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Study protocol for a cluster-randomised controlled trial of hybrid parents and health workers adaptive intervention for optimal routine childhood immunisation coverage in the communities of Ebonyi state, Nigeria: the AGINTOPIC trial protocol

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ABSTRACT

Introduction Vaccine-preventable infectious diseases (VPDs) are major causes of morbidity/mortality among children under 5 years of age worldwide and in Nigeria/Ebonyi state. Routine childhood immunisation is an invaluable prevention strategy for many VPDs. Due to suboptimal coverage and untimely receipt/delay in receipt of vaccinations, outbreaks of VPDs such as measles, yellow fever, diphtheria and others continue to reoccur around the world and in Nigeria/Ebonyi state. This study aims to evaluate the effectiveness of hybrid parents and health workers adaptive intervention in increasing the optimal/timely (cumulative age-appropriate) routine childhood immunisation coverage in the communities in Ebonyi state, Nigeria.

Methods and analyses A two-arm, parallel, open label, covariate-constrained cluster-randomised controlled trial with 1:1 allocation of 16 geographical clusters (the nearest catchment areas for at least one public primary healthcare (PHC) facility with at least 500 households or a population size of 3000) will be used to evaluate the effects of hybrid/combined parents and PHC workers adaptive engagement compared with control. The primary outcomes are the optimal/timely (cumulative age-appropriate) receipt of the recommended vaccines in the routine childhood immunisation schedule by children aged 5–9 completed months and 10–11 completed months and the age-appropriate vaccines receipt score for the recommended vaccines. The outcomes will be measured through a population-based household survey of at least 15 children aged 5–9 and 10–11 months per cluster at baseline and at the end of the study using a structured interviewer-administered questionnaire in KoBoCollect installed in android devices. All analyses will be done using a cluster-level method on as-randomised basis.

Ethics and dissemination Ethical approval for the trial was obtained from the Ebonyi State Health Research and Ethics Committee (EBSHREC/01/06/2022–31/05/2023) and verbal consent will be obtained from participants. Study findings will be reported at local/national and international levels as appropriate.

Trial registration number ISRCTN59811905.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study will assess and deliver intervention to increase the optimal/timely (cumulative age-appropriate) receipt of routine childhood immunisation which enhance the validity of immunisation coverage, make the protection against vaccine-preventable infectious diseases optimal and is a very good measure of immunisation programme performance.
⇒ The assessment of timeliness as a continuous variable will give an important insight to the extent/scale of timeliness in routine childhood immunisation coverage.
⇒ The study will be implemented based on prospective registration with ISRCTN and on available/accessible or disseminated study protocol.
⇒ The random allocation of clusters was based on baseline covariates.
⇒ Blinding of study participants and interviewers will not be possible because of the pragmatic nature of the intervention.

INTRODUCTION

Vaccine-preventable diseases, especially vaccine-preventable infectious diseases (VPDs), are major causes of morbidity and mortality worldwide and particularly in Nigeria and especially among children under 5 years of age. More than 90 million cases of VPDs occurred worldwide among children younger than 5 years in 2015 while more than 30 million (about 33%) of the global cases and

more than half a million (about 58%) of the global deaths from VPDs among these children occurred in Africa due to poor access to childhood immunisation.[1] VPDs such as lower respiratory infections (especially pneumococcal diseases), acute diarrhoeal diseases (rotavirus infection), whooping cough (pertussis), measles etc are major causes of mortality and morbidity among children younger than 5 years in Africa, including Nigeria and Ebonyi state.[1 2]

Routine immunisation and vaccinations in general are an invaluable prevention and control strategy for many VPDs.[3] Over the past decade, significant progress has been made in the global, national and subnational immunisation coverage and millions of lives are being saved by immunisation each year as the rates of death and disability (especially among young children) from VPDs have remarkably declined.[3 4] However, this recorded progress has stagnated, and even reversing, in some countries[3 4] and in many cases only a fraction of those who completed their routine immunisation schedule received the doses in a timely manner.[5–9] Delayed receipt of vaccination increases the risk of VPDs outbreak due to delay in vaccine-induced (herd) immunity.[5 6 9 10] Consequently, perhaps due to suboptimal coverage and/or untimely receipt/delay in receipt of vaccinations, outbreaks of VPDs such as measles, yellow fever, diphtheria and others continue to reoccur around the world[3 4 9 11] and in Nigeria.[12–14]

In Nigeria, after briefly achieving immunisation coverage targets between 1988 and 1990, a peak of 81.5% for all scheduled vaccines,[15] immunisation coverage has perpetually stagnated far below national/international targets and has been characterised by fluctuations and wide disparities between different parts of the country.[15 16] Although the proportion of children aged 12–23 months who received all basic vaccinations increased from 23% to 31% and those who received none of the basic vaccinations declined from 29% to 19% between 2008 and 2018,[17] the improvement lagged far behind the current global targets and there are wide variations in the coverage of all age-appropriate vaccinations by 12 months of age between different states of the country and between urban (33.4%) and rural areas (12.9%).[17] The state of routine immunisation is a public health emergency in Nigeria which had the highest number of unimmunised children in the world: accounted for over 4.3 million or over 25% of all unimmunised children globally in 2018,[16] accounted for the highest proportion of more than 15% (3.05 of the 19.7 million) of the children that were either not vaccinated or partially vaccinated in 2019 and (together with Angola and Democratic Republic of the Congo) had the lowest coverage of third dose of Diphtheria-Tetanus-Pertussis vaccine (DTP-3) of 57% in 2019.[11]

Although routine childhood immunisation services are regularly provided in primary healthcare (PHC) facilities in Ebonyi state (like other states in Nigeria), the proportion of children aged 12–23 months who received all age-appropriate vaccinations by 12 months of age was 26.3% in 2018,[17] one of the least in the southeast geopolitical zone, and far below the national target of 80% by 2015[18] and global target of 80% by 2020.[19] Also, the mortality rate among children younger than 5 years was 91 per 1000 live births in 2018,[17] highest among the states in the southeast geopolitical zone and higher than the national target of 75 per 1000 live births by 2015.[18] Moreover, outbreaks of VPDs such as measles and yellow fever have been reoccurring in Ebonyi state[12 13 20] and the yellow fever outbreak in 2019 reportedly involved 8 out of the 13 local government areas (LGAs) of the state, with more than 55 suspected cases, 9 confirmed cases and 20 deaths (as of the period between May and September, 2019).[20] Although a mass yellow fever vaccination campaign was held in Ebonyi state, and two neighbouring states, following the 2019 outbreak, yellow fever outbreak still occurred in 2020.[12] The aforementioned trends indicate persistent and large gaps in routine immunisation coverage and perhaps in timeliness.

In principle, the ward development committees (WDCs) and the community development committees (CDCs) or village development committees (VDCs) have the responsibilities to manage the PHC system, respectively, in the wards and communities/villages.[21] In theory, their roles should include: identifying health and social needs; identifying and mobilising human, financial and material resources for health; planning and implementation of health and social interventions; supervising health and social intervention projects; liaising with government and other non-governmental organisations to find solutions to health and social problems in the wards and communities/villages.[21] However, as part of the weak PHC system/infrastructure in Nigeria, in practice the CDCs/VDCs are non-existent/non-functional while the WDCs are dysfunctional in most of the communities/villages and wards in Ebonyi state (like other states in Nigeria). Poor PHC service delivery and weak PHC infrastructure are among the factors responsible for the very low childhood immunisation coverage in Ebonyi state (and other states in Nigeria).[16]

Demand creation through multilevel social and behaviour change communication strategies is part of the current national strategic interventions to increase immunisation coverage.[16] Parents are the primary caregivers of their children and have the primary responsibility for the optimal/timely receipt of routine childhood vaccinations by their children. PHC workers are local providers of healthcare services, are often members of the served communities, and have regular contact with community members including parents. The involvement of PHC workers providing immunisation services in community engagement interventions for uptake of immunisation is vital.[3 19] Moreover, the sensitisation of community groups (which consist of parents) has been shown to be effective in increasing the demand for malaria rapid diagnostic test among rural community members in Ebonyi state[22] and context-specific and people-oriented community engagement approaches have been advocated for addressing the problem of vaccine hesitancy and poor immunisation

coverage.[3] All the aforementioned facts call for hybrid parents and health workers adaptive intervention for optimal routine childhood immunisation coverage.

The scheduling/timing of routine immunisation is informed by the knowledge of vaccination immunology, local epidemiological profile of the disease and policy choices[10] and is intended to achieve optimal immunological response and high population coverage in order to achieve herd immunity at an affordable cost.[9 10] For routine immunisation programmes, the recommended time-interval between an initial and a subsequent dose (dosage timeliness) for multiple-dose vaccines is more important than the age at receipt of the subsequent dose when the initial dose was off schedule,[9] especially the recommended minimum interval between prior and subsequent doses.[10] Therefore, the receipt of the recommended vaccinations by the recommended ages and time-interval between doses (optimal/timely (cumulative age-appropriate/dosage-appropriate) receipt of vaccinations) will enhance the validity of vaccination coverage[23] and make the protection against VPDs optimal.

However, singular age-appropriate receipt of recommended vaccinations (by a recommended age) has been the focus of interventional studies in the literature on routine childhood immunisation coverage/uptake.[24–31] Most of these studies involved reminder calls and/or mobile SMS (short messaging service) or financial incentives to caregivers/mothers and a few involved training/engagement of health workers and community members. We could not identify any interventional study or randomised trial to increase cumulative age-appropriate/dosage-appropriate receipt of recommended vaccinations. To our knowledge, this is the first intervention/randomised trial that seeks to increase the cumulative age-appropriate/dosage-appropriate receipt of vaccinations (optimal/timely receipt of every recommended vaccine dose) and that involves hybrid parents-health workers adaptive engagement. A cluster design is used because the intervention will be delivered to groups of individuals and the need to prevent contamination between the study arms.

This study aims to evaluate the effectiveness of hybrid parents and health workers adaptive intervention in increasing the optimal/timely routine childhood immunisation coverage in the communities in Ebonyi state, Nigeria, in order to generate evidence for routine immunisation policy planning and programming in Ebonyi state and other parts of Nigeria.

METHODS AND ANALYSES

Design

The study is a pragmatic, two-arm, parallel, open label, covariate-constrained cluster-randomised controlled trial with 1:1 allocation. A cluster is defined as the nearest catchment area (geographical communities/villages/settlements) for at least one public PHC facility with at least 500 households or a population size of 3000. In this **A**daptive **G**roup **Int**ervention for **Op**timal routine childhood **I**mmunisation **C**overage—AGINTOPIC trial—there will be hybrid or combined parents and PHC workers adaptive engagement in the intervention arm to increase their enlightenment and foster regular communications and working relationships between them regarding optimal routine childhood immunisation uptake. There will be no intervention in the control arm where there will only be the usual practice of PHC facilities providing routine childhood immunisation services.

The trial protocol development was guided by the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) 2013 checklist.

Study area

The study will be conducted in Ebonyi state, in south-eastern geopolitical zone of Nigeria, located between latitude 5^0 40' and 6^0 54'N and longitude 7^0 30' and 8^0 30'E with a land area of 5953 km^2. The population of the state is projected to be 3 407 310 in 2022 based on the 2006 national census figure and a growth rate of 2.8%. Most of the inhabitants of the state practice Christianity. Ebonyi state is structured into 13 LGAs, 171 political wards and autonomous communities comprising larger villages called autonomous villages and smaller villages (settlements) with village heads. The state comprises mostly rural settlements (urban or semi-urban settlements are few).

The Federal Ministry of Health (FMOH) provides policy guidance for public and private health service delivery in all states in Nigeria including Ebonyi state. The FMOH provides health services in the state through its parastatals (tertiary health facilities) while the State Ministry of Health (SMOH) provides health service through secondary health facilities (general hospitals). The SMOH and the State Primary Health Care Development Agency (SPHCDA) provide healthcare in the local governments through PHC facilities (PHC centres). There is at least one PHC centre in each political ward.

The National Primary Health Care Development Agency oversees the planning and implementation of immunisation/vaccination services in Nigeria and provides vaccines and related products. The SMOH and SPHCDA oversee the implementation of immunisation/vaccination service delivery at the state level and LGA level through the tertiary, secondary and PHC facilities. Most of the PHC facilities provide weekly routine immunisation or vaccination services in immunisation clinics (vaccination sessions occur once in a week) and the PHC workers have health talks with mothers/parents during the immunisation clinics. The PHC facilities also carry out supplemental (routine) immunisation activities during immunisation outreaches and campaigns. Private healthcare providers include private and missionary hospitals and clinics, private maternity homes, pharmacies and patent medicine vendors, traditional healers and traditional birth attendants. Some private hospitals and clinics also provide routine immunisation services, and

in most cases, monthly or twice monthly. The schedule of the routine childhood immunisation in Ebonyi state for infants aged 0–9 months by the time the implementation of the trial began was: At birth (BCG, hepatitis B vaccine-0, oral polio vaccine (OPV)-0), 6 weeks (OPV-1, pneumococcal conjugate vaccine (PCV)-1, pentavalent vaccine (Penta)-1, inactivated polio vaccine (IPV)-1), 10 weeks (OPV-2, PCV-2, Penta-2), 14 weeks (OPV-3, PCV-3, Penta-3, IPV-2), 6 months (vitamin A-1) and 9 months (MCV-1 (first dose of measles containing vaccine), yellow fever vaccine, meningitis vaccine).

Participants and participant timeline

Participants

The participants will include clusters and within each cluster, PHC workers, parents and household members (mother–child pairs).

Eligibility criteria

Clusters

1. The catchment PHC facilities are providing maternal and child healthcare services including routine childhood immunisation and have weekly immunisation clinics/sessions.
2. The estimates of the average number of monthly deliveries are at least 20.
3. Easily accessible/close to a road that is drivable even during the rainy season.
4. No similar intervention is ongoing or occurred within the preceding year.
5. Are at least 10 km apart or separated by a buffer area/natural barrier (to minimise contamination between clusters).[32 33]
6. The cluster heads and PHC workers (the officers-in-charge) in the catchment PHC facilities give consent to participate.

Primary healthcare workers

1. Are involved in the provision of routine childhood immunisation services in the PHC facilities within the selected clusters.
2. Give consent to participate in the study intervention.

Parents

1. Parents, mothers and fathers or primary caregivers/guardians of infants aged 0–2 months within the selected clusters.
2. Are permanent and regular residents of the clusters.
3. Do not plan to travel or migrate within the next 1 year.
4. Give consent to participate in the study intervention.

Household members (mother–child pairs)

1. Children aged 5–23 months (subdivided into 5–9, 10–11 and 12–23 months).
2. Their mothers/primary caregivers give consent to participate in population-based household surveys.

Participant timeline

Informed consent to participate in the study will be obtained from: the heads of the selected eligible clusters and the PHC workers within the clusters before baseline survey; from the respondent mothers/primary caregivers of 5–23 months children during the baseline and follow-up population-based household surveys; and from the parents of 0–2 months aged children before they are registered (during months 1–5 of the intervention) to participate in the intervention. The study outcomes will be measured through the household survey at baseline before the clusters are randomised to the two study arms. The intervention will then be delivered within a 10-month period after which the study outcomes will again be measured through the follow-up household survey. The participant timeline is depicted in figure 1 in accordance with the SPIRIT guideline.

Intervention

The intervention will be delivered within 10 months (figure 1) and is a composite action consisting of two broad strategies: basic and adaptive intervention actions. The intervention actions are presented in table 1.

After randomisation, the investigators will engage the PHC workers, the cluster heads, the community resource persons (CORPs) and other locally relevant community members in each of the intervention clusters about the study and formation of Promoters of Optimal Routine Childhood Immunisation Coverage (PORCHIC) group. The PHC workers will then start registering women who give birth in the health facility, together with their accompanying husbands, and parents of children aged 0–2 months who are visiting the health facility to receive maternal and child health services, as PORCHIC group members and their contact information will be taken. The men who did not accompany their wives to the health facility will be contacted and registered thereafter. The PHC workers will continue to register eligible parents over a 5-month period or up to 5 months before the follow-up household survey. The CORPs will be tasked with identifying parents of children aged 0–2 months outside of the health facility including those delivered at home, traditional birth attendants (TBAs), etc across the cluster and referring them to the PHC workers for registration as PORCHIC members. Whenever the CORPs learn (from relatives, friends, neighbours, etc) of any mother who is nursing a child aged 0–2 months, they will go to the woman and confirm whether she has been registered by the PHC workers or not before making the referral. The PHC workers and CORPs will receive conditional stipend for mobile phone airtime and transportation which are necessary for the following intervention actions as appropriate: contacting the husbands of eligible mothers who are not in the company of their wives during registration as PORCHIC members, identifying and referring eligible parents to PHC facilities for registration and invitation of PORCHIC members to the physical group discussions/meetings. The stipend will depend on the estimated amount spent by the PHC workers and CORPs, subject to verification by the investigators.

	STUDY PERIOD												
	Enrolment	Baseline survey	Allocation	Post-allocation									Follow-up survey
				Intervention									
TIMEPOINT	-2 months	-1 month	0	1–10 months									11 month
				1	2	3	4	5	6	7	8	9	10	
ENROLMENT:													
Eligibility screen	1												
Informed consent	2	3						C5					6
Allocation			4										
AGINTOPIC INTERVENTION:				5		5		5		5		5	
Basic action:													
Form PORCHIC & register parents of children aged 0–2 months				—									
PORCHIC discussion (Episodes 1–4)				1ST		2ND				3RD		4TH	
Register more parents of children aged 0–2 months as PORCHIC													
Enlightenment discussion in immunization clinic													
Adaptive action:													
ASSESSMENTS:													
Baseline survey of 5–23 months children & their mothers		3											
Follow-up survey of 5–23 months children & their mothers													6

Figure 1 Schedule of enrolment, intervention and assessments. 1=Eligibility screening of clusters. 2=Informed consent from the heads of selected clusters and primary healthcare workers within the clusters. 3=Informed consent from mothers of 5–23 months old children during baseline survey and baseline survey of 5–23 months old children and their mothers. 4=Randomisation of clusters. 5=Intervention. C5=Informed consent from parents of 0–2 months old children during their registration as members of the PORCHIC group. 6=Informed consent from mothers of 5–23 months old children during follow-up survey and follow-up survey of 5–23 months old children and their mothers. AGINTOPIC, Adaptive Group Intervention for Optimal routine childhood Immunisation Coverage; PORCHIC, Promoters of Optimal Routine Childhood Immunisation Coverage.

The PORCHIC group will have physical group discussions/meetings about every alternate month and preferably at the health facility on an immunisation day or on any other day chosen by majority of the members to enhance intervention adherence. There will be about three or four episodes of discussions within a 10-month period. The main objectives of the discussions will be: to explore the proximal demand-side and supply-side determinants of non-receipt and untimely receipt of routine childhood vaccinations and strategise on feasible and readily available solutions; to enlighten the PORCHIC group members, and by extension other community members, regarding optimal/timely receipt of routine childhood vaccinations; and to foster communication and working relationship between the PORCHIC members. Each discussion will be a 1–2 hours event and semi-structured into two parts: (1) determinants and solutions/strategies and (2) enlightenment.

Table 1 Intervention actions

	Basic intervention action	Main activities
1	Formation of the Promoters of Optimal Routine Childhood Immunisation Coverage (PORCHIC) group: ► Primary members: Investigators, parents of newborn babies who were registered when their babies were aged 0–2 months, and primary healthcare (PHC) workers. ► Other members: Key community members (the cluster heads, community resource persons (CORPs), religious leaders and traditional birth attendants (TBAs) as locally relevant.	By investigators: ► Engage the PHC workers, cluster heads, CORPs and other locally relevant community members about the study and formation of the PORCHIC group. By PHC workers: ► Register parents of children aged 0–2 months who are seeking care at the PHC facility as PORCHIC members. By CORPs: ► Identify and refer to the PHC workers, for registration as PORCHIC members, parents of children aged 0–2 months: – Who the CORP heard (from relatives, friends, neighbours, etc) delivered their babies outside of the PHC facility (at home, TBA, etc) – Who the CORP has confirmed have not been registered by the PHC workers
2	Physical PORCHIC group discussion:	
	► Regarding non-receipt and untimely receipt of routine childhood vaccinations. ► To identify the determinants/proximal barriers and possible feasible solutions/strategies to addressing these barriers. ► To enlighten the PORCHIC group members and by extension other community members. ► To foster regular communications and working relationships between PORCHIC members.	First PORCHIC discussion/meeting (first episode): Part 1 (Focus Group Discussion (FGD) on determinants): ► Discuss determinants of non-receipt and untimely receipt of routine childhood vaccinations, possible solutions and feasibility of executing these solutions during the study. ► Subdivide the FGD into two: – Female PORCHIC FGD to consist of the investigators, female parents, PHC workers, CORPs, TBAs, etc as necessary. – Male PORCHIC FGD to consist of the investigators, male parents, PHC workers CORPs, village heads, etc as necessary. Part 2 (enlightenment group discussion): ► Introduce the research problem and purpose of the study. ► Let participants express their knowledge and perceptions regarding vaccines/vaccinations and routine childhood immunisation schedule. ► Explain key facts about vaccines/vaccinations, routine childhood immunisation schedule and optimal/timely receipt of vaccinations. ► Highlight key life-saving actions to practice and promote. ► Discuss comments, questions and answers.
	Second, third and fourth PORCHIC discussions or meetings: ► To get the views of the new PORCHIC members (registered after the previous discussion(s)) on the determinants of non-receipt and untimely receipt of routine childhood immunisations and possible solutions. ► To enlighten the new members and by extension other community members. ► To reinforce the knowledge and perceptions of the old PORCHIC members. ► To implement other solutions/strategies informed by the findings from the previous discussion(s) and engagements.	Second to fourth PORCHIC discussions/meetings (second to fourth episodes): Part 1 (group discussion on determinants): ► Discuss determinants of non-receipt and untimely receipt of routine childhood vaccinations and possible solutions. Part 2 (enlightenment group discussion): ► Introduce the research problem and purpose of the study to the new participants. ► Let the old participants express their knowledge and perceptions regarding vaccines/vaccinations and routine childhood immunisation schedule. ► Let the new participants express their knowledge and perceptions regarding vaccines/vaccinations and routine childhood immunisation schedule. ► Explain key facts about vaccines/vaccinations, routine childhood immunisation schedule and optimal/timely receipt of vaccinations. ► Let the old participants highlight key life-saving actions to practice and promote. ► Highlight key life-saving actions to practice and promote. ► Discuss comments, questions and answers.
3	Subsequent registration of parents of newborn babies as new members of the PORCHIC group:	By PHC workers: ► Continue to register parents of children aged 0–2 months as PORCHIC members. ► Briefly have enlightenment discussion with each mother or parent about optimal/timely receipt of routine childhood vaccinations. By CORPs: ► Continue to identify and refer parents of children aged 0–2 months to the PHC workers for registration as PORCHIC members.

Continued

Table 1 Continued

	Basic intervention action	Main activities
4	Weekly enlightenment discussions with parents in immunisation clinics: ► To reinforce the knowledge and perceptions of the PORCHIC members attending the immunisation clinics. ► To enlighten the other mothers or parents attending the immunisation clinics.	By PHC workers: ► Facilitate enlightenment discussions with mothers or parents, using an abridged PORCHIC group discussion format, during the health talk sessions in the weekly immunisation clinics.
	Adaptive intervention action	
	Other cluster-specific intervention strategies: ► Informed as appropriate by any proximal solutions or strategies identified during the basic intervention. ► Which are feasible considering the time frame and perspective of the study.	► Implement new solutions and strategies as appropriate.

During the first episode of the PORCHIC group discussions, this first part of the discussion will be subdivided into two: The female PORCHIC group discussion to consist of the investigators, female parents, PHC workers, CORPs, TBAs, etc and the male PORCHIC group discussion to consist of the investigators, male parents, PHC workers, CORPs, village heads, etc as appropriate. Considering the patriarchal nature of the study environment, this subdivision is necessary to separate the mothers from their husbands and other male village leaders so that the mothers can freely express their views regarding the determinants/solutions to non-receipt and untimely receipt of routine childhood immunisation. One investigator will moderate each discussion with a group discussion guide. During the first part of the discussion, participants will share their perceptions about the determinants of non-receipt and untimely receipt of routine childhood immunisation/vaccinations, the possible solutions/strategies and the feasibility of executing the identified solutions within the time frame and perspective of the study. When expressing their views, participants will be encouraged to share their experiences regarding proximal supply-side and demand-side barriers to keeping up to appointment dates for their children immunisation and the measures taken if any to overcome the barriers.

The second part of the discussion will begin with introductory statements about the research problem and purpose of the research. Individual participants will then express their knowledge and perceptions regarding vaccines/vaccinations (main constituents, mechanism of action, safety, effectiveness, routes of administration, side effects and their management, duration of protection) and the schedule of routine childhood immunisation (when to vaccinate children and number of doses required for each vaccine). Participants will comment on each other's views and there will be questions and answers from participants. Thereafter the moderator will explain key facts about vaccines/vaccinations/immunisation,[34] routine childhood immunisation schedules/scheduling rationale and timely receipts of vaccinations (importance of timely receipts, possible problems from untimely receipts, how to achieve timely receipts of all routine vaccinations for children and to keep to appointment dates). This will be followed by comments, questions and answers. The moderator will then highlight eight key life-saving actions that, if practiced and promoted, will help in addressing the research problem, and there will be comments, questions and answers. The key actions include: (1) to always book for antenatal care (ANC) at health facility when pregnant, (2) to always keep to ANC appointment dates, (3) to always plan for and go to health facility for delivery, (4) to always take the newborn babies to health facilities for routine immunisation/vaccinations, (5) to always plan and try to achieve timely receipts of all routine vaccinations for children/keep to appointment dates, (6) to always follow the advice of the health worker on how to manage common side effects, (7) to always seek for truthful information about vaccines from known health workers and (8) and to always encourage relatives/friends/neighbours to practice these actions. This will be followed by comments, questions and answers. The PHC workers at the health facility will then commence the immunisation session for the day and this will serve as a demonstration of vaccination. PORCHIC members, especially the first-time parents of newborns, whose appointment date falls outside the group discussion dates, will be encouraged to briefly observe the immunisation session before leaving. Within the time frame and perspective of the study, implementation of feasible new solutions/strategies, if any, will commence immediately. The intervention will be discontinued for any participant whenever such request is made.

Each of the second, third and fourth episodes of the PORCHIC group discussions will take similar format as the first episode as described above and will focus on: getting the views of the new PORCHIC members (who were registered after the previous discussion(s)) on the determinants of non-receipt and untimely receipt of routine childhood immunisations and possible solutions and enlightening them; reinforcing the knowledge and perceptions of the old PORCHIC members; and implementing other solutions/strategies informed by the findings from the earlier discussion(s)/engagements.

After the first PORCHIC discussion, the PHC workers will continue to register parents of 0–2 months old children as new members of the PORCHIC group and will

hold brief enlightenment discussions with them during the registrations. During the health talk sessions in the weekly immunisation clinics, the PHC workers will facilitate enlightenment discussions with parents using an abridged PORCHIC group discussion format.

Conceptualisation and operationalisation of optimal routine immunisation coverage

Optimal/timely routine immunisation is conceptualised in terms of the receipt of every recommended vaccine dose at the recommended age and time-interval between doses. Optimal/timely routine immunisation coverage/uptake therefore refers to the receipt of every recommended vaccine dose at the recommended age and time-interval between doses by the target population. This is the cumulative age-appropriate or cumulative dosage-appropriate receipt of recommended vaccinations.

This definition is operationalised, as shown in table 2, based on the fact that routine immunisation sessions occur once in 7 days (once in a week) in most of the PHC facilities in Ebonyi state. Optimal/timely receipt of a vaccine dose is the receipt of the dose on the scheduled date. A 7 days-forward window will be given for birth, 6 weeks and 9 months doses (and 6 months vitamin A-1) because birthday and 6 weeks and 9 months dates may fall outside (before/after) the immunisation day and birth can even occur later on an immunisation day after immunisation session. In these situations, the first appointment/opportunity will then be the next immunisation day 1–7 days later.

No 7 days-forward window will be given for 10 and 14 weeks doses because their scheduled dates are on immunisation days (4 weeks from the preceding doses). For birth doses, there is no 7 days-backward window. For 6–14 weeks doses, no 7 days-backward window will be given for early receipt (before the scheduled date) due to some reasons. The design of vaccinations schedule (including age range and time-intervals) aims to achieve a balance between early protection and best immune response by scheduling vaccinations early enough to protect before acquisition of disease but spacing out the vaccinations enough to allow immune maturity.[10] Also, the pattern of global routine immunisation schedules indicates that delays in receipt of subsequent doses of multidose vaccines are generally more acceptable than early receipts. While the maximum time-intervals vary, the minimum time-interval between the doses of multidose vaccines in routine immunisation schedules across countries is 4 weeks in order to prevent interference in primary waves of immune response.[10] However, a 7 days-backward window will be considered for 9 months vaccine doses (and 6 months vitamin A-1) because of the length of the age (duration of time from birth) and the 9 months date may fall outside the immunisation day.

Categorisation and scoring of the receipt of vaccinations

The receipt of each recommended vaccine dose will be categorised, as depicted in table 2, into (1) optimal/timely (2) suboptimal/untimely (early and delayed/late) (3) non-receipt. It is important to note that due to the fact that routine immunisation sessions are conducted once in a week, 1 week/7 days delay corresponds to 1-day delay in settings with daily routine immunisation sessions.

The optimal receipt of a multidose vaccine is the optimal receipt of every dose of the vaccine (cumulative age-appropriate receipt of such vaccine). Overall, the optimal receipt of all the recommended vaccines in an immunisation schedule (cumulative age-appropriate vaccines receipt) is the optimal receipt of every recommended vaccine in the schedule. The suboptimal receipt of a multidose vaccine is the delayed or early receipt of at least one dose of the vaccine or non-receipt of less than the total number of doses. Non-receipt of a multidose vaccine is the non-receipt of all the vaccine doses. The receipt of each recommended vaccine dose as a continuous variable will be scored as depicted in table 2. Optimal receipt of each dose will receive the maximum score of 100. The score will progressively reduce by 7 for each succeeding week's delay until the score reaches 2. This means a score of 93 for 1 week delay, 86 for 2 weeks delay, 79 for 3 weeks delay, down to 2 for 14 weeks or more delay. Early receipt will receive a score of 2 and non-receipt will receive the minimum score of 0. The reason for this scoring approach include: (1) the need to maintain the practical boundaries of 0 and 100 on a percentage scale (for non-receipt and optimal receipt) in line with most performance scores (2) the use of seven as the scoring interval reflects the fact that routine immunisation sessions occur weekly in the participating PHC facilities (3) those with 14 weeks or more delay and early receipts are scored 2 to make the aforementioned reasons possible and because of the fact that the vaccination rates after about 12 weeks of the scheduled dates (and before the scheduled dates) are very small,[8 9 17 35] indicating that after 12 weeks delay, most of the unvaccinated remain unvaccinated up to the time of data collection (hence those with 14 weeks or more delay and early receipts are expected to constitute a very little proportion of the population).

The score for each vaccine dose (dose receipt score) is the vaccine receipt score for a single-dose vaccine. The vaccine receipt score for a multidose vaccine is the average of the dose receipt scores for all the doses of that vaccine. The overall or cumulative vaccine receipt score for all the recommended vaccines in the immunisation schedule (age-appropriate vaccines receipt score) is the average of the vaccine receipt scores for all the vaccines.

Primary objectives

1. To evaluate the effectiveness of the hybrid parents and health workers adaptive intervention in increasing the optimal/timely (cumulative age-appropriate) routine childhood immunisation coverage compared with control.
2. To evaluate the effectiveness of the hybrid parents and health workers adaptive intervention in increasing the timeliness (as a continuous variable) of routine

Table 2 Categories and scores of vaccination receipt (the receipt of the recommended vaccines in the routine childhood immunisation schedule)

Vaccine dose	Optimal or timely receipt (receipt score)	Suboptimal (untimely) receipt		Non-receipt (receipt score)
		Delayed receipt (receipt score)	Early receipt (receipt score)	
Birth doses (BCG, HBV-0, OPV-0)	Receipt of a birth dose on the day of birth or within the first 7 days after (100)	Receipt of a birth dose beyond the first 7 days after the day of birth (93–2)*	–	No receipt of a birth dose up to the time of data collection (0)
6 weeks doses				
OPV-1	Receipt of OPV-1 on the scheduled date (6 weeks from the date of birth) or within the first 7 days after and not less than 4 weeks from the date of receipt of OPV-0 (100)	Receipt of OPV-1 beyond the first 7 days after the scheduled date (93–2)*	Receipt of OPV-1 before the scheduled date or less than 4 weeks from the date of receipt of OPV-0 (2)	No receipt of OPV-1 up to the time of data collection (0)
PCV-1	Receipt of PCV-1 on the scheduled date (6 weeks from the date of birth) or within the first 7 days after (100)	Receipt of PCV-1 beyond the first 7 days after the scheduled date (93–2)*	Receipt of PCV-1 before the scheduled date (2)	No receipt of PCV-1 up to the time of data collection (0)
Penta-1	Receipt of Penta-1 on the scheduled date (6 weeks from the date of birth) or within the first 7 days after and not less than 4 weeks from the date of receipt of HBV-0 (100)	Receipt of Penta-1 beyond the first 7 days after the scheduled date (93–2)*	Receipt of Penta-1 before the scheduled date or less than 4 weeks from the date of receipt of HBV-0 (2)	No receipt of Penta-1 up to the time of data collection (0)
IPV-1†	Receipt of IPV-1 on the scheduled date (6 weeks from the date of birth) or within the first 7 days after (100)	Receipt of IPV-1 beyond the first 7 days after the scheduled date (93–2)*	Receipt of IPV-1 before the scheduled date (2)	No receipt of IPV-1 up to the time of data collection (0)
10 weeks doses (OPV-2, PCV-2, Penta-2)	Receipt of a 10 weeks dose on the scheduled date (4 weeks from the date of receipt of the 6 weeks dose) (100)	Receipt of a 10 weeks dose beyond the scheduled date (93–2)*	Receipt of a 10 weeks dose before the scheduled date (2)	No receipt of a 10 weeks dose up to the time of data collection (0)
14 weeks doses				
OPV-3, PCV-3, Penta-3	Receipt of a 14 weeks dose on the scheduled date (4 weeks from the date of receipt of the 10 weeks dose) (100)	Receipt of a 14 weeks dose beyond the scheduled date (93–2)*	Receipt of a 14 weeks dose before the scheduled date (2)	No receipt of a 14 weeks dose up to the time of data collection (0)
IPV-2†	Receipt of IPV-2 on the scheduled date (8 weeks from the date of receipt of IPV-1) (100)	Receipt of IPV-2 beyond the scheduled date (93–2)*	Receipt of IPV-2 before the scheduled date (2)	No receipt of IPV-2 up to the time of data collection (0)
6 months vitamin A-1	Receipt of vitamin A-1 on the scheduled date (the date the child became 6 months old) or within the 7 days before or after (100)	Receipt of vitamin A-1 beyond the first 7 days after the scheduled date (93–2)*	Receipt of vitamin A-1 before the 7 days before the scheduled date (2)	No receipt of vitamin A-1 up to the time of data collection (0)
9 months doses (MCV-1, YFV, MV)	Receipt of a 9 months dose on the scheduled date (the date the child became 9 months old) or within the 7 days before or after (100)	Receipt of a 9 months dose beyond the first 7 days after the scheduled date (93–2)*	Receipt of a 9 months dose before the 7 days before the scheduled date (2)	No receipt of a 9 months dose up to the time of data collection (0)

Continued

Table 2 Continued

Multidose vaccine	Optimal or timely receipt	Suboptimal (untimely) receipt		Non-receipt
		Delayed or late receipt	Early receipt	
OPV, PCV, Penta, IPV	Optimal receipt of every dose (cumulative age-appropriate receipt of a vaccine)	Delayed or early receipt of any dose or all the doses, or non-receipt of less than the total number of doses		Non-receipt of all the doses (the total number of doses)
Eg: for OPV	Optimal receipt of OPV-0, OPV-1, OPV-2 and OPV-3 (cumulative age-appropriate receipt of OPV)	Delayed or early receipt of OPV-0 or OPV-1 or OPV-2 or OPV-3 or all the four doses, or non-receipt of any one, two or three of the doses		Non-receipt of all four doses
All recommended vaccines in immunisation schedule	Optimal receipt of every recommended vaccine in the immunisation schedule (cumulative age-appropriate vaccines receipt)	Delayed or early receipt of any of the recommended vaccines or non-receipt of less than the total number of the recommended vaccines		Non-receipt of every recommended vaccine
Vaccine receipt score	A vaccine receipt score=the average of the receipt scores for all the doses Eg: OPV receipt score=the average of OPV-0, OPV-1, OPV-2 and OPV-3 receipt scores			
All recommended vaccines receipt score	=the average of the vaccine receipt scores for all the recommended vaccines in the immunisation schedule (age-appropriate vaccines receipt score)			

*Scores range from 93 for 1 week delay to 2 for 14 weeks or more delay.
†For children aged ≥13 completed months during the baseline survey, who were older than 6 weeks before the 6 weeks dose of IPV (IPV-1) was implemented in 2021, IPV at 14 weeks (the former single dose regime) was used as IPV-1 and the scheduled date was 14 weeks from the date of birth as timely receipt of IPV-2 was not applicable to them.
HBV, hepatitis B vaccine; IPV, inactivated polio vaccine; MCV-1, first dose of measles containing vaccine; MV, meningitis vaccine; OPV, oral polio vaccine; PCV, pneumococcal conjugate vaccine; Penta, pentavalent vaccine (diphtheria-pertussis-tetanus, hepatitis B, haemophilus influenza B); YFV, yellow fever vaccine.

childhood immunisation coverage compared with control.

Secondary objectives

1. To evaluate the effectiveness of the hybrid parents and health workers adaptive intervention in increasing the up-to-date routine childhood immunisation coverage compared with control.
2. To evaluate the effectiveness of the hybrid parents and health workers adaptive intervention in increasing the (12 months) age-appropriate routine childhood immunisation coverage compared with control.
3. To evaluate the effectiveness of the hybrid parents and health worker adaptive intervention in reducing the rate of dropout from Penta-1 to Penta-3 compared with control.
4. To assess the optimal/timely (cumulative age-appropriate) routine childhood immunisation coverage in the communities in Ebonyi state.
5. To assess the timeliness (as a continuous variable) of routine childhood immunisation coverage in the communities in Ebonyi state.
6. To assess the up-to-date routine childhood immunisation coverage in the communities in Ebonyi state.
7. To assess the (12 months) age-appropriate routine childhood immunisation coverage in the communities in Ebonyi state.
8. To assess the rate of dropout from Penta-1 to Penta-3 in the communities in Ebonyi state.

Hypotheses

1. The hybrid parents and health workers adaptive intervention is more effective in increasing the optimal/timely (cumulative age-appropriate) routine childhood immunisation coverage compared with control.
2. The hybrid parents and health workers adaptive intervention is more effective in increasing timeliness (as a continuous variable) of routine childhood immunisation coverage compared with control.

The initial trial logical framework (figure 2) for the hypothesised effect of the intervention on the study outcomes incorporates the '3Cs' Vaccine Hesitancy Model[36] based on the understanding that the determinants of vaccine hesitancy (delay in acceptance or refusal of vaccines) are also determinants of untimely uptake of vaccinations. The performance of PHC workers in engaging parents regarding timely uptake of routine childhood immunisation and the parents' timely uptake of routine childhood immunisation for their children are expected to remain the same in the control arm. The hybrid parents and health workers adaptive intervention is expected to enlighten parents and PHC workers about optimal/timely receipt of routine childhood vaccinations and increase effective communication and working relationship between them. This will lead to decrease in complacency, increase in confidence and increase in convenience regarding optimal/timely receipt of routine childhood vaccinations and will thus result in an increase in optimal/timely (cumulative age-appropriate) coverage of routine childhood immunisation in the intervention arm.

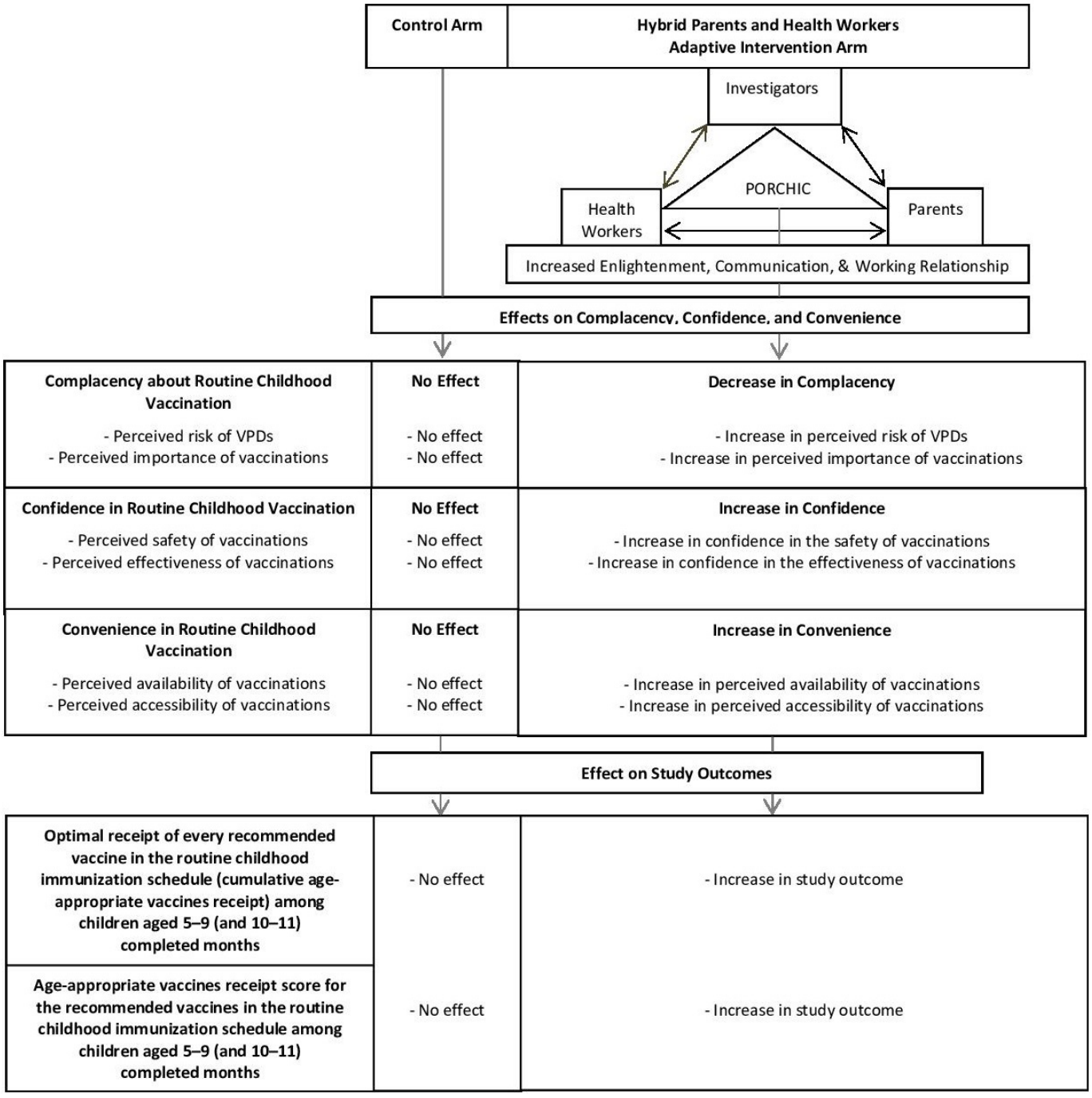

Figure 2 Initial trial logical framework. PORCHIC, Promoters of Optimal Routine Childhood Immunisation Coverage; VPDs, vaccine-preventable infectious diseases.

Outcome measures

The primary outcome measures will be restricted to the children aged 5–9 and 10–11 completed months because of the following reasons. For the children who were born in months 1–5 of the intervention: the parents in the intervention clusters are expected to have full exposure to the intervention, these children will, respectively, be aged 9–5 (or 5–9) completed months during the follow-up survey, and the full impact of the intervention on optimal receipt of birth to 14 weeks vaccine doses can be assessed among this subgroup. Similarly, for the children who were born in months −1 and −2 of the intervention: the parents in the intervention clusters are expected to have exposure to the intervention only after the birth to 6 weeks vaccinations, these children will, respectively, be aged 10–11 completed months during the follow-up survey, and the near-full impact of the intervention on optimal receipt of birth to 9 months vaccine doses can be assessed among this subgroup.

Primary outcomes

1. The optimal/timely (cumulative age-appropriate) receipt of the recommended vaccines in the routine

childhood immunisation schedule by children aged 5–9 completed months (5 to <10 months of age) defined as the proportion of children aged 5–9 completed months who had optimal/timely receipt of every recommended birth to 14 weeks vaccine. This is a composite outcome comprising of the optimal receipt of each birth to 14 weeks vaccine including each dose of the multidose vaccines.
2. The optimal/timely (cumulative age-appropriate) receipt of the recommended vaccines in the routine childhood immunisation schedule by children aged 10–11 completed months (10 to <12 months of age) defined as the proportion of children aged 10–11 completed months who had optimal/timely receipt of every recommended birth to 9 months vaccine. This is a composite outcome comprising of the optimal receipt of each birth to 9 months vaccine including each dose of the multidose vaccines.
3. The age-appropriate vaccines receipt score for the recommended vaccines in the routine childhood immunisation schedule (birth to 14 weeks vaccines) by children aged 5–9 completed months. Co-outcomes are the individual vaccine receipt scores and dose receipt scores.
4. The age-appropriate vaccines receipt score for the recommended vaccines in the routine childhood immunisation schedule (birth to 9 months vaccines) by children aged 10–11 completed months. Co-outcomes are the individual vaccine receipt scores and dose receipt scores.

Secondary outcomes

1. The proportion of children aged 5–9 completed months who had received every recommended birth to 14 weeks vaccine and the proportion of children aged 10–11 completed months who had received every recommended birth to 9 months vaccine (up-to-date receipt of the recommended vaccines in the routine childhood immunisation schedule).
2. The dropout rate between Penta-1 and Penta-3, respectively, defined as the proportion who did not receive Penta-3 among the children aged 5–9 completed months and 10–11 completed months who received Penta-1.
3. The proportion of children aged 10–11 completed months who had optimal/timely receipt of vitamin A-1; who had received vitamin A-1; and the vitamin A-1 receipt score among children aged 10–11 completed months.
4. The proportion of children aged 12–23 completed months who had received every recommended birth to 9 months vaccine (up-to-date receipt of the recommended vaccines in the routine childhood immunisation schedule). At follow-up, this measure will be used for the assessment of the extended and 'catch-up' effect of the intervention on the vaccination status of these children.
5. The proportion of children aged 12–23 completed months who had received every recommended birth to 9 months vaccine by 12 months of age ((12 months) age-appropriate receipt of the recommended vaccines in the routine childhood immunisation schedule). At follow-up, this measure will be used for the assessment of the extended and 'catch-up' effect of the intervention on the vaccination status of these children.
6. The optimal/timely (cumulative age-appropriate) receipt of the recommended vaccines in the routine childhood immunisation schedule by children aged 12–23 completed months defined as the proportion of children aged 12–23 completed months who had optimal/timely receipt of every recommended birth to 9 months vaccine. This measure will be important during baseline assessment.
7. The age-appropriate vaccines receipt score for the recommended vaccines in the routine childhood immunisation schedule (birth to 9 months vaccines) by children aged 12–23 completed months. This measure will be important during baseline assessment.
8. The dropout rate between Penta-1 and Penta-3 among the children aged 12–23 completed months. This measure will be important during baseline assessment.

Measurement of study outcomes

Population-based household questionnaire survey

Outcomes will be measured through population-based household questionnaire surveys at baseline and follow-up. The questionnaire was adapted from the WHO vaccination coverage questionnaire[37] and will be pretested in non-participating clusters before the survey. The questionnaire was programmed into tablet devices using the KoBoToolbox software. Interviewers will receive 2 days training on how to administer the electronic questionnaire. There will also be refresher training for interviewers before the follow-up household survey which is expected to take place about 11 months after the baseline survey. The training will include routine childhood immunisation scheduling, a detailed review and explanation of vaccination card data and the questionnaire items, how to obtain consent from respondents, interview techniques and household revisiting techniques. The trainee interviewers will administer the electronic questionnaire to simulated caregivers who will provide hypothetical vaccination cards (vaccination cards obtained and prefilled by the investigators for training purposes).

During the household surveys, all the eligible children will be enlisted and assigned ID numbers/codes on separate household forms before administering the anonymised questionnaire. The vaccination data of children aged 5–23 months will be collected from their vaccination cards and through verbal history/recall from their mothers/primary caregivers (the respondents). Data will also be collected on socio-demographic and background characteristics: gender, age, place of delivery, birth order; number of antenatal visits by mother, age, marital status, educational level and occupation of mother; age,

educational level and occupation of the husband of the mother; household income; and geographical factor such as travel time to catchment immunisation facility.

Eligible households where the mothers/primary caregivers are not available and the vaccination cards cannot be found by the fathers/other adults will be revisited up to twice. For households where the primary caregivers are not available but the vaccination cards are available, data will be collected from the vaccination cards and the fathers or other adults will be the respondents. For households where the primary caregivers are available but the vaccination cards are not available, only verbal vaccination history will be collected.

Focus group discussion (the first part of the first PORCHIC group discussion)

Qualitative data will be measured during the first episode of the PORCHIC group discussions when only a few members are expected to have been registered. The first part of the first episode of the PORCHIC group discussions, which will explore the determinants of receipt and timely receipt of routine childhood immunisation and possible solutions/strategies, will involve no more than 12 participants. The discussion will be conducted with the use of focus group discussion(FGD) guide (online supplemental file 1) pre-tested in non-participating clusters. There will be about 16 of such discussions in the eight intervention clusters (one female and one male per cluster) and they will be audio recorded and later transcribed (and translated into English) verbatim before analysis.

Data quality control

The electronic questionnaire was designed with KoboToolbox software and data collection quality was enhanced with the use of skip logic and validation criteria. Two anonymous photographs of the vaccination evidence on the vaccination card of each child will be taken (without the child's name and address). This photograph will be used for quality control and to double-check on errors/inconsistencies in the transmitted vaccination date data because the entry of 'dates' is particularly prone to error due to the number of digits involved. People that will be selected and trained as interviewers are preferably those who are familiar with the use of tablet devices/smartphones and particularly those who have the experience of data collection with KoBoCollect/ODK Collect. The fact that the entry of 'dates' is particularly prone to error and the need to be very careful when collecting data will be emphasised and re-emphasised during the training of the interviewers.

The interviewers will transmit only completed anonymised questionnaires to the online survey records at the end of each day's survey and the transmitted questionnaires will be reviewed for missing, incoherent and illogical data. Any identified error will be corrected soonest after communicating with the respective interviewers, who will cross-check with the respective respondents, or by reviewing the corresponding photograph of vaccination card as appropriate. Errors in the date variables including errors in the digits of the dates; inconsistencies between date of birth and completed age in months; discrepancies between vaccine doses usually given together such as the birth, 6 and 14 weeks doses and 9-month doses; and inconsistencies in the chronology of the dates such as the chronology between the dates of birth and dates vaccination doses were given and between the dates the birth, 6 and 14 weeks doses and 9-month doses were given, respectively, will be assessed using Stata and Excel software. Any errors/inconsistencies identified will be corrected after cross-checking with the transmitted photograph of the vaccination record and if corrections cannot be made because of obvious errors in the transmitted vaccination record, the data will be discarded as appropriate.

Sample size

Sample size was estimated using Stata/SE V.15·1 (StataCorp, College Station, Texas, USA). Assuming 26.3% of the children in Ebonyi state have received all the recommended vaccinations appropriate for their ages[17] and about 50% of them (13.15%) had optimal/timely receipt of all the vaccinations,[5] the proportion of children aged 10–11 completed months who had optimal/timely receipt of every recommended birth to 9 months vaccine dose (based on vaccination data from their vaccination cards) could plausibly be estimated to be 13.15% in the control arm. With an intracluster correlation coefficient of 0.05, a cluster size of 15 eligible children aged 10–11 completed months whose vaccination data were collected from their vaccination cards, 80% power at 5% probability of type I error, the trial will require eight clusters per arm to detect a 20%-point increase in the outcome in the intervention arm (an increase from 13.15% to 33.15%). This gives a total of 16 clusters, minimum of 120 children aged 10–11 completed months per arm and 240 in total. The same sample size estimates also apply for the children aged 5–9 and 12–23 completed months.

Recruitment/sampling technique

Eligible study participants will be selected by multistage sampling technique. The list of eligible clusters will be stratified into rural and urban/semi-urban and a random sample of 16 clusters, 12 rural and 4 urban/semi-urban (3:1 rural–urban ratio) will be selected using the sample command in Stata. If verbal consent/permission is not given by the heads of any of the selected clusters or consent is not given by the PHC worker who is the officer-in-charge in the catchment PHC facility before the baseline survey, replacement cluster will be selected from the remaining list of eligible clusters using the same technique. The summary of the trial profile is shown in figure 3.

In each of the selected clusters: the PHC worker in-charge of the PHC facility with the coworkers will be selected; all the eligible parents of infants aged 0–2 months old will be selected; and all the eligible children

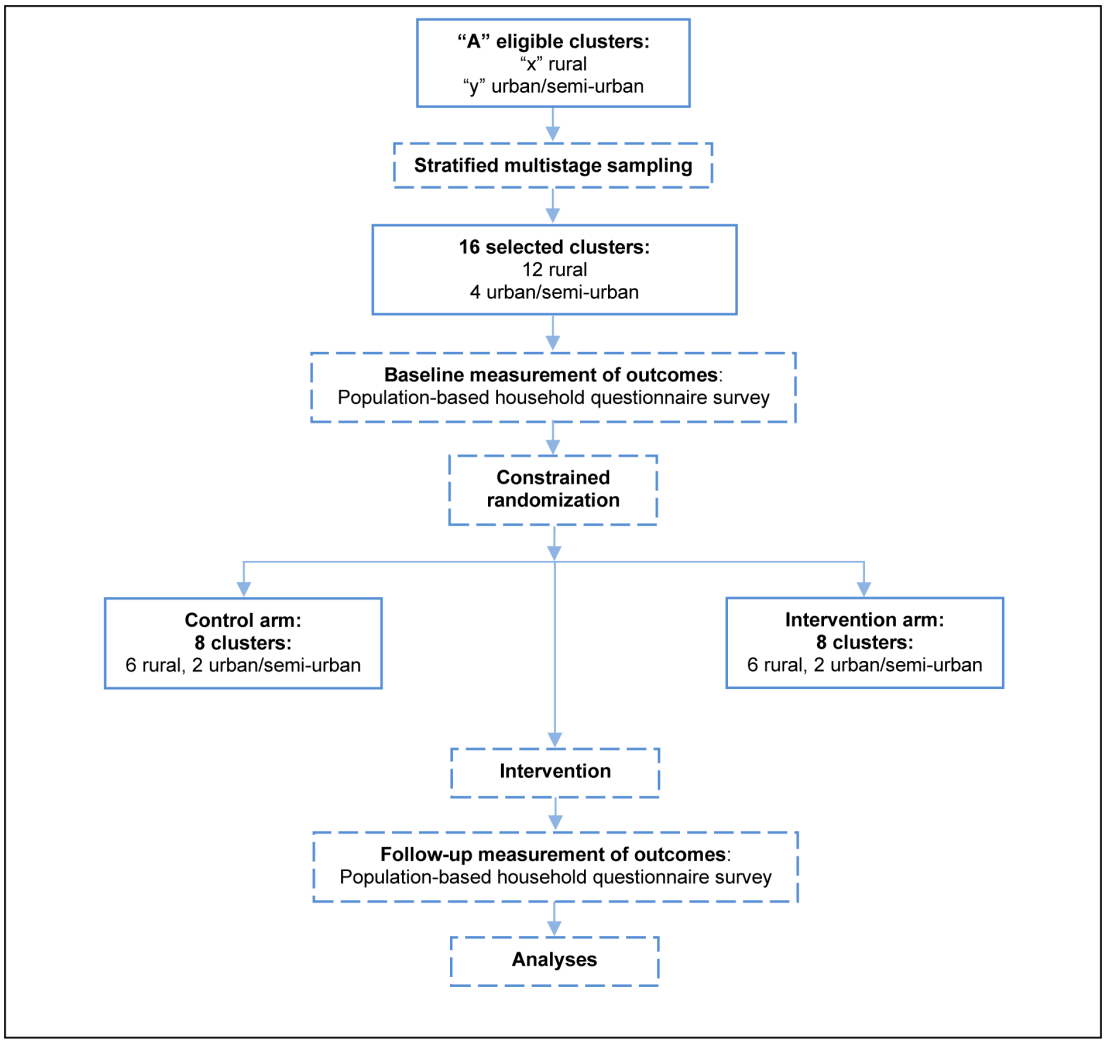

Figure 3 Summary of trial profile.

aged 5–23 months and their mothers/primary caregivers (mother–child pairs) will be selected (for the population-based household surveys). All the households in the selected clusters will be visited and assessed for eligibility during the household surveys. For households where no adult is at home to answer questions on eligibility, such questions will be addressed to the neighbours as appropriate to limit revisits to only eligible households.

Randomisation and blinding

Covariate-constrained randomisation of selected clusters will be done by the principal investigator and an independent statistician. The principal investigator will generate the randomisation schemes using a programme written in Stata.[38] Based on 10% cut-off of the balance score and l2 balance metric, overall balance will be sought on potentially important factors and baseline covariates among children aged 5–9 and 10–11 (5–11) completed months, whose vaccination data were collected from their vaccination cards, such as the primary outcomes; delivery at health facility, birth order of the child; number of antenatal visits by mother and educational level of mother; educational level of the husband of the mother; household income; travel time to catchment immunisation facility; and location of cluster (rural and urban/semi-urban). After running the programme, the chosen scheme will not be used, rather, an independent statistician will randomly select the final randomisation scheme from the data set of the constrained randomisation space. The final randomisation scheme will then be entered into the input data set and the balance across study arms will be summarised in a table.

The 'chosen scheme' variable in the constrained randomisation space data set will also be updated to reflect the final chosen randomisation scheme. The validity of the constrained randomisation will be assessed by observing the number of restricted allocation schemes (in the constrained space) to make sure they are not too few (eg, less than 100) compared with the unrestricted allocation schemes[32 33 38] and by creating a 16×16 matrix of cluster allocations to observe the number or percentage of times out of the total number of acceptable allocations (in the constrained space) that each pair of clusters was allocated to the same treatment arm (whether any pair was never or always allocated to the same arm).[32 33]

It will not be possible to mask the investigators, participants (parents, health workers, household members) and interviewers because of the open nature of the intervention.

Data analyses

Data analyses will be done with Stata/SE V.15.1 (StataCorp, College Station, Texas, USA). All analyses of the effect of the intervention on the outcome measures will be on an as-randomised basis and only the vaccination data from the vaccination cards will be used in the analyses of optimal/timely immunisation coverage/uptake.

The primary analyses (for the primary outcomes) will involve a cluster-level method of analysis for cluster randomised trials with small number of clusters per treatment arm.[32 33] Prevalence difference (risk difference) in the intervention arm compared with control will be computed from the cluster-level summaries, proportions for dichotomous outcomes and medians/means for continuous outcomes, in each study arm. Unadjusted statistical inference will be via bivariate linear regression of the cluster-level summaries of the outcome measures on the study arms to obtain the corresponding p value and 95% CI of each prevalence difference. Adjusted statistical inference will be done via multivariate linear regression of the cluster-level summaries of the outcome measures on the study arms and cluster-level summaries of baseline covariates of interest. Only cluster-level summaries of baseline covariates will be used in the adjusted analysis because baseline and follow-up data will not necessarily be on the same individuals because of the repeated cross-sectional design of the outcome measurement. The baseline covariates of interest will include the most appropriate and predictive subsets of the covariates used for the constrained randomisation[38 39] such as the respective outcomes, delivery at health facility, number of antenatal visits by mother and travel time to catchment immunisation facility.

Randomisation-based inference will be done to check the robustness of the main findings[32 33 38 39] by carrying out adjusted clustered permutation tests (controlling for the respective outcomes, delivery at health facility, number of antenatal visits by mother and travel time to catchment immunisation facility) that incorporate the constrained randomisation schemes. The adjusted clustered permutation tests will be done at the individual level using a programme written in Stata.[38]

The same cluster-level method will be used for the unadjusted and adjusted analyses of the effect of the intervention on the secondary outcomes. Descriptive and inferential statistics of baseline data at the individual level will be used to assess optimal/timely (cumulative age-appropriate), timeliness (as a continuous variable), up-to-date, and 12 months age-appropriate routine childhood immunisation coverage, and rate of dropout from Penta-1 to Penta-3.

The transcripts of the focus group discussion will be analysed thematically based on predetermined themes in the study's logical framework.

Patients and public involvement

Patients or the public were not involved in the design and reporting or dissemination plans and will not be involved in the conduct of our research.

Trial status

The trial is ongoing. The overall trial start date is 06 May 2021 and overall trial end date is 31 May 2023. Recruitment of participants began on 30 June 2022 and is expected to end by 31 May 2023. Protocol version: Original. Date: 29 June 2022.

Ethics and dissemination

Ethical approval for the trial was obtained from the Ebonyi State Health Research and Ethics Committee (EBSHREC/01/06/2022–31/05/2023). The investigators will obtain verbal consent or permission from the heads of the selected clusters and from the PHC workers (who are the officers-in-charge in the catchment PHC facilities) before the baseline survey. The PHC workers will obtain verbal consent from the parents of 0–2 months aged children before registration as PORCHIC members and the interviewers will obtain verbal consent from the respondent mothers/primary caregivers of 5–23 months children (or the father/other adults as appropriate) during the household surveys. The purpose of the study, the kind of participation, likely duration of participation, voluntary nature of participation and freedom to withdraw at any time, absence of potential harm, potential benefit and confidential nature of the study will be duly communicated to participants as appropriate (online supplemental file 2). The online record of the anonymised data will be passworded to prevent unauthorised access.

Any significant amendments to the trial protocol after protocol publication will be reported to the research and ethics committee and the registry body. Study findings will be reported at local, national and international levels in high impact peer-reviewed journals and conferences as appropriate.

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Contributors UIO conceptualised and designed the study, designed the data collection tools and programmed the software and wrote the protocol and manuscript. RLE, CIA, COI, GEN, CCI and LCE contributed to the development of the study design, data collection tools and protocol. All authors contributed to the revision of the manuscript and read, edited and approved the final manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

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