Vaccine 33 (2015) 6778–6785

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Individual level determinants for not receiving immunization, receiving immunization with delay, and being severely underimmunized among rural western Kenyan children

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ARTICLE INFO

Article history:
Received 21 May 2015
Received in revised form
22 September 2015
Accepted 6 October 2015
Available online 16 October 2015

Keywords:
Vaccination coverage
Vaccination timeliness
Fully immunized child
FIC
Underimmunization
Immunization
Vaccination
Kenya

ABSTRACT

Background: Estimating vaccination coverage and delays are important because these measures can identify at risk sub-populations who can be targeted with interventions and public health policies. This paper sought to determine estimates and risk factors for children in rural western Kenya who did not receive immunization, received immunization with delay, or were severely underimmunized.
Methods: Caregivers of children aged 12–23 months old were surveyed for immunization history using written records from the immunization booklet. Risk factors for not receiving immunization, delayed immunization, and severe underimmunization were calculated using log-binomial regression. Children were categorized as delayed if a given immunization was received greater than four weeks from the age-appropriate scheduled date. Severely underimmunized children were those who were fully unvaccinated for more than 90 days and had three or more vaccines delayed or not given.
Results: Immunization coverage for pentavalent1, pentavalent3, measles, and fully immunized child (FIC; BCG, three doses of polio, three doses of pentavalent, and measles vaccines) were 99%, 94%, 83%, and 80%, respectively. Approximately, 10%, 24%, and 29%, of children were delayed for pentavalent1, pentavalent3, and measles, respectively. Each model produced a unique combination of risk factors with only advanced maternal age as a risk factor common to all models. Children with delayed receipt of pentavalent1 were at risk for not receiving pentavalent3 (RR: 5.20; 95%CI 3.48, 7.77), measles vaccine (RR: 1.48; 95%CI 1.12, 1.95), and not achieving FIC (RR: 1.88; 95%CI 1.51, 2.34) compared with children who received pentavalent1 on time.
Conclusions: Immunization coverage among 12–23 month old children was high, yet a substantial proportion of children were vaccinated with delay. Although vaccine coverage and timeliness are often conceptualized as separate measures, the finding that delayed pentavalent1 receipt was a strong risk factor for not receiving future immunizations indicates the two measures are intertwined.

1. Introduction

Few interventions available to public health practitioners rival the cost-effectiveness of vaccines for reducing childhood morbidity and mortality [1]. Numerous studies have identified risk factors for being unimmunized [2–5] and receiving vaccines with delay [6,7]. Estimating vaccination coverage and delays are important because these measures can identify at risk sub-populations which can be targeted with interventions and public health policies [8–11].

In Kenya, the Division of Vaccine and Immunization (DVI) recommends children receive bacillus Calmette–Guerin (BCG) and polio vaccines at birth, three doses of polio and pentavalent (diphtheria, tetanus toxoid, pertussis, hepatitis B, and *Haemophilus influenzae type b* antigens) vaccines at 6, 10, and 14 weeks of age, and measles vaccine at 9 months of age [12]. Kenya added pneumococcal conjugate vaccine (PCV) and rotavirus vaccine to their national immunization plan in 2011 and 2014, respectively.

Coverage estimates for three doses of pentavalent (pentavalent3), or DTP3 in countries where pentavalent is not available, in children 12–23 months old is a common indicator of a country's

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http://dx.doi.org/10.1016/j.vaccine.2015.10.021
0264-410X/

health and vaccine system strength [13,14]. Data from successive Kenyan Demographic and Health Surveys found improvements in DTP3 coverage of infants 12–23 months old from 2003 (72%) to 2009 (86%) [15]. Although the DTP series should be completed by 14 weeks of age, if all doses are received on time and in most low-income countries, the standard coverage measure is DTP3 vaccination by 12–23 months of age, which does not differentiate timely or delayed receipt.

Delayed vaccination has been associated with increased cases of pertussis [16,17], hepatitis B [18], and *Haemophilus influenzae* type b [19], all which have high morbidity and mortality in early infancy. Furthermore, timely vaccination heightens population herd immunity levels [20], thereby protecting those who are too young to be vaccinated, have medical contraindications, or who do not produce an adequate immunological response.

Vaccination delays are prevalent across lower income countries. Two systematic reviews identified a median delay of 6.2 and 6.3 weeks for DTP3 across 76 lower and middle-income countries (10 countries were included in each review) [6,7]. In Kenya, the median estimated delay in DTP3 was 3.2 weeks, a value lower than the global median, but 25% of Kenyan children had DTP3 delays greater than 7.5 weeks [7].

The objectives of this study were to determine the proportion and risk factors of children in rural Western Kenya: (1) not receiving immunization; (2) receiving immunizations with delay; and (3) being severely underimmunized.

2. Methods

2.1. Study design

During March and April of 2013, a cross-sectional survey was conducted in Gem District, Siaya County, Kenya to ascertain immunization coverage in children 12–23 months old. Gem District is nested within the study area of the Kenya Medical Research Institute (KEMRI) and Centers for Disease Control and Prevention (CDC) Health and Demographic Surveillance System (HDSS). The HDSS follows a population of approximately 220,000 residents living in 54,869 households from 385 villages. HDSS residents are defined as living within the study area for at least four months or individuals that are born to residents. Approximately 45% of the population is aged 15 years and younger [21]. Most of this rural population belongs to the Luo ethnic group with subsistence farming as the primary occupation. The survey's primary purpose was to collect immunization coverage for sample size calculations of the Mobile Solutions for Immunizations (M-SIMU) randomized controlled trial (ClinicalTrials.gov NCT01878435).

The HDSS provided a census of enumerated HDSS-consented households from 120 villages with children aged 12–23 months. Using this list of eligible households, HDSS community interviewers approached all eligible mothers, sought consent, and administered the survey.

The study protocol received ethical clearance from the Scientific Steering Committee (SSC), the KEMRI-Nairobi Ethical Review Committee (SSC#2409), Johns Hopkins University Bloomberg School of Public Health, and CDC.

2.2. Data collection and management

KEMRI/CDC staff conducted surveys using smart-phones programmed with the Open Data Kit (ODK) application. Staff members asked the caregiver of children aged 12–23 months if the maternal and child health (MCH) booklet was available, and if so, immunization dates were recorded. If no MCH booklet was present, immunization history was collected verbally (data excluded from present analysis). A multiple correspondence analysis of household assets (livestock and valuable goods), cooking fuel and water sources, and household head's source of income was conducted to assign socio-economic status (SES) quintiles to each participant [22]. SES was then dichotomized to lower 40% and upper 60% SES. Straight-line distances from a child's household to the nearest health facility were calculated using ArcView Geographic Information Systems (GIS; Esri, Redlands, CA).

2.3. Primary outcome definitions

The three primary outcomes for regression analyses were: (1) Not receiving immunization; (2) Receiving delayed immunization; and (3) being severely underimmunized. Not receiving immunization and delayed immunization estimates were restricted to pentavalent1 (delayed only), pentavalent3, measles vaccine, and fully immunized child (FIC; not receiving-immunization only), defined as receiving BCG, three doses of polio vaccine, three doses of pentavalent vaccine, and one dose of measles vaccine. Not receiving immunization was the vaccine-specific proportion of children who were not vaccinated when surveyed at ages 12–23 months of age, independent of timeliness. Not achieving FIC was defined as the proportion of children who were not immunized for at least one vaccine by the time of survey.

Delayed vaccination was defined as the vaccine-specific proportion of children who were immunized greater than four weeks from the DVI recommended age [23]. For pentavalent1, pentavalent3 and measles, children were delayed if vaccination occurred after 10 weeks, 18 weeks, and 10 months (303 days), respectively. Delayed immunization was the vaccine-specific proportion of children who were delayed in vaccination over all children that received vaccination. Catch-up schedules for pentavalent series vaccine were not included in primary analyses.

Severe underimmunization was defined as children who, cumulatively across five vaccines (BCG, the three pentavalent vaccines, and measles), had greater than 90 days of underimmunization (either not receiving immunization at all or receiving it with delay) in the first 12 months of life and were delayed for at least three of the five aforementioned vaccines. Days delayed began to accumulate after the four week window had lapsed. The 90 days of underimmunization and the number of vaccines delayed were both required for a child to be considered underimmunized.

2.4. Data analysis

The age at vaccination was calculated by subtracting the child's birth date from vaccination date. Vaccinations received were then dichotomized into delayed and timely as defined above.

For severe underimmunization, vaccination data were censored at 12 months of age. For BCG, pentavalent1–3, and measles vaccines, the number of days underimmunized (delayed or not receiving vaccination) were summed to produce the total number of days underimmunized in the first 12 months of life. Children who received vaccination within 4 weeks of scheduled date were given 0 days of underimmunization for that vaccine. Days underimmunized were not double counted if underimmunized vaccines overlapped. For example, if a child did not receive BCG and measles vaccine, but received all other vaccines on time, the child would be underimmunized 337 days for BCG ($365 - 28$ days) and 62 days for measles ($365 - 303$ days; where $303 = 10$ months). Since BCG and measles underimmunization periods overlapped, the child would be considered underimmunized for 337 days. The number of vaccines delayed and not given were summed for each child. Children with three or more such vaccines were considered severely underimmunized if the total number of days underimmunized was greater than 90 days.