimulated following tsunami by requesting health care facilities in the district to report occurrences of measles and other diseases of epidemic potential [17]. For each case, we collected information regarding date of onset, age, sex, vaccination status and place of residence. We sorted places of residence to determine whether the case occurred in any of the 58 coastal villages declared as tsunami affected (2005 population = 87,284) by the Government of Tamil Nadu [18]. In the absence of reported major measles outbreak since 1988, we modeled the accumulation of children susceptible to measles since 1988, according to census data, population growth rate, birth rate, administrative vaccination coverage for the state of Tamil Nadu and the expected vaccine efficacy of 85% for measles vaccine administered at 9 months of age [19] according to the method proposed by de Quadros [20]. We calculated the coverage of supplementary measles immunization in tsunami-affected areas using the administrative method by dividing the number of doses of vaccine administered during the campaign by the number of children aged six to sixty months in this area. We applied the proportion of population aged 6–60 months in the district to the size of the affected population to calculate number of children in this age group in tsunami-affected area. The administrative coverage may exceed 100% because of census inaccuracies, population movements and vaccination of children beyond the recommended age group.

Laboratory confirmation
We collected blood samples from randomly selected case patients with active clinical measles and examined sera for IgM antibodies against measles virus (Behring, Germany). We collected throat swabs from case patients with active clinical measles and performed RT PCR using N gene primers [21]. We performed the sequence alignment and phylogenetic tree analysis using Clustal X (version 1.83) and MEGA (version, 2.1) software and built a phyloge-
netic tree with standard WHO sequences of each genotype.

**Ethical clearance**

We conducted this investigation under the responsibility of the National Institute of Epidemiology, according to the ethical guidelines for biomedical research on human subjects of Indian council of Medical Research. The National Institute of Epidemiology has its own Ethical Committee. However, this investigation was conducted in the context of a public health response to an outbreak and therefore ethical committee review was not indicated.

**Data analysis**

We entered and analyzed the data using Epi Info software (Version 3.3). We calculated the attack rates for measles in areas affected and un-affected by the tsunami in Cuddalore district using population data obtained from the district health authorities. As the age distribution was not available at the village level, we applied the age distribution of the district to calculate the age-group specific attack rates in affected and unaffected areas. The median ages of measles cases in tsunami affected and un-affected population was compared using non-parametric test.

**Results**

We identified 101 cases that met the WHO case definition for measles. There were no deaths. We collected eleven blood samples from the case-patients for serological testing. Of these, eight were positive for IgM antibodies against measles virus. We took throat swabs from two children with active measles for the isolation of the virus. Phylogenetic analysis indicated that both the sequences of measles virus belonged to genotype D8.

Cases were reported with dates of onset between December 2004 and January 2005 (Figure 1) from tsunami-affected and unaffected areas. In both areas, the number of cases reported peaked during the second week following the first case. In tsunami-affected areas, 30 of the 71 cases (42%) occurred within 14 days of the tsunami. 71 measles cases were reported from 20 tsunami-affected villages (2005 population: 53,104) while the remaining 30 cases were from nine unaffected villages (2005 population: 17,357). The attack rate in tsunami-affected areas was lower than in tsunami un-affected areas, although the difference was not statistically significant (p = 0.24). The median ages of case-patients in tsunami-affected and un-affected areas were 54 months (range: 4 months-12 years) and 60 months (range: 6 months-21 years), respectively (p = 0.471). There was no major difference in the age-specific attack rates in tsunami-affected and unaffected areas (Table-1). 26 of the 71 case patients (36.2%) from tsunami-affected areas and 14 of 30 (46.7%) cases in tsunami unaffected areas were above 60 months of age. Among the 101 cases, three (3%) had vaccination records indicating they had received measles vaccine, three (3%) had vaccination records indicated that they had not received measles vaccine and 95 (94%) had no vaccination records.

The supplementary measles immunization initiated on 29 December 2004 lasted till 9 January 2005 (second week after tsunami). The estimated population of children aged 6 to 60 months in tsunami-affected area was 8803. A total of 10,319 children were administered measles vaccine (Director of Public Health, Govt. of Tamil Nadu, unpublished data). The coverage for the supplementary campaign calculated using the administrative method was 117.2%. The results of our modeled estimate of population size of susceptible children suggested that between 1988 and 2004, the population of susceptible children in the district was 97,401 exceeding the size of two birth cohorts (Table 2).

**Discussion**

Measles virus circulated between December 2004 and February 2005 in tsunami-affected and un-affected areas of the district of Cuddalore, Tamil Nadu. Transmission occurred despite high one-dose measles vaccine coverage in the state. Active surveillance in tsunami affected areas with early case detection and management might have contributed to the absence of fatality. In addition, supplemental measles immunization targeting children between six and sixty months might have decreased the population of susceptible children in tsunami affected areas which might have limited the spread of this cluster.

The findings of the present investigation suggest that measles transmission in the affected area was unrelated to the tsunami for a number of reasons. First, attack rates were not statistically different in tsunami affected and unaffected areas. Second, the attack rate over time showed a
similar pattern in both areas. Third, a large proportion of cases occurred within one incubation period after the occurrence of the tsunami. Fourth, the age distribution of the cases did not differ in tsunami affected and unaffected areas. Finally, the size of shelters in tsunami affected areas in Cuddalore ranged from 115 to 2500 (average: 656) [17]. It was much smaller than the major population concentration usually leading to outbreaks in refugee setting [22].

This cluster of measles occurred despite a high one-dose measles vaccine coverage in Tamil Nadu (Director of Health Services, unpublished data). An independent LQAS vaccine coverage survey conducted in one primary health care center area also confirmed high one-dose coverage in the state [23]. The results of the phylogenetic analysis indicated that both the sequences of measles virus belonged to genotype D8. Genotype D4 and D8 have been isolated from different districts of Tamil Nadu over the last four years from sporadic cases as well during outbreaks (National Institute of Virology, unpublished data). The absence of importation of a new genotype further supports the hypothesis that a measles virus of that genotype circulates in the area despite high one-dose vaccination coverage. Measles transmission in areas with high one-dose vaccination coverage points to

### Table 1: Incidence of measles by age and sex in tsunami affected and un-affected villages of Cuddalore district, Tamil Nadu, December 2004- January 2005

| Age group (years) | Tsunami affected areas | Tsunami un-affected areas |
|-------------------|------------------------|--------------------------|
|                   | Number of cases (%)    | Population | Incidence per 1000 | Number of cases (%) | Population | Incidence per 1000 |
| 0–4               | 31 (43.7)              | 4360       | 7.1                | 11 (36.7)           | 1425       | 7.7                |
| 5–9               | 32 (45.1)              | 4786       | 6.7                | 16 (53.3)           | 1564       | 10.2               |
| 10–14             | 8 (11.3)               | 5138       | 1.6                | 2 (6.7)             | 1679       | 1.2                |
| >14               | 0 (0.0)                | 38820      | 0.0                | 1 (3.3)             | 12689      | 0.1                |

| Sex               | Tsunami affected areas | Tsunami un-affected areas |
|-------------------|------------------------|--------------------------|
| Male              | 32 (45.1)              | 26720       | 1.2                | 16 (53.3)           | 8734       | 1.8                |
| Female            | 39 (54.9)              | 26384       | 1.5                | 14 (46.7)           | 8623       | 1.6                |
| Total             | 71 (100.0)             | 53104       | 1.3                | 30 (100.0)          | 17357      | 1.7                |

### Table 2: Accumulation of children susceptible to measles in the Cuddalore district, Tamil Nadu, India, 1988 – 2004

| Year       | Estimated population# | Birth cohort | Vaccination coverage* | Vaccine efficacy** | Children susceptible | Cumulated susceptible population |
|------------|-----------------------|--------------|------------------------|-------------------|---------------------|----------------------------------|
| 1988       | 2,076,264             | 44,432       | 103.19%                | 85%               | 5,459               | 5,459                            |
| 1989       | 2,091,648             | 46,853       | 105.50%                | 85%               | 4,837               | 10,296                           |
| 1990       | 2,107,146             | 44,461       | 101.67%                | 85%               | 6,038               | 16,334                           |
| 1991       | 2,122,759             | 44,153       | 100.65%                | 85%               | 6,378               | 22,712                           |
| 1992       | 2,138,488             | 44,267       | 104.57%                | 85%               | 4,921               | 27,633                           |
| 1993       | 2,154,333             | 42,009       | 102.70%                | 85%               | 5,337               | 32,970                           |
| 1994       | 2,170,295             | 41,670       | 102.51%                | 85%               | 5,362               | 38,332                           |
| 1995       | 2,186,376             | 44,383       | 104.92%                | 85%               | 4,803               | 43,135                           |
| 1996       | 2,202,576             | 42,289       | 101.57%                | 85%               | 5,779               | 48,913                           |
| 1997       | 2,218,896             | 42,603       | 100.74%                | 85%               | 6,124               | 55,037                           |
| 1998       | 2,235,337             | 42,918       | 99.28%                 | 85%               | 6,700               | 61,737                           |
| 1999       | 2,251,900             | 43,462       | 101.25%                | 85%               | 6,058               | 67,795                           |
| 2000       | 2,268,586             | 43,784       | 101.13%                | 85%               | 6,148               | 73,944                           |
| 2001       | 2,285,395             | 44,108       | 105.18%                | 85%               | 4,674               | 78,617                           |
| 2002       | 2,302,329             | 44,435       | 102.56%                | 85%               | 5,697               | 84,314                           |
| 2003       | 2,319,388             | 44,764       | 101.46%                | 85%               | 6,159               | 90,473                           |
| 2004       | 2,336,574             | 45,096       | 99.57%                 | 85%               | 6,928               | 97,401                           |

#Census data 2001. Population growth rate of 11.19%
*Vaccination coverage using administrative method
**Vaccination between nine and 12 month of age.
opportunities for immunization are important to identify measles immunization in this investigation. Missed opportunities for immunization activities on the dynamic of the outbreak were not able to quantify the impact of supplementary campaigns as the outbreak ended rapidly. More generally, we continued to be stimulated for a number of weeks following the campaign that targeted children of 6–60 months between 29 December 2004 and 9 January 2005 in the affected areas and (2) a practice referred to as ‘ring immunization’ under which children aged 6–60 months of age living within a radius of 5 kilometers of the case of measles. The present cluster of measles was unrelated to the tsunami. The World Health Organization recommends vaccinating children aged six months to 14 years in refugee and internally displaced persons camps [14] but also mentions that age group to be targeted during such campaigns depends on the local epidemiology of the disease. In Tamil Nadu, the high one-dose coverage may have contributed to the decision to restrict the target age group to children 6 to 60 month of age after the tsunami emergency. However, vaccinating children only up to five years of age might have left some children susceptible to measles as more than 36% of the cases were older than five years of age. The results of our investigation support the recommendation to vaccinate children up to 14 years of age during complex emergencies, even if the one-dose coverage is high. It is also necessary that information, education and communication activities targeting mothers as well as health care workers emphasize the importance of vaccination cards to allow appropriate evaluation of vaccination coverage in Tamil Nadu. In the longer term, the ministry of health of the government of India will be examining how best to address measles as a public health problem given the heterogeneity of the country with respect to measles vaccination coverage. While some states will need to focus on increasing the one-dose vaccination coverage, a number of southern states might be considered for second opportunity of measles vaccination.

Conclusion
The present cluster of measles was unrelated to accumulation of susceptible population on account of tsunami. Measles transmission despite high one-dose vaccination coverage points towards the need of second opportunity of measles immunization. During complex emergencies, measles immunization should be offered to children from 6 month to 14 years of age.

Abbreviations
WHO: World Health Organization
UNICEF: United Nations Children’s Fund
PCR: Polymerase Chain Reaction
Conflict of interest
The author(s) declare that they have no competing interests.

Authors’ contributions
AM and MVM were involved in data acquisition, analysis and interpretation of the data, MVM and NSW were involved in drafting the manuscript, NSW carried out laboratory analysis, MDG and YH have made substantial contributions to conception and design of the investigation and revised it critically for intellectual content. All authors read and approved the final manuscript.

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