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Vaccine wastage in Nigeria: An assessment of wastage rates and related vaccinator knowledge, attitudes and practices

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Abstract

Introduction—The introduction of new vaccines highlights concerns about high vaccine wastage, knowledge of wastage policies and quality of stock management. However, an emphasis on minimizing wastage rates may cause confusion when recommendations are also being made to reduce missed opportunities to routinely vaccinate children. This concern is most relevant for lyophilized vaccines without preservatives [e.g. measles-containing vaccine (MCV)], which can be used for a limited time once reconstituted.

Methods—We sampled 54 health facilities within 11 local government areas (LGAs) in Nigeria and surveyed health sector personnel regarding routine vaccine usage and wastage-related knowledge and practices, conducted facility exit interviews with caregivers of children about missed opportunities for routine vaccination, and abstracted vaccine stock records and vaccination session data over a 6-month period to calculate wastage rates and vaccine vial usage patterns.

Results—Nearly half of facilities had incomplete vaccine stock data for calculating wastage rates. Among facilities with sufficient data, mean monthly facility-level wastage rates were between 18 and 35% across all reviewed vaccines, with little difference between lyophilized and liquid vaccines. Most (98%) vaccinators believed high wastage led to recent vaccine stockouts, yet only 55% were familiar with the multi-dose vial policy for minimizing wastage. On average, vaccinators reported that a minimum of six children must be present prior to opening a 10-dose MCV vial. Third dose of diphtheria-tetanus-pertussis vaccine (DTP3) was administered in 84% of sessions and MCV in 63%; however, the number of MCV and DTP3 doses administered were similar indicating the number of children vaccinated with DTP3 and MCV were similar despite less frequent MCV vaccination opportunities. Among caregivers, 30% reported being turned away for vaccination at least once; 53% of these children had not yet received the missed dose.

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Discussion—Our findings show inadequate implementation of vaccine management guidelines, missed opportunities to vaccinate, and lyophilized vaccine wastage rates below expected rates. Missed opportunities for vaccination may occur due to how the health system's contradicting policies may force health workers to prioritize reduced wastage rates over vaccine administration, particularly for multi-dose vials.

Keywords

Measles; Immunization; Nigeria; Wastage

1. Introduction

Since the 1980s, wide-scale use of vaccinations against diseases such as measles, polio, pertussis and hepatitis B has resulted in substantial childhood mortality reductions worldwide. New vaccines against pneumonia, rotavirus and other diseases are rapidly being introduced in low-income countries to further reduce childhood mortality. Effective vaccine management is continues to be crucial [1] since these new vaccines are substantially more expensive than existing vaccines [2]. Appropriate vaccine management includes recommendations to minimize vaccine wastage [1], however, concern exists about how wastage policies may contribute to missed opportunities to vaccinate (MOV), particularly in low-income countries with high vaccine-preventable disease burden [1,3–7].

A vaccine dose is considered wasted if not used to vaccinate an eligible child [6]. Global guidelines address ways to reduce wastage, including the multi-dose vial policy (MDVP) which states open vials of specific (generally liquid) vaccines can be reused up to 28 days [8]. However, the MDVP does not apply to lyophilized vaccines without preservative, including commonly used 10-dose measles-containing vaccine (MCV) and 20-dose Bacillus Calmette Guérin (BCG) vaccine, as they must be discarded within 6 h of reconstitution or end of the vaccination session (whichever comes first). The World Health Organization (WHO) considers the discard of remaining doses in lyophilized vaccine vials to be an unavoidable reason for wastage [6]. Reasons for wastage that are considered avoidable include: vaccine expiration, vial breakage, inappropriate vial freezing, discarding liquid vaccine before 28 days, prolonged heat exposure and theft of the vaccine [6]. Both unopened and opened vaccine wastage rates should be monitored to help determine appropriate response strategies [6] since unopened wastage is largely due to supply chain practices, whereas opened wastage is due to both supply chain and immunization practices. Globally, recommended maximum wastage rates range from 15% to 50% for lyophilized vaccines and from 5% to 25% for liquid vaccines [9,10]. How well these various policies and recommendations are known and implemented at the service delivery level is not well documented.

An MOV occurs when an individual interacts with the health system and does not receive the vaccines for which they are eligible [11,12]. Studies have found associations between wastage practices and MOV [5,13]. WHO recommends that vaccines be administered anytime an eligible child presents for vaccination, irrespective of the total number of children present in the clinic (i.e. 'every opportunity' or 'vial-opening' recommendation)

[6,14]. Yet, multiple MOV assessments in low-income countries using health facility exit interviews with child caregivers indicate that children are turned away specifically for BCG and MCV vaccinations [4,5]. Few studies have conducted in-depth vaccinator surveys to examine the decision-making processes that lead to children being turned away, particularly to the roles of vaccine wastage concerns and vial usage practices. Although studies have examined vaccine wastage rates [15–19], none have done so while also examining vaccinator knowledge, attitudes and practices associated with vaccine vial usage and management guidelines. Examining both wastage rates and related vaccinator knowledge and attitudes could provide a more in-depth understanding of observed vaccine usage patterns and assist with developing interventions to address identified issues.

In 2011, Nigeria began preparations to introduce pneumococcal conjugate vaccine, replace diphtheria-tetanus-pertussis (DTP) vaccine with DTP-hepatitis B-Haemophilus influenzae type b (pen-tavalent) vaccine and endorse a goal to eliminate measles by 2020. In this study, we assessed health sector staff knowledge, attitudes and practices related to vaccine vial usage and wastage guidelines, calculated vaccine wastage rates and usage patterns over a 6-month period at both service delivery and storage levels, compared vaccine wastage rates between liquid and lyophilized vaccines to determine if rates differed based on policies such as the multi-dose vial policy, and evaluated child caregiver experiences with MOV. This information provides evidence for policy-makers in Nigeria regarding strategies to improve vaccination coverage, and informs future research addressing the relationship between wastage rates and vaccination coverage.

2. Materials & methods

2.1. Definitions

In Nigeria, routine vaccinations are generally administered by one or more trained health workers at health facility level. Routine vaccinations are generally administered during a multi-hour vaccination session, which may be held at the facility, or at an outreach site in a village far from the facility; one or more routine vaccines may be administered during this session. Health workers who provide vaccinations are supervised by local government area (LGA, equivalent to districts in most countries) immunization officers and vaccine logisticians. Vaccines are supplied from the national level to states, and then to LGAs. Vaccines are stored in LGA cold stores until they are needed for administration at health facility level. Unopened vaccine wastage is defined as loss of doses in an unopened vial; opened vaccine wastage is defined as loss of doses in an opened vial. A wastage rate is the sum of both opened and unopened wastage rates. An MOV in this study is defined as the event when a child eligible for vaccination attended the health facility for health services (vaccination, curative care) and did not receive the vaccine(s) for which they were eligible.

2.2. Sampling

We conducted two-stage random sampling of LGAs and health facilities where routine vaccinations are provided in each of Nigeria’s six zones and its Federal Capital Territory (FCT). In each zone, we used probability proportional-to-size sampling to randomly select two LGAs; in FCT, the team randomly selected one LGA. In each LGA, the team used

simple random sampling to select five health facilities – on average, 20% of the facilities in each LGA –to conduct vaccinator interviews. At each facility, we aimed to interview 5 caregivers of children <24 months as they exited the facility after receiving health services for the child, using convenience sampling. Our total target sample was 13 LGAs, 65 health facilities and 325 caregivers.

2.3. Data collection

2.3.1. Data collection team and activities—Data collection occurred in August 2011. The data collection team was composed of national and state vaccine logistics officers employed at Nigeria National Primary Health Care Development Agency (NPHCDA) and UNICEF. We assigned logistics officers as data collectors in areas where they were not employed to minimize interviewer bias. In selected LGAs, data collectors interviewed the LGA immunization officer (who supervises health facility vaccinators) and vaccine logistician (who maintains the LGA-level vaccine supply chain) and reviewed vaccine stock records. At health facilities, data collectors interviewed the health worker who provided the majority of the vaccinations (whom we refer to as the vaccinator) and reviewed vaccine stock and vaccination session records. The data collectors also conducted facility exit interviews with caregivers of children aged <24 months who had received any health services.

2.3.2. Information collected—To calculate monthly LGA and health facility wastage rates and assess vaccine usage patterns, data collectors abstracted vaccine stock management data from January through June 2011 from vaccine management ledgers designed to track routine use of vaccine. Abstracted data per month were: starting monthly balance of vaccine doses, number of vaccine doses received from a higher administrative level, vials opened (collected at facility level only), number of children vaccinated (collected at facility level only), ending monthly balance of vaccine and reason for discard of unopened doses (expiration, breakage, VVM status, freezing, other).

To calculate vaccination session wastage rates and assess usage patterns, data collectors abstracted vaccination session data for the immediately preceding three months (June–August 2011) from vaccination session tally sheets used to tally vaccine use per daily vaccination session. Abstracted data per session were: number of vials received, vials opened, vials returned unopened and children vaccinated per session. We abstracted data for the following vaccines: DTP, MCV, BCG, oral polio vaccine (OPV), tetanus toxoid (TT) and hepatitis B (HepB).

We used Nigeria's national vaccination guidelines [20] (Table 1) and WHO policies and guidelines [6,21] to develop KAP questionnaires. Health workers at the LGA and facility level were asked about their knowledge of target wastage rates, how they managed vaccine stock, and how they monitored and reported on vaccine stock and storage indicators. Additionally, they were asked about awareness and implementation of the MDVP and 'vial-opening' guidelines, perceived influence of wastage on vaccine supply, strategies used to manage wastage, and factors leading to high wastage rates. Lastly, caregivers were interviewed about whether they had been turned away for vaccination recently, which

vaccines they were seeking when turned away, and whether they had returned later for the missed vaccination.

2.4. Data analysis

All data were collected on paper and then entered into Micro-soft Excel. All analyses used survey procedures in SAS 9.2 and were weighted based on the sampling design.

2.4.1. Datasets for calculating vaccine wastage and assessing usage patterns—Using abstracted data, we created datasets for (1) LGA-level vaccine stock data, (2) health facility vaccine stock data, and (3) vaccination session vaccine vial usage. All vial data were converted to into doses. Monthly or session records for a vaccine were excluded from analysis if they were not interpretable for any of the following reasons:

- Data for a vaccine were missing for either the number of doses administered or the number of vials opened;
- The number of doses administered to children exceeded the number of vials opened for use
- For session data only: the number of doses returned to cold chain exceeded the number of doses expected to be returned based on number of doses supplied and number of doses used

We used WHO-recommended formulas for calculating wastage (WHO, 2005). Before analyses, we assessed the monthly availability of data for each indicator in the formula.

2.4.2. Calculation of facility (service-delivery) level vaccine wastage—Due to data availability concerns, we calculated facility-level wastage rates using data from two sources: vaccine stock management ledger datasets and vaccination session monitoring form datasets. The following formula was used for calculating monthly vaccine-specific wastage rates using data from the vaccine stock management ledger dataset:

$$=\frac{(monthly\ opening\ balance\ doses+number\ of\ doses\ received)-monthly\ closing\ balance\ of\ doses-number\ of\ doses\ administered}{(monthly\ opening\ balance\ of\ doses+number\ of\ doses\ received)-monthly\ closing\ balance\ of\ doses}$$

We calculated unopened and opened vaccine-specific wastage rates using the following formulas:

$$\text{Un opened vaccine wastage rate}=\frac{(Doses\ discarded\ unopened)}{(monthly\ opening\ balance\ of\ doses+number\ of\ doses\ received)-monthly\ closing\ balance\ o}$$

$$\text{Opened vaccine wastage rate}=\frac{(Doses\ opened\ for\ use)-(number\ of\ children\ immunized)}{(monthly\ opening\ balance\ of\ doses+number\ of\ doses\ received)-monthly\ closing\ balance\ of\ o}$$

To obtain a monthly mean of wastage rates across facilities, we calculated a mean across all six months per facility and then calculated a mean across all facility means. The following formula was used for calculating vaccine-specific wastage rates per session using data from the vaccination session monitoring form dataset:

$$=1-\frac{number\ of\ doses\ administered\ in\ vaccination\ session}{number\ of\ doses\ opened\ in\ vaccination\ session-number\ of\ doses\ returned\ to\ cold\ chain\ at\ end\ of\ session}$$

To obtain a monthly mean across all sessions, we calculated a mean across all sessions per facility and then calculated a mean across all session means. We also summed the total number of doses of each vaccine administered across all sessions to determine if any differences were present in this indicator across vaccines.

2.4.3. Calculation of LGA (storage-level) vaccine wastage—Since vaccines are only stored and not administered at the LGA level, we used the following formula to calculate unopened LGA-level vaccine-specific wastage rates:

$$=\frac{number\ of\ doses\ discarded\ unopened\ for\ any\ reason}{(monthly\ opening\ balance+number\ of\ doses\ received)-monthly\ closing\ balance}$$

We then calculated a monthly vaccine-specific mean per LGA and then calculated a mean across these LGAs.

We also calculated presence of a monthly facility-level vaccine stockout (i.e. when no vaccine is available) by analyzing whether the monthly vaccine stock balance per the vaccine stock management ledger was equal to zero for the entire month (i.e. monthly opening balance, number of vials received and monthly closing balance were all equal to 0).

2.4.4. Analysis of vaccine usage patterns during vaccination sessions—We calculated the proportion of sessions where each vaccine was given and the mean number of doses given per session for each vaccine (in sessions where ≥1 doses were administered). We also calculated the total number of doses given per vaccine across all sessions.

2.4.5. Statistical analysis of interview data—For categorical indicators, we calculated proportions and 95% confidence intervals (95% CIs) based on our sampling method. For numerical indicators, we calculated means and 95% CIs. We used *t*-tests for comparing means and Rao-Scott chi-square tests for comparing proportions and an alpha level of 0.05 for any hypothesis testing of differences between two indicators.

3. Results

Data were collected from 11 (85% of target) LGAs, 54 (83% of target) facilities and 263 (81% of target) caregivers across 6 zones and FCT; remaining target areas were excluded due to security concerns that arose during data collection. We abstracted and analyzed 576 vaccination session records, 324 months of facility-level stock management records and 66 LGA-level stock management records.

3.1. Vaccine stock and vaccination session data availability and quality

Among LGA stock records, 36% provided sufficient data to calculate LGA-level wastage rates. Among health facility stock records, a mean of 51–55% of facilities (varying by

vaccine) had sufficient data to calculate facility-level wastage rates. Data were most commonly missing for number of vials received (23–34% of facilities without data, varying by month), number of vials opened (37–39%) and number of vials returned unopened (41–43%). No facilities distinguished opened from unopened wastage, so unopened vaccine wastage rates could not be calculated. Using facility-level vaccination session records, 24–41% (varying by vaccine) of sessions provided sufficient data to calculate facility-level wastage rates.

3.2. LGA and facility-level vaccine supply and wastage rates

LGA-level unopened vial wastage rates were 0% for all vaccines and months in all LGAs except for 20% BCG wastage in one LGA for one month. Using vaccine stock records, the mean monthly facility-level wastage rate during the 6-month period was highest for TT (28%) and lowest for DTP (18%) (Fig. 1, Table 2). Using vaccination session records, the mean monthly wastage rate was highest for OPV at 35% and lowest for DTP vaccine at 21%. On a month-by-month basis, mean facility-level wastage rates were all under 34%, ranging 16–34% for BCG, MCV, OPV and TT, and 9–25% for HepB and DTP [data not shown].

The mean monthly proportions of facilities with stockout of BCG or OPV were 42% and 32%, respectively. For all other vaccines, the mean monthly proportions were 5–15%.

3.3. Vaccination session vaccine usage patterns

On average, facilities held vaccination sessions 3.6 times per month, with 44% conducting vaccination sessions more than once per week. HepB1, HepB3, DTP1 and DTP3 were all administered in >77% of the 576 reviewed sessions (Table 2) MCV and BCG vaccines were administered in a significantly lower proportion of sessions (63%, and 26%, respectively; p-value < 0.02 for all pairwise comparisons) compared to DTP1 (86% of sessions) and DTP3 (84% of sessions). Although MCV was administered in fewer sessions, the total number of MCV doses administered across all sessions (4740) was slightly higher than the number of DTP3 doses administered (4286). In sessions with MCV vaccination, a mean of 10.0 doses (range = 1–38), were administered per session; in comparison, during sessions with DTP vaccination, a mean of 7.5 DTP1 doses (range = 1–70) and 6.7 DTP3 doses (range = 1–51) were administered per session. A slight majority (51%) of sessions with MCV vaccination involved administration of 7–10 doses from the presumed final MCV vial used in a session (i.e. sessions with 7–10, 17–20, 27–30, or 37–38 total MCV doses administered) and the highest proportion of sessions (20%) involved 8 administered doses from the final vial, i.e., 8, 18 or 28 doses given in a session (Fig. 2). In 61% of sessions with BCG administration, 11–20 doses from the final BCG vial were administered (data not shown).

3.4. Vaccine stock management and monitoring knowledge and practices

Nearly all (97%) vaccinators requested vaccine when stocks were low; the remaining 3% reported that the LGA sent vaccine to the facilities based on LGA-level estimates of vaccine need (Table 3). When determining the number of vials to request, 53% of vaccinators reported using the number of doses administered in previous vaccination sessions, 33% used their target population and the remaining 12% were uncertain.

Routine stock management monitoring was infrequent; 18% of vaccinators monitored cold chain temperatures twice daily, and 9% routinely calculated wastage rates (Table 3). No vaccinators monitored unopened-vial wastage although 39% indicated lost or damaged unopened vials in the previous six months. Few vaccinators (12%) knew the national wastage rate targets or the variables needed to calculate wastage rates (16%). Although most (91%) LGA staff knew the national wastage rate targets and most (83%) routinely monitored wastage rates, but only 38% could accurately recall the proper information needed to calculate wastage.

3.5. Knowledge and implementation of vaccine usage policies

When asked about the re-use of an opened liquid vaccine vial with remaining doses, vaccinators at 55% of facilities reported they were familiar with the MDVP-defined conditions for re-use (Table 3). However, <50% of vaccinators could, without prompting, recall specific MDVP conditions for re-use and only 11% knew an opened liquid vaccine vial could be re-used up to 28 days. Contrary to MDVP recommendations, 47% reported discarding opened, reusable polio vaccine at the end of a vaccination session rather then returning it to the cold chain. Among vaccinators who were familiar with the MDVP, 76% reported reusing an opened polio vaccine vial, versus only 10% among those vaccinators who were unfamiliar with the MDVP (odds ratio = 27.1, p-value < 0.01) [not shown].

When vaccinators were asked how they decide to open any vial, 54% stated they open vials on pre-scheduled vaccination session days. When specifically asked how they decide when to open an MCV vial, 98% of vaccinators stated they open only on a special MCV vaccination day or wait for a certain minimum number of children, while only 2% open for any eligible child present (Table 3). Sixty percent stated that they “batch” children, i.e. waiting for a desired number to arrive during a session, before deciding to open an MCV vial. On average, vaccinators reported that 6 (95% CI: 5–7) children needed to be present before they would open a MCV vial.

In comparison to vaccinators, 6% of LGA staff reported that an MCV vial should be opened anytime a child presents for vaccination and 77% stated an MCV vial should be opened either if a certain number of children are present or if it is a scheduled MCV vaccination day. All LGA staff reported familiarity with MDVP but only 35% knew opened vials of liquid vaccines could be used up to 28 days.

3.6. Knowledge, attitudes and practices regarding wastage

Nearly all vaccinators (98%) perceived vaccine wastage to be a cause of recent vaccine stockouts (Table 3) and 79% indicated they made efforts to reduce wastage. Most (78%) vaccinators indicated they were told during supervision visits from LGA level of the need to reduce vaccine wastage. Strategies used by vaccinators to reduce wastage included improving stock management (reported by 48% of vaccinators), better community mobilization (38%), batching children (25%) and implementing the MDVP (19%). When asked to list the reasons why wastage can happen, vaccinators’ knowledge was highly variable; many cited vial breakage (58%), discarding doses 6 h after reconstitution (43%) and vial exposure to high temperature (37%) [Data not shown]. When asked to list the

reasons why wastage happened at their own health facility, vaccinators most frequently cited vial spillage (57%) and inability to retrieve all doses from the vial (34%). At the LGA level, staff believed the leading reasons for facility-level wastage were discarding doses six hours after reconstitution (47%) and inability to retrieve all doses from the vial (28%). To manage wastage, LGA staff most frequently recommended improved stock management (53% of LGA staff), better-organized outreach sessions (46%) and batching children (41%).

3.7. Caregiver-reported missed opportunities

During exit interviews with caregivers of a child <24 months of age, 90% reported the child had received at least one routine vaccination [data not shown]. Of these, 52% reported that their infants received the most recent vaccination during a first attempt at attending a vaccination session, 40% received the vaccination on a second attempt (and were turned away in the first attempt), and 8% were unsure. Among the 40% turned away, the primary reported reason for being turned away was lack of vaccine or lack of a vaccination session (41%). Among all caregivers, 30% reported bringing their child for vaccination and being turned away at least once. Of these, 33% reported being turned away for BCG, 26% for MCV, 19% for HepB, 12% for DTP and 10% for other vaccines Approximately half (47%) of the 30% turned away reported the child had eventually received the missed vaccination while the other half (16% of all mothers) had not yet returned for the missed vaccination.

4. Discussion

To our knowledge, this study is the first to simultaneously assess vaccine wastage rates, vaccine usage patterns, and vaccinators' knowledge, attitudes and practices regarding implementation of a country's policies for managing and using vaccine. We documented that vaccinators' reported practices regarding when they open a vial for certain vaccines differs from global, national and supervisors' guidelines while their knowledge of recommended vaccine usage and wastage practices was suboptimal. Estimated monthly wastage rates were near 25% for all vaccines and differed little between liquid and lyophilized vaccine presentations, indicating that vaccinators could be overly focused on minimizing wastage for lyophilized vaccines but not fully implementing recommended policies like the MDVP to minimize wastage further for liquid vaccines. Quality of vaccine stock record data was inadequate, and unopened versus opened vial wastage was not monitored despite reports that both types of wastage occurred. MCV and BCG were administered in significantly fewer sessions compared to DTP3; suggesting children may experience MOVs if they came during sessions when MCV and BCG were not given. However, MCV and DTP3 coverage rates were similar, suggesting that children who are turned away for MCV may eventually return to receive it at the same rate as DTP3 receipt. Lastly, caregivers reported being turned away for vaccination, most frequently for BCG and MCV, and a substantial proportion had not yet received the missed vaccine. These missed opportunities lead to under-vaccination (or late vaccination) against measles and tuberculosis at a vulnerable age for the child and contribute to an increase in the unprotected cohort size.

Despite global and national recommendations to ensure a vaccine vial is opened at every opportunity, our study indicates vaccinators may prioritize minimizing wastage over opening

a vial for every eligible child, risking the achievement of timely, complete and cost-effective immunization. In our study, the administration of MCV and BCG vaccine during special MCV/BCG vaccination days and/or when a minimum number of children are present was evident not only from vaccinator reporting but also from vaccination session data. This may partly explain why liquid and lyophilized vaccine wastage rates are similar despite country and global guidelines stating that acceptable wastage rates are higher for MCV (up to wastage of 50%) and BCG compared to other vaccines [10,20]. In other countries where implementation of policies around when to open a vial may differ from that in Nigeria, substantial differences between lyophilized and liquid vaccine wastage rates have been observed [16]. In Nigeria, the number of MCV and DTP3 doses provided in the analyzed sessions were similar, which may indicate that even if infants are turned away for MCV, eventually they receive MCV at similar levels as DTP3. However, delayed vaccination can lead to increased economic burden for the caregiver who travels multiple times for the same vaccination and prolonged period of disease risk for children. In recent measles outbreaks in Ethiopia and other African countries, substantial disease burden occurred among children 9–12 months of age, indicating the need to ensure a timely dose at 9 months of age in high burden settings [22,23].

Vaccinators may employ multiple strategies to minimize vaccine wastage without causing missed opportunities. Proper vaccination session planning, delivery of key reminder messages to mothers during the vaccination session and use of a community-level mobilizers to inform mothers of vaccination session dates can also reduce the number of mothers who accidently come on non-vaccination days [24]. Ensuring vials are opened at every vaccination opportunity, despite the likelihood that wastage could occur, guarantees a child will be vaccinated and at reduced risk of infection. Multiple strategies exist to ensure policies to reduce missed opportunities are prioritized over wastage concerns, including health program manager and health worker trainings and dissemination of job aids to workers. Vaccine forecasting may also need to incorporate the expectation that wastage rates for lyophilized vaccines may rise to incorporate vial-opening practices, which reduce missed opportunities. Future work should examine the relationship between MCV vaccine wastage rates and MCV vaccination coverage and couple this assessment with cost-effectiveness analyses of interventions designed to address wastage-coverage relationship. For instance, changing the MCV vaccine vial size from 10 doses to 5 doses may nudge vaccinators into opening a vial, although the impact of such a change on timely coverage, wastage rates and associated costs is unknown [25,26]. Additionally, our results of relatively high wastage rates for MDVP-eligible liquid vaccines (i.e. OPV and DTP) which could be re-used for up to 28 days, coupled with low levels of MDVP vaccinator knowledge indicate the need to address the MDVP in health worker trainings. Such activity could appropriately reduce liquid vaccine wastage rates and save costs, while not leading to MOVs.

Our study is subject to certain limitations. Our facility sample size is small, affecting the precision of our estimates. A substantial number of facilities had incomplete vaccine management records which may have introduced bias in our estimates; we are uncertain the direction of this bias. We only reviewed vaccine usage patterns for 6 months, so our data may be affected by seasonal differences. Our caregiver survey was a convenience sample of those who came to the health facility to use health services and was not representative of the

general population. Additionally, do to increasing security restrictions during the study period, we had to eliminate certain areas that were initially selected for the survey, which could introduce selection bias issues. Lastly, caregiver reasons for being turned away were based on self-report and not individually verified with vaccinators.

Low-income countries like Nigeria face pressure to minimize vaccine wastage, and this may result in vaccinators diverging from acceptable methods and practices intended to ensure high and timely vaccination coverage. When faced with a single child who presents for MCV vaccination, vaccinators must choose whether to turn the child away or to immediately vaccinate the child, potentially resulting in high wastage and vaccine stockout. National level immunization teams should examine the implementation of vaccine management policies at the service delivery level and then appropriately adjust vaccine procurement and supply, health worker training materials and other efforts to ensure that missed opportunities are minimized while wastage rates are appropriately managed. National staff should also explore utilizing facility-based supervision visits to monitor implementation of recommended vaccine management and usage policies to reinforce the theme of reducing missed opportunities while appropriately managing vaccine wastage.

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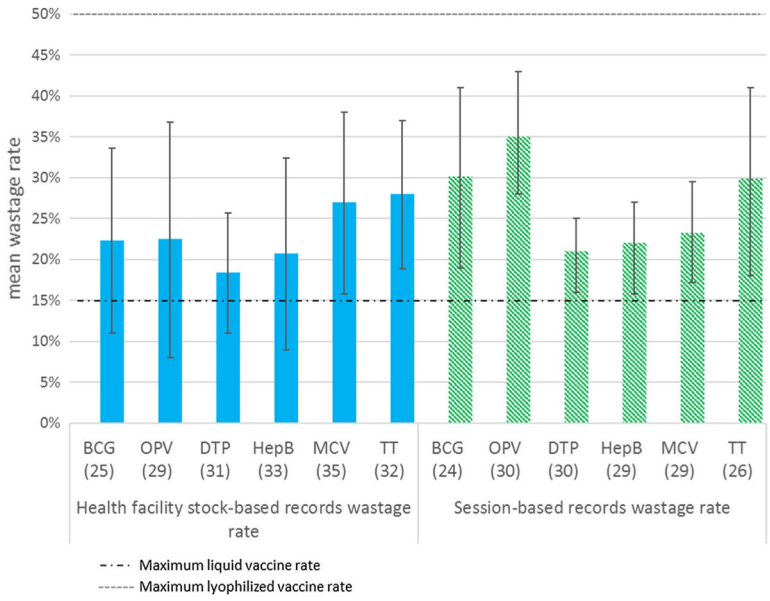

Fig. 1.

Mean monthly vaccine wastage, by vaccine, for health facilities and vaccination sessions; selected Nigerian health facilities, 2011. Facility stock-based records wastage calculated using data from health facility monthly stock management ledgers. Session-based records wastage calculated using data from vaccination session ledgers. Numbers in parentheses represent number of health facilities with data available to calculate given wastage rate. Error bars represent the 95% confidence interval for given estimate. Broken lines indicate target maximum wastage for lyophilized vaccines (MCV and BCG) and for liquid vaccines (all others listed) based on 2011 Nigeria national vaccination policy. BCG = Bacillus Calmette-Guérin vaccine; OPV = oral polio vaccine; DTP = diphtheria-tetanus-pertussis vaccine; HepB = hepatitis B vaccine; TT = tetanus toxoid.

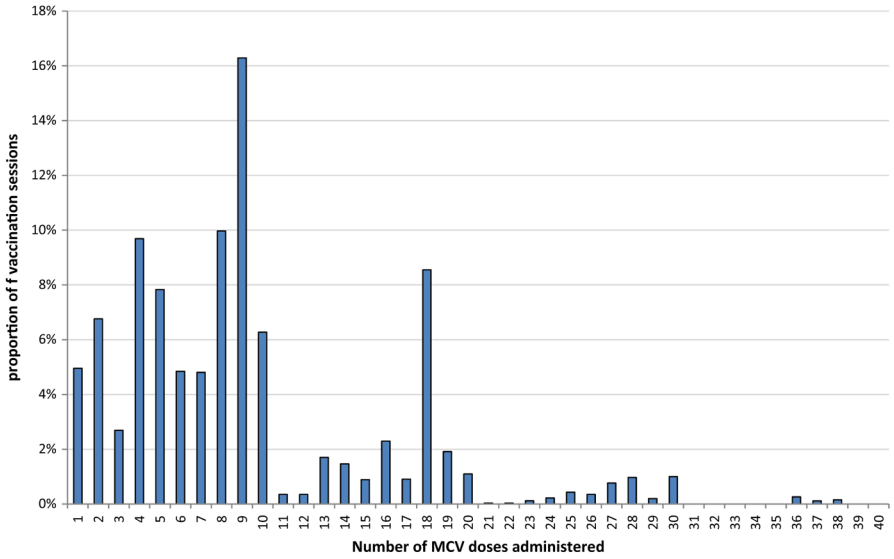

Fig. 2.

Number of measles-containing vaccine (MCV) doses administered at vaccination sessions at 54 health facilities, Nigeria 2011 (N = 390 vaccination sessions where MCV was administered).

Table 1

Vaccinations recommended and vaccine vial presentations used in Nigeria in 2011.

Vaccine	Number of doses per vial	Type	Target maximum wastage rate	Recommended schedule
Bacillus Camille-Guérin vaccine	20	Lyophilized[a]	50%	1 dose: Birth
Oral polio vaccine	20	Liquid	15%	4 doses: Birth and ages 6 weeks, 10 weeks, 14 weeks
Diphtheria-tetanus-pertussis vaccine	10	Liquid	15%	3 doses: ages 6 weeks, 10 weeks, 14 weeks
Hepatitis B	10	Liquid	15%	3 doses: ages 6 weeks, 10 weeks, 14 weeks
Measles-containing vaccine	10	Lyophilized[a]	50%	1 dose: age 9 months
Yellow fever	10	Lyophilized[a]	50%	1 dose: age 9 months
Tetanus toxoid	10	Liquid	15%	4 doses: Child-bearing age women

[a]Once opened, vaccine must be used within 6 h of reconstitution or by the end of the vaccination session, whichever comes first; otherwise, all remaining doses are discarded.

Table 2

Summary of key vaccine vial usage indicators across 576 routine vaccination sessions conducted in 54 selected health facilities of Nigeria during May–June 2011.

Indicator	BCG	OPV	OPV3	DTP	DTP1	DTP3	HepB	HepB3	MCV	TT
Total number of doses administered in all sessions	3351	12,904	3546	12,766	4751	4286	11,271	4179	4740	6179
Mean number of doses administered per session (95% CI)	14 (10, 18)	23 (11, 35)	7 (4, 11)	19 (12, 26)	8 (4, 11)	7 (4, 9)	17 (11, 24)	6 (4, 8)	10 (5, 15)	13 (7, 18)
Proportion of sessions where vaccine or dose was administered (95% CI)	26 (5, 47)	71 (50,91)	64 (43, 84)	90 (85, 95)	86 (79, 92)	84 (79, 89)	87 (76, 98)	77(67, 88)	63(56, 69)	71 (59, 82)

Abbreviations: BCG = Bacillus Calmette-Guerin vaccine; OPV = oral polio vaccine, doses 1, 2 and 3; DTP = diphtheria-tetanus-pertussis vaccine, doses 1, 2 and 3; HepB = hepatitis B vaccine; MCV = measles-containing vaccine; TT = tetanus toxoid.

Table 3

Knowledge, attitudes and practices regarding vaccine vial usage and vaccine wastage among vaccinators at 54 selected health facilities and their supervisors at 11 selected local government areas (LGAs) of Nigeria, 2011.

Indicator	Vaccinator (N = 54); % responding "yes", (95% CI)	LGA supervisor (N = 11); % responding "yes", (95% CI)
General vaccine wastage-related knowledge and attitudes:		
I am familiar with the multi-dose vial policy (MDVP)	55 (0, 100)	100 (100,100)
MDVP knowledge: I can reuse an open vial of an eligible vaccine if stored in appropriate cold chain conditions	33 (5, 61)	100 (100,100)
MDVP knowledge: I can reuse an open vial of an eligible vaccine if vaccine vial monitor is in stage 1 or 2	43 (9, 78)	64 (3, 100)
MDVP knowledge: I can reuse an open vial of an eligible vaccine for up to 28 days	11 (0, 29)	35 (0, 96)
I received vaccine wastage targets from supervisor	12 (0, 25)	91 (68,100)
Vaccine supply has been affected by vaccine wastage	82 (42, 100)	38 (6,70)
There was wastage due to vaccine storage space constraints	0 (0, 1)	NA
High wastage rates were a reason for recent vaccine stockouts	98 (93, 100)	NA
I have attended a vaccine management training	2 (0, 5)	NA
General vaccination-related practices:		
In general, a vial is opened as soon as an eligible child comes to the facility	46 (0, 100)	76 (42, 100)
In general, a vial is opened only on certain days or when a certain number of children are present at the facility	54 (0, 100)	24 (0, 59)
Measles-containing vaccination-related knowledge:		
Re-constituted measles-containing vaccine (MCV) can be kept for up to 6 h	85 (65, 100)	NA
Measles-containing vaccination-related practices:		
An MCV vial is opened as soon as an eligible child comes to the facility	2 (0, 5)	6 (0, 20)
An MCV vial is opened only on certain days or when a certain number of children are present at the facility	98 (95, 100)	77 (48, 100)
I wait for children to gather to a minimum number before opening a MCV vial	60 (25, 95)	NA
General vaccine wastage-related practices:		
I forecast vaccine needs based on target population	33 (3, 64)	NA
I forecast vaccine needs based on previous number of vaccines used	53 (11, 94)	NA
I request vaccine from LGA when needed (pull approach)	97 (92, 100)	NA
I make an effort to reduce wastage	79 (63, 96)	79 (35, 100)
Vaccines were wasted due to cold chain failure at least once in the last six months	35 (0, 78)	NA
Vaccine vials were lost/damaged at least once in the last six months	39 (24, 54)	NA
I calculate wastage rates monthly for each vaccine	9 (0, 20)	83 (51, 100)
I calculate open vial wastage rates monthly for each vaccine	0 (0, 0)	NA
I know the vaccine wastage rate targets	12 (0, 25)	91 (68, 100)
I know the variables needed to calculate wastage	16 (0, 31)	38 (0, 100)
I monitor cold chain temperatures twice daily	18 (6, 30)	NA
I discard opened, usable polio vaccine vial at the end of session	47 (5, 89)	NA
The national policy for when to open a vial is different than the practice in my LGA	NA	36 (5, 67)
The practice in this LGA on use of the multi-dose vial policy is different than the official policy	NA	7 (0, 22)

Indicator	Vaccinator (N = 54); % responding "yes", (95% CI)	LGA supervisor (N = 11); % responding "yes", (95% CI)
Main reasons why wastage occurs at your facility(s)		
Spillage of vaccine	57 (30, 86)	12 (0, 31)
Inability to get all doses from vial	34 (6, 64)	28 (0, 64)
Discard 6 h after reconstitution	31 (11, 5)	47 (0, 100)
Exposure to high temperature	16 (0, 34)	35 (6, 64)
Breakage of vial	11 (0, 25)	0 (0, 0)
Exposure to freezing	5 (0, 18)	6 (0, 17)
Discarding an open vial with usable vaccine	1 (0, 4)	9 (0, 25)

Definitions: NA = statement not applicable or asked to this level; LGA = local government area; CI = Confidence interval; MCV = measles-containing vaccine; MDVP = multi-dose vial policy. For the MDVP, an eligible vaccine was described as those vaccines which could be stored past the 6-h mark after opening of the vial and vaccine was still in the vial.