Implementation research to develop and evaluate a mother-infant centred, pandemic-resilient, scalable model for improving the identification and management of possible serious bacterial infections in young infants in Uttar Pradesh, India

Research Protocol v3.1, 1 Oct 2022

Community Empowerment Lab
PI: Aarti Kumar
Co-PI: Dr. Vishwajeet Kumar
Co-PI: Dr. Rashmi Kumar
Co-PI: Dr. Jai Vir Singh

GSVM Medical College, Kanpur Nagar, UP
Co-PI: Dr. Yashwant Kumar Rao

Shyam Children's Charitable Hospital
Co-PI: Dr. KK Dokania

Technical Support Unit to Govt. of UP
Co-PI: Dr. Vasanthakumar N.

Abbreviations

ANM	Auxiliary Nurse Midwife
ASHA	Accredited Social Health Activist
AWW	Anganwadi Worker
CHC	Community Health Centre
CHO	Community Health Officer
CSI	Clinical Severe Infection
FBNC	Facility Based Newborn Care
F-IMNCI	Facility-based Integrated Management of Newborn and Childhood Illnesses
HBNC	Home Based Newborn Care
HWC	Health and Wellness Centre
IMCI	Integrated Management of Childhood Illnesses
IMNCI	Integrated Management of Newborn and Childhood Illnesses
INAP	India Newborn Action Plan
IR	Implementation research
JSSK	Janani Shishu Suraksha Karyakram
JSY	Janani Suraksha Yojana
KMC	Kangaroo Mother Care
MAA	Mother's Absolute Affection (Breastfeeding promotion programme)
NBCC	Newborn Care Corner
NBSU	Newborn Stabilisation Unit
NMR	Neonatal Mortality Rate
PM-JAY	Pradhan Mantri – Jan Arogya Yojana (health insurance scheme)
PSBI	Possible Serious Bacterial Infection
SAANS	Social Awareness and Action plan to Neutralise Pneumonia Successfully
SNCU	Special Newborn Care Unit
UP	Uttar Pradesh
WHO	World Health Organization

Executive Summary

Infections account for nearly half of all deaths in under-5 children globally, and more than a third of all newborn deaths in the state of Uttar Pradesh (UP), India. In developing country settings, infants aged <60 days are particularly vulnerable with their nascent immune systems, compromised breastfeeding and hygienic care practices, and lack of protection from vaccine-induced immunity. Due to the risk of rapid deterioration in condition and paucity of suitable diagnostic resources, infections in the 0-59 day age group of infants (referred to as 'young infants') are identified using clinical sign-based algorithms, and are therefore referred to as 'possible serious bacterial infections' (PSBI). The incidence of PSBI in South Asia and sub-Saharan Africa is approx. 10% of all livebirths.

The World Health Organization (WHO) recommends a comprehensive approach to address PSBI in young infants, including primary prevention, early identification and care-seeking and rational management, based on an extensive body of evidence. Within India, PSBI prevention, identification and management is spread across several policies and programs, with untested assumptions and gaps in policy and implementation. The COVID-19 pandemic has also led to widespread disruptions in maternal and child health services that has impacted PSBI care as well. The proposed implementation research aims to apply a **mother-infant centred approach** to develop and test a scalable model in UP to identify and manage PSBI in young infants, that is robust to pandemic-related disruptions.

Previous PSBI implementation research studies conducted in Haryana, Himachal Pradesh, Maharashtra and UP adopted a service-strengthening approach to operationalise WHO's policy on community-based PSBI management where referral is not possible, and faced several implementation challenges which could not be adequately resolved. These include differences between national and WHO guidelines on PSBI identification and management, lack of trust in the health system and preference for private providers, poor coverage and quality of home visitations by Accredited Social Health Activist (ASHA) workers, low feasibility of utilizing Auxiliary Nurse Midwives (ANMs) – the primary provider for community-based management designated in the Indian guidelines, requirement of intensive handholding support for medical officers and staff nurses in lower level facilities, blind referrals to higher facilities, and systemic problems of dysfunctional equipment and medicine supply shortages.

The proposed implementation research will be conducted in Kanpur Nagar district with a population of 4.8 million with a third of the population living in ten rural blocks surrounding a vibrant city centre. The health system infrastructure in Kanpur Nagar consists of 3 district-level hospitals (including one with a medical college) equipped with special newborn care units and 10 rural community health centres providing secondary level care. There are also several private clinics and hospitals catering to the paediatric age group, some also equipped with neonatal intensive care units. Two of the district level facilities and one private charitable hospital are also sites for an ongoing WHO-sponsored trial on optimising place of treatment and care regimens for young infants with PSBI that is led by the same team of investigators. Kanpur Nagar also has a large number of unqualified healthcare providers who serve an unmet need for medical care across underserved areas in UP and other Indian states. These providers exist in the same ratio of 1:1000 population as ASHA workers and are currently the preferred providers for primary care of young infants in rural blocks.

Prior to operationalisation of the trial, which was impeded due to the impact of the COVID-19 pandemic, we conducted formative research during December 2020 – March 2021 to understand the broader context of PSBI prevention, identification and management in the district and how it was impacted by the pandemic. Based on this work, we developed a strategy for operationalisation of the trial, refined processes through a two-month long pilot study and started enrolling participants from August 2021. The findings from this formative research and the subsequent pilot have informed our theory of change for prevention, identification and management of PSBI in young infants.

The **primary outcome** of the research is **PSBI identification coverage**, defined as the proportion of young infants identified with PSBI by trained providers as compared to an assumed PSBI incidence rate of 10% of all young infants. The model will be designed to achieve a PSBI identification coverage of at least 80%, and achieve a near universal coverage of treatment in the infants identified with PSBI. We will also do a cascade analysis to assess effective coverage and barriers and bottlenecks at each step of the cascade.

We will follow the Design-Outcome Cascade implementation research framework in order to design and evaluate the PSBI model, and therefore begin by first designing solutions to meet user-level endpoints (mothers and family members), and then by designing solutions to meet provider-level service delivery endpoints. The model development and refinement process will be based on a generic pathway for illness identification and management and optimization of corresponding process outcomes using an iterative human-centred design approach. This will be strategized, reviewed and guided through quarterly **plan-do-study-act cycles** with co-investigators and key block and district-level health system and community stakeholders.

The model development, refinement and evaluation will be conducted in a rural block (population ~150,000; annual birth cohort ~3,000) in Kanpur Nagar over a period of 12 months across 4 plan-do-study-act cycles of 3 months each. Each cycle will have a specific focus on aspects of model development and refinement, and specific goals with respect to model outcomes for each cycle will be identified based on the results of the previous cycle.

The target population for the evaluation consists of all live births of usually resident mothers in the study area, who will be registered upon notification and concurrently followed up, after due consent, for 60 days at age 15, 30, 45 and 60 days. Infants identified with PSBI will be followed up at treatment initiation and 8 days after treatment initiation or upon discharge from facilities (based on place of treatment) for study-related outcomes. Further, verbal autopsies will be conducted for all deaths reported in enrolled young infants.

The sample size requirement is based on an assumed PSBI incidence rate of 10% among all young infants. In order to conclude with 95% confidence that the PSBI identification coverage attained through the model is 80% or more of the assumed PSBI incidence rate with a precision of 10%, we will need to enrol at least 2,828 young infants. Thus, one block with a population of approx. 150,000 and approx. 3,300 births per annum is sufficient to provide this sample size over a 10 to 12-month follow-up period.

Evaluation data would be collected on Android-based tablet devices, with inbuilt checks for missing values, inconsistencies and skip logic. Measures to conduct aggregate-level data quality checks and ensuring timeliness of data collection for each young infants will be put in place.

The study will be reviewed by the Ethics Review Committee at the WHO and the Institutional Ethics Committee of the Community Empowerment Lab (CEL). It will be led by investigators at CEL who have a proven track record of conducting high quality implementation research in partnership with the government. Collaborators will include investigators at GSVM Medical College and Shyam Children's Charitable Hospital, the district administration and health system leadership in Kanpur Nagar who are already involved of the ongoing PSBI trial. State-level collaborators will include the UP National Health Mission and the UP Technical Support Unit.

Introduction

Despite a steady rate of decline in childhood mortality, the global burden of under-5 deaths is still immense at 5.3 million per annum, with more than 80% of these deaths occurring in sub-Saharan Africa and South Asia.[1,2] The proportion of newborn deaths among under-5 deaths has been steadily rising, currently accounting for 46% of all under-5 deaths. Infection is amongst the most important causes of death, accounting for nearly half of all deaths among children aged 1-59 months,[1] and more than a third of all newborn deaths.[3] In Uttar Pradesh (UP), India – the site for the proposed implementation research (IR), severe neonatal infections account for 39% of all newborn deaths.[3] This amounts to 67,000 deaths annually across UP in the newborn period alone, nearly all of which could be averted through appropriate and timely measures for prevention and management of infections.

The term 'possible serious bacterial infections' (PSBI) was coined for the 0-59 day age group of infants, as these are typically identified and treated based on clinical signs without waiting for confirmatory lab results, given the paucity of diagnostics in low-resource settings and the likelihood of rapid deterioration in condition without antibiotic treatment of bacterial infections in this age group. Further, with regards to PSBI, the epidemiological profile, clinical signs and management of infants in the age group of 28-59 days is the same as newborns (age 0-27 days), and therefore they are grouped together into a single age category of 0-59 days called 'young infant'.[4] A systematic review across 22 studies estimated the pooled global PSBI incidence risk in newborns alone as 7.6% with a case fatality rate of 9.8%,[5] however a wide variation in PSBI incidence has been reported across countries.[6] More recently, IR studies on community management of PSBI cases in young infants in the states of Haryana, Himachal Pradesh, Maharashtra and UP in India succeeded in identifying respectively 7.0%, 8.0%, 5.7% and 5.3% of live births with PSBI signs. [7–10] However the actual incidence rate was unknown in the absence of rigorous surveillance, and is expected to be higher in regions with higher mortality rates. Further, the incidence also depends on the algorithm used for identifying PSBI and cut-off values for temperature, respiratory rate, etc.

A significant body of research has focused on identifying clinical sign-based diagnostic algorithms[11–13] and treatment regimens for PSBI[14–17] that are amenable for implementation in low-resource community settings through minimally trained health workers.[18,19] The WHO recommends a comprehensive approach to address PSBI in young infants along the continuum of care from community to facility (and back), that involves prevention, timely identification of PSBI symptoms and care-seeking, hospitalization for antibiotic treatment and supportive care, and subsequent follow-up of sick young infants post-discharge.[4] Current WHO guidelines regarding identification and classification of PSBI based on clinical sign-based algorithms and corresponding treatment recommendations are summarized in Table 2. Multiple IR studies have focused on operationalizing WHO guidelines for managing PSBI in young infants where referral is not feasible to expand treatment for the maximum possible infants.[7–10,20–27]

Within India, prevention, identification and management of PSBI is spread across several programs such as Janani Suraksha Yojana (JSY), Janani Shishu Suraksha Karyakram (JSSK), Home Based Newborn Care (HBNC), Facility Based Newborn Care (FBNC), Integrated Management of Newborn and Childhood Illnesses (IMNCI), breastfeeding promotion programs such as Mother's Absolute Affection (MAA), and the recently launched Social Awareness and Action plan to Neutralise Pneumonia Successfully (SAANS) program. Yet, the high rate of infection-related deaths implies that there continue to be implementation gaps that need to be addressed at scale.

The 4 recently conducted IR studies in India in Haryana, Himachal Pradesh, Maharashtra and UP assessed the feasibility of operationalizing the WHO guidelines involving simplified treatment regimens for PSBI management in young infants where referral is not possible. While these studies found it feasible to operationalize these guidelines, they identified several challenges that need to be addressed at scale. Challenges identified related to timely identification of PSBI included limited ability of mothers to recognize danger signs, poor ability among community

health workers (ASHAs) to recognize danger signs despite prior training, dysfunctional equipment like thermometers and weighing scales with ASHAs, and non-compliance of ASHA workers to the expected schedule and frequency of home-based newborn care visits. Challenges identified related to care-seeking included a general mistrust among families towards the public health system, preference for private providers including unqualified medical practitioners, and poor referral support. Challenges identified related to community case management of PSBI included low feasibility of utilizing Auxiliary Nurse Midwives (ANMs) – the designated primary care provider for case management as per existing guidelines, and further, the requirement of intensive handholding support over a long duration for medical officers and staff nurses in primary and secondary care facilities.

While the studies addressed the above challenges to some extent through intensive interventions within a single district, there is a need to develop solutions that can be rapidly scaled with high fidelity for large state/ country-wide deployment in order to achieve impact at scale. Further insights highlighting key gaps and issues in PSBI implementation based on formative research and activities within an ongoing PSBI trial being conducted by the investigators have also contributed to shaping the proposed IR strategy, discussed later in this protocol. Overall, a quantum improvement in PSBI outcomes requires a fundamental shift from a service delivery-centred paradigm where multiple health programs are implemented in parallel without sufficient integration, to a mother-infant centred paradigm that integrates care around every young infant regardless of the delivery channel, and is tuned to address their unmet needs and implicit barriers. Additionally, the COVID-19 pandemic has led to a widespread disruption in maternal and child health services across the spectrum, thus magnifying pre-existing challenges and introducing new ones with respect to prevention, identification and management of PSBI. **The proposed IR, therefore, aims to apply a mother-infant centred approach to develop and test a scalable model for improving the identification and management of PSBI in young infants, that is robust to pandemic-related disruptions.** Specific outcomes that will be addressed through this IR are highlighted in a subsequent section.

Implementation Context

One of the main goals of any IR is to contextualise solutions based on the realities and needs of the geopolitical entity where implementation is to be optimised. The national, state, district and other contextual factors related to the study are therefore an important consideration for solution design and presented below.

National policy context

India has a very proactive policy environment with regards to improving newborn survival. It was quick to launch the India Newborn Action Plan (INAP) in 2014, in the same year as the global Every Newborn Action Plan. The 'Care of the small and sick newborn' package of INAP includes IMNCI and community-based case management as key strategies for PSBI in newborns. Various national policies aimed at reducing the neonatal mortality rate (NMR) were introduced over a period of time, and cover aspects of PSBI prevention and management (see Table 1).

Table 1. National policies with linkages to PSBI prevention and management

Policy & Year of Latest Revision	Linkages with PSBI prevention and management
Janani Suraksha Yojana (JSY), 2007	Promotes institutional deliveries by incentivizing mothers and frontline health workers known as Accredited Social Health Activists (ASHA). Has a role in PSBI prevention through safe and hygienic delivery and promoting preventive practices such as early initiation of breastfeeding.
Home based newborn care (HBNC), 2014	Lays out a schedule for home visitations by ASHA workers on days 1, 3, 7, 14, 21, 28 and 42 (with the day 1 visit optional for

	facility births).[28] ASHA workers are expected to promote essential newborn care practices such as breastfeeding, cord care, etc. during these visits, and also assess the newborn for danger signs, including those of PSBI. They are expected to refer newborns identified with danger signs to the nearest appropriate referral facility.
Facility-based Integrated Management of Newborn & Childhood Illnesses (F-IMNCI), 2008	The IMNCI programme in India was introduced in 2005 with an added focus on the newborn component of care, and primarily emphasized on training community-based health workers on prevention, identification and referral of sick children.[29] This was later absorbed into the HBNC program. The F-IMNCI program was subsequently introduced to train medical professionals in in-patient management of under-5 children focusing on acute respiratory infections, diarrheal diseases, measles, malaria and malnutrition.[30]
Facility-based newborn care (FBNC), 2011	Involves a focused strategy for in-facility care of neonates at multiple levels of care, with newborn care corners (NBCC) at all delivery points, newborn stabilisation units (NBSU) at first referral units and special newborn care units (SNCU) at district-level facilities.[31] The FBNC programme includes assessment, referral, triaging and management of newborns with PSBI at the appropriate level of care.
Janani Shishu Suraksha Karyakram (JSSK), 2011	Strengthens community-facility linkages by providing free transportation for sick infants through the 102 ambulance service from home to health facilities, between facilities in referral cases, and drop back from facilities to home post-treatment.[32]
Guidelines for community-based case management of young infants with PSBI when referral is not feasible, 2014	Designates Auxiliary Nurse Midwives (ANM), who typically administer vaccines to children and other emergency injectable medications to mothers, and have previously received training on assessment of children as part of the IMNCI program – to provide injectable antibiotics and prescribe oral antibiotics to young infants with PSBI. The ANM is expected to provide pre-referral dose of antibiotics prior to referral, ensure completion of antibiotic therapy post discharge, and provide a 7-day course of antibiotic therapy to young infants with PSBI when referral is not possible or refused.[33] The original guideline had a list of 11 clinical signs of PSBI, which was subsequently revised (date unknown) to align with the latest WHO guidelines with a reduced set of 7 signs.[34]
Social Awareness and Action plan to Neutralise Pneumonia Successfully (SAANS), 2019	Promotes a 'protect, prevent and treat' approach to prioritize the elimination of childhood deaths from pneumonia. The revised 'Childhood Pneumonia Management Guidelines' for under-5 children released as part of the SAANS campaign includes a consolidated protocol for assessment, classification, referral and community-based management of PSBI in young infants by primary care providers (Figure 1), as well as facility-based treatment of young infants with PSBI (Figure 2).[35] It also entails multisectoral engagement of stakeholders, supply chain management and equipment maintenance, cascade-based training of health staff, awareness generation, supportive supervision and monitoring, reporting, feedback and periodic

	review by pneumonia management committees at block, district at state levels.
Pradhan Mantri – Jan Arogya Yojana (PM-JAY)	Provides health insurance to poor and vulnerable families for availing treatment from private facilities empanelled with the scheme.[36] PM-JAY covers basic costs of treatment of PSBI in newborns and children under separate categories in empanelled facilities.

The existing national guidelines are not completely in alignment with the WHO guidelines for PSBI. These differences are summarized in Table 2. The national guidelines are currently in the process of being reviewed for greater alignment with the WHO guidelines, but the updated guidelines are yet to be released.

Table 2. Comparison between WHO and Govt. India guidelines for PSBI identification/ classification and treatment

Domain	**WHO guidelines**	**Govt. of India guidelines**
Age differentiation for fast breathing (≥ 60 breaths per minute) as a single sign	Fast breathing alone in 7-59 day old infants not considered a sign of PSBI. Referral is recommended only for infants aged <7 days, and outpatient treatment with oral amoxycillin alone recommended for age range of 7-59 days.	Fast breathing is considered as a sign of PSBI across 0-59 day age group. Recommend referral and facility-based treatment with injectable antibiotics for the entire age spectrum from 0-59 days.
Temperature cut-off for fever	≥ 38°C (100.4°F) The higher cut-off is chosen to improve the specificity of the algorithm for the diagnosis of bacterial infection and exclude mildly ill infants who would recover without antibiotic therapy.[37]	≥ 37.5°C (99.5°F) (based on IMCI)
Classification of signs into categories for community-based case management	Classify signs into severe pneumonia (age <7 days with fast breathing alone), clinical severe infection (CSI; one or more of fever, severe chest indrawing, hypothermia*, movement only upon stimulation and stopped feeding well) and critical illness (one or more of convulsions, no movement at all, no feeding at all). Simplified antibiotic treatment for community case management (if referral is refused/ unfeasible) of severe pneumonia consists of oral amoxycillin alone; for CSI consists of gentamicin injections	Give the same weightage to each sign – no differential action for different categories. No re-classification of signs based on severity. Community based case management for any PSBI sign consists of a combination of injection gentamicin with oral amoxycillin.

* Hypothermic defined as temperature < 35.5°C (95.9°F)

	along with oral amoxycillin. For critical illness, referral is re-emphasized.	
Treatment dosage of oral amoxycillin for community-based case management	For indicated conditions, recommended daily dosage of amoxycillin is 100mg/kg body weight in two divided doses, for 7 days.	Recommended daily dosage of amoxycillin is 50mg/kg body weight in two divided doses, for 7 days. (half that in the WHO guidelines)
Treatment dosage of injection gentamicin for community-based case management	For indicated conditions, recommended dosage of inj. gentamicin is 5-7.5 mg/kg body weight once daily for 2 or 7 days. Although 7 day treatment is preferred, treatment with only 2 days of injectable gentamicin (single daily dose of 5mg/kg body weight) was found to be equivalent to the pre-existing standard of care of 7 days of inj. gentamicin in rigorously conducted trials of simplified antibiotic regimens in South Asia and sub-Saharan Africa.[14,16,17,38] WHO recommends that a 2-day treatment may be adopted in countries where 7-day treatment is difficult.	Recommended daily dosage of inj. Gentamicin is similar to WHO guidelines at 5mg/kg body weight once daily. The treatment is to be continued for 7 days. Reduction in the treatment course of injectable gentamicin from 7 to 2 days significantly simplifies the logistics of managing PSBI without compromising on treatment efficacy, but these findings have not yet been incorporated in the Indian guidelines.

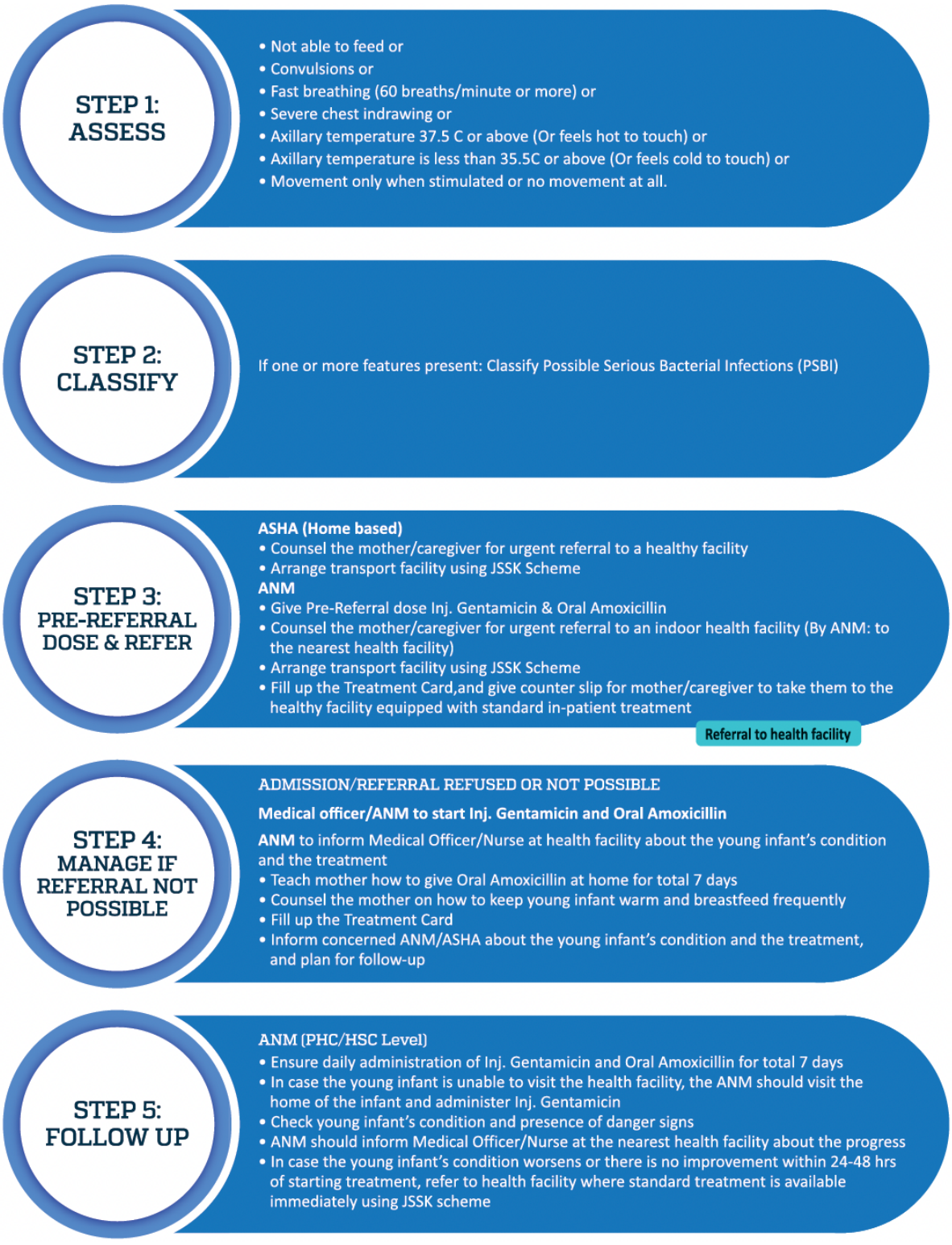

Figure 1. Protocol for management of PSBI by primary care providers laid out in the SAANS guideline

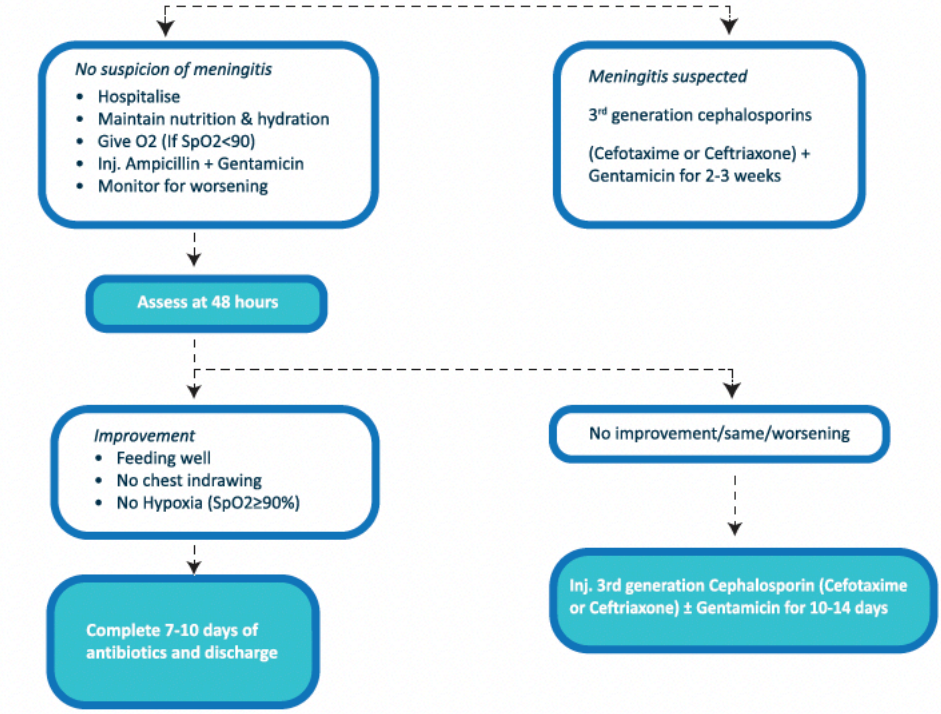

Figure 2. SAANS protocol for facility-based management of young infants with PSBI

Despite a multi-pronged policy outlay, several gaps exist in the linkages between the various policies along the continuum of care with respect to PSBI management in young infants. Key gaps are mentioned below:

- **Infants aged between 28-59 days fall through the cracks across several policies.** The HBNC program covers home visits till age 42 days, but SNCUs (at least the ones in UP) only admit infants upto 28 days of age. Further, each policy has been created independent of the others at different time points, leading to fragmentation in the approach to PSBI management.
- **Individual policies are protocol-centric, but there is a need to integrate them through a mother-infant centric approach for impact.** Each policy independently lays out the roles of providers to accomplish its objectives, but there is a lack of integration in (i) designing the workflow from a mother-infant perspective, of how the infant should move from provider to provider, and (ii) consolidating the roles and activities of each provider that spans across policies. From assessment by a frontline health worker, to pre-referral management, to facility-based care and post-discharge adherence, the young infant changes location and providers multiple times. Without robust handshake mechanisms that ensure safety and appropriate handover, the care of the infant can fall through the cracks.
- **Guidelines & their implementation need to recognise the central importance of the mother in early recognition of danger signs.** Infections in young infants require urgent attention and management, and therefore the 7 pre-scheduled home visits by ASHA workers over 42 days are inadequate in terms of timely recognition of danger signs. Increasing the number of visits further is also not realistic, considering that ASHAs typically do not accomplish more than half of the scheduled visits.[7] Mothers and families need to be equipped such that they are able to immediately notify danger signs, which may result in unscheduled home visits for verification and referral by ASHAs.
- With regards to promotive-preventive care like breastfeeding, Kangaroo Mother Care (KMC) and hygienic care, etc., **current programmatic implementation is limited to awareness messages** like ‘do not feed your newborn anything other than breastmilk for

6 months'. However, for behaviour change, mothers need empathetic counselling that involves understanding and addressing their beliefs, needs and practical challenges in following the recommended behaviours and fostering a supportive home environment. This requires greater time and effort but is likelier to give positive results – however, it is not accorded due importance, and neither monitored nor incentivised.

- **The Indian guidelines are not yet completely aligned with the WHO guidelines** that are based on robust evidence generated through multi-centre trials and aimed at rationalising and streamlining treatment modalities. However, we await the revised Indian guidelines that reportedly have greater alignment with the WHO guidelines.
- **Given significant care-seeking from private providers, even by the poorest of families, the PM-JAY addresses a critical need.** However, there is currently no way for mothers and families to know which facilities are empanelled and suitable (based on services offered, quality of care, distance, transport, out-of-pocket expenses, etc.) for seeking immediate care for their sick young infants.

State & district implementation context

UP, with its population of 241 million, is comparable in size to the fifth largest country globally, and therefore, requires review, adaptation and integration of policies and programmes to suit its health system and sub-regional contexts. In line with the national policy guidelines, UP's current approach to PSBI management is spread across several programmes. An integrated and child-centred approach to PSBI management would be instrumental in bridging programmatic gaps and achieving planned reductions in infection-related deaths.

This research would be conducted in Kanpur Nagar district of UP. The district is the site of an ongoing individually randomised trial on optimizing the place of treatment and antibiotic regimens for young infants presenting with PSBI signs. It was chosen to leverage the synergy between the two studies without compromising on research integrity.

Figure 3. Location of Kanpur Nagar district

Kanpur Nagar district (Fig 2) comprises Kanpur city and 10 rural blocks with a total population of 4.8 million. The district center is located about 95kms from the state capital of Lucknow. It is amongst the most densely populated districts (1521 persons/sq km) with a two-thirds population residing in urban areas. The female literacy rate of 81% is the highest in the state, with 40% of rural women and 68% of urban women having more than 10 years of education. Figure 4 shows the administrative map of the district, with secondary-level health facilities and key population and health system indicators summarized in Table 4.

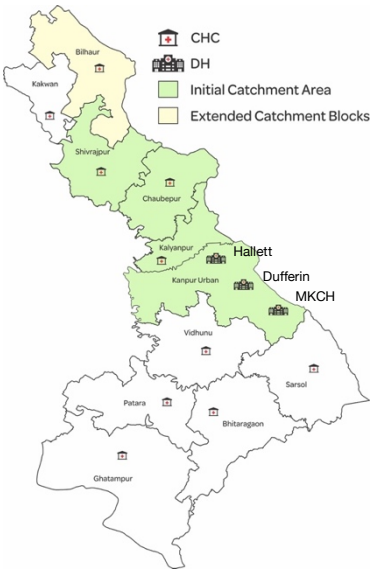

Figure 4. Map of Kanpur Nagar district with key facilities and catchment area for the WHO-sponsored PSBI trial to optimize hospital stay

Table 3. Public health system indicators for Kanpur Nagar district

Birth cohort	100,000 live births per annum
Institutional births	76% (urban: 78%, rural: 74%)
Births in public health facilities	49% (urban: 41%, rural: 63%)
NMR (based on AMANHI study)	42 per 1000 Severe neonatal infections: 39%
Estimated PSBI prevalence	10,000 per annum (based on ANISA & SATT studies)
District-level hospitals with delivery facility & SNCU	• Hallet District Hospital (operated by GSVM Medical College) • Dufferin District Women's Hospital • MKCH District Hospital
Community Health Centres	10 (of which 5 have paediatricians)
Primary health facilities	92 (urban: 50, rural: 42)
Private birthing facilities	207 (urban: 157, rural: 50)
Community health workers	Urban: ANM-263, ASHA-457 Rural: ANM-345, ASHA-1688

UP districts that are predominantly rural typically have a district women's hospital that provides delivery and newborn care (0-27 days only) services and a district common hospital that caters to the rest of the paediatric age group, including 28-59 day old infants. Being an urban centre, Kanpur Nagar district has four district-level government health facilities – three of them are equipped with Sick Newborn Care Units (SNCU). The District Women's Hospital, called Dufferin Hospital, mainly serves urban Kanpur, but does not provide any services for infants older than 28 days except for follow-up care for infants discharged from the SNCU. MKCH hospital is the referral hospital for the rural blocks in the south of Kanpur Nagar district and provides care for all paediatric age groups with an SNCU that caters only to the newborn age group. Hallet is a large hospital providing comprehensive services for all age groups, including delivery and newborn care. It the main referral facility for rural blocks in the north of Kanpur Nagar district. It has an associated medical teaching college and is therefore the highest referral facility in the district. Kanpur city also has a primary health care setup for the urban slum population that consists of 50 urban primary health centres with medical officers in-charge, 263 urban auxiliary nurse midwives and 457 urban ASHA workers. There is also a vast network of private practitioner paediatricians, and multiple private hospitals offering referral care for newborns and young infants.

Each rural block (population 150k-200k) has a community health center (CHC), which is a secondary care facility. At the block level, the medical officer in-charge of the CHC, Block Community Process Manager and Health Education Officer are key stakeholders. At the population level, ASHA workers are meant to be deployed for every 1000 population, though this is highly variable at a ground level. Other grassroot level workers include the Sangini who are ASHAs designated as team leads for a group of 18-25 ASHAs; the Anganwadi workers (AWW) who mainly focus on nutrition and early child development; the ANM – a trained rural midwife who administers vaccines and conducts deliveries; and the CHO – a trained nurse, as a recent addition as part of the government's Health and Wellness Center initiative but not yet fully deployed and integrated in most districts. Rural areas also have unqualified healthcare providers, who are often the first point of care for many families due to proximity, availability and many other factors. From an administrative and governance perspective, the gram sabha

(population ~3,500) is the smallest unit of self-governance, with a governance chain consisting of elected representatives at the block and district levels.

All aspects of district level administration and governance are led by the District Magistrate, who also chairs a monthly meeting to review all district-level health system related programs and initiatives. The District Magistrate is assisted by the Chief Development Officer in coordinating day-to-day operations at the district level. All health-related programs and their budgets are coordinated through the office of the Chief Medical Officer of the district, who belongs to the medical services cadre.

PSBI trial context

The ongoing PSBI trial in Kanpur Nagar is part of a WHO collaborative multi-centre trial to optimize the place of treatment and antibiotic regimen for young infants with PSBI. Secondary data analysis from the AFRINEST study found that the various PSBI signs are not equivalent in terms of their risk for mortality.[39] Based on this analysis, PSBI signs were further classified into low mortality risk, moderate mortality risk and critical illness signs. Young infants presenting with only one of fever (axillary temperature ≥ 38°C), fast breathing in 0-6 day old infants (≥60 breaths per minute) or severe chest indrawing and no other PSBI signs had a low case fatality rate, and these signs occurring alone were therefore classified as low mortality risk signs. Young infants presenting with either hypothermia (axillary temperature < 35.5°C) or not feeding well or movement only upon stimulation, or multiple signs of clinical severe infection had a higher case fatality rate, and these signs were classified as moderate mortality risk signs. Young infants presenting with one or more signs of critical illness – convulsions, not feeding at all, no movement at all, had the highest case fatality rate. Further, the analysis found that infants presenting with low or moderate mortality risk signs had a higher chance of survival when treated at home than at the facility, whereas those with critical illness signs had a higher chance of survival when treated in facilities.

The ongoing PSBI trial seeks to confirm these findings through a randomised controlled trial design, and consists of 2 parallel studies that evaluate whether outpatient treatment is non-inferior to inpatient treatment for (i) young infants presenting with a single low mortality risk sign (Study 1), and (ii) hospitalised young infants with a high mortality risk sign or two more signs of clinical severe infection who clinically improve 48 hours after initiation of treatment and have a negative C-reactive protein (CRP) laboratory test (Study 2). The trial is currently recruiting young infants presenting in the outpatient or emergency departments in two government and a private charitable hospital.

The PSBI trial requires its own strategy to ensure adequate enrolment as per its sample size requirement of 1000 and 750 young infants for Study 1 and 2 respectively, over a period of 24 months. The trial only impacts the treatment of infants who are referred to the participating hospitals (based on allocation to home or facility care), and does not touch upon the treatment of infants who refuse referral. Thus, improvement in hospital referral for PSBI cases, an important goal of PSBI management and this IR, will lead to increased enrolment in the trial. As part of this trial, various aspects of PSBI management will be strengthened, including high-quality protocolised care at treating facilities, referral facilitation, identification of PSBI by mothers and frontline health workers, follow-up care, etc. Thus, **the goals of the proposed implementation research that aims to develop and test scalable solutions for PSBI are in alignment and complementary to the goals of the PSBI trial**.

Insights and lessons from formative research

The implementation of the trial was delayed due to Covid-19 lockdowns and situations arising due to the pandemic, and consequent attrition in care-seeking from public health facilities. A formative research study was conducted between December 2020 and March 2021 to understand the impact of the pandemic on PSBI to develop a strategy for operationalising the trial, and to lay the groundwork for the proposed implementation research study. It aimed to understand the role of various stakeholders, and identify challenges and opportunities with

regards to care of young infants with PSBI in general, with specific focus on the shifts in context that took place during the pandemic.

The formative research study involved interviews with mothers, ASHA, ANM, govt. and private health providers, and program managers and health facility leads; focus group discussions with mothers/caregivers, as well as unqualified healthcare providers. It also reviewed data on deliveries, outpatient registrations and admissions to get some quantitative estimates of the impact of the pandemic.

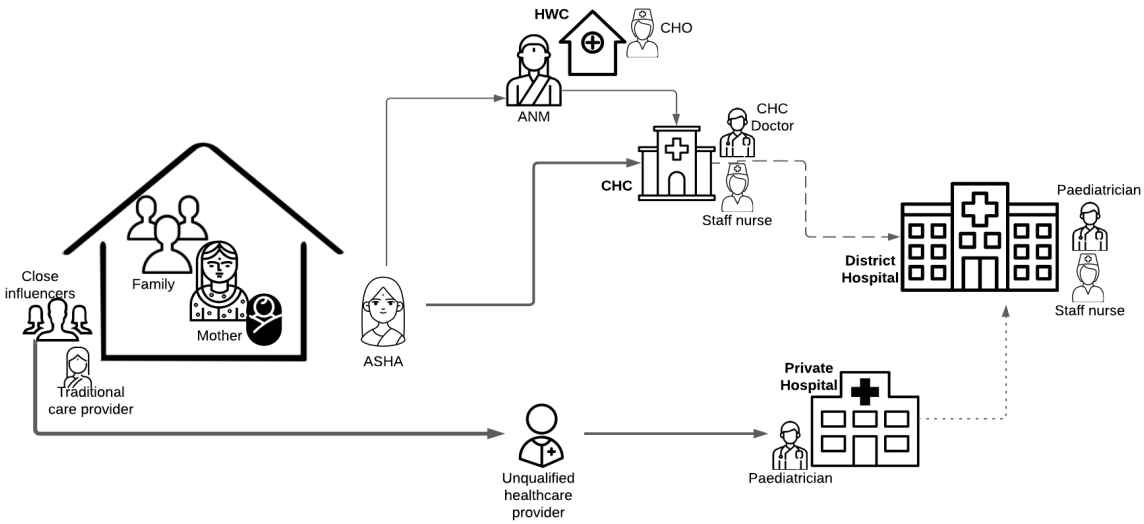

Figure 5. Key stakeholders and locations for PSBI identification & management with typical care-seeking pathways

Figure 5 depicts the key stakeholders and locations for PSBI identification and management and lays out typical care-seeking pathways. Prior to the pandemic, 39% of newborn deaths in this region were attributable to severe infections[3] due to a cascade of challenges that have not been adequately addressed. A chain of key touchpoints modulate risk and opportunities for PSBI prevention, identification and management along the continuum of care:

- delivery and postnatal care in facilities,
- postnatal home-based care,
- home visitations by ASHA workers,
- identification and early response to illness (not specific to PSBI) by mothers/ families,
- care-seeking for illnesses (not specific to PSBI) from external providers (ANM/ CHO, CHC, district hospital, unqualified healthcare providers, private hospitals) through intermediaries (ASHA or family contacts),
- PSBI-related care provided by various care providers,
- referral management
- home adherence to treatment and follow-up

Antenatal care has not been considered a major touchpoint with regards to PSBI, although it provides a long window of opportunity for education, general nutritional care and screening of mothers for infections, which are likely to impact both preterm delivery and early onset sepsis. Findings on the pre-Covid-19 scenario with regards to these touchpoints and how they were impacted during the pandemic are shared in Appendix I. **These touchpoints can be seen as a chain, whose weakest link currently determines the ultimate outcome of young infants**.

Following this study, another deadly wave of Covid-19 swept across India with very high number of cases (see Figure 6), hospitalisations and deaths.

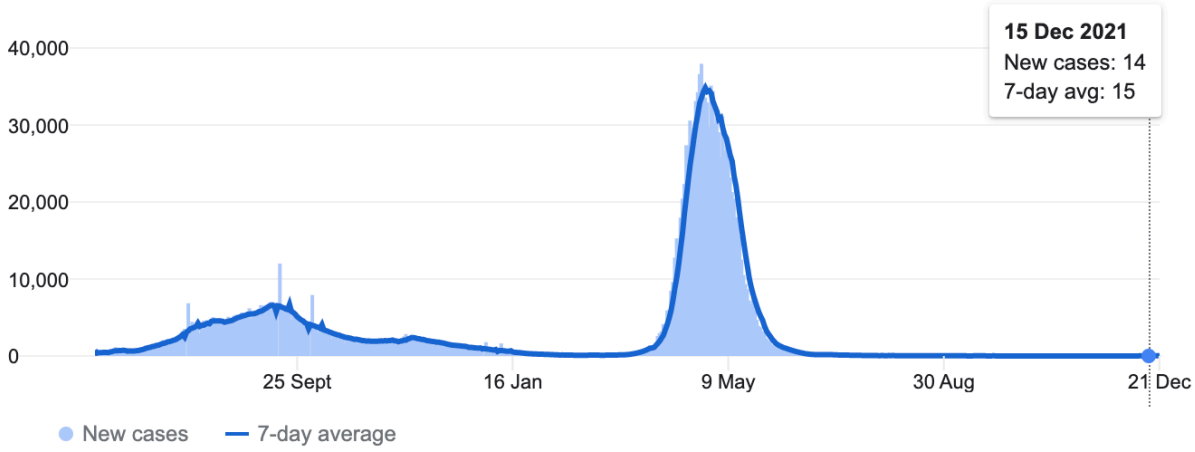

Figure 6. Covid-19 cases in Uttar Pradesh from June 2020 to December 2021

A pilot study was conducted to refine and adapt the various study procedures in preparation for the main trial in June-July 2021. The trial was subsequently initiated in August 2021.

Key insights and lessons from the formative research, pilot study and ongoing trial implementation from a mother-infant centred perspective are summarised below:

1. **Mothers need to be coached and supported to build their skills (and not just knowledge) in providing preventive-promotive care and recognizing danger signs in their young infants**: Equipping mothers with the knowledge to improve newborn care practices and to identify danger signs is an important component of current policies and programs. However, the methods used to achieve this objective largely include mass media campaigns, information-education-communication (IEC) materials, and behaviour change communication (BCC) through health workers, that are primarily based on transmitting certain messages about ideal behaviours, such as “breastfeed exclusively for the first 6 months”, or in the case of danger sign recognition, naming these signs, sometimes with pictorial representations. These methods, while readily scalable, lack impact, as they are not in tune with advances in behavioural science. Behaviour change requires contextualized knowledge, skills, motivation and an enabling environment,[40] while these existing approaches only focus on factual knowledge without due recognition of the importance of motivation, skills and an enabling environment. Thus, innovations need to focus on how to develop scalable approaches to address all the essential factors for behaviour change. For example, in the ongoing PSBI trial, teaching mothers the skills for assessing their babies to recognize danger signs prior to discharge from facilities has contributed to an improvement in notification and care-seeking for illnesses by families.

2. **The choice of intermediaries and care providers for illnesses depends upon the families’ perception of their accessibility and trustworthiness**: Accessibility is a composite of the availability, approachability and affordability of care providers, and trust is a composite of the family’s perception of their responsiveness, expertise and accountability (see Fig. 7). Figure 8 illustrates the typical placement of intermediaries and care providers for PSBI on this matrix. Thus, while ASHAs are highly accessible and trusted for antenatal care and delivery related care-seeking, they are not currently the trusted intermediaries for newborn illnesses. The trusted intermediaries for care-seeking are typically the families’ close social contacts who can connect them to care providers who can actually provide treatment.

Accessibility = perception of Availability: how near is the provider and is he/ she currently available? Approachability: is the provider(s)/ facility familiar to me/my close contacts? How easy is it to navigate care at the facility? Affordability: can I afford the services of the provider?	**X**	**Trust** = perception of Responsiveness: Is the provider responsive to my needs, do they give time & check in on my infant regularly? Expertise: How capable is the provider? Do they have a reputation of good care and speedy alleviation of symptoms Accountability: Can I rely upon the provider? Are they accountable to me?

Figure 7. Factors that determine choice of provider/ facility for care-seeking

3. **Typical care-seeking pathways move from providers with higher accessibility to those with lower accessibility along higher trust** (see Fig. 8): The predominant care-seeking pathway even prior to the pandemic involved close family contacts as intermediaries, unqualified healthcare providers as primary providers and private hospitals as secondary providers of care for young infant illnesses. The care-seeking pathway from public health facilities is broken because lower-level facilities like CHCs, despite prior training on IMNCI, etc., mostly do not provide any care for newborn and young infant illnesses. CHCs will need to provide quality services for at least outpatient care for illnesses in young infants to gain public trust and restore the care-seeking pathway from the health system.
4. **Care providers need to respond to a broader spectrum of illnesses and conditions and not just PSBI in order to improve their trust quotient**: While scientists, policy-makers and implementers consider PSBI as important as we are focused on mortality

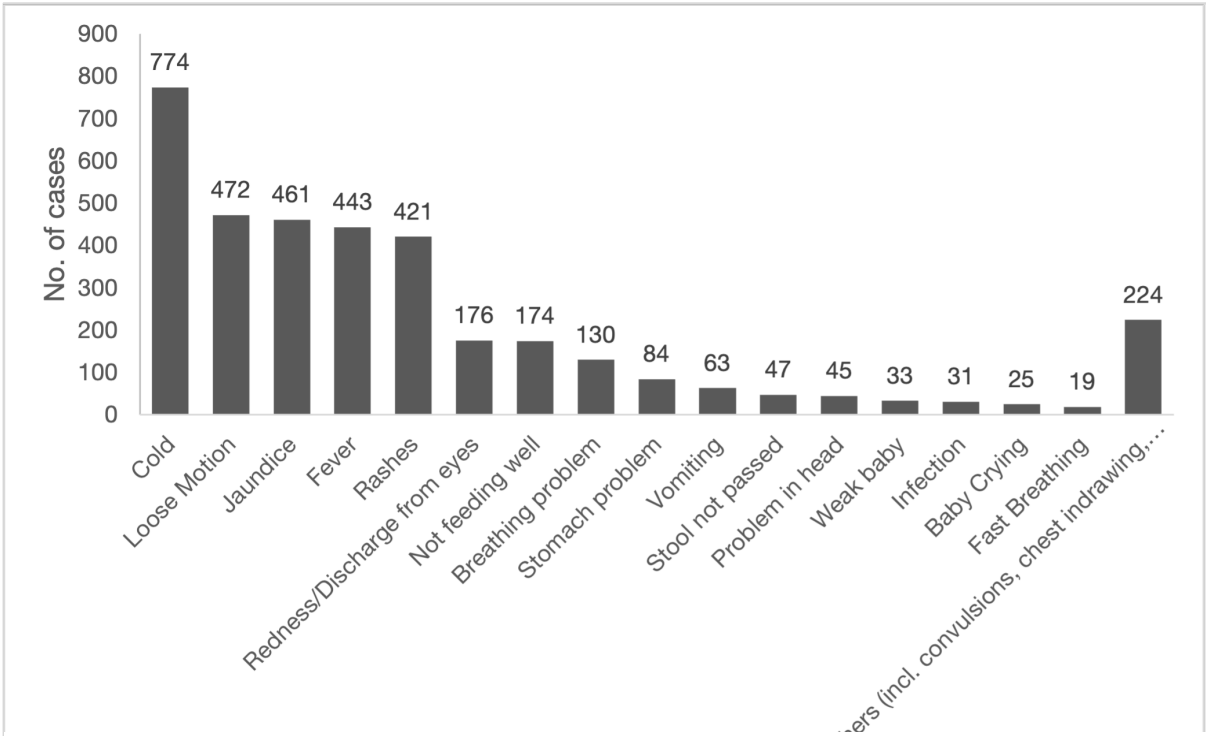

Figure 8. Complaints reported by families to the call centre (n=3622)

reduction, mothers and families need support for a host of other conditions that concern them, for example, excessive crying, regurgitation of milk, etc. Common complaints reported by mothers to our call centre (see Figure 8) include cold (22%), loose motions (14%), jaundice (13%), fever (13%) and rashes (12%). Families naturally expect a resolution and support for all these problems, and not just PSBI related signs. Care providers need to be able to address these common concerns of mothers and not just PSBI related signs to enjoy greater trust and become preferred providers.

5. **Pandemic-control measures incentivised unlicensed providers that provide irrational treatment at the cost of licensed providers that are more likely to provide rational care**: During the pandemic, OPD services of licensed facilities were shut down as part of COVID-19 regulations, and even when these services were opened to the public, RT-PCR tests became mandatory prior to OPD consultation, especially during the peak of the pandemic waves. This led to a shift in care-seeking away from licensed facilities – unqualified healthcare providers moved higher on both accessibility and trust, whereas both the accessibility of and trust in public health facilities for PSBI care went down substantially. Even the accessibility of ASHAs reduced significantly. The accessibility of registered private hospitals also went down.
6. **Unqualified healthcare providers are the big elephant in the room whose role in PSBI care needs to be acknowledged and reshaped**: These providers have always enjoyed the trust of the community as they address an unmet need for clinical care in underserved communities, but their existence has largely been ignored by the health system. During the pandemic, they have consolidated their base and gained an even higher legitimacy within their communities. At present, they are the primary providers of PSBI care in their communities, but their treatment is irrational and hazardous (refer Appendix I for details) – not only for the young infant, but also from the larger public health perspective of increasing antibiotic resistance and creation of superbugs. It is not advisable to continue to turn a blind eye to them, and policy makers need to rethink how to engage with them and reshape their role. Is there a potential for tapping into this huge trusted resource within the community for improving early identification and care-seeking for PSBI? This could be a double-edged sword, but can be explored while being cognizant of unintended harms.

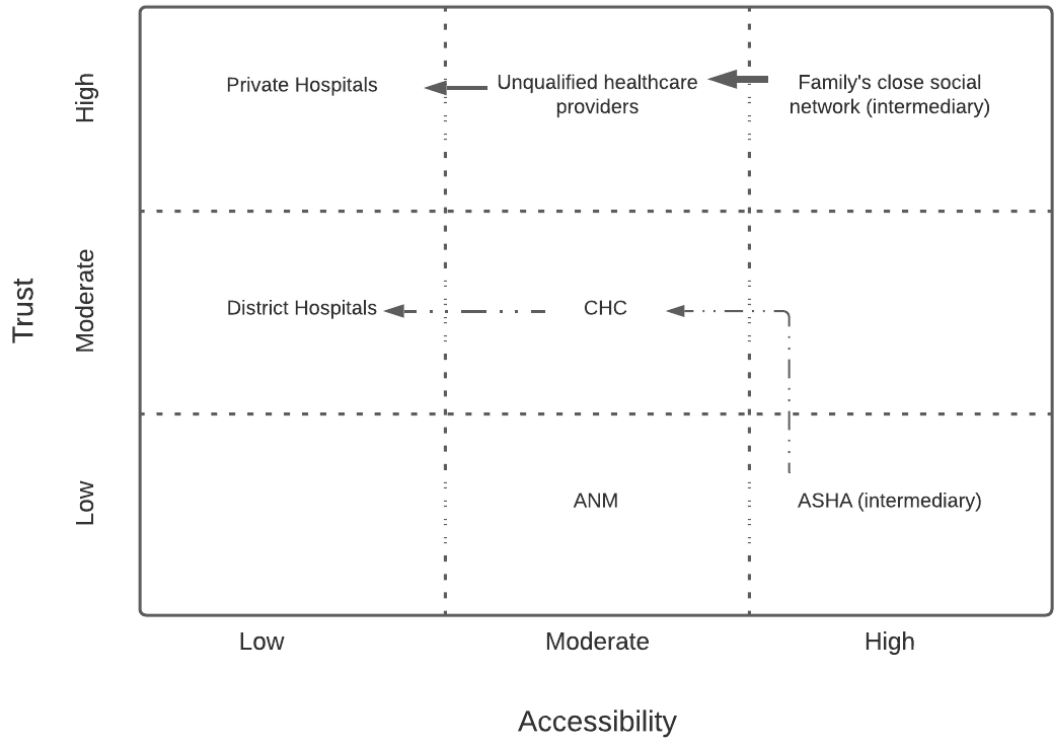

Figure 9. Typical pre-pandemic placement of care providers for young infant illnesses along the Accessibility x Trust matrix. Actual placement may vary for each individual family and provider combination. Care-seeking pathways move from higher to lower accessibility & along higher trust

7. **A system is needed to handhold mothers and families throughout the end-to-end process of seeking care, receiving care within facilities, post-discharge adherence at home and follow-up until recovery**: Families face several daunting difficulties along the care-seeking pathway – deciding on an appropriate care provider; arranging for transport; running around an unfamiliar city to look for available beds for their young infants; navigating unfamiliar facilities for care, laboratory tests and medications; arranging for food and accommodation for accompanying family members including the mother, etc.

   As part of the pilot study and trial, we have set up a system with a call-centre in the backend and a facilitation team stationed at study hospitals in the frontend to support families. This system is currently registering all births from 22 birthing facilities (i.e. about one-fifth of all births in Kanpur Nagar district). The system receives notification of any illness or health complaint for 35% of all births registered within the first 60 days of age. There are two ways that this can happen: either (a) mothers call in themselves and notify the problem, and (b) the call-centre team makes 4 person-to-person calls in the first 2 weeks and one automated dialler call per week subsequently for the next 6 weeks to check with the mother regarding the health of her baby. During the person-to-person calls made by the call-centre team in the first two weeks, they also reinforce the method of assessing babies with mothers and ask them to check for each danger sign, step-by-step.

   These complaints are immediately reviewed by a physician in-charge, to either recommend care-seeking at an appropriate facility (about 66% of all cases reported) or home care for simple complaints. Of all the families recommended care-seeking, about 60% actually reach the recommended facility and are received immediately by a study team member to facilitate physician consultation within 10 minutes of arrival at the facility. Recommended facilities include Hallet hospital (GSVM Medical College), Dufferin

District Women's Hospital, Shyam Children's Charitable Hospital (private charitable facility), and some non-PSBI and minor cases are also referred to a community health centre. This system is working well, and needs to be developed into a full-fledged scalable solution. Transportation support to families for follow-up visits to treating facilities needs to also be considered to cover the care-seeking pathway end-to-end – this can be done through improved coordination with the JSSK system. At present, there is no call-centre for young infant illnesses, but there are several successful examples of call-centre based solutions that have been previously rolled out by the government, and therefore the system developed through this study is easily scalable going forward.

8. **In order to pandemic-proof PSBI care and for long-term sustainability, a wider network of stakeholders needs to be engaged**: Care providers and facilities had very little control over care protocols and decisions during the lockdown and peak of the pandemic, as Covid-19 related protocols that were set by higher authorities at the district, state and national level overrode all existing protocols. Engagement, sensitisation and brainstorming on these study findings with key stakeholders involved in pandemic-related decision-making would be needed in order to come up with strategies to mitigate pandemic-related disruptions to PSBI care.

The proposed implementation research will build on these lessons and those from prior PSBI implementation research studies in India to design scalable solutions for PSBI prevention, identification and management.

Objectives

Research Objectives

The primary research objectives of the study are:

1. To develop a scalable mother-infant centric model to improve the identification of PSBI and coverage of recommended treatment in young infants with PSBI. We aim to develop an integrated model that overcomes the challenges identified in previous PSBI studies and builds on the insights gained through the PSBI trial and formative research in Kanpur Nagar district.
2. To compare the PSBI identification rate achieved through the model against an expected PSBI incidence rate of 10% of all young infants (based on a pooled PSBI incidence of 9.5% in South Asia found by the Aetiology of Neonatal Infection in South Asia – ANISA study, and the assumption that incidence of PSBI in UP would be higher than the pooled PSBI incidence.)[41]. The model will aim to achieve at least 80% coverage of PSBI identification based on an expected incidence rate of 10%. In other words, at least 8% of all young infants should be identified with PSBI through the model.

Secondary research objectives include:

1. To conduct a cascade analysis using the 'health service coverage cascade' approach to measure effective coverage of PSBI management and identify barriers and bottlenecks at each step of the cascade[42]
2. To assess process outcomes captured during the course of model refinement (see Table 4, column 2)
3. To document the evolution of the model and strategies over time

Methods

Study Design

This study is designed as a mixed methods implementation research that will involve human-centred design techniques to co-design the PSBI implementation model as an integrated set of scalable components with relevant stakeholders, followed by implementation, concurrent evaluation and data-driven refinement over 12 months in one rural block (population approx. 150,000; annual livebirth cohort approx. 3000) of Kanpur Nagar district.

Population

The Shivrajpur block of Kanpur Nagar district has been chosen for this study, which has a population of approx. 146,000 without about 29,000 households. Shivrajpur has one CHC, which is located approximately in the centre of the block, at a distance of approx. 32km from its nearest referral centre, Hallet hospital in Kanpur city. The CHC is visited by a paediatrician thrice a week, and is designated as a newborn stabilization unit (NBSU), which is not currently functional. Shivrajpur has 4 primary health centres, 140 ASHA workers, 7 ASHA Supervisors (Sangini), and 27 ANMs. All live births of usually resident mothers in this block (notified through sentinel surveillance and key informant networks) will be enrolled and followed up until age 60 days.

Implementation Science Frameworks

We will utilize the Design-Outcome Cascade Framework developed by CEL, which is useful for designing a cascading set of interventions focused on health impact (see Figure 9). The framework consists of multiple levels. Starting from the bottom-most, these are: (a) beneficiary or user level, where we aim to have the intended health impact – these users may be expected to adopt and adhere to certain behaviours that will contribute to the intended impact; (b) provider/ service level, which are the various intermediaries or services through which interventions will be provided to the ultimate users/ beneficiaries in order to achieve the intended impact; (c) program level, which will involve a set of interconnected components that will need to be integrated and harmonized such that intermediaries are able to achieve the desired performance outcomes needed to translate into outcomes lower down in the cascade; and (d) systems level, which involves higher level elements such as policies, organizational design, resources, infrastructure, manpower, supplies, etc. The outcome cascade flows from top to bottom, and outputs of higher-level elements flow as inputs to the lower-level elements.

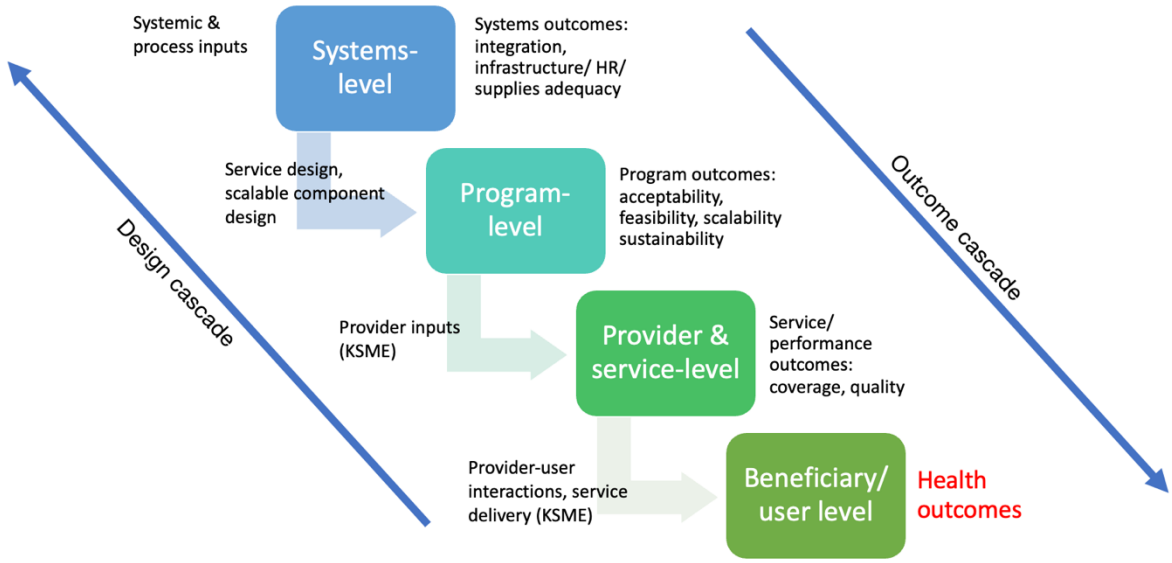

Figure 10. Design-Outcome Cascade

However, in order to design for precision and impact, an optimal strategy is to design from the bottom-up, i.e., from the actors and factors most proximal to the intended health outcome, and then moving up at every level to design the elements that are need to influence outcomes at the next lower level.

We will utilize the Knowledge-Skills-Motivation-Enabling Environment (KSME) framework[40] that explores barriers and enablers along these four domains to understand the needs of users/ providers and design model elements and interactions for successful behaviour change.[43]

The Design-Outcome Cascade is also helpful in building a robust theory of change and in applying diagnostics to identify gaps and challenges. The theory of change will inform model requirements, which will form the basis for model development.

Model design

Needs assessment of mothers

As per the Design-Outcome Cascade framework, we will design from the bottom-up, and therefore first map the needs of mothers (and family members) in order to identify danger signs and illnesses in their young infants and to be able to access appropriate care and adhere to treatment for young infants identified with PSBI.

From a mother-infant centric perspective, we have identified the following pathway for timely and appropriate care of sick infants (see Figure 11). The pathway caters to any reported illness, and not just PSBI, as from a mother/ family perspective any problem, complaint or illness needs to be managed, and the entity that is able to address a wide range of problems faced will also enjoy greater trust, making it a preferred care provider.

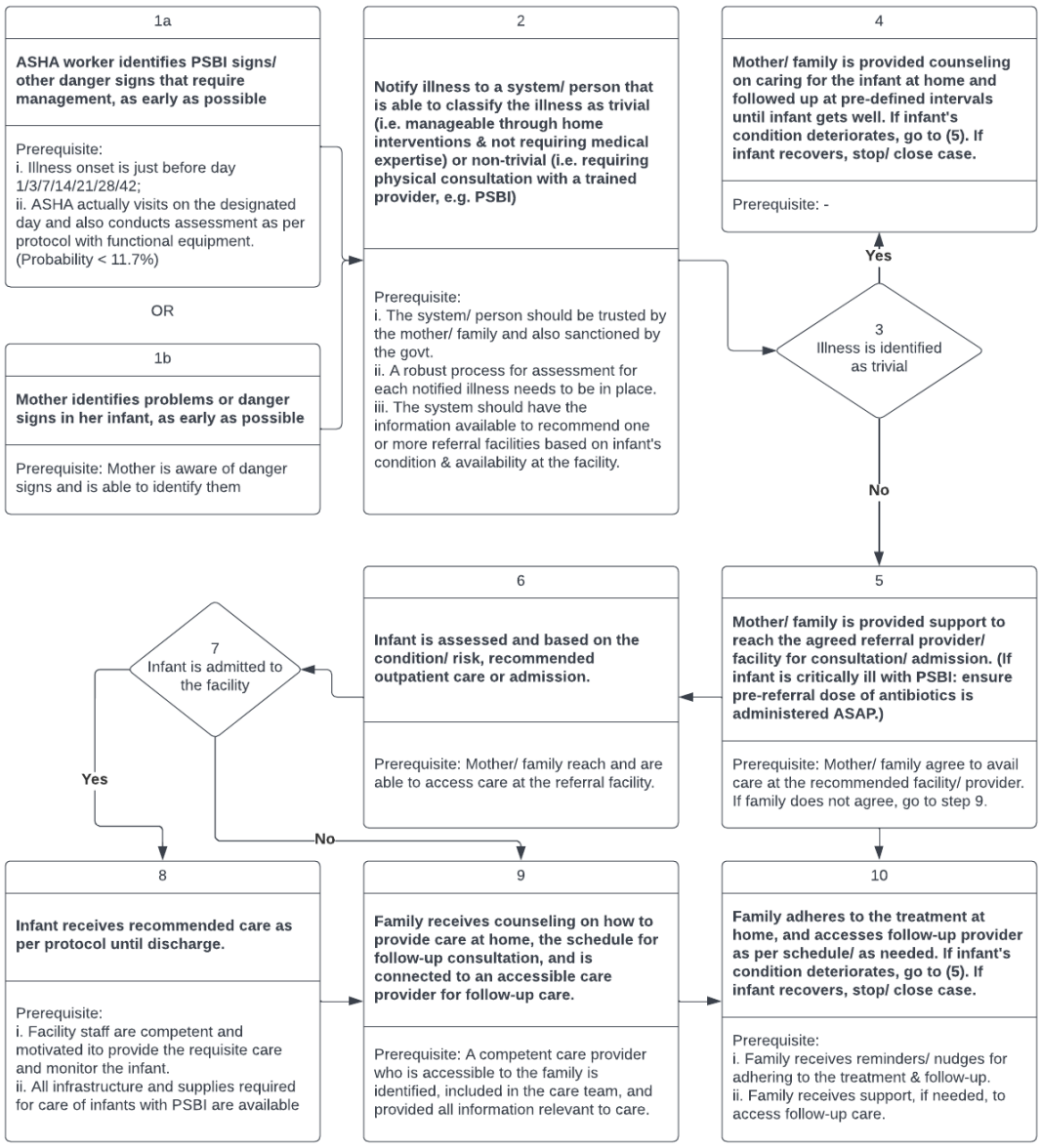

Figure 11. Generic pathway for illness identification and management

Step 1a/b involves illness identification by either the health worker or the mother. There are only 7 predefined visits by ASHA workers, and for them to identify the illness earlier, the onset of illness should have happened prior to the visit such that the signs are visible during the visit, a probability of 7/60 = 11.7%. Further, as ASHA workers typically make less than half of those visits[7] and may not be able to conduct the assessment as per protocol, the actual probability of ASHA workers identifying the illness episode first (prior to the mother), is less than 11.7%. The mother has a higher likelihood of identifying that something is wrong with her infant *earlier*, provided she is generally aware of key danger signs. As noted earlier, mothers are more likely to identify and report general morbidities like cold, vomiting, diarrhoea, etc. It is also possible that some of these are also precursors to more serious illness in the future, and therefore early assessment, management and follow-up of these illnesses may reduce the incidence of PSBI overall.

Step 2 involves notifying this illness to a person (for e.g. mothers may notify ASHA workers) or system (for e.g., the call-centre based system that we will be designing) that is able to conduct an assessment and identify whether it is a non-trivial problem and requires care-seeking (e.g. PSBI), or is trivial and can be managed at home with appropriate counselling and simple remedies (e.g. erythema neonatorum). An important pre-requisite for this is that mothers/ families are able to trust this system, such that it becomes the first port of call for any problem

or illness that is observed by the family. Further, this system needs the sanction of the health system, such that ASHA workers also report to the same system. A unified reporting system will also be extremely helpful from a policy/ program perspective, in understanding the pattern of illnesses in infants, and improving preventive and curative measures to address them.

Step 3 is a decision borne out of the assessment in Step 2 on whether the illness requires physical consultation from a trained medical officer/ paramedic or potential admission to a health facility. If the illness can be managed at home (Step 4), then the family needs to be provided appropriate counselling or even support with medication if needed. Further, the family can be followed up to ensure that the infant's condition is progressively improving, else the family needs to be redirected for a physical consultation, as appropriate. If the family is in need of physical consultation (Step 5), they need to be provided appropriate options for care-seeking, along with distance & timings, expected cost of treatment, previous client feedback, etc. to help them in choosing a suitable care provider. They need to be provided referral support and facilitation, which will include arranging for transport, alerting the provider/ facility about the patient, checking regarding availability of beds and booking it, etc., and forwarding the necessary details to the referral facility.

Once a sick infant reaches a facility (Step 6), it will be assessed there and advised outpatient care or admission. If the infant requires admission to the facility (Step 8), he/she will need to be provided recommended care and monitoring as per protocol until discharge. An important pre-requisite for this is that the referral facility has all the required competent and motivated manpower, infrastructure, supplies to be able to provide the requisite level of care. At the time of discharge, Step 9 will be followed.

If the patient can be treated with outpatient management (Step 9), the family needs appropriate counselling on how to care for the infant at home, including instructions for administration of medication. They may also need follow-up care, which may include administration of injectable medications, assessment and treatment calibration, etc., for which they need to be made aware of the schedule and connected to a follow-up care provider who will be included in the care team for the baby and will receive the necessary information to be able to provide appropriate care. An important pre-requisite for this is that an accessible follow-up provider needs to be identified who is competent in providing the necessary care to the infant.

Finally, for outpatient/ post-discharge care (Step 10), the family needs to adhere to the treatment at home as per the counselling/ prescription, and also seek follow-up care as per schedule. This might require reminders/ nudges, and even support in accessing follow-up care. The infant's condition also needs to be monitored, and if it deteriorates, Step 5 onwards can be followed.

*How the pathway can serve as a template to **integrate** existing services*

It is important to note that the necessary raw elements for the entire pathway are already available. In terms of manpower, there are community health workers (ASHA) for every 1000 population, an auxiliary nurse midwife (ANM) and a community health officer at outreach Health & Wellness Centres, a medical officer and sometimes a paediatrician and staff nurses at community health centres (some community health centres also have newborn stabilization units with additional nurses), paediatricians and neonatologists along with a team of nurses and paramedics at district hospitals and medical colleges with level 2/3 neonatal intensive care units. Further, there are also a number of private paramedics, doctors and nurses and private facilities with neonatal intensive care units, some of which may be more accessible/ preferred by families. There are services such as the JSSK for transport of sick infants and e-Sanjeevani app for teleconsultation. Further, there is also an ongoing rollout of an app for ASHA workers to register and follow-up every pregnant mother and infant.

The main challenge is that these services are not integrated and optimized around the mother-infant to provide the best possible care, which is what we aim to achieve during the course of this implementation research.

Re-cap of the care coordination system set up for the PSBI trial:

The call-centre backbone that we have already established for the purpose of the PSBI trial provides the necessary framework for care integration and coordination, and direct accessibility by mothers/families. The process begins at birth, wherein each birth is registered and the mother/ family is provided with counselling on recognizing danger signs, along with a card with a 24x7 helpline number to call in case of any illness. Currently, all births in 22 facilities in Kanpur district are being registered @ about 2,000 births per month. Given that the call centre receives an illness notification for about 35% of all registered infants, it has already been established as a trusted service for mothers/families to seek help with illnesses in the infants. Often, the call centre also receives calls for notifying and seeking help for postpartum problems in mothers as well. Clearly, the helpline serves an important unaddressed need among families.

Further, a physician on call is tele-consulted for each notified illness and if needed, a referral facilitation system is activated for families identified as needing physical consultation or admission. This includes alerting the referral facilities and ensuring that every family is received at the referral facility by a designated worker who ensures that they are attended to by a treating physician/ nurse within 10 minutes of their arrival at the facility.

The system has already been identified as an important innovation within Kanpur district, and we have already received requests by the Chief Medical Officer and district administration system to extend this service to the entire district, also as a centralized information source to guide district health officials.

Model design requirements:

The goal of this IR is to design a system to achieve the ideal pathway in Figure 11 for every sick infant, especially focusing on those with PSBI.

The current call centre backend can easily be improved, extended and integrated with existing services to serve as a central care coordination system for achieving the ideal pathway for illnesses in young infant in the following ways:

1. Building an integrated case management solution around the call centre: This will include detailed information on all registered health workers/ providers/ facilities including public and private in and around the entire catchment area; integrating information for the entire pathway including all interactions with health workers, care providers and services availed including case notes, prescriptions, etc., for each case; nudges and reminders for care teams & families, and feedback from families on the quality of care provided.
2. Co-developing, implementing and refining solutions with concerned stakeholders to meet the pre-requisites for each step of the pathway. For example, for step 2, what would be the best process to assess each reported case based on the principles of task shifting and efficiency and fidelity at scale. This could be a combination of teleconsultation and physical assessment to maximise efficiency. We would also need to identify who is best positioned to conduct the physical assessment, if needed, ideally at home, to classify illness as trivial or needing physical consultation – is it ASHA workers/ ASHA supervisors/ CHOs, etc. For step 5, we need to understand what are the essential requirements of families in terms of information, counselling and support to agree to avail recommended care. These and other design questions are listed in the following section.
3. Designing a roadmap to integrate existing health system services with the call-centre solution: The call-centre solution will need to integrate with various existing programs and services to optimize care and efficiency, for e.g., (a) ASHA worker app for following up every mother and newborn, (b) JSSK for ambulance services, (c) e-Sanjeevani app

for OPD consultations with physicians, etc. During the course of this IR, it will not be possible to achieve complete integration with all the available services. The integration gaps will be identified and a roadmap to achieve integration will need to be laid out.

Design Questions for IR innovations

As noted above, there are multiple aspects of a scalable solution to achieve high coverage of the ideal pathway for all sick young infants with high quality and fidelity of services that need to be co-developed with concerned stakeholders. These are presented in Table 4. IR outcome refers to key steps/ prerequisites that need to be met in order to achieve the ideal pathway, user-level design questions are framed to consider the needs of mothers/ families, and provider-level design questions are framed to consider the needs of intermediaries/ providers in the design of the model. Note: This is not an exhaustive list. There could also be other IR questions that could emerge during the course of this study, and some may be deemed redundant if other solutions have already been identified previously. Further, the values of process indicators mentioned in column 2 of Table 4 are aspirational and are intended to guide the process of design, refinement and optimization of the model over time. In reality, the model may not be able to achieve these aspirational outcomes, but they will help to steer the direction for improving the model and also help in identifying bottlenecks and challenges that need further resolution.

Table 4. Design questions for IR: Target indicator values are aspirational and intended to guide the design, refinement and optimization of the model over time

SNo.	IR Outcome (with process indicators)	User level: Mother-infant centric IR design questions	Provider level: Provider-centric IR design questions
1	All mothers are made aware of the 24x7 helpline number and associated services. (Target indicator, REACH: 80% of all mothers from low SES should be aware of the helpline number.)	a. What channels need to be activated to ensure that all mothers and families are aware of the helpline number, e.g., mass media, ASHA workers, public and private health facilities, etc.?	a. What are the barriers to this strategy?
2	Step 1b: Mothers are aware of danger signs and are able to identify them early. (Target indicator, Mothers' Knowledge: >70% mothers are able to recall all danger signs of PSBI during the evaluation survey at age 30 days)	a. Potential strategies and barriers for coaching mothers to recognize illness early in their young infant and notify it immediately to the system? (For early reporting, we want this identification to be more sensitive than specific – i.e., we don't mind mothers reporting trivial problems or illnesses, as long as serious illnesses are not missed.) For e.g., we could improve counselling prior to discharge from facilities, or have a simple app to	a. What mediums are best positioned to deliver this in a scalable and effective manner (e.g. prior to discharge by staff nurses, at home by ASHA workers)? b. What interventions (e.g. training, job aids, accountability, etc.) are needed to ensure that this cadre delivers the interaction with high fidelity at scale?

		connect with mothers and families	
3	Step 2 Prerequisite i: The system/ person should be trusted by the mother/ family and also sanctioned by the govt. (Target indicator, Mothers' ADOPTION: >75% of all illnesses reported by mothers in the evaluation survey are notified a priori to the system.)	a. What will it take mothers/ families to trust the system? b. What factors are involved in establishing and degrading trust? c. What are the unmet needs of mothers/ families that the system still does not address by the end of the study?	
4	Step 2 Prerequisite ii: A robust process exists for assessment when an illness is notified to the system. (Target indicator, System FIDELITY: >80% of complaints classified as trivial are actually trivial; >90% of infants who have PSBI are classified as non-trivial by the system)	a. Protocolize the helpline system. b. What would be the criteria used to classify an illness as trivial (can be managed at home without physical consultation with a competent provider, for e.g., erythema neonatorum) or non-trivial (requires physical consultation, e.g., PSBI)? Accordingly, how should the call centre record the complete history of the infant? Potential strategies could be a combination of tele-assessment by a paediatrician/ trained provider and physical assessment by a community-based health worker.	a. Task-shifting: Identify which provider would be the most suitable for doing the physical assessment at home within 2 hours of notification? (e.g, ASHA, Sangini, CHO, private untrained medical practitioners) b. How should these providers be certified for assessment? What measures need to be put in place to ensure accountability? c. Can this process be integrated with e-Sanjeevani service? What are the interface gaps that need to be addressed?
5	Step 2 Prerequisite iii: The system should have the information available to recommend one or more referral facilities based on infant's condition & availability at the facility. (Target indicator, System Optimization: >60% infants with	a. What should be the criteria for recommending a set of facilities to a family? b. What information needs to be provided to families so that they can choose the option that best suits their care-seeking preferences?	a. How can a database of all facilities/ providers offering various levels of care in each district be populated in the most scalable manner? b. How can newborn stabilization units in districts be activated to ensure complete care for infants with low or moderate mortality risk signs of PSBI?

	PSBI should be able to receive their entire care at the chosen facility without further up-referral)		
6	Step 4: Optimal home care for trivial illnesses. (Target indicator, Home care effectiveness: >70% of families do not need to seek care from any other source for trivial illnesses)	a. Identify possible trivial illnesses/ problems and develop a home care protocol and tele-follow-up schedule for each of them that can be advised to families through teleconsultation. This could potentially also be potentially integrated into the app for mothers/ families	a. How can we best use task-shifting for teleconsultation?
7	Step 5: Mother/ family agree to avail care at the recommended facility/ provider. (Target indicators, ACCEPTABILITY: i. >90% families of critically ill infants with PSBI agree; ii. Care-seeking proportion in girl infants with non-trivial illnesses is at least 90% that of boy infants with non-trivial illnesses.)	a. What needs/ fears of mothers/ families need to be factored into negotiating care-seeking with them? b. How can we ensure that >90% of infants critically ill with PSBI are administered antibiotics within 2 hours of being assessed? c. There is a huge disparity between care-seeking for boys and girls. In the PSBI trial, the ratio of boys to girls is 65:35. This level of gender difference is unacceptable, and we need to proactively work out how we can improve care-seeking for girls.	a. How should the system be designed to maximize care-seeking acceptance? (e.g. escalation matrix for tele-callers, etc.) b. Which local care providers (public/ private) can be engaged in administering pre-referral dose of antibiotics? c. How can we enlist sufficient providers such that each baby has access to a provider within 1 hour distance?
8	Step 6: Mother/ family reach and are able to access care at the referral facility. (Target indicator, FEASIBILITY – Facility care: >70% infants with PSBI receive care at the referral facility within 3 hours of referral negotiation)	a. What proportion of cases are able to avail transport through the JSSK scheme in a timely manner? b. How can the gap between demand and supply of referral transport be met?	a. What measures need to be taken such that: (i) transport is available within 1 hour of successful referral negotiation, (ii) families do not face any problems with respect to admission or accessing care immediately upon arrival at the referral facility, (iii) admission is secured and infant details are already transmitted to the referral facility prior to arrival?

9	Step 8: Prerequisite i: Facility staff are competent and motivated to provide the requisite care and monitor the infant. (Target indicator, QUALITY: >80% infants with PSBI receive rational and appropriate care at the referral facility.)		a. What are the continuing medical education needs of staff nurses and paediatricians in terms of knowledge and skills for newborn illnesses, esp. PSBI? b. What are the motivation and enabling environment needs of staff nurses and paediatricians to ensure high quality care to all sick infants? c. How should the care received by infants be transparently assessed/ audited in order to maintain quality, and identify staff in need of re-skilling?
10	Step 8: Prerequisite ii: All infrastructure and supplies required for care are available. (Target indicator, SYSTEM READINESS: All facilities recommended for PSBI-related referral have availability of infrastructure and supplies based on the level of care.)		a. What processes are in place/ need to be put in place to ensure that supply matches demand?
11	Step 9: A competent care provider who is accessible to the family is identified, included in the care team, and provided all information relevant to care. (Target indicator, FEASIBILITY – home care: >70% of all infants with PSBI that are discharged/ assigned to outpatient care are able to access follow-up care within 10km distance.)		a. Which local providers are most suitable (optimize accessibility with need for training and handholding support) for providing follow-up care for PSBI including administration of prescribed antibiotics & assessment of treatment success? (e.g. CHC doctors, private providers, CHOs, etc.) b. How can these providers be certified and held accountable?
12	Step 10: Prerequisite i. Family receives reminders/ nudges for	a. How can we design the delivery of nudges/ reminders to maximize	

	adhering to the treatment & follow-up. (Target indicator, EFFECTIVE COVERAGE: >80% infants identified with PSBI complete their prescribed treatment.)	adherence to treatment. (incl. frequency, content, etc.) We could explore various channels for this, including physical (e.g., nudges by ASHA) and electronic-guided (e.g. app and/or call centre)	
13	Step 10: Prerequisite ii. Family receives support, if needed, to access follow-up care (Target indicator, EFFECTIVE COVERAGE: >80% infants identified with PSBI complete their prescribed treatment.)	a. What are the support needs of families to access follow-up care from the recommended providers? We can also explore the possibility of teleconsultation combined with physical assessment by a community health worker.	
14	Overall functioning of the system.		a. What metrics should be tracked by the system and shared at various levels to monitor and improve the quality of care and respectful care over time?

Throughout this IR, we will follow the process of **human-centred design** to (a) understand the design needs of families and care providers using fly-on-the-wall observations, in-depth interviews (IDIs), focus group discussions (FGDs), (b) develop prototype solutions based on consultations and co-design sessions with families, care providers and other health system and community stakeholders, and (c) implement and test these solutions with the help of data collected programmatically (e.g. call centre data) as well as data collected through the formal evaluation process described later and (d) identify areas of refinement by repeating this process.

The data collection activities for the human-centred design process are tabulated below:

Aim	**Participants**	**Data Collectors**	**Methods**	**Number, Frequency**
1. Map and understand the identification, care-seeking and treatment journey of young infants	Mothers and other family members of infants who have reported any illness in the first 60 days of life (to the helpline/ ASHAs/identified during	Qualitative researchers will obtain consent from the family at their home prior to the interview and proceed with the interview if	In-depth interviews conducted physically at home. Purposive sampling to cover participant types across various SES categories, maternal education and severity of disease.	With 30 participants at the beginning of the study, and subsequently @ 5-10

	quantitative data collection).	consent is granted.	The researchers will ask detailed questions on birth and early care, recognition, home-based initial care if any, care-seeking from external providers, referrals, etc., adherence, until final outcome to map the entire journey of the young infant, including who were involved, what was done, where, when and how, and rationale if any.	participants per month.
2. Understanding the acceptance of model strategies and utilization of key services among caregivers, and suggestions/ feedback on model/ service improvement	Mothers and other family members of young infants, both sick and healthy	Qualitative researchers will obtain prior consent from the family on the telephone to schedule the date, time and place of the FGD and conduct the FGDs at the designated location after administration of the consent. There will also be an additional observer/note-taker.	Focus Group Discussions with 8-10 participants in the community will be held at a place of convenience. Purposive sampling will be done to cover participant types across various SES categories, maternal education and severity of disease. The various themes covered will include various services that participants are able to recall, personal narratives, and their feedback on the services that have been utilized, as well as ways to improve coverage, scope and quality of services.	Separate FGDs with families of healthy and sick young infants, every 2-3 months.
3. Documenting how sick young infants are cared for at home to understand various care practices, caregiver	Non-participant observation of young infants with PSBI being cared for at home/ post discharge	Qualitative researchers will obtain consent at the home of the participant and conduct the non-participant observation if	Non-participant observation at home. Purposive sampling will be done to cover participant types across various SES categories, maternal education and severity of disease.	10 observations of 10-12 hours for each infant at the beginning of the study.

involvement, use of medication, challenges, etc.		consent is given.	All activities involving the infant will be documented, including what was done, by whom, when, how, etc.	
4. Understanding the care of sick young infants in hospitals, including processes of outpatient consultation, emergency care, admission, discharge, treatment, record-keeping, supplies, etc.; common challenges faced by care teams, etc.	Non-participant observation of the paediatric ward and hospital services involving young infants with PSBI admitted to hospitals	Qualitative researchers will obtain consent from the facility head and head of paediatrics department at the beginning of the study/ inclusion of the facility into the research. The non-participant observations will be scheduled with facility in-charge of consenting facilities each time.	Non-participant observation of hospital processes for caring for sick young infants. All consenting facilities will be included. The various wards of the facility where young infants receive care – outpatient, emergency, inpatient, patient registration, etc. will be observed to document patient interactions, assessment, care provided, record-keeping, supply chain, etc.	24 hours of observation for all consenting facilities once in 3 months.
5. Understanding the existing role, and existing knowledge, skills, motivation and enabling environment for community health workers who may potentially play a role in PSBI identification, care-seeking and follow-up and assessing their suitability for the same.	ASHA workers, supervisors (called Sanginis)	Qualitative researchers will obtain consent from the health workers at their home/ facility prior to the data collection activity.	1. Field observations: Community health workers will be shadowed by a qualitative researcher to observe activities conducted in a typical work day, engagement with families, practices, challenges encountered, etc. 2. In-depth interviews will be conducted with the same participants to discuss field observations and explore their beliefs, knowledge, attitude, practices, etc. 3. Focus Group Discussions will be conducted with a different set of	1. Observations: 4-5 ASHA workers and 2 Sanginis consisting of high and low performers (as identified by their supervisor) at the beginning of the study. 2. Same as 1. 3. Separate FGD with 6-8 ASHA workers from the study block and 6-8 Sanginis from multiple blocks in the study district 1-2 times

			workers to triangulate the information and understand their perspectives on their potential role in PSBI identification, care-seeking and follow-up	during the first 2 quarters of the study.
6. Understanding the existing role, and existing knowledge, skills, motivation and enabling environment for existing service providers (incl. govt. and private) who may potentially play a role in community-based PSBI management and assessing their suitability for the same.	Staff nurses, ANM, community health officer (CHO), pharmacists, trained and unqualified medical practitioners who reside/ practice in the community	Qualitative researchers will obtain consent from the health service providers at their home/ place of work prior to the data collection activity. For government providers, a representative set of both high and low performing providers will be selected based on inputs from their supervisors. For private providers, those who already play some role in PSBI management will be selected.	1. Field observations: Health service providers will be shadowed by a qualitative researcher to observe activities conducted in a typical work day, engagement with families, practices, challenges encountered, etc. 2. In-depth interviews will be conducted with the same participants to discuss field observations and explore their beliefs, knowledge, attitude, practices, etc. 3. Focus Group Discussions will be conducted with a different set of providers to triangulate the information and understand their perspectives on their potential role in PSBI identification, care-seeking and follow-up	1. Observations: 1-2 per provider type at the beginning of the study. 2. IDIs: same as above. 3. 6-8 providers from various blocks of the study districts.
7. Understanding the policy and implementation climate, implementation, information and management needs and challenges of health system,	Program Managers, Facility-In-Charges, and other program implementers at block, district and state levels; Political representatives at village, block	Qualitative researchers will obtain consent from the health service providers at their home/ place of work prior to the data collection activity. We will	1. In-depth interviews: 1-2 in-depth interviews from each management/ leadership position will be conducted on various themes related to intersection of PSBI management with their scope of	1. IDI – beginning of the study. 2. Co-design sessions: at least once every quarter.

political and administrative leaders for improving PSBI management	and higher levels; Leaders of professional medical and nursing associations.	aim to engage leaders at the district level, and those from various blocks of the district to ensure maximum representation.	work and accountability. 2. Brainstorming/ co-design workshops: These will be conducted with sets of 4-6 managers/ leaders from time-to-time to share study findings and get feedback and suggestions.	

A system designed around the helpline as a backbone, with the above considerations, can serve an all-round purpose of facilitating care, integrating various services and programs for mother-infant centric delivery, and providing the necessary metrics to improve care quality over time and refine the system itself. A centralized notification system and subsequent facilitation of care-seeking and care also confers significant resilience to future pandemic scenarios, as the system would have the data to learn and adapt facilitation mechanisms as per emerging needs and challenges.

Implementation Plan

An initial version of the core of the model, i.e. the helpline, with some integrations, is already in place as part of the PSBI trial. Since the helpline is the core of our intervention strategy for PSBI management, we will continue to operate it by the CEL team in order to refine processes through the course of the study. The assumption is that a helpline-based model by itself is inherently scalable, and has demonstrated prior success within the health system in UP, for example emergency transport, COVID-19 management, etc. How we integrate all other programmatic components, including service delivery by public and private providers into this helpline-based model for achieving high scalability, acceptability, adoption, fidelity and effective coverage is at the heart of this IR. This will be done through iterative cycles of implementation, evaluation and refinement of strategies.

Preparatory work

The preparatory phase (prior to initiation) will involve the following activities conducted under the aegis of the PSBI trial:

- Identification of a pilot area consisting of 2 ASHA supervisors (called Sanginis) and approx. 30-40 ASHA workers
- Stakeholder identification, engagement and informal consultations in the entire study area
- Recruitment, training and deployment of the study team
- Finalization of protocols and study instruments and securing IRB approvals
- Establishing the data management system
- Mapping and profiling of all health facilities and providers in the study area
- Establishing existing rate of PSBI identification by the health system through ASHA workers by examining submitted records of home based newborn care visits
- As part of the pilot phase, we will refine the existing helpline-based model by addressing the user-level design questions and some provider-level design questions outlined in Table 4 within the small pilot area of the study using a human-centred design approach
- The overall implementation of the study and initial goals for each quarterly cycle will be planned with key stakeholders.

Model implementation, evaluation and refinement

The generic pathway for illness identification and management (see Figure 11) and the corresponding design questions at the user and provider-level to optimize the process outcomes outlined in Table 4 will form the basis of model design, implementation and refinement. During the pilot phase (preparatory work), some of these design questions and corresponding strategies will be explored to finalize a basic implementation model that can be rolled out across the study area during the first quarter.

Table 4 with its aspirational targets of process outcomes in column 1 will steer the entire IR towards an optimized model. Throughout the IR, we will apply **human-centred design** to (a) understand the design needs of families and care providers using fly-on-the-wall observations, in-depth interviews, focus group discussions, (b) develop prototype solutions/ improvements based on consultations and co-design sessions with families, care providers and other health system and community stakeholders, and (c) implement and test these solutions/ improvements with the help of data collected programmatically (e.g. call centre data) as well as data collected through the formal evaluation process described later and (d) identify areas of improvement by repeating this process.

The initial focus would be on optimizing the design of the solution to fulfil user-level design requirements as per the Design-Outcome Cascade framework. Initially, any gaps in the system identified on an ongoing basis during care facilitation by the helpline will be supplemented by the study team, including health workers and providers. The gaps in service delivery thus identified will be recorded, and fed into the refinement of the model to optimize the provider-level design and leverage and strengthen existing health services and infrastructure – including public and private and wean dependencies on the study team over quarters 2, 3 and 4.

The quantitative evaluation of the model will be done concurrently, as described in the subsequent section. Evaluation data will be shared with health system stakeholders on a monthly basis to feed into ongoing quality improvement. Physical assessment of health facilities using structured surveys, along with unstructured/ semi-structured in-depth interviews, fly-in-the-wall observations, consultations and discussions with health workers/ potential providers/ health facilities, will be undertaken to optimize the design of provider-level model components.

Model refinement will involve collaborative goal-setting, strategy review and action through quarterly **plan-do-study-act cycles** with co-investigators and key block and district-level health system and community stakeholders. The optimization goals (for the primary and process outcomes in Table 4) for each quarter will be decided in the beginning of the quarter with these stakeholders, and progress towards attainment of these optimization goals will be tracked on a monthly basis. Key decisions and actions taken during the course of optimization and refinement of the model will be documented along with evidence and rationale. This will serve as a reference for future adaptions of the model at larger scale.

Policy alignment

To our knowledge, the WHO guidelines for PSBI are in the process of being included in the latest version of the national guidelines in India. However, this document is not currently available to the general public. Any policy recommendations emerging out of this IR will be shared with key decision-makers at the state and national levels.

Outcomes

Primary Outcome

The first primary outcome of this study is the model itself. The other primary outcome of this study relates to the performance of the model, measured by the coverage of PSBI identification achieved by the model. This has been chosen since identification of PSBI is fundamental to subsequent management. We will assume that the actual incidence of PSBI is 10% of all young

infants – this is based on data from a previous study in South Asia and the fact that UP would in general have poor indicators when compared to other states in India, or even Bangladesh.[41] Therefore to aim at a PSBI identification coverage of 80%, the model should correctly identify PSBI in 8% of all young infants. **PSBI identification will be based on confirmation of PSBI by a trained provider.**

Secondary outcomes

Secondary outcomes of the study include:

A. Effective coverage of PSBI estimated through cascade analysis, and analysis of barriers and bottlenecks at each step of the effective coverage cascade. We have mapped the effective coverage cascade for PSBI as follows:[42]
    a. Target population (population in need): all live births in the study area
    b. Service contact coverage (contacts health service):
        i. proportion of infants who receive at least one ASHA visit or call through the helpline
        ii. proportion of infants who received home-based screening (telephonically or physically) for PSBI at least once (infants assessed by ASHA workers will be considered screened-in but not confirmed cases of PSBI)
        iii. proportion of infants who were screened-in for PSBI and recommended consultation by a trained provider
    c. Input-adjusted coverage (contacts health service that is ready, i.e. referral success, PSBI assessment and confirmation):
        i. proportion of infants who were assessed by a trained provider
        ii. proportion of infants who were assessed by a trained provider and confirmed as PSBI
    d. Intervention coverage (receives health service): Proportion of infants who were initiated treatment as per existing guidelines
    e. Quality-adjusted coverage (receives health service according to standards):
        i. Proportion of infants who were initiated treatment within 24 hours of notification to the system (by mother or ASHA worker)
        ii. Proportion of infants who receive complete treatment dose by health providers (as per existing guidelines for hospital and/or community-based care depending on place of treatment)
    f. User adherence-adjusted coverage (user adheres to treatment): proportion of infants who completed follow-up as recommended and completed the treatment dose at home (as per existing guidelines)
    g. Outcome-adjusted coverage (positive health outcome achieved): proportion of infants who were clinically well 8 days after treatment initiation (if discharged prior to treatment completion/ cared at home) OR successfully discharged after recovery from hospital (as applicable)
B. Process outcomes, as outlined in Table 4, column 2.
C. Process of model development & refinement, i.e. the evolution of the model over time.

Sample size

The primary outcome of interest is the PSBI identification coverage. In order to evaluate if the model is able to identify PSBI in at least 80% of the expected number of infants with PSBI (based on an assumed incidence of 10%), we will require the following sample size:

$$N = \frac{Z^2 P(1-P)}{d^2}$$

where

Z = Z-score for desired level of statistical significance

P = expected coverage in the population

d = desired level of precision

80% of young infants with PSBI = 80% of 10% of all young infants in the population = 8% of all young infants in the population. Thus, P = 0.08. A precision of 1% will allow us to estimate P at 8±1%, and therefore PSBI identification coverage of 80±10%.

Thus, for a desired confidence level of 95%, precision of 1%, we get N = $(1.96/0.01)^2$ * (0.08)*(0.92) = 2,828 young infants in the population. In order to conclude with 95% confidence that the PSBI identification coverage attained through the model is 80% or more of the assumed PSBI incidence rate with a precision of 10%, we will need to enrol at least 2,828 young infants. Thus, one block with a population of approx. 150,000 and approx. 3,300 births per annum is sufficient to provide this sample size over a 10 to 12-month follow-up period.

Evaluation

Evaluation will be conducted through a system of concurrent evaluation, that would involve notification and registration of all live births in the study population and follow-up at days 15, 30, 45 and 60 for PSBI incidence related outcomes. Infants identified with PSBI will be further followed up upon notification, treatment initiation and 8 days after initiation of treatment. Verbal autopsy will be conducted for all deaths among enrolled young infants.

The methods for the concurrent evaluation are as follows:

- A system will be set-up to identify all livebirths based on inputs from key delivery facilities (institutional deliveries), ASHA workers and other community informants. Data collectors will visit the facility/ home where the newborn and mother are located as soon as possible after the birth has been reported in order to administer consent for enrolling the babies into the study and conducting follow-up visitations. Newborns of consenting mothers will be enrolled and a birth registration form with basic details of the delivery and birth will be administered.
- All infants will be followed up by field surveyors at age 15 days (delivery details, newborn care practices, morbidities, ASHA visitations), 30 days (newborn care practices, morbidities, ASHA visitations, mother's knowledge and skills in assessing danger signs), 45 days (infant care practices, morbidities, ASHA visitations) and 60 days (socio-economic status, infant care practices, morbidities, ASHA visitations). If any morbidity is reported at each of these visits, then a detailed questionnaire will also be administered to capture details related to signs & symptoms and care-seeking.
- Any registered young infant identified with PSBI through the health system/ helpline or confirmed by any other competent provider outside of the system will be further followed up upon treatment initiation (referral, treatment, delays), and 8 days post treatment initiation (treatment outcome, adherence, service satisfaction, etc.).

- Verbal autopsy will be conducted for all deaths among enrolled young infants using the latest WHO verbal autopsy instrument.

Data collectors with a minimum of 15 years education and the ability to understand aspects of research ethics and engagement with families, use tablet devices, understand and correctly record information will be recruited for the evaluation. Verbal autopsies will be conducted by the supervisor who will have superior rapport-building and community engagement skills with at least 5 years of experience in data collection, including previous experience with sensitive data such as verbal autopsies.

Data management, governance & confidentiality

Qualitative research data will include audio recordings of IDIs and FGDs; their transcriptions and any other profile or background information captured of the participants; and photo/ video documentation of the observations (where consent is granted) along with detailed notes of observed activities and other background information on the family. Audio recordings of IDIs and FGDs will be assigned a unique case identifier and backed up on a secure and password protected database accessible only to authorized research team members for transcription and erased from the recording device. The digital recording of interviews, focus group discussions, etc. will be transcribed verbatim in the language of data collection. All transcripts will be anonymized to ensure privacy and confidentiality of participants. The audio recordings will be subsequently verified by a senior researcher to finalize the analytical datasets, and will be completely destroyed at the end of the study. Photo/ videography of observation sessions will be assigned unique case IDs, tagged based on activities, and preserved in a secure and password protected database accessible only to select members of the research team for future analysis and/ or publication as per the consent granted by the participant. Detailed observation notes will be assigned a unique case id, anonymized and stored in a secure and password protected database for further analysis by authorized research team members.

Data for the concurrent evaluation will be collected on Android-based tablet devices. The data tablet devices will be secured through a device management software which allows for remote management through a central system. The device management system protects the data on the tablet devices and does not allow unauthorized apps to be installed on the device any other application to be installed or delete the data on it. A data monitoring module will have features such as to produce data outputs for regular data quality check, generation of the visit schedules and data completeness checks. The study forms will have built-in checks for missing values, inconsistencies and skip logic. The collected data will be synchronized in real-time (or upon availability of network) to the cloud server. Data will also be backed-up on a daily basis on an in-house encrypted MySQL database, as well as an encrypted MySQL database on a cloud server located in India. Once the data is downloaded, the system will run basic and aggregate checks for data quality. Any discrepancy found will be daily emailed/communicated to the respective data collectors and their team leaders by the system for necessary rectification. An overdue forms report will also be generated and sent to ensure timeliness of data collection. Discrepancies flagged to concerned team leads and discussed in routine review meetings for feedback and quality improvement.

The entire data management system will be GCP compliant and will protect participant data in every aspect of data management from data collection to data analysis. Protecting the confidentiality of the data will be a high priority. The following safety measures will be employed to ensure data protection and safe handling. At the time of registration of birth, each young infant will be given a unique identification number. Data will be linked to participant identification numbers, and the table linking the identifier to identifying information will be stored in a separate encrypted database which will only be accessible to the data management steward during the course of the study. The consent form, and any other physical forms linking participant personal information to the study ID code number will be kept in securely locked filing cabinets. Proper documentation and storage of the metadata and any files or protocols relevant to data

management will be handled with utmost care. Regular backups of the existing data will be done in appropriate intervals. All computers being used in the study will be password protected and will have restricted access to specific study staff to protect confidentiality. None of the participants' names or identifiers will be used in any publications or discussions regarding the study. Data will be accessible only to authorized research team members.

The analytical datasets will be created from the de-identified raw data by merging various tables, as required, into a flat database.The raw data and consent forms will be stored for 7 years and subsequently destroyed. The table linking the participant identifiers with the identifying information will be maintained indefinitely by the data management steward under direct supervision by the principal investigator, to allow for future follow-up studies, if needed.

The call-centre solution will store the programmatic data of beneficiaries as well as providers, tracking each case of reported illness with facilitation of care until recovery. It will have a robust, secure and encrypted database backend to ensure confidentiality. All analysis will be performed on de-identified data.

COVID-19 related measures

The study will be conducted during the ongoing pandemic of COVID-19. We will adopt the following measures to ensure that we have safeguarded our team as well as participants:

- Obtain required clearance from relevant authorities if movement restrictions in place
- Make everyone in the team (team leaders, enumerators, drivers, logisticians etc.) aware of the most recent information from the WHO, government of India and UP, and adhere to their guidelines
- Make everyone in the team aware of referral mechanisms for suspected COVID-19 cases to share with respondents if asked
- Make sure that the relevant IEC materials on COVID-19 (factsheets, brochures, etc.) are available and shared with all staff
- Develop and train staff on appropriate reporting and communication channels to ensure safety and early response (if needed). We will have a notification system to ensure that all COVID-19 cases in the study team are notified within the organization as well as to health authorities, as per government guidelines.
- Inform everyone involved in data collection of the following protocol and clarify that this applies both during and outside of data collection activities:
    - Check temperature every morning. In case of a high temperature (above 37.5 Celsius), or any other mild symptoms such as tiredness, dry cough (common symptoms), shortness of breath, aches and pains, sore throat, or runny nose (other symptoms), inform the team leader. Any person with these symptoms should not engage in data collection and self-quarantine for 14 days. Inform your team leader immediately if feeling unwell with any other symptoms, and follow his/ her guidance.
    - Team leader to ask if enumerators have been in contact with any confirmed or suspected case of COVID-19. If yes, the person should not be participating in the activity and self-quarantine for a minimum of 14 days.
    - Wash hands thoroughly and regularly (ideally every 1 to 2 hours and definitely in between each interview conducted) with soap and water or alcohol-based hand rub.
    - Follow the recommended cough etiquette at all times.
    - Do not touch your (or anyone else's) face – particularly eyes, nose and mouth.

- Keep at least 1 metre distance from other people at all times. Close-up contact should be limited to less than 15 minutes. Keep distance also in cars, i.e. use enough cars so you are maximum 3 people per car. If not enough cars, see if you can use fewer enumerators and extend data collection time.
- Sanitize all data collection items prior to each interview (pens, phone, tablets, notebooks, ID cards, etc.)
- Don't spit in public

- Additionally, for team leaders:
  - Ensure you know the protocol to follow and referral mechanisms to use to inform the right people about any observations of symptoms or sickness among field staff during data collection
  - Procure relevant supplies for staff screening and sanitation (for individuals as well as of common and personal objects): Thermometers, Hand hygiene items (hand sanitisers and soaps, ideally liquid soap instead of soap blocks)
  - Each staff travelling to the field should have their own hand sanitiser with them
  - Enough soap should be available at all times in the office and for all staff
  - Soap should also be brought along with the data collection teams, together with water, so that team members can wash their hands properly once field activities are done for the day
  - Hand-disinfectant rub for enumerators and others involved in data collection (e.g. drivers) and other cleaning material to sanitize common spaces including office, cars, and data collection equipment

Oversight

Oversight for the study will be provided by the WHO, Geneva. The study progress and data will also be shared on a regular basis with the district administration and state health system leadership as part of program review and corresponding action, as needed.

Ethical & regulatory considerations

All research data will be collected after administration of due consent, kept confidential and analysed after de-identification. The study will be reviewed by the Ethics Review Committee at the WHO, Geneva and the Institutional Ethics Committee of the Community Empowerment Lab. Although not a clinical trial and therefore, not a requirement, the study will also be registered in the ISRCTN registry.

Timelines

The study will be conducted over a period of 17 months. The preparatory phase will be conducted over a period of 3 months under the aegis of the existing PSBI trial. Subsequently, the implementation, concurrent evaluation and refinement will be done over a period of 12 months. Final data analysis and report writing will be done over 2 months.

Limitations, Risks & Mitigation

This study aims to co-develop a model to significantly improve the coverage of PSBI identification and management in a rural setting in northern India, based on lessons and insights gained through previous work, and has multiple limitations. It does not address primary prevention of PSBI through appropriate counselling/ coaching of mothers/ family members,

which is an important need identified by the study team, but not feasible within the budget and timelines for this study. The study therefore mainly focuses on developing a scalable model to improve identification and management of PSBI, and in the process, accommodates the need to cover other illnesses perceived as important/ needing attention by the family. Further, given the limited timeframe and budget, the study does not promise to eliminate all barriers with respect to identification and management of PSBI, but instead aims to optimize the model to achieve certain process targets, gain a better understanding of the needs of mothers and families, and document gaps in service delivery that are identified during the course of implementation that were both addressed and unable to be addressed during the course of the study. Unaddressed gaps can subsequently be taken up as a subject of future implementation research.

Pandemic related disruptions are the main risks to the study, but also present an opportunity to make the model robust to these disruptions. This risk will be mitigated by ensuring engagement of key district and state level government stakeholders throughout the period of the study.

Study team & partnerships

The study will be led by investigators at the Community Empowerment Lab (CEL) that have a proven track record of high-quality implementation research and scale-up through the government health system. The study will be conducted in collaboration with investigators at the GSVM Medical College and Shyam Children's Charitable Hospital in Kanpur Nagar, and the district administration and health system leadership that are already involved in the ongoing PSBI trial. The implementation research will be conducted in close partnership with the UP National Health Mission and the Technical Support Unit for Reproductive, Maternal, Newborn and Child Health and Nutrition to the Government of Uttar Pradesh that closely supports the health system across 75 districts of the state. Other institutional partnerships will also be sought, as needed.

Aarti Kumar is a public health researcher & bioinformatician who currently leads all major research initiatives at CEL as its CEO. She has led several large community-based epidemiological studies, cluster randomized controlled trials and implementation research as Co-PI, and has published in The Lancet, PLOS Medicine and other international peer-reviewed journals. **Dr. Vishwajeet Kumar** is a physician, public health scientist and co-founder of CEL who has laid the foundations of community-entrenched public health research in Uttar Pradesh. Dr. Kumar has previously served as faculty at Johns Hopkins University and has led several seminal research studies on newborn and maternal survival in Uttar Pradesh that have informed global and national policy, and has published in NEJM, The Lancet, and PLOS Medicine, among other peer-reviewed medical journals. The evidence-based model for scaling up Kangaroo Mother Care developed by the CEL team as part of a WHO-coordinated implementation research led by Dr. Vishwajeet and Aarti Kumar, is currently being scaled across UP, making it the leading state in the country for KMC scale-up. **Dr. Rashmi Kumar** is a senior technical advisor at CEL, and recently superannuated as Head of Department of Paediatrics from King George's Medical University, Lucknow. Dr. Kumar is a paediatrician-scientist with a focus on paediatric neurology, and has done seminal work in the field of paediatric infectious diseases, particularly, tuberculosis and Japanese encephalitis. Including vaccine efficacy trials. She has published widely, including The Lancet and NEJM. **Dr. Jai Vir Singh** is a senior technical advisor at CEL, and has previously served as Head of Department of Community Medicine at King George's Medical University, Lucknow, and recently retired as principal of a reputed private medical college. Dr. Singh has led several community-based studies and surveys, and has worked with a broad spectrum of stakeholders on the implementation of various public health programs in Uttar Pradesh.

Dr. Yashwant Kumar Rao is the Head of Department of Paediatrics at GSVM Medical College, Kanpur Nagar. He established the 34-bedded SNCU-NICU unit at the college, which is one of the best performing units in UP and serves as a center for clinical care, research, education and

training. He is also the co-PI of the WHO coordinated multi-country trial on PSBI evaluating inpatient vs outpatient care. **Dr. KK Dokania** is a highly regarded paediatrician based in Kanpur Nagar, who has established a sustainable model of care to provide low-cost maternity and paediatric clinical services to disadvantaged communities, and is also a co-PI of the WHO coordinated multi-country trial on PSBI. **Dr. Vasanthkumar Namasivayam**, IAS is a member of the Indian Administrative Services and Executive Director of the UP-TSU, which is providing technical support to the Govt. of UP for reproductive, maternal, newborn & child health & nutrition activities across 75 districts. He provides strategic guidance to the GOUP to implement evidence-based policies, scale successful innovative models and health system strengthening including human resources.

Besides the above team of investigators, a consultative committee consisting of the General Manager, Child Health, National Health Mission, Govt. of Uttar Pradesh, The District Magistrate, Chief Development Officer and Chief Medical Officer of Kanpur Nagar will be involved in decision-making roles for action on PSBI management within the Kanpur Nagar district and at the state level in Uttar Pradesh. Besides these government officials in key administrative positions, health system functionaries at the community (frontline ASHA workers, ASHA supervisors called Sanginis), block (medical officers in-charge of community health centres, Block community process managers, etc.), district (chief medical superintendents of the district hospitals, district program manager, etc.) and division (divisional program manager, etc.) levels in Kanpur Nagar district will participate regularly in co-design workshops to discuss findings from the study and co-develop appropriate strategies. Further, community representatives, including political representatives at the village, block, assembly and parliamentary constituency levels, self-help groups, medical and health provider associations, other non-governmental and community-based organizations, and representative groups of mothers, family members, traditional health workers, etc. will also be part of co-design workshops to come together and develop solutions that integrate 360° perspectives.

The roles and responsibilities of the study investigators are as follows:

Investigator Name	**Institution**	**Role**	**Key areas of responsibility**
Aarti Kumar	Community Empowerment Lab	PI	Overall responsibility for the study, including finalization of the study protocol, instruments, review, audits, ethical and regulatory compliances.
Dr. Vishwajeet Kumar	Community Empowerment Lab	Co-PI	Key inputs on study design, evaluation, strategy review, and overall guidance to the study team.
Dr. Rashmi Kumar	Community Empowerment Lab	Co-PI	Clinical guidance and inputs into study design and strategy, study instruments and evaluation, etc.
Dr. Jai Vir Singh	Community Empowerment Lab	Co-PI	Public health guidance and inputs into study design and strategy, engagement with key stakeholders, policy feedback, etc.
Dr. Yashwant Kumar Rao	GSVM Medical College, Kanpur Nagar	Co-PI	Local leadership for the study in Kanpur Nagar district, clinical guidance and facility management of sick children, and inputs into other aspects of study design, strategy and evaluation.

Dr. KK Dokania	Shyam Children's Charitable Hospital, Kanpur Nagar	Co-PI	Clinical guidance, strategy for inclusion and engagement of private providers to expand the net for ethical, appropriate and affordable PSBI treatment, and inputs into other aspects of study design, strategy and evaluation.
Dr. Vasanthakumar N.	Uttar Pradesh Technical Support Unit	Co-PI	Strategic inputs for health system interventions, state-level policy and programming, scale-up, and inputs into other aspects of study design, strategy and evaluation.

Dissemination of results

Data from the study will be shared with key stakeholders on an ongoing basis. Final results from the study will be published in international peer-reviewed journals, through formal presentations at appropriate forums with experts and policy-makers at a state, national and global level, and also through other news media for the wider public.

References

1. Perin, J. *et al.* Global, regional, and national causes of under-5 mortality in 2000–19: an updated systematic analysis with implications for the Sustainable Development Goals. *The Lancet Child & Adolescent Health* (2021) doi:10.1016/S2352-4642(21)00311-4.
2. United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). *Levels & Trends in Child Mortality: Report 2020, Estimates developed by the United Nations Inter-agency Group for Child Mortality Estimation*. (2020).
3. Alliance for Maternal and Newborn Health Improvement (AMANHI) mortality study group. Population-based rates, timing, and causes of maternal deaths, stillbirths, and neonatal deaths in south Asia and sub-Saharan Africa: a multi-country prospective cohort study. *Lancet Glob Health* **6**, e1297–e1308 (2018).
4. World Health Organization. *Guideline: Managing possible serious bacterial infection in young infants when referral is not feasible*. (2015).
5. Seale, A. C. *et al.* Estimates of possible severe bacterial infection in neonates in sub-Saharan Africa, south Asia, and Latin America for 2012: a systematic review and meta-analysis. *Lancet Infect. Dis.* **14**, 731–741 (2014).

6. Hibberd, P. L. *et al.* Trends in the incidence of possible severe bacterial infection and case fatality rates in rural communities in Sub-Saharan Africa, South Asia and Latin America, 2010-2013: a multicenter prospective cohort study. *Reprod. Health* **13**, 65 (2016).
7. Mukhopadhyay, R. *et al.* Lessons from implementation research on community management of Possible Serious Bacterial Infection (PSBI) in young infants (0-59 days), when the referral is not feasible in Palwal district of Haryana, India. *PLoS One* **16**, e0252700 (2021).
8. Goyal, N. *et al.* Management of possible serious bacterial infection in young infants closer to home when referral is not feasible: Lessons from implementation research in Himachal Pradesh, India. *PLoS One* **15**, e0243724 (2020).
9. Awasthi, S. *et al.* Identification and management of young infants with possible serious bacterial infection where referral was not feasible in rural Lucknow district of Uttar Pradesh, India: An implementation research. *PLoS One* **15**, e0234212 (2020).
10. Roy, S. *et al.* Feasibility of implementation of simplified management of young infants with possible serious bacterial infection when referral is not feasible in tribal areas of Pune district, Maharashtra, India. *PLoS One* **15**, e0236355 (2020).
11. Bang, A. T. *et al.* Simple clinical criteria to identify sepsis or pneumonia in neonates in the community needing treatment or referral. *Pediatr. Infect. Dis. J.* **24**, 335–341 (2005).
12. THE WHO YOUNG INFANTS STUDY GROUP. Clinical prediction of serious bacterial infections in young infants in developing countries. *Pediatr. Infect. Dis. J.* **18**, S23 (1999).
13. Young Infants Clinical Signs Study Group. Clinical signs that predict severe illness in children under age 2 months: a multicentre study. *Lancet* **371**, 135–142 (2008).
14. Lokangaka, A. *et al.* Simplified antibiotic regimens for treating neonates and young infants with severe infections in the Democratic Republic of Congo: a comparative efficacy trial. *Matern Health Neonatol Perinatol* **4**, 8 (2018).
15. Tshefu, A. *et al.* Oral amoxicillin compared with injectable procaine benzylpenicillin plus gentamicin for treatment of neonates and young infants with fast breathing when referral is not possible: a randomised, open-label, equivalence trial. *Lancet* **385**, 1758–1766 (2015).

16. Mir, F. *et al.* Simplified antibiotic regimens for treatment of clinical severe infection in the outpatient setting when referral is not possible for young infants in Pakistan (Simplified Antibiotic Therapy Trial [SATT]): a randomised, open-label, equivalence trial. *The Lancet Global Health* **5**, e177–e185 (2017).
17. Baqui, A. H. *et al.* Safety and efficacy of alternative antibiotic regimens compared with 7 day injectable procaine benzylpenicillin and gentamicin for outpatient treatment of neonates and young infants with clinical signs of severe infection when referral is not possible: a randomised, open-label, equivalence trial. *Lancet Glob Health* **3**, e279-87 (2015).
18. Darmstadt, G. L. *et al.* Validation of community health workers' assessment of neonatal illness in rural Bangladesh. *Bull. World Health Organ.* **87**, 12–19 (2009).
19. Tripathi, A., Kabra, S. K., Sachdev, H. P. S. & Lodha, R. Home visits by community health workers to improve identification of serious illness and care seeking in newborns and young infants from low- and middle-income countries. *J. Perinatol.* **36**, S74–S82 (2016).
20. Ahmed, S. *et al.* Implementation research to support Bangladesh Ministry of Health and Family Welfare to implement its national guidelines for management of infections in young infants in two rural districts. *J. Health Popul. Nutr.* **38**, 41 (2019).
21. Berhane, M. *et al.* Implementation research on management of sick young infants with possible serious bacterial infection when referral is not possible in Jimma Zone, Ethiopia: Challenges and solutions. *PLoS One* **16**, e0255210 (2021).
22. Ayede, A. I. *et al.* Management of possible serious bacterial infection in young infants where referral is not possible in the context of existing health system structure in Ibadan, South-west Nigeria. *PLoS One* **16**, e0248720 (2021).
23. Leul, A. *et al.* Innovative approach for potential scale-up to jump-start simplified management of sick young infants with possible serious bacterial infection when a referral is not feasible: Findings from implementation research. *PLoS One* **16**, e0244192 (2021).
24. Bhura, M. *et al.* Evaluating implementation of "management of Possible Serious Bacterial Infection (PSBI) when referral is not feasible" in primary health care facilities in Sindh province, Pakistan. *PLoS One* **15**, e0240688 (2020).

25. Wammanda, R. D. *et al.* Implementation of the WHO guideline on treatment of young infants with signs of possible serious bacterial infection when hospital referral is not feasible in rural Zaria, Nigeria: Challenges and solutions. *PLoS One* **15**, e0228718 (2020).
26. Guenther, T. *et al.* Feasibility of implementing the World Health Organization case management guideline for possible serious bacterial infection among young infants in Ntcheu district, Malawi. *PLoS One* **15**, e0229248 (2020).
27. Rahman, A. E. *et al.* Managing possible serious bacterial infection of young infants where referral is not possible: Lessons from the early implementation experience in Kushtia District learning laboratory, Bangladesh. *PLoS One* **15**, e0232675 (2020).
28. Ministry of Health & Family Welfare, Government of India. *Home Based Newborn Care: Operational Guidelines*. https://www.healthynewbornnetwork.org/hnn-content/uploads/Revised_Home_Based_New_Born_Care_Operational_Guidelines_2014.pdf (2014).
29. Mohan, P. *et al.* Assessment of implementation of integrated management of neonatal and childhood illness in India. *J. Health Popul. Nutr.* **29**, 629–638 (2011).
30. Maheshwari, A., Kumar, P. & Dutta, A. K. Facility based IMNCI. *Indian J. Pediatr.* **79**, 75–84 (2012).
31. Neogi, S. B. *et al.* Inpatient care of small and sick newborns in healthcare facilities. *J. Perinatol.* **36**, S18–S23 (2016).
32. Ministry of Health & Family Welfare, Government of India. *Guidelines for Janani-Shishu Suraksha Karyakram*. http://nhm.gov.in/images/pdf/programmes/jssk/guidelines/guidelines_for_jssk.pdf (2011).
33. Ministry of Health and Family Welfare, Government of India. *Use of Gentamicin by ANMs for management of sepsis in young infants under specific situations: Operational Guidelines*. https://www.healthynewbornnetwork.org/hnn-content/uploads/Operational-Guidelines_India.pdf (2014).
34. Ministry of Health & Family Welfare, Government of India. Addendum to Operational Guidelines on Use of Gentamicin by ANMs for Management of Sepsis in Young Infants

under Specific Situations. *Addendum* https://nhm.gov.in/New_Updates_2018/Om_and_orders/rmncha/child_health/Addendum.pdf.

35. Ministry of Health & Family Welfare, Government of India. *Childhood Pneumonia Management Guidelines*. https://nhm.gov.in/index1.php?lang=1&level=4&sublinkid=1336&lid=716 (2019).
36. About Pradhan Mantri Jan Arogya Yojana (PM-JAY). *About Pradhan Mantri Jan Arogya Yojana (PM-JAY)* https://pmjay.gov.in/about/pmjay.
37. Zaidi, A. K. M. *et al.* Scientific rationale for study design of community-based simplified antibiotic therapy trials in newborns and young infants with clinically diagnosed severe infections or fast breathing in South Asia and sub-Saharan Africa. *Pediatr. Infect. Dis. J.* **32 Suppl 1**, S7-11 (2013).
38. Tshefu, A. *et al.* Simplified antibiotic regimens compared with injectable procaine benzylpenicillin plus gentamicin for treatment of neonates and young infants with clinical signs of possible serious bacterial infection when referral is not possible: a randomised, open-label, equivalence trial. *Lancet* **385**, 1767–1776 (2015).
39. Puri, D. *et al.* Prevalence of clinical signs of possible serious bacterial infection and mortality associated with them from population-based surveillance of young infants from birth to 2 months of age. *PLoS One* **16**, e0247457 (2021).
40. Kumar, V., Kumar, A. & Darmstadt, G. L. Behavior change for newborn survival in resource-poor community settings: bridging the gap between evidence and impact. *Semin. Perinatol.* **34**, 446–461 (2010).
41. Saha, S. K. *et al.* Causes and incidence of community-acquired serious infections among young children in south Asia (ANISA): an observational cohort study. *Lancet* **392**, 145–159 (2018).
42. Marsh, A. D. *et al.* Effective coverage measurement in maternal, newborn, child, and adolescent health and nutrition: progress, future prospects, and implications for quality health systems. *Lancet Glob Health* **8**, e730–e736 (2020).

43. Kumar, V. *et al.* Enculturating science: Community-centric design of behavior change interactions for accelerating health impact. *Semin. Perinatol.* **39**, 393–415 (2015).

44. International Institute for Population Sciences (IIPS) & ICF. *National Family Health Survey (NFHS-5), 2019-21: Uttar Pradesh District-wise factsheets*. http://rchiips.org/nfhs/NFHS-5_FCTS/COMPENDIUM/Uttar_Pradesh.pdf (2021).

APPENDIX I. Review of barriers and enablers identified through PSBI implementation research studies conducted in India

Four implementation research studies were conducted in India to understand the feasibility of operationalizing the WHO guidelines with simplified treatment regimens for PSBI management in young infants where referral is not possible. These studies were conducted in Palwal district of Haryana, Sangrah district of Himachal Pradesh, Pune district of Maharashtra and Lucknow district of UP, and reported a treatment coverage of 70%, 80%, 57% and 53% respectively.[7–10] The studies did not measure actual incidence of PSBI cases, but estimated coverage of identification and treatment based on an assumed incidence of 10% of live births in the first two months of life. This assumption was based on previous research that involved rigorous surveillance for PSBI, such as the AFRINEST study in sub-Saharan African countries which reported a PSBI incidence of 11.7% in the young infant period[38] and the ANISA study in South Asian countries that reported a PSBI incidence of 9.5% in the neonatal period.[41] Crucially, both these studies had a fever cut-off of 38.0°C as per WHO guidelines, while the PSBI implementation research studies in India employed a fever cut-off of as 37.5°C as per IMCI. The 0.5°C difference in fever cut-off is likely to yield a much higher number of cases of PSBI in the Indian studies. Therefore, **the assumed incidence of 10% likely underestimates the actual incidence of PSBI in the population based on the fever cut-off and overestimates the treatment coverage.**

The key challenges identified, strategies adopted, and lessons learnt are summarised below.

Policy

A national policy dialog at the inception of these studies led to a consolidation of PSBI signs from previously 11 to 7 signs as per the WHO guidelines, with the exception that the cut-off for fever was retained as 37.5°C as per IMCI vs. the WHO guideline of 38.0°C, and led to an addendum to the previously released guidelines for community-based case management by ANMs.[33,34] Two other policy decisions reported in these studies include alignment on the dosage of amoxycillin as well as non-requirement of referral and treatment with oral amoxycillin alone for infants aged 7-59 days with fast breathing as the only sign of PSBI.[8,10] However, these seem to not have been formally integrated or possibly reversed, as none of the subsequent guidelines reflect these decisions. **Policy alignment and consensus among major stakeholders is an important priority.**

Identification of illness by mothers

Across studies, mothers had limited ability to recognise danger signs. All studies succeeded in improving danger sign recognition by mothers to various extents through a combination of one or more approaches including mass media, group as well as individual strategies. At an individual level, messages around danger signs were communicated variously at antenatal clinics, during discharge and during HBNC visits, typically with the help of visual aids. None of the studies reported any efforts in improving counselling mothers on promotive-preventive care.

Care-seeking preferences

Other than Himachal Pradesh where there was a dearth of private practitioners, all other sites reported communities' general lack of trust in the health system and preference for private providers including unqualified healthcare providers. Despite significant interventions for health system strengthening by the study teams, 31.4% and 42.0% families in Maharashtra and Haryana respectively preferred to seek care from private providers as against only 18.6% in the Lucknow, UP site. Given the local health system context, this likely reflects under-reporting of PSBI cases managed by private providers in UP, rather than a true reduction in care-seeking from private providers. Thus, **private providers present a huge untapped opportunity to improve coverage of PSBI treatment.**

Home visits by ASHA workers

There were several challenges with HBNC home visits of ASHA workers. While ASHA workers had received prior training on HBNC through typical cascade-based training approaches, their ability to recognise danger signs was found to be poor. All studies put focused efforts in retraining ASHAs to build their skills in newborn assessment and classification of danger signs. There were also issues with equipment issued to them being non-functional and needing replacement.

During formative research across all studies, mothers reported a much lower frequency of HBNC visits than the HBNC guideline. However, coverage of ASHA home visitations during the study was measured based on self-reported data by ASHAs, which showed significant improvements across all sites. Importantly, the Haryana site compared the self-reported coverage of ASHA home visits with maternal reports and found a drastic difference. ASHAs reported a coverage of between 80% to 96% for the 6 visits starting from day 3, whereas mothers reported a coverage of 39-54%, with 17% families not receiving a single visit. The Haryana site did not find improvements in actual frequency of visits, record-keeping by ASHAs and supervision of ASHA workers despite intensive efforts including 12 training and re-orientation sessions. Thus, **it is critical to introduce effective measures to ensure accountability of ASHA workers.**

The proportion of PSBI cases reported by ASHA workers in Haryana, Himachal Pradesh, Maharashtra and UP was 11.4%, 28.0%, 35.4% and 81.3% respectively. The unexpectedly high proportion of PSBI cases reported by ASHA in UP likely reflects a high incidence of PSBI cases that went undetected. All other sites found that the majority of PSBI cases were reported by mothers. Thus, **scalable solutions for PSBI identification cannot just rely on ASHA workers and need to keep the mother in the centre.**

PSBI care by community-based providers

All sites reported challenges with utilizing ANMs as the primary provider of PSBI case management in the community. Challenges reported included many ANM sub-centres being non-functional, ANMs not being aware of their role in PSBI case management, and hesitancy of ANMs in handling sick babies as their role primarily involves immunisations, preventive care and conducting non-complicated deliveries. The Haryana, Himachal Pradesh and Maharashtra sites could not successfully overcome these challenges and had to involve medical officers and ayurvedic medical officers in PHCs and CHCs in community-based case management. Even these medical officers were reluctant to treat young infants and typically referred them to higher centres prior to the studies. Intensive handholding by study staff and paediatricians over six months was conducted to improve their confidence in managing sick young infants. Widespread non-compliance with treatment documentation by ANMs and medical officers was reported despite intensive efforts. Thus, the **feasibility of utilizing ANMs for community-based case management appears to be low.** Since these studies, health and wellness centres co-located with ANM sub-centres have been established in many parts of UP where resident trained nurses called Community Health Officers (CHO) have been deployed – feasibility of their role in PSBI case management should be explored. The long periods of intensive handholding required even for medical officers implies that the typical programmatic approach of 2-7 days long cascade-based training and refresher trainings may not be adequate for ensuring PSBI management in non-critically ill young infants in lower-level facilities. **Scalable solutions are needed to provide intensive handholding support to medical officers and staff nurses for PSBI management in lower-level facilities.**

Referral

Lack of referral facilitation to district level facilities was reported as another major problem across the sites that largely remained unresolved. **The problem of blind referral**, i.e., referring patients for care to higher level facilities without adequate documentation, counselling and without confirming with the referral facilities regarding availability of beds and services **is extremely common and needs effective solutions**. Availability of referral transportation was

not a problem in other sites except for Himachal Pradesh, where the hilly terrain poses unique challenges. PSBI treatment in higher district and sub-district level facilities was not a focus of these studies but has its own challenges that will need to be addressed in the proposed research.

Systems

Common systemic issues related to infrastructure and supplies included dysfunctional equipment at various levels right down to ASHA workers, and shortage of the key PSBI medications including inj. gentamicin, inj. ampicillin and oral/ dispersible amoxycillin. Some of these issues remained unresolved during the studies, probably since their resolution required engagement of other stakeholders and departments within the health system at the state, rather than district level, which was beyond the mandate of these studies. **Scalable solutions for equipment and supplies-related problems may include automation of resource planning and inventory systems.**

APPENDIX II. Findings from initial formative research on impact of the COVID-19 pandemic on PSBI

Table 5. Key touchpoints for PSBI prevention, identification and management - Pre-Covid-19 and pandemic scenario

Key touchpoints	**Pre-Covid-19 Scenario**	**Pandemic scenario**
Delivery & postnatal care within facilities	An opportunity missed: In Kanpur Nagar, 86.6% of all births are institutional, and 60.3% occur in public facilities, however, only 34.8% mothers reported to have initiated breastfeeding within an hour of birth.[44] While newborns are typically weighed, routine assessment of the newborn is typically not done. Institutional births also present an opportunity for focused counselling and support to mothers on postpartum and newborn care practices – however, it is not the norm in most facilities. Even though there is a government directive to ensure postpartum stay of at least 48 hours, mothers typically leave the facility within hours of birth in lower-level facilities. A key intervention is 'Mother and Child Protection Cards' issued to the mother that contain a host of written information, however, they are not effective unless accompanied with empathetic counselling and support in performing the recommended practices, such as breastfeeding, KMC, handwashing, newborn assessment for danger signs, etc. – which is typically absent.	The pandemic severely disrupted delivery care, especially in public facilities leading to the following changes: • Drop in institutional deliveries: due to the strict lockdown during the initial phase and declaration of areas with a high number of cases as containment zones with restricted movement; further due to designation of some hospitals as Covid-only facilities and temporary closures in non-Covid hospitals for sanitisation upon patients or care providers testing positive. Delivering mothers from containment zones were turned away from non-Covid facilities. • Shift away from public facilities to private ones, particularly unregistered providers that were not under the government scanner: due to strict imposition of RT-PCR testing for Covid-19 prior to delivery and fear of testing in the community. • Reduced stay: Postpartum stay of mothers which was already low, reduced further to less than 24 hours in district hospitals as well. KMC wards that were established for promotive care of <2000g infants in facilities did not have any admissions throughout the pandemic period in 2020 and during the second wave and its aftermath in 2021. • Increased stress amongst health workers & impact on quality of care: Redeployment of maternal & newborn care workforce into Covid care, quarantine rules,

		infections and some deaths among staff and family members substantially increased the workload and stress amongst existing staff and severely impacted quality of care.
Postnatal home-based care	Exposure to high-risk practices: Post discharge from the delivery facility, mothers typically return home with their newborns in less than 24 hours unless hospitalised with complications, and stay in postpartum confinement for 6-12 days. Home care practices are mainly influenced by the newborn's grandmother, other close influencers such as neighbours and relatives who have multiple interactions with the family during this period, and traditional care providers such as the masseuse who have daily interactions with the mother and newborn. This is how traditional care practices are perpetuated, including some like delayed breastfeeding initiation that may be detrimental to the health of the newborn. During this period of postpartum confinement, the mother and newborn are considered 'polluted' due to their exposure to blood and fluids during the birthing process. Clothes worn during this period by the mother are typically discarded, and the newborn is typically kept unclothed but covered until ritual cleansing. Cloths used to over and wipe the newborn could be old rags that potentially may not be washed. Families typically carry such a cloth with them even to lower-level facilities such as the CHC, where birth attendants use it to rub the newborn with mustard oil to remove the vernix, which is believed to cause skin pustules. Mothers are not allowed to bathe for a few days until ritual cleansing, as it is believed that bathing cools the body and interferes with the process of uterine involution. For the same reason, she is also made to drastically reduce her water intake, which may likely impact breastmilk output. Higher educational status of mothers typically improves their adherence to hygienic practices, without impacting other postpartum care practices.	Families consider newborns and young infants extremely vulnerable, and became extra vigilant and cautious during this time. Improvements in handwashing practices were reported, and families took care reduce contact of their young infants with outsiders, especially those who were symptomatic. Newborn care practices such as breastfeeding and KMC were negatively impacted due to the absence of counselling and support of any kind in facilities and at home. Other traditional care practices continued as usual.

Home visits by ASHA workers	Unreliable coverage and quality in rural areas: ASHAs are a cadre with a lot of potential for leverage, as their reach extends to nearly all pregnant women and mothers in rural areas. There are still a few rural pockets that lack an ASHA worker. Kanpur Nagar has ASHAs in rural areas as well as in the city in pockets of urban poor. The coverage of HBNC visits of rural ASHAs was not assessed in this study, but is likely to be similar or worse than that reported in the Haryana PSBI site, where 17% mothers did not receive any visits at all. Further, there is a high likelihood that coverage is inequitable, and the ones missed have a greater baseline vulnerability to PSBI. ASHAs typically asked mothers how their newborn was doing rather than conducting an actual assessment. They were not confident of using their equipment (thermometer, weighing scale, stopwatch, etc.), some of which could be dysfunctional. ASHA's understanding of counselling is a one-way advice in the form of messages, rather than a dialogic interaction and support. ASHAs not a key player in urban areas: Urban ASHAs were appointed in 2016 and have unique challenges. Urban ASHAs in Kanpur were yet to receive HBNC training and kits, and not conduct any postnatal home visits. Their cash incentives, although the same as the rural ASHAs, was perceived to be very low. They were also yet to establish a good rapport with the women that they served, who did not value them as much as they had direct access to private providers and hospitals. There is also greater migration amongst the urban poor, which makes it more difficult for the urban ASHAs to track and follow up pregnant women and infants.	Home visits by ASHA workers were severely impacted: • Reduced coverage: ASHAs were assigned several Covid-specific duties such as screening of immigrants, enforcing quarantine rules, screening, facilitating Covid immunisations, etc., which drastically cut down their availability for maternal and newborn care. Home visits do not have any accountability checks, and ASHAs can just claim their incentives through self-reported visits, which most of them did during this period as well. Further, the performance of Block Community Process Managers, who supervise all ASHAs at the block level, is measured by the quantum of disbursement of incentive money to ASHAs, and not by any quality measures. Managers are therefore incentivized to disburse the home visit incentives to ASHA workers based on their claims without verification. • No actual assessments and poor counselling: There was a national policy of zero-contact visits for ASHAs during the pandemic. Thus, even when ASHA workers did visit homes, they did not enter, and spoke to mothers or family members at a distance from outside to know the status of the infant and mother and convey some messages. Families in turn were wary of contact with the ASHA due to their exposure to suspected Covid cases. An ASHA remarked, "*People were afraid of even touching our shadows.*"
Identification & initial response to illnesses by mothers/ families	Process of sensing rather than 'identification': Mothers' prior understanding of newborn illnesses largely derives from their experience of illnesses in adults and older children. Thus, fever, cold and cough (and associated symptoms of grunting, wheezing, etc.), loose motions are symptoms that they can identify with ease. Other newborn-specific symptoms that they commonly identify are	Increased sensitization to Covid-like signs: Despite reduced counselling on danger signs, mothers were extra vigilant of signs that they typically understood, especially those that were also associated with Covid-

	skin pustules, discharge from the eyes, discharge from the umbilicus, colic, etc. They are also able to observe and sense changes in the behaviour of the newborn from day to day, and therefore can tell based on excessive crying, poor feeding, lethargy, etc. that something is wrong. With regards to other signs of PSBI such as fast breathing and severe chest indrawing, they may be able to identify them as problems only when they become very prominent. Hypothermia and convulsions are the most difficult for them to identify. Care-seeking is typically delayed: The first port of call for the mother upon sensing a problem is her mother-in-law or experienced elder women in the neighbourhood. They resort to widely practiced home remedies for common problems that are considered mild and amenable to home remedies, such as cold, colic, etc. The severity of the problem is assessed based on the duration and frequency of the presenting symptom, increase in its intensity and progression of symptoms with time. Only when they perceive the problem to be of moderate to high severity do they consider seeking care from an external provider. External care-seeking also requires the concurrence of male members of the family on the choice of care provider, arrangement of transport and typically a responsible male person to accompany the mother. This typically leads to delays in care-seeking and treatment, worsening the prognosis of the infant.	19, such as fever, signs of breathing difficulty like grunting, fast breathing, chest indrawing, etc. Prompt care-seeking for Covid-like signs: Mothers were more prompt in seeking external care for Covid-like signs in their infants. However, they avoided formal channels to evade testing, and instead resorted to unregistered, untrained healthcare providers. This reduced delay in the care-seeking due to increased sensitisation is a very encouraging finding and implies that if mothers and family members are sensitised to the risk of PSBI and trained well on danger sign recognition, they are likely to seek care early.
Choice of intermediary/ provider for care-seeking	Mothers'/ family's choice of external provider for care-seeking is mainly dependent on two factors – accessibility and trust. Accessibility is a composite of availability, approachability and affordability. Trust is a composite of perceived responsiveness, expertise and accountability (see Fig. 6). Family's social network of influencers (high accessibility, high trust): Families typically consult their relatives and influencers whom they trust to decide where to seek care for their young infants, and they typically point them to known unqualified	Care-seeking patterns shifted considerably during the pandemic. Amongst rural and urban poor communities, fear of social stigmatisation due to Covid was far greater than the fear of Covid itself. Families were highly secretive about Covid-like signs, and evaded testing by resorting to informal channels and providers in the hope of getting cured without being 'found out' and stigmatised. Care-seeking decisions became complex as families were sometimes compelled to seek care from

	healthcare providers (rural areas) or private nursing homes/ hospitals (urban areas). ASHA (high accessibility, low trust): Rural ASHAs are highly accessible, but they are not seen as credible intermediaries to advise on the treatment or facilitate care-seeking for young infants. Mothers only approach ASHA if they want to seek care at the CHC, where ASHAs enjoy a good rapport. ASHAs are typically bypassed in the chain of care-seeking for young infants. ANM (moderate accessibility, low trust): ANMs are not considered very accessible, as they typically do not reside in the sub-centre/ HWC and neither do they make any home visits. Further, they are not perceived as competent in providing care for young infants. CHC (moderate accessibility, moderate trust): While they are easy to reach from within their catchment area, 24x7 services for care of children are not available, and young infants are typically referred to the district hospital. Trust depends on the reputation of the CHC in its catchment population and varies across CHCs. District hospital (low accessibility, moderate trust): For rural families, district hospitals are perceived as too far and too unapproachable, despite availability of referral transport for some age categories. Disrespectful care is common, and therefore families often do not trust the intent of providers, despite well-equipped SNCUs. ASHAs are not useful as intermediaries as they also face difficulty in navigating care at district hospitals. In the words of a mother, "*If you (ASHA) are not respected here, then what of us?!"* They are considered more accessible by urban mothers, especially those who have delivered there. Hallet hospital, being a teaching hospital, is the final referral facility in Kanpur Nagar. While it is generally well trusted, patients generally only go there as a final port of call due to its low approachability. Unqualified Healthcare Providers (moderate accessibility, high trust): We mapped 421 providers in 3 blocks of Kanpur Nagar district, which means that the ratio of these providers is about	providers that they did not fully trust but were highly accessible during this time. • Even greater reliance on close contacts instead of ASHA workers as intermediaries: Accessibility of ASHA workers to mothers and infants decreased due to Covid duties. Families did not view ASHAs as useful intermediaries for seeking care for their infants even prior to the pandemic, and we found that their preference shifted further towards close contacts, especially for Covid-like signs. • Even further shift away from public hospitals to private ones for seeking care: Overall, the pandemic diminished both the accessibility of and trust in public health facilities due to shifts in protocols such as requirement of Covid-19 testing prior to consultation/ admission, and deterioration in the quality of care. This drove a fear of seeking care from public facilities, and families preferred seeking care from unregistered and untrained healthcare professionals who did not adhere to these testing and triage protocols. Only severely ill young infants turned up at public health facilities. A nurse from an urban PHC remarked: "*Earlier fever was the most common problem for which people sought care from us. Now no one has fever.*" • Reduced affordability of medical care: The cost of care overall substantially increased across providers, and affordability reduced further due to the impact of the pandemic and lockdowns on livelihoods. • 'Legitimisation' of unqualified healthcare providers as primary care providers for rural and urban poor communities: Despite a very high prevalence of unqualified healthcare providers in underserved

	1:1000 population, similar to ASHAs. They are highly accessible, have a very good understanding of the communities that they service, and enjoy a high level of trust. They are typically the first external providers sought for PSBI care, and usually refer patients that need inpatient care to private providers. Private hospitals (low accessibility, high trust): There are multiple private hospitals in urban Kanpur Nagar that provide paediatric care and some of them have well-equipped neonatal intensive care units. While their accessibility is low due to distance and high cost of care, families place greater trust in private providers than public hospitals due to perception of greater accountability.	communities, their role and even their existence is not recognized by the government, as their providing clinical care without a license is a very contentious issue. They exist because there is an unmet need for medical care in these underserved communities with a very low physician to population ratio and poor accessibility of qualified doctors. Families value the care that they provide and are often unable to distinguish between licensed and unlicensed providers and treat them as real doctors. During the pandemic, as outpatient services of all recognised public and recognised private providers had nearly shutdown, the unqualified healthcare providers were the only go-to providers that had their doors open for care. Like other providers, unqualified healthcare providers also increased their charges during this period, but typically allowed patients to pay them in instalments over time. Their responsiveness to people's needs during the pandemic and increased accessibility legitimised their services, and further established them as trusted providers in their catchment communities.
PSBI care by various providers/ health facilities	ANMs/ CHOs: ANMs were not aware of their role as de-facto providers for community-based PSBI care. It has been several years since they received IMNCI training, but they never really put the training into practice as the care-seeking pathway was not streamlined. The CHOs are co-located with the ANMs in Health and Wellness Centres and currently do not have any designated role in PSBI care. CHCs: They mainly provide outpatient services for 6 hours from 8am to 2pm. While all 3 rural CHCs have a paediatrician, two of them are administratively engaged as facility heads, and NBSUs are not functional. Sick newborns and young infants are typically referred to the district hospital. A CHC doctor remarked, *"If a child*	Public health facilities: both outpatient and inpatient care were severely impacted: • Outpatient services of all public health facilities were closed during the early lockdown in 2020, and thereafter restricted to 50 patients per day in district hospitals (less than a quarter of typical daily load), and gradually opened up. Prior RT-PCR testing and Covid negative status was a requirement even for outpatient consultation in district hospitals. • In CHCs, outpatients were administered rapid antigen tests, and typically not allowed inside the building.

	has diarrhoea or minor health issues, then I admit, but if they appear sicker, then we don't take the risk as we do not have adequate laboratory facilities for investigation." District hospital: Of the 3 district hospitals equipped with SNCUs, Dufferin hospital does not provide any services for infants >28 days old, and the other hospitals have segregated care with SNCUs for newborns only and a general paediatric ward for older infants. Hospitals do not have adequate number of doctors to handle the patient load, and average consultation time for outpatients is <2 minutes. Hallet being the highest referral facility is always short of beds in the SNCU as well as the paediatric wards, and often multiple infants are kept on the same bed due to lack of space. Other district hospitals do not admit more than their capacity and refer infants to Hallet hospital if they lack space. Protocols for PSBI identification and management are not strictly followed with different challenges at different hospitals. Antibiotics are commonly administered in the SNCU, even when there is no indication of PSBI, and on the other hand, at times infants presenting in the outpatient department with fever as a single sign may sometimes be sent away with paracetamol alone. Antibiotic prescriptions and mode of administration (injectable vs oral) vary by treating physician. Doctors remarked that patients often come pre-treated, but without any documentation of clinical history, which complicates management. Unqualified healthcare providers: Their goal is to ensure patient satisfaction so they can grow their business. Thus, their treatment is focused on improving the patients' perception of the quality of their care, rather than the care itself. These providers are adept in giving injectables, and they typically give an injection to every patient who seeks care, as patients typically equate injections with good care. They are not medically trained and study prescriptions of established clinicians for a given set of symptoms to cobble together their own prescription as a cocktail of medications that they think has a high chance of both curing the illness and	They were assessed from a distance and prescribed treatments or referred to higher facilities. • Patients coming into SNCU and emergency were kept in the triage area with minimal care provision until their RT-PCR report was received (within 24-48 hours). They were shifted to the appropriate ward upon a Covid negative report. In case of a positive report, they were shifted to a Covid ward, if a separate ward existed in the hospital, or referred to a Covid hospital. Hospitals preferred admitting inborn infants rather than those from the community. Staff shortage due to redeployment, quarantine, etc. further weakened the quality of care. Private facilities: Care in private facilities was also similarly impacted as similar rules regarding testing, declaration of Covid test results and other protocols were imposed on them as well. Failure to comply to these rules invited closure and strict action. Large facilities with a high patient load were more severely impacted as they could not risk flaunting the rules. Smaller clinics and nursing homes that were not under the public scanner thrived as they did not comply strictly to the government guidelines. However, quality of care in these facilities was poor. Unqualified healthcare providers: They were the most accessible care providers during the pandemic. They did their best to upscale themselves to serve the needs of their increasing clientele, including care of Covid patients/ suspects.

	providing quick symptomatic relief such that their patients return satisfied. For young infants with PSBI, these providers frequently prescribe/ administer final line antibiotics such as carbapenems along with corticosteroids for quick symptomatic relief from fever, etc. – these medications are commonly available over-the-counter in pharmacies. If they perceive the need for inpatient treatment, they typically refer patients to private hospitals, that may have some commission-based arrangements to reward referrals. Private hospitals: There is a wide variation in quality of care across private providers. Some private paediatricians have an established reputation for treating severely ill infants, and they also have a high case load of outpatients. Across providers, there is wide variation in identification and treatment protocols for PSBI. Facilities that have neonatal intensive care units are more flexible about admitting infants in the >28 day age group.	Overall improvement in infection control practices across providers: There was a high compliance to the use of masks, gloves, etc. and practices like handwashing, sanitisation, etc. across public and private providers.
Referral management	The predominant care-seeking and referral pathway for PSBI involves families' social contacts as intermediaries, unqualified healthcare providers as primary care providers and private hospitals as secondary or tertiary care facilities. Referral transport in these cases is arranged by families themselves. There is minimal care coordination. Unqualified healthcare providers sometimes provide follow-up care providers post discharge from facilities. Private hospitals may refer families that are unable to afford their services or infants who are extremely sick and likely to deteriorate to Hallet hospital. The care-seeking and referral pathway for the public health system which caters to the most vulnerable families is broken at multiple points, and largely dysfunctional. The government has a well-functioning system of referral transport through the 102 and 108 emergency services that can be used to transport young infants with PSBI, however, at present, it is typically not availed for PSBI-related referrals. Even for non-PSBI related conditions, referral coordination is absent, with lower-level facilities referring sick infants without providing pre-referral care, checking in regarding	Referral management took a further beating during the pandemic, as even the well-functioning system of emergency transport came under stress. Some ambulances were reserved for transporting Covid patients, and therefore their accessibility to mothers and infants was reduced. Further, families themselves were not comfortable about availing public emergency transport, as they feared that they were transporting Covid patients and they may get infected if they travel in them.

	bed availability and informing the higher facility to ensure preparedness, and sometimes, without even a proper referral slip. Families also prefer not to seek emergency care from large public hospitals as they see them as completely alien systems where they find it difficult to communicate and navigate, due to which there can be further delays in receiving care even after families reach the facility.	
Home adherence to treatment & follow-up	Families place a great emphasis on quick relief from symptoms, which they regard as a sign of recovery. They tend to discontinue medication as soon as they notice alleviation of symptoms, and therefore may not complete the treatment course as prescribed, and also may not adhere to follow-up visits. On the other hand, they may sometimes change providers if they do not notice immediate benefits from the treatment. Another policy gap in the JSSK scheme is that it can only be availed for one-time return transport of young infants to the treating facility and back home post discharge; but it does not cover follow-up visits. Families have to arrange for their own transport for follow-up visits, and this is a key barrier to adherence to follow-up care. SNCUs have a system for nudging families for follow-up visits, but such a system does not exist for the paediatric wards (for >28 day old infants), and outpatient treatment at CHCs.	There was no observed difference in home adherence to treatment during the pandemic. However, one positive development in follow-up care was increased use of teleconsultation. Doctors resorted to telephonic monitoring and prescriptions to improve patients' accessibility to follow-up care, including for young infants.

Per request of reviewers, please find below trends at Hallet Hospital (operated by GSVM Medical College) in Kanpur Nagar for number of OPD registrations (total, including adults as well), number of deliveries and NICU admissions during the year immediately prior to onset of Covid-19 (April 2019 – March 2020, and subsequent two years during the pandemic. Total number of OPDs has reduced by more than 50%, demonstrating the shift in pattern of care-seeking for outpatient consultations. Number of deliveries has reduced by about 25% since pre-pandemic year. NICU admissions have also correspondingly reduced by about 25% primarily driven by reductions in inborn admissions.

Outborn admissions remain similar to pre-pandemic year, which is an indication that the proportion of extremely sick/ critical infants overall may be similar to pre-pandemic levels with the institution continuing to remain a preferred place of care. However, consultations for apparently non-serious ailments appears to have reduced by half.

Hallet Hospital, Kanpur Nagar			
Year	**Number of OPD**	**Number of Deliveries**	**Total Admission in NICU (Inborn + Outborn)**
April'2019 – March'2020	43,272	4,136	1916+510=2426
April'2020 – March'2021	19,021	2,910	1349+638=1987
April'2021 – March'2022	19,899	3,250	1321+530=1851