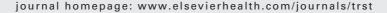# Use of Lot Quality Assurance Sampling (LQAS) to estimate vaccination coverage helps guide future vaccination efforts

K.P. Alberti [a,*], J.P. Guthmann [a,1], F. Fermon [b],
K.D. Nargaye [c], R.F. Grais [a]

[a] Epicentre, 8 rue Saint Sabin, 75011 Paris, France
[b] Médecins Sans Frontières—France, 8 rue Saint Sabin, 75011 Paris, France
[c] Ministry of Health, N'Djamena, Chad

Summary   Inadequate evaluation of vaccine coverage after mass vaccination campaigns, such as used in national measles control programmes, can lead to inappropriate public health responses. Overestimation of vaccination coverage may leave populations at risk, whilst underestimation can lead to unnecessary catch-up campaigns. The problem is more complex in large urban areas where vaccination coverage may be heterogeneous and the programme may have to be fine-tuned at the level of geographic subunits. Lack of accurate population figures in many contexts further complicates accurate vaccination coverage estimates. During the evaluation of a mass vaccination campaign carried out in N'Djamena, the capital of Chad, Lot Quality Assurance Sampling was used to estimate vaccination coverage. Using this method, vaccination coverage could be evaluated within smaller geographic areas of the city as well as for the entire city. Despite the lack of accurate population data by neighbourhood, the results of the survey showed heterogeneity of vaccination coverage within the city. These differences would not have been identified using a more traditional method. The results can be used to target areas of low vaccination coverage during follow-up vaccination activities.
© 2007 Royal Society of Tropical Medicine and Hygiene. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Measles remains a major public health problem in many developing countries and is a principal cause of vaccine-preventable mortality in children under 5 years of age in sub-Saharan Africa. In recent years, the WHO Africa Region has been using Supplemental Immunisation Activi-

* Corresponding author. Tel.: +33 1 40 21 29 04;
fax: +33 1 40 21 28 03.
   E-mail address: kalberti@epicentre.msf.org (K.P. Alberti).
[1] Present address: Institut de veille sanitaire, 12 rue du Val d'Osne, 94415 Saint-Maurice, France.

ties, including mass vaccination campaigns, in an effort to control the disease and to decrease measles mortality (Otten et al., 2005). These activities provide an opportunity for unvaccinated children to receive a first dose of vaccine and for previously vaccinated children to receive a second dose.

In early 2005, a measles epidemic was detected in N'Djamena, the capital of Chad. As part of the epidemic control effort, the non-governmental organisation Médecins Sans Frontières, in collaboration with the Ministry of Health, carried out a mass vaccination campaign. The objective of the campaign was to vaccinate 100% of children aged 6—59 months living in the city. Further details of this epidemic can be found elsewhere (Dubray et al., 2007).

During the campaign, some vaccination sites were very busy, whilst at others fewer children than anticipated were seen. It was decided to evaluate the coverage of the campaign by conducting a vaccination coverage survey, with a specific objective of identifying differences in vaccination coverage between neighbourhoods. As a second campaign was planned 5 months later, the idea was to use the results of the survey to better target areas with inadequate vaccination coverage following the first campaign.

Two methods are commonly used to estimate vaccination coverage, the administrative method and surveys using cluster sampling (WHO, 2006). The administrative method compares the number of doses given with the number of children in the target population of the campaign. Accurate population figures are necessary for this method to be reliable. This method can provide information on coverage by geographic area if the population of subareas is available and the origin of the children vaccinated is known. If population figures are inaccurate, this method leads to either an overestimate (Zuber et al., 2003) or underestimate (Huhn et al., 2006). Overestimation can result in part of the population remaining at risk of the disease; underestimation may result in the organisation of unnecessary public health measures, such as follow-up vaccination campaigns. Vaccination coverage surveys using cluster sampling do not require accurate population figures but provide only a global figure for the entire survey area. Vaccination coverage by subarea or neighbourhood cannot be estimated from the results of one survey (Hoshaw-Woodard, 2001).

In our context, neither method adequately responded to our specific question regarding the heterogeneity of vaccine coverage. The population of N'Djamena has more than doubled in the past 15 years with significant in-migration from rural areas of the country. At the time of the last census in 1993 the population was 513 000, whilst current population estimates range from 1.2 million to 1.7 million inhabitants. In addition, the exact proportion of the population under-five is unknown. The city is heterogeneous, with some areas densely populated whilst the outskirts are semirural. Health services are also heterogeneous, with some areas well served and others underserved.

Because of the range in population figures, administrative estimates for citywide campaign vaccination coverage, based on the vaccination of 175 470 children and the extremes of the population estimates of 191 643 and 272 000 children between 6 months and 5 years of age, were as low as 65% and as high as 92%. Furthermore, vaccination teams and experienced supervisors, based on the daily volume of children at each vaccination site, suspected that neither of these values was accurate. They also suspected vaccination coverage was heterogeneous, but had neither an idea of the origin of children at each site nor whether children visited the vaccination sites closest to their homes.

2. Materials and methods

It was decided that Lot Quality Assurance Sampling (LQAS) would be the most appropriate evaluation method in this context as it has been used successfully in past evaluations of vaccination coverage (Dubray et al., 2006; Tawfik et al., 2001). LQAS provides both a citywide estimate and estimates for geographic subunits. The limitation of the method is that a specific estimate for each subunit cannot be evaluated, but they are classified as having 'acceptable' or 'unacceptable' vaccination coverage based on upper and lower cut-offs defined for the specific survey (Hoshaw-Woodard, 2001).

The city was divided into 25 non-overlapping lots based on administrative neighbourhoods with well known boundaries. When necessary, neighbourhoods were regrouped to create lots of equivalent population size and homogeneity. A lower threshold of 70% vaccination coverage below which a lot was considered to have 'unacceptable' vaccination coverage and an upper threshold of 85% above which a lot was considered to have 'acceptable' vaccination coverage were selected. In neighbourhoods with vaccination coverage >85% the campaign was considered a success, whilst in neighbourhoods with vaccination coverage <70% the population was considered to be still at risk for measles and in need of particular attention during the follow-up campaign. Using these thresholds, sample size and threshold values were calculated using cumulative binomial probabilities (Sample LQ v1.10; Brixton Health, London, UK) using $\alpha = 0.05$ and $\beta = 0.10$. The sample size per lot was calculated as 65 and, if less than 13 unvaccinated children were identified, the lot was classified as having 'acceptable' vaccine coverage (>85%), otherwise the lot was classified as having 'unacceptable' vaccination coverage (<70%). As we wished to calculate an average vaccination coverage for the city as well as determining whether each lot had 'acceptable' or 'unacceptable' coverage, information was collected for all 65 children in each lot.

To select households within each of the 25 lots, a systematic sampling plan was developed. A central location in each lot, such as an intersection or health centre, was predetermined by the supervision team. From this point, teams randomly selected a direction by spinning a pen and the closest compound in that direction was selected as the starting household for the lot. From this point, every fourth compound on the right was included in the survey. If multiple households were found in one compound, teams numbered all the households and then selected one household using a random number table.

Oral informed consent was obtained before beginning the interview. The objectives of the survey were explained to potential respondents who were free to refuse participation before or at any time during the survey. Information on age, sex and vaccination status before and after the campaign from one 6—59-month-old child per family was obtained from the head of the household. In households with multiple children in this age group, one child was randomly selected