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# Outbreak response immunisation: the experience of Chad during recurrent measles epidemics in 2005 and 2010

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ABSTRACT

Despite impressive gains in measles control globally, measles epidemics continue to occur in countries with insufficient vaccination coverage. WHO guidelines now recommend outbreak response immunisation (ORI) for controlling measles outbreaks in certain contexts. The objective of this study was to describe late and early response vaccination activities during two consecutive measles outbreaks that occurred in 2005 and 2010 in N'Djamena, Chad. Using Lot Quality Assurance Sampling, vaccination coverage was estimated to be low before the interventions. Following mass vaccination campaigns, measles cases declined. The timeliness and quality of ORI activities are crucial determinants of success. However, effective outbreak response should be accompanied by strong routine vaccination programmes to ensure sustainable high vaccination coverage.


## 1. Introduction

Despite significant progress, measles epidemics continue to occur in countries that have not fully implemented the comprehensive strategy developed by the WHO and the United Nations Children's Fund (UNICEF) for measles control.[1] Recently modified WHO guidelines recommend the use of outbreak response immunisation (ORI) for responding to measles epidemics in urban areas,[2] in addition to reinforced routine immunisation, measles case management and improved surveillance. Vaccination coverage (VC) achieved during the response plays a key role in the number of cases that may potentially be averted. The timing of the intervention is the other major factor to control a measles outbreak.[3]

Here we describe late and early response vaccination activities during two consecutive measles outbreaks in N'djamena, Chad. The aim of this study was to provide insight into the potential impact of ORI according to the timing of the intervention and VC achieved.

## 2. Methods

The city of N'Djamena is divided into four districts, each with a public hospital. There were 29 Centres de santé intégré (CSI), or public health centres, throughout the city in 2005 and 49 in 2010. Estimates of the size and age structure of the population were obtained from the 1993 Chad National Population Census.[4] Assuming a 5.7% annual growth rate, the city population at the time of the epidemic was estimated to be 1 211 116 in 2005 and 1 597 941 in 2010. Surveillance data consisted of reported measles cases to each CSI between Week 1 and Week 25 in 2005 and between Week 1 and Week 17 in 2010. Hospitalised patients were referred by a CSI. Chad has a routine measles vaccination schedule consisting of a single dose at 9–11 months of age, with all children under 5 years of age

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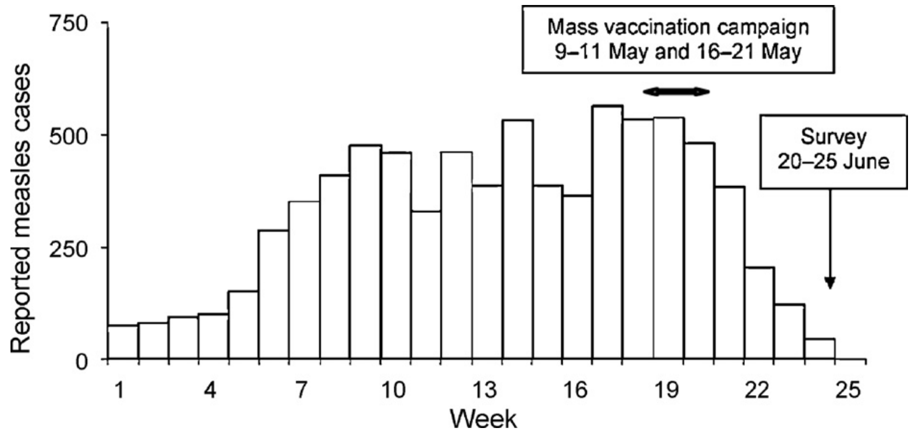


**Figure 1.** Reported measles cases, N'Djamena, Chad, 2005 (6849 patients).

eligible. National coverage for measles in children under 5 was estimated to be 48% in 2005 and 72% and 2009.

In early 2005, and 5 years later in 2010, the surveillance system in Chad identified an increased number of measles cases in the capital, N'Djamena. Measles was laboratory-confirmed at the beginning of each epidemic following the WHO measles surveillance protocol,[1] and subsequent cases were diagnosed clinically using the WHO case definition.[2,5]

In collaboration with the Ministry of Health (MoH), the non-governmental organisation Epicentre/Médecins Sans Frontières (MSF) was involved in the investigation and response to both epidemics. Outbreak response included reinforced case management, free access to treatment and a mass vaccination campaign. Enhanced clinical case management included training and provision of treatment kits comprising antibiotics, paracetamol, vitamin A and oral rehydration salts. The objective of the campaigns was to vaccinate 100% of children living in the city, aged 6–59 months in 2005 and aged 6 months to 15 years in 2010. Vaccination activities were organised during the epidemics, taking place 22 weeks and 8 weeks after the beginning of the epidemic in 2005 and 2010, respectively. Children were vaccinated regardless of previous vaccination status or history of measles illness. VC surveys were conducted immediately after both campaigns using Lot Quality Assurance Sampling (LQAS).[6]

Between January and April, 7822 cases were reported in 2005 and 8481 cases in 2010, corresponding to global attack rates of 64.6 per 10 000 population and 54.5 per 10 000 population, respectively (Figures 1 and 2). Specific attack rates among children under 5 years were estimated to be 295 per 10 000 in 2005 and 221 per 10 000 in 2010, assuming the age group represented 17% and 18.2% of the population in 2005 and 2010, respectively (Ministry of Public Health, Chad). Cases were reported for 24 weeks in 2005 and for 14 weeks in 2010, with peaks occurring at Week 17 and Week 12, respectively. Strengthening of clinical case management was implemented 16 weeks after the epidemic was detected in 2005 and 7 weeks after in 2010. Epidemic curves and the timing of interventions are shown in Figures 1 and 2. Further details of the 2005 epidemic can be found elsewhere.[7,8]

The city was divided into 25 non-overlapping lots based on administrative neighbourhoods with well known boundaries in 2005. In 2010, three additional lots were included in the survey to match the new administrative distribution of the city. When necessary, neighbourhoods were regrouped to create lots of equivalent population size

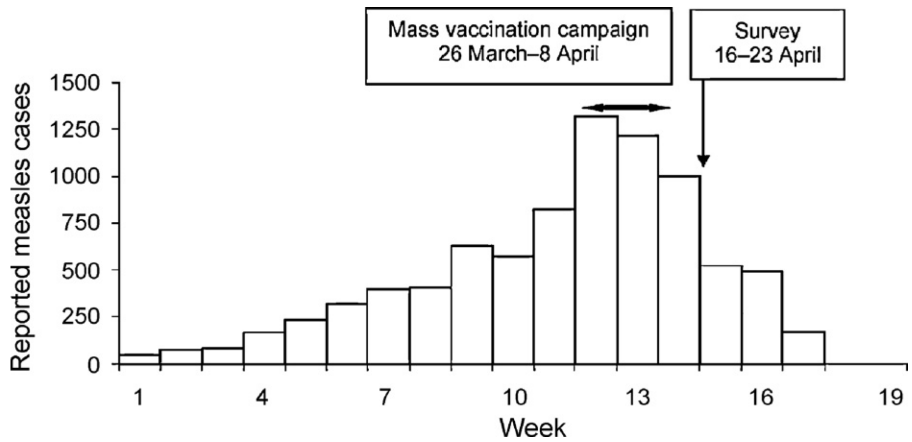


**Figure 2.** Reported measles cases, N'Djamena, Chad, 2010 (7695 patients).

**Table 1**
Number of lots rejected (vaccination coverage <70%) by district and information source for children aged 6–59 months in N'Djamena, Chad, before and after measles mass vaccination campaigns in 2005 and 2010

| District | Lots (*N*) | | Before [*n* (%)] | | | | After [*n* (%)] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2010 | 2005 | | 2010 | | 2005 | | 2010 | |
| | | | Card | Card/recall | Card | Card/recall | Card | Card/recall | Card | Card/recall |
| North | 1 | 1 | 1 (100) | 1 (100) | 1 (100) | 1 (100) | 1 (100) | 1 (100) | 1 (100) | 1 (100) |
| Centre | 14 | 14 | 14 (100) | 14 (100) | 14 (100) | 7 (50) | 14 (100) | 9 (64) | 14 (100) | 2 (14) |
| South | 7 | 8 | 7 (100) | 6 (86) | 8 (100) | 6 (75) | 7 (100) | 0 (0) | 8 (100) | 0 (0) |
| East | 3 | 5 | 3 (100) | 3 (100) | 5 (100) | 3 (60) | 3 (100) | 2 (67) | 5 (100) | 2 (40) |
| N'Djamena (total) | 25 | 28 | 25 (100) | 24 (96) | 28 (100) | 17 (61) | 25 (100) | 12 (48) | 28 (100) | 5 (18) |

and homogeneity. LQAS sample size calculations use two thresholds, an upper threshold to accept lots and a lower threshold to reject lots. In our case, we were interested in only the lower threshold as this would identify where immediate additional vaccination activities were needed. We considered that in lots with VC <70% the population remained at risk of measles. Sample size was calculated using cumulative binomial probabilities.[9] To correctly identify 95% of the lots with low VC (<70%), 65 children had to be sampled in each lot ($\alpha = 0.05$, $\beta = 0.10$). A maximum of 12 unvaccinated children in each lot were allowed, otherwise the lot was considered to have inadequate VC. To calculate the average VC for the city, information was collected for all 65 children in each lot.

A systematic sampling plan was developed to randomly select children within each lot. A starting point in each lot was randomly chosen either by using standard immunisation programme methods[10] (in 2005) or using global positioning system coordinates (in 2010) and the closest compound was visited. A household was defined as a group of people who usually live under the same roof and share meals. If more than one household was present in the same dwelling, one was randomly selected. Empty households were re-visited later in the day. If during the second visit the occupants could not be found or if they refused to participate, that household was skipped. Subsequent households were selected with a sampling interval of four to cover the largest geographic area within each lot.

A standardised, pre-tested questionnaire was used for data collection. This survey instrument was tested in a non-surveyed area, including training performed over 3 days. Each survey team included two local persons who spoke Arabic, Haoussa and French, as well as a member of the expatriate MSF staff who acted as a supervisor. The questionnaire was in French and the questions were asked in local language(s).

The survey team identified children between 6 months and 59 months within the household and, if more than one child within the age range was present, one child was chosen randomly. The age, sex and vaccination status before and after the campaign were assessed by asking the head of household present. The number of doses received and reasons for non-vaccination during the mass campaign were recorded. This information was noted on a standardised data collection form. A local event calendar was used to determine age. Vaccination status was noted as either verified by vaccination card or by oral confirmation. Oral informed consent was obtained before the interviews started. Authorisation for this survey was provided by the MoH of Chad.

Results of the LQAS surveys are presented for card-confirmed vaccination status and for vaccination status based on parental recall. A child was considered vaccinated regardless of whether the child was vaccinated during reinforcement activities or previously. The citywide VC was estimated by calculating the weighted average of the VC of all lots before and after the mass vaccination campaigns.

## 3. Results

Surveys were performed from 20 to 25 June 2005 and from 16 to 23 April 2010. The mass vaccination campaign occurred 4 weeks prior to the survey in 2005 and 1 week earlier in 2010. Overall, 1624 and 1820 children were included in the survey in 2005 and 2010, respectively. The sex ratio (M/F) was 1.18 in 2005 and 1.02 in 2010. Fifty-four heads of households (3%) refused to take part in the survey in 2005 and 64 (3%) in 2010.

Before and after the campaigns, all lots had low VC (<70%) in 2005 and 2010 considering vaccination status based on vaccination cards only. Results based on card and parental recall combined indicated VC improved from all but 1 of 25 lots being rejected before the campaign to 12 lots rejected post campaign in 2005. In 2010, the proportion of lots with VC of <70% decreased from 17 before to 5 after the vaccination campaign. Table 1 presents the number of rejected lots (<70%) and VC by year and information source.

**Table 2**
Citywide measles vaccination coverage before and after the mass vaccination campaigns in 2005 and 2010 for children aged 6–59 months, N'Djamena, Chad

| | Before | | After | |
|---|---|---|---|---|
| | 2005 | 2010 | 2005 | 2010 |
| Card % (95% CI) | 7.6 (6.3–8.9) | 5.5 (4.1–5.6) | 53.0 (50.6–55.4) | 40.2 (36.9–43.5) |
| Card/recall % (95% CI) | 33.0 (30.9–35.1) | 70.4 (68.5–72.3) | 80.6 (78.6–82.6) | 82.5 (81.5–83.5) |

**Table 3**
Number of reported cases of measles in 2005 and 2010 (April–October) by age group, N'Djamena, Chad

| Age (years) | 2005 ($N$ = 6849) $n$ (%) | 2010 ($N$ = 7695) $n$ (%) |
|---|---|---|
| <1 | 1712 (25) | 1462 (19) |
| 1–4 | 4041 (59) | 3694 (48) |
| ≥5 | 1096 (16) | 2539 (33) |

**Table 4**
Number of doses of measles vaccination after outbreak response immunisation in 2010 for children aged 6 months to 15 years, N'Djamena, Chad

| Age group | $n$ (%) | | |
|---|---|---|---|
| | 1 dose | 2 doses | 3 doses |
| 6–11 months ($n$ = 78) | 50 (64) | 24 (31) | 4 (5) |
| 12–23 months ($n$ = 176) | 48 (27) | 77 (44) | 51 (29) |
| 24–59 months ($n$ = 552) | 94 (17) | 216 (39) | 242 (44) |
| 5–15 years ($n$ = 911) | 124 (14) | 333 (37) | 454 (50) |
| Total ($n$ = 1717) | 316 (18) | 650 (38) | 751 (44) |

**Table 5**
Reasons for non-vaccination during mass vaccination campaigns for children aged 6–59 months in 2005 and children aged 6 months to 15 years in 2010, N'Djamena, Chad

| Reason | $n$ (%) | |
|---|---|---|
| | 2005 | 2010 |
| Lack of information | 153 (37) | 29 (14) |
| Fear of side effects | 55 (13) | 50 (25) |
| Lack of time | 54 (13) | 74 (37) |
| Previous immunisation (measles or vaccination) | 22 (5.4) | 3 (1.5) |
| Miscellaneous | 127 (31) | 45 (22) |
| Total | 411 | 201 |

Citywide VC (card and parental recall) before the campaign was 33.0% (95% CI 30.9–35.1%) in 2005 and 70.4% (95% CI 68.5–72.3%) in 2010. After the campaign, citywide VC (card and parental recall) was 80.6% (95% CI 78.6–82.6%) in 2005 and 82.5% (95% CI 81.5–83.5%) in 2010 (Table 2).

The numbers of reported cases in 2005 and 2010 according to age group are shown in Table 3. Among vaccinated children in 2010, 316 (18%) received their first dose of measles vaccine, 650 (38%) received their second dose and 751 (44%) received three injections (Table 4). Reasons given for non-vaccination during the mass vaccination campaign included lack of information regarding vaccination campaigns, fear of side effects, lack of time and previous history of measles (Table 5).

## 4. Discussion

These results provide information about outbreak response in a city that has experienced recurrent measles epidemics. The intervention in 2005 was very late in the epidemic, whilst the 2010 mass vaccination campaign occurred much earlier. Unfortunately, as often is the case in the context of rapid assessments, it was not possible to provide data showing the state of immunity prior to or after vaccination. In addition, ORI was conducted over 2 weeks in different areas of the city, making a comparison of the age distribution of cases before and after the intervention campaigns over a long period difficult. Thus, it is hard to conclude from the study what was the real impact of vaccination on the epidemics. However, in 2010 the number of reported cases dropped dramatically after the campaign even though attack rates were particularly high in 2010. The shorter duration of the outbreak may not entirely be due to the early timing of intervention, but prompt reaction may have limited the extension of the disease. It has also been hypothesised that vaccinating a larger age range of cases, including older children who are more mobile and more likely to transmit the disease, may have an added benefit in reducing cases in all age ranges.

There were no measles epidemics reported between 2005 and 2010, probably due to the high coverage supplemental immunisation activities achieved in 2005. However, chronically low vaccine coverage among infants and young children combined with a failure to reach older children through routine services allowed the number of measles-susceptible children to build up and to precipitate the 2010 epidemic. The results of the survey confirm the low VC in N'Djamena prior to both epidemics in 2005 and 2010. Despite VC increasing from 33% to 70%, the 2010 outbreak had higher incidence rates compared with 2005. Several factors might explain this finding. First, older children were infected in 2010 (33% vs. 16% ≥5 years old). Second, early detection of the outbreak in 2010 shows significant progress of the surveillance system compared with 2005, with improved case detection and reporting systems. Finally, immunity levels are not constant after vaccination. Seasonality does not seem to play a role in the differential dynamics since both outbreaks emerged during the dry season.

Reasons for non-vaccination were roughly similar during both epidemics, including lack of information, fear of side effects and lack of time. Lack of information and fear of vaccination underline the importance of appropriate communication during immunisation activities, whilst lack of time suggests that accessibility of vaccination sites should be improved. Of the children vaccinated in 2010, 18% received their first dose, suggesting that previously vaccinated children were easier to reach during the outbreak than unvaccinated children. Interestingly, areas with low VC before and after the intervention in 2005 were also rejected lots during the following epidemic. This suggests that not only at-risk areas remain the same over time but hard to reach targeted children are located in similar places. This finding should be taken into account to develop innovative and tailored strategies of immunisation in order to improve routine and catch-up campaigns. In the present case, identification of areas with inadequate VC allowed appropriate public health measures to be taken.

There are several important limitations to these surveys. Specific VC figures for each neighbourhood cannot be easily evaluated using the LQAS method. Moreover, choice of lots was based on homogeneity of the population and geographic proximity. Uncertainty of population figures due to assumptions of constant and homogeneous growth may lead to dissimilar population sizes among lots and unreliable attack rates. However, a weighted average of the VC overcomes this potential non-homogeneity and the chosen threshold allowed for classification regardless of population figures.

Second, ages of children may have not been recalled reliably, leading to either overestimates or underestimates. Interviewers used a tailored calendar of events to assess as accurately as possible the age of children, but determining exact ages of children remains problematic in contexts such as N'Djamena.

Third, some children in each survey received one dose and some two or more doses of measles vaccine. Since the efficacy of one, two or three doses is not identical, this provides only a rough proxy of the population immunity profile. However, the majority of children (82%) had received at least two doses of vaccine in 2010, with the 'one dose' status being most prevalent among the <1 year age group. This is expected as the first dose of measles vaccine is delivered between 9 months and 11 months in the routine programme. Attempts were made to minimise the potential for misclassification of vaccination status by differentiating between vaccination card-confirmed and parental recall-confirmed vaccination status. Easily identifiable vaccination records were systematically distributed during the mass vaccinations and teams were specifically trained to look for appropriate cards. Moreover, both surveys quickly followed the vaccination activities, presumably reducing the risk of parental recall bias.

Fourth, refusals were a source of misclassification of lots for acceptable or unacceptable VC. As the reasons were unknown, it was not possible to determine the impact of refusal on the results in areas where refusal rates were the highest. The small number of lots affected with refusal may have limited this bias.

## 5. Conclusion

Despite an improved surveillance system and better VC, measles epidemics represent a continuing public health problem in Chad, and mass vaccination campaigns may be effective in quickly reducing measles morbidity during epidemics. The timeliness and quality of ORI activities are crucial determinants of success. However, effective outbreak response should be followed by appropriate routine vaccination programmes to ensure a sustainable high VC.

**Authors' contributions:** GG, JG, RFG and FF conceived the study; GG, JG, RFG, FF and WBT designed the study; GG, JG, RFG, FF and JS interpreted the data; GG, JG and RFG drafted the paper. All authors revised the paper critically for substantial intellectual content and read and approved the final version. GG and RFG are guarantors of the paper.

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**Conflicts of interest:** None declared.

**Ethical approval:** Authorisation for the vaccination coverage study was given by the Ministry of Health, Chad. The objectives of the survey were explained to potential respondents, who were free to refuse participation before or at any time during the survey.

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