

Vaccination coverage survey versus administrative data in the assessment of mass yellow fever immunization in internally displaced persons—Liberia, 2004

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Received 6 June 2005; accepted 16 August 2005

Available online 8 September 2005

Abstract

Yellow fever (YF) is a mosquito-borne vaccine-preventable disease with high mortality. In West Africa, low population immunity increases the risk of epidemic transmission. A cluster survey was conducted to determine the effectiveness of a mass immunization campaign using 17D YF vaccine in internally displaced person (IDP) camps following a reported outbreak of YF in Liberia in February 2004. Administrative data of vaccination coverage were reviewed. A cluster sample size was determined among 17,384 shelters using an 80% vaccination coverage threshold. A questionnaire eliciting demographic information, household size, and vaccination status was distributed to randomly selected IDPs. Data were analyzed to compare vaccination coverage rates of administrative versus survey data. Among 87,000 persons estimated living in IDP camps, administrative data recorded 49,395 (57%) YF vaccinated persons. A total of 237 IDPs were surveyed. Of survey respondents, 215 (91.9%, 95% CI 88.4–95.4) reported being vaccinated during the campaign and 196 (83.5%, 95% CI 78.6–88.5) possessed a valid campaign vaccination card. The median number of IDPs living in a shelter was 4 (range, 1–8) and 69,536 persons overall were estimated to be living in IDP camps. Coverage rates from a rapid survey exceeded 90% by self-report and 80% by evidence of a vaccination card, indicating that the YF immunization campaign was effective. Survey results suggested that administrative data overestimated the camp population by at least 20%. An emergency, mop-up vaccination campaign was avoided. Coverage surveys can be vital in the evaluation of emergency vaccination campaigns by influencing both imminent and future immunization strategies.

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Keywords: Yellow fever; Vaccination; Internally displaced persons; Epidemic; Liberia

1. Introduction

Yellow fever (YF), a vaccine-preventable viral hemorrhagic disease, causes infection in approximately 200,000 persons annually and is responsible for an estimated 30,000 deaths per year [1]. The vast majority of disease and mortality occurs within the YF belt (latitude 15° north to 10°

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south) in Sub-Saharan Africa [1]. In West Africa, the virus is transmitted in three cycles – a sylvatic cycle in which transmission occurs between forest-dwelling mosquitoes and non-human primates, an intermediate cycle in which transmission occurs between mosquitoes and both non-human primates and humans in moist savanna areas of Africa, and an urban cycle where it can cause large epidemics [1]. Urban cycle epidemics develop from anthroponotic, also known as human-to-human, transmission in which humans serve as the sole host reservoir of the peridomestic *Aedes aegypti* mosquito vector. Urban epidemics occur when anicteric but viremic persons who are not yet severely ill travel from jungles and savannas to cities where they infect local *A. aegypti* mosquitoes, a species that is abundant in urban areas and in areas where humans store water. When YF is identified in any setting, the likelihood that it resulted from human-to-human transmission or its possible introduction into an urban setting must be rapidly assessed to determine the need for emergency vaccination.

Immunization coverage of the at-risk population is an important determinant for human-to-human transmission because the potential for an epidemic increases when there is low prevalence of neutralizing antibody to YF virus from previous vaccination or naturally acquired infection. The 17D YF vaccine is highly effective and safe; Over 400 million estimated doses have been administered worldwide, with rare reports of serious adverse events following immunization (AEFI) [2–11]. Monitoring AEFI during mass vaccination campaigns are important to ensure not only the timely identification of possible events which may signal compromised safety of the vaccine, but to detect potential programmatic errors that may occur when a large number of doses are administered over a short time period.

In Liberia, 14 years of civil war during 1989–2003 devastated much of the country's healthcare infrastructure and severely disrupted public health disease surveillance and immunization programs. On February 13, 2004, the World Health Organization (WHO) declared an outbreak of YF after laboratory confirmation of four cases. All cases had illness onset January 1–9, 2004, of which three were fatal. Two cases occurred in men aged 19 and 26 years living in densely populated internally displaced person (IDP) camps, settlements of citizens displaced from their in-country homes because of civil strife, in Salala District, Bong County, in central Liberia. Roughly 365,000 Liberians, one-sixth of the country's estimated population, had lived in IDP camps throughout the country since the end of the civil war in August 2003 [12]. Because of the potential for human-to-human transmission in overcrowded IDP camps with extension into the surrounding area, YF mass vaccination campaigns were launched in Salala District IDP camps and neighboring communities during February 26 to March 6, 2004 and March 16 to March 20, 2004.

Administrative data, a simple formula used to estimate vaccination coverage that divides the number of persons vaccinated during the campaigns by the number of vaccine-

eligible persons estimated residing in the camps, indicated that, of the estimated 87,000 persons living in these camps, only 49,395 (56.8%) were immunized against YF with the 17D YF vaccine (Institute Pasteur, Dakar, Senegal) during the campaigns [13–16]. Because validation studies to determine IDP camp population size had not been performed, a coverage survey was needed to more precisely evaluate vaccination coverage after the campaigns. We report findings of a rapid vaccine coverage survey that underscores the importance of accurately estimating the population at risk for YF to assist decisions regarding future vaccination strategies.

2. Methods

The IDP camps in Salala District of Bong County were built in 2002 and administered by the Liberian government through the Liberia Refugee Repatriation and Resettlement Commission (LRRRC). Medical services were coordinated by Médecins Sans Frontières – France (MSF-F) and food was supplied by the World Food Programme (WFP). Camp shelters were uniformly designed, each measuring approximately 4 m × 5 m (Fig. 1). A census of the camps had not been performed. Instead, a WFP formula of five persons per shelter was used to estimate the camp population. All six IDP camps in the district were included in the study (Fig. 2).

2.1. Sampling method

Camp managers provided maps and registration logs of habitable shelters in each camp. Each camp was partitioned into alphabetical blocks and each shelter within each block was given a sequential integer number. Each of the 17,384 total shelters in these six camps had a unique identification that included the camp name, a block letter and a shelter number. We developed a two-stage cluster sampling design to select survey participants.

Sample size was calculated based on 5% allowable margin of error. The design effect was equal to one because one person per shelter cluster was to be randomly selected for the survey. We chose the conjectured vaccination coverage rate to be 80%, the threshold that is believed to eliminate the likelihood of human-to-human transmission [17–18]. Sample size was calculated by a standard random cluster formula [19]:

$$\frac{(t^2)(\text{design effect})(\text{coverage rate})(I - \text{coverage rate})}{(\text{margin of error})^2}$$

$$= 248 \text{ persons} [t = 1.96 \text{ for } 95\% \text{ level of confidence}]$$

As a contingency for missing persons in selected shelter households, an additional 5% (12 persons) were added for a total sample size of 260.

The sum total of all shelters ($n = 17,384$) served as the overall denominator for the population. At the first stage, we



Fig. 1. Physical design and spatial location of shelters in internally displaced persons' camps, Bong County, Liberia, 2004.

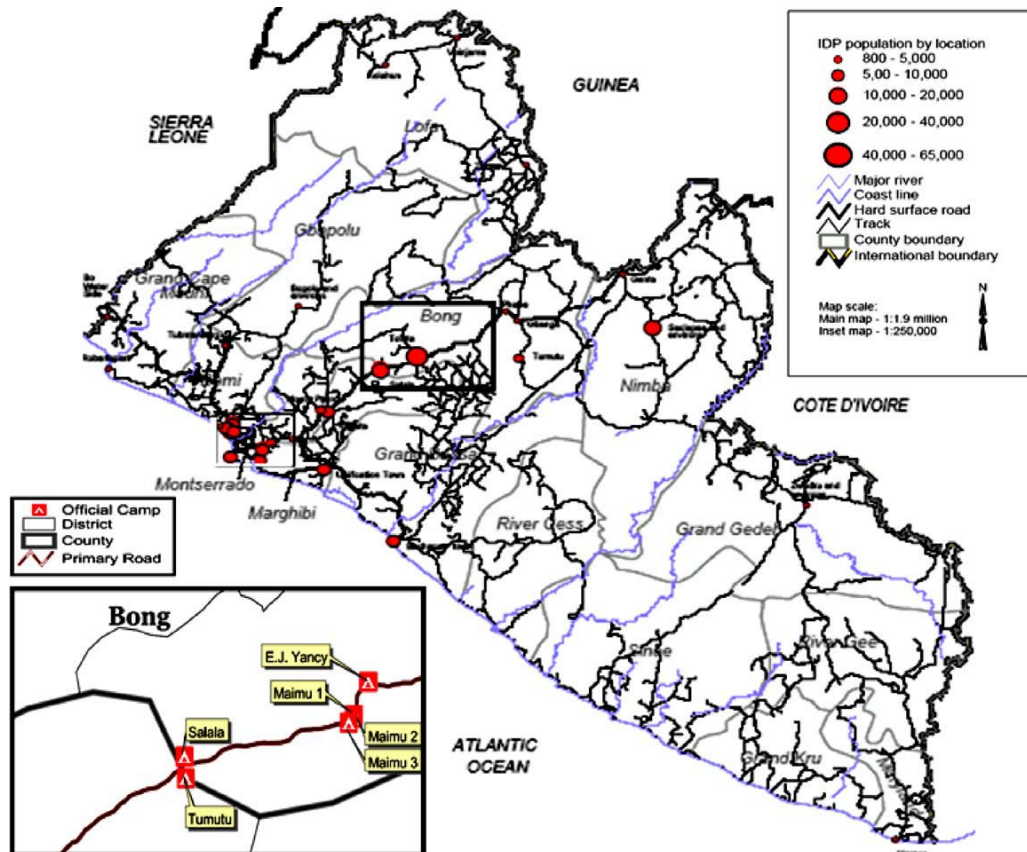


Fig. 2. Geographic location of six internally displaced persons' camps included in yellow fever coverage survey, Bong County, Liberia, 2004.

constructed a single sampling frame (x) among all six camps by using an alphabetical and numerical hierarchy of shelter addresses to create a linear list of all shelters. Thus, the first cluster on the list was shelter A1 from EJ Yancy camp and the 17,384th and final cluster was shelter D361 from Tumutu camp. We divided the total number of shelters by the sample size ($17,384/260 = 67$) to determine an interval-sampling instrument (r) to systematically select shelter clusters. A two-digit number x , between 01 and r , from a random number table was chosen as the first sampling point on the frame, with subsequent points provided by $x + r$, $x + 2r$, $x + 3r$, etc. until $x + 259r$. Wherever a point fell on the cumulative shelter population list, that shelter was assigned as a cluster. The number of clusters chosen per camp was proportional to camp size.

The second stage sampling was performed on site. Persons aged ≥ 6 months living in the shelter were assigned a number based on their height, from the shortest person in the shelter to the tallest. A person was considered to be a household member if he/she routinely slept overnight in the shelter during the vaccination campaign. Household members present during the survey supplied height estimates for absent persons who lived in the shelter. One person per shelter cluster was randomly chosen for the survey using a random number table. No replacement of shelters or persons in shelters occurred during the survey.

2.2. Data collection

Approval for the survey was granted by local authorities in the LRRRC. A standardized questionnaire in English eliciting demographic information, household size, awareness of the YF vaccination campaign, YF vaccination status, and reports of AEFI (see Appendix A) was distributed to 12 teams of interviewers. In addition, a signed and dated YF vaccination card was requested from each person who was interviewed. Each team consisted of three to four interviewers proficient in English and at least five other local languages (Kpelle, Mende, Loma, Vai, and Southern Kisi) spoken by a substantial majority of IDPs in the camps. Teams were formed at each camp and were trained in the use of the questionnaire by role-playing. During April 5–7, teams conducted face-to-face interviews with randomly selected survey participants. Questionnaires were translated as needed. If an absent adult was selected, the survey team queried present household members to schedule a return appointment based upon the availability of the selected adult. If after three consecutive days the selected adult remained unavailable, a present household member was surveyed as a proxy regarding the adult's information. If a young child was selected, a present adult household member was surveyed as a proxy about the young child's information. Oral, informed consent was obtained from all respondents prior to interviews. To minimize response bias of over-reporting household size, respondents were clearly informed that the survey was not linked to a registration or food-distribution process.

2.3. Statistical analysis

Data were entered and analyzed on EpiInfo 6.04d [20]. Variables were weighted by the number of persons per household. Point estimates for sex, awareness of the campaign, and vaccination status were computed in CSAMPLE, a program which performs statistical analysis from complex sampling strategies, and applied to calculate 95% confidence intervals (CI). A Wilcoxon Mann-Whitney test was used to calculate p values for age and a Mantel Haenszel chi-square test was used to calculate p values for sex.

3. Results

One of the 260 shelters did not exist. Of 259 shelters that were visited, 22 were either unoccupied for three successive days during the survey (15 shelters) or were incomplete shelters that were not yet inhabited (seven shelters). Data were analyzed for 237 survey respondents (one person per shelter). There were no missing data from IDPs surveyed and no AEFI reported.

The median number of household members living in a shelter was four (range, 1–8). We estimated that 69,536 persons lived in these six camps compared to the estimate of 87,000 used prior to the campaign by camp administrators. The median age of respondents was 20 years (Table 1); of the 237 respondents, one-half ($n = 119$) were aged 15–44 years. Females outnumbered males by an almost 2:1 ratio (Table 2).

Of the 237 respondents, 230 (97.6%, 95% CI 95.5–99.6) were informed of the vaccination campaign; 215 (91.9%, 95% CI 88.4–95.4) had been vaccinated during the campaign by their self-report; and 196 (83.5%, 95% CI 78.6–88.5) possessed a signed and dated vaccination card from the recent campaign. Self-reported vaccination rates were highest in the 5–14-year age group, 94.8% (95% CI 89.0–100.7) and lowest in the 15–44-year age group, 89.7% (95% CI, 84.1–95.2) (Table 3). Sex distribution was similar among vaccinated versus unvaccinated respondents ($p = 0.63$) and no difference existed in the median age among respondents reporting vaccination (aged 20 years) during the campaign compared to unvaccinated respondents (aged 21 years) ($p = 0.86$).

Among 22 unvaccinated respondents, eight (38%) did not participate in the campaign because of prior YF vaccination within the past 10 years; five (24%) stated that they were

Table 1
Age and yellow fever vaccination status among internally displaced persons living in Bong County, Liberia, 2004

Population (number)	Age (years) ^a		
	Median	Range	Interquartile range (25 and 75 percentile)
Total sample (237)	20	1–87	10, 36
Vaccinated (215)	20	1–87	10, 37
Unvaccinated (22)	21	1–62	16, 31

^a No significant difference between vaccinated and unvaccinated; $p = 0.86$.

Table 2
Yellow fever vaccination coverage estimates using administrative and survey methods among internally displaced persons living in Bong County, Liberia, 2004

Characteristic	Number			
	Total	Vaccinated in 2004	Coverage (%)	95% CI
Administrative				
Total	87,000	47,676 ^a	54.8	NA ^b
Age group (%)				
6 months–4 years	13,920 (16.0%)	9,422	67.7	NA
5–14 years	25,230 (29.0%)	12,238	48.5	NA
15–44 years	34,800 (40.0%)	18,427	53.0	NA
>44 years	13,050 (15.0%)	7,589	58.2	NA
Sex				
Female	NA	NA	NA	NA
Male	NA	NA	NA	NA
Survey				
Total	237	215	91.9	88.4–95.5
Age group (%)				
6 months–4 years	28 (11.8%)	26	96.2	90.9–101.6
5–14 years	54 (22.8%)	51	94.8	89.0–100.7
15–44 years	119 (50.2%)	105	89.7	84.1–95.2
>44 years	36 (15.2%)	33	91.5	81.2–101.9
Sex ^c				
Female	151 (63.7%)	138	92.7	88.6–96.9
Male	86 (36.3%)	77	90.2	84.2–96.8

^a An additional 1719 IDPs reported YF vaccination within the past 10 years and did not participate in the 2004 campaign. Ages of previously vaccinated IDPs were not collected. The total number of IDPs considered appropriately immunized using the administrative method was 49,395 (56.8%).

^b NA: not applicable.

^c No significant difference between vaccinated females and males; rate ratio = 1.0 (95% CI 0.94–1.1, $p = 0.63$).

Table 3
Survey results of yellow fever vaccination coverage survey for 237 internally displaced persons, Bong County, Liberia, 2004

Characteristic	Positive response	Percentage	95% CI
Knowledge of campaign	230	97.6	95.5–99.6
Vaccinated, 2004	215	91.9	88.4–95.4
Possessed 2004 vaccination card	196	83.5	78.6–88.5
Vaccinated, 1994–2003	8	2.9	0.9–5.0
Appropriately vaccinated ^a	223	94.8	92.0–97.7

^a Vaccinated either in 2004 or within past 10 years.

unaware of the campaign; and five (24%) stated that vaccination was “inconvenient.” Two respondents were absent from the IDP camps during the campaign and one respondent had no access to the vaccination site. One respondent provided no explanation. Including respondents reporting prior YF vaccination within the past 10 years with the persons with self-reported recent vaccination, 223 respondents (94.8%, 95% CI 92.0–97.7) were immunized against yellow fever.

4. Discussion

Over the past two decades, YF epidemics have regularly occurred in West Africa [21]. In response to an outbreak in Liberia in 2004, the WHO, UNICEF, and MSF conducted an

emergency vaccination campaign in large camps of IDPs after two of the initial four cases of yellow fever were confirmed among camp residents. In assessing the need for additional vaccination, administrative data suggested that less than 60% of potentially at-risk IDP camp inhabitants were vaccinated during a mass YF vaccination campaign. As a result, an emergency, follow-up vaccination campaign was planned to achieve the 80% threshold level of the immunization campaign goal. Vaccination coverage rates from our rapid survey following mass vaccination actually exceeded 90% by self-report and 80% when using evidence of a vaccination card. Based on our survey data, an additional vaccination campaign was avoided. In addition, we were able to determine that there was near-universal knowledge and broad acceptance of the campaign among IDPs, which highlights the high degree of YF disease awareness in this population generated through effective social mobilization.

Concerns with the quality of administrative data used to estimate vaccine coverage have prompted several retrospective surveys following National Immunization Days in other settings [22–29]. However, to our knowledge, this is the first reported survey to evaluate YF vaccination coverage in IDP or refugee camps. One reason for the discrepancy between the administrative and our coverage survey rates is that camp authorities relied on a WFP formula of the estimated number of persons occupying a shelter as the sole determinant of the target population. The results of our survey suggest that this administrative calculation overestimated the size of

the camp's population by at least 20%, which may partially explain the difference between the administrative and survey coverage rates. In addition, nearly 27,000 persons were vaccinated during the campaign at sites in surrounding communities, not in the camps [16]. A lot quality assurance sampling coverage survey of these communities undertaken immediately following our survey, using the same questionnaire and interviewer teams, showed that 89% of persons living in communities adjacent to IDP camps had been vaccinated during the campaign [30]. These neighboring communities hosted weekly market days attracting many IDPs. Numerous IDPs were reportedly vaccinated at community sites on market days and not in the camps. This would have resulted in fewer doses being administered in the camps and therefore a lower coverage estimate using administrative data.

Our study had at least four limitations that may have affected data interpretation. First, some interviews were conducted by proxy. However, proxy interviewees were members of the same shelter and usually very familiar with the demographic and vaccination status of the selected person. Second, proof of vaccination was not obtained from 19 persons (9%) who claimed to have been immunized during the campaign, which may have introduced recall bias. This occurred most commonly when an absent person was selected and their vaccination card was unavailable either because the card was locked with their personal belongings inside the shelter or the absent person had taken the card with them outside the camp for documentation if traveling on main roads, registering for school, or seeking medical treatment. Also, because no other vaccination programs occurred within the IDP camps during the YF immunization campaign, bias by inadvertently attributing YF immunization to another vaccine was likely diminished. For these reasons, self-report or proxy report of vaccination was considered an adequate indicator of immunization status. Third, though we verified the dates and county of vaccination in 2004 for nearly all (>90%) survey participants, because data was not available on the validated vaccination cards specifying the exact vaccination site during the campaign, we could not quantify estimates of IDPs vaccinated outside the camps in 2004. Lastly, the reason for the low proportion of males surveyed remains unclear. More men may have moved from IDP camps in search of employment near the capitol city Monrovia since the civil war ceasefire. And of the estimated 200,000 Liberians killed during the civil war, most were male combatants [31], which may have changed the distribution of gender in the country overall. A national census has not been conducted in Liberia since 1984 [32].

In addition to intensive social mobilization, efficient logistical networks, well-trained health staff, and safe vaccine delivery, successful mass immunization programs require accurate estimations of their target populations. For refugees and IDPs, the United Nations High Commissioner for Refugees (UNHCR) has established minimum standards for registration in camp settings in order to quantitatively track both stable and mobile populations [33]. In emergency situa-

tions when mass vaccination may be needed, such as potential epidemics among refugees or IDPs, reliable population estimates are critical to decisions regarding interventions [34]. Imprecise population estimates in the early planning stages may impact vaccine procurement decisions and compromise the overall feasibility and cost-effectiveness of mass vaccination in refugee or IDP camp settings [35]. Coverage surveys can be a vital instrument in the rapid evaluation of emergency vaccination campaigns by influencing both imminent (i.e. mop-up activities) and future immunizations strategies. Our study established a more precise measurement of population estimates for IDPs aged ≥ 6 months for future health interventions.

Worldwide, nearly 35 million refugees (9.7 million) and IDPs (25 million) existed by 2004; more than seven million of these persons have been warehoused in camps and settlements for at least 10 years [36–38]. In developing countries, advances against vaccine-preventable diseases through the Expanded Program on Immunization (EPI) may be threatened when large populations of refugees and IDPs are disenfranchised from routine health services over prolonged periods. Analytic models since the 1990s have supported inclusion of YF vaccination in EPI in endemic areas [39]. Incorporating vaccination status into validated refugee and IDP population assessment tools might be useful to assess immunization needs when routine services have been disrupted by displacement [40]. Adequately protecting vulnerable refugees and IDPs against a wide range of deadly vaccine-preventable diseases, including YF, will likely require an integrated approach. Routine programs such as EPI should be extended to include stable IDP camps and settlements and supplemented with timely and appropriate mass vaccination programs to maintain immunization continuity.

4.1. *Role of the funding source*

WHO, UNICEF, MSF-F, and CDC provided funding for the study design, collection, analysis, and interpretation of data; the writing of the report; and decision to submit the paper for publication.

Ethics requirement

The study was programmatic research in response to an emergency public health outbreak and therefore not subject to an ethical review board by CDC, WHO, UNICEF, or Medecins Sans Frontieres.

Acknowledgments

The authors wish to thank Angela Kearney of UNICEF and Lynn Thomas of USAID for their assistance and guidance in this study. We value the time and cooperation from all the survey team members and IDPs who participated in the study.

Authorship and Contributorship: All authors – G. Huhn, J. Brown, W. Perea, A. Berthe, H. Otero, G. LiBeau, N. Maksha, M. Sankoh, S. Montgomery, A. Marfin, M. Admassu – can take responsibility for the content of the paper and the conception and design of the study. Gregory Huhn, Jennifer Brown, William Perea, Susan Montgomery, Anthony Marfin, Mekonnen Admassu contributed to analysis and interpretation of data. All authors assisted in drafting or critically revising the article and approved the final version for publication. G. Huhn as the guarantor accepts full responsibility for the work and conduct of the study, had access to the data, and controlled the decision to publish. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the funding agency.

Appendix A

Adverse events following immunization (AEFI) definition—any of the following adverse events occurring within 4 weeks of injection and believed caused by vaccination in persons immunized during the mass vaccination campaign: Injection site abscess, severe local reaction, fever $\geq 39.5^{\circ}\text{C}$, severe allergic reaction, anaphylaxis, acute encephalitis, convulsions, toxic shock syndrome, sepsis, and death.

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