mHEALTH AND NEONATAL RESUSCITATION

A Review of Interventions, Approaches and Applications

Namita Agravat, MPH

December 2013

mHEALTH ALLIANCE

Prepared for the United Nations Commission on Life-Saving Commodities Neonatal Resuscitation Technical Reference Team

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Acronyms and Abbreviations

AAP	American Academy of Pediatrics
CCEM	Cold Chain Equipment Management
CRVS	Civil Registration and Vital Statistics
ENAP	Every Newborn Action Plan
GSMA	Global System for Mobile Communication Association
HBB	Helping Babies Breathe
ICT	Information Communication Technology
IPA	International Pediatric Association
LMIC	Low- and Middle-Income Countries
LMIS	Logistics Management Information System
M&E	Monitoring & Evaluation
MCHIP	Maternal and Child Health Integrated Program
MDG	Millennium Development Goals
ODK	Open Data Kit
PATH	Program for Appropriate Technology in Health
PDA	Personal Digital Assistant
SIAPS	Systems for Increased Access to Pharmaceuticals and Services Program
TB	Tuberculosis
TWG	Technical Working Group
UNCoLSC	United Nations Commission on Life-Saving Commodities
UNFPA	United Nations Family Planning Association
UNICEF	United Nations Children's Fund
URC	University Research Corporation
USAID	United States Agency for International Development
WHO	World Health Organization

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EACH YEAR, APPROXIMATELY FOUR MILLION BABIES DO NOT SURVIVE THE FIRST MONTH OF LIFE

1

Introduction to Child Mortality and mHealth

Reducing child mortality rates has been made a global priority. In existing policy, this is evident through the United Nations (UN) Millennium Declaration that established eight Millennium Development Goals (MDGs) in 2000 to improve conditions for the world's poorest and with the more recent *Every Woman, Every Child* effort launched by the UN Secretary-General. Progress has occurred – 4.4 million more children survive every year compared to 20 years ago [1]. However, MDG 4, which aims to reduce child mortality by two-thirds from 1990 to 2015, is not on track, and it will not be achieved in the near future without stronger and directed investments and efforts in reducing neonatal mortality [2].

Each year, approximately four million babies do not survive the first month of life. The majority of these deaths occur in low- and middle-income countries (LMICs). For 23% of these deaths, death is attributed to birth asphyxia, which is the failure to initiate and sustain breathing at birth.[a] For the majority, death is avoidable since knowledge of basic interventions already exists, but the right resources do not reach the most at-risk communities.

With the number of mobile phone subscriptions expected to surpass the world population of seven billion in 2014, a technology exists for the first time that can reach individuals who live in all corners of the world [3,4]. In the past decade, the explosion in popularity of mobile technologies and wireless networks has made many interested in the mobile potential to improve population health. This has led to mHealth, which is medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices. There is no excuse to leverage mobile to do as much as possible to reduce the number of unnecessary deaths among newborn children. The objective of this paper is to review existing mHealth interventions, successful approaches, and applications, as well as identify gaps in knowledge for the use of mHealth in neonatal resuscitation.

[a] These figures underestimate the issue as an estimated 1.02 million intrapartum stillbirths occur every year with an unknown number of these stillbirths could have been live births but misclassified as a fresh stillbirth, which is when the skin is still intact suggesting that death occurred within the 12 hours before delivery [6].

APPROXIMATELY 10 MILLION OF THE 136 MILLION BABIES BORN EVERY YEAR AROUND THE WORLD REQUIRE SIMPLE STIMULATION AT BIRTH TO BREATHE

2

Background

From another perspective, approximately 10 million of the 136 million babies born every year around the world require simple stimulation at birth to breathe. Six million require basic resuscitation with a bag or mask, and less than one million require more advanced resuscitation. Table 1 demonstrates the three categories of resuscitation interventions (immediate assessment and stimulation of the newborn baby, basic newborn resuscitation, and advanced newborn resuscitation) and the actions involved in each one to prevent birth asphyxia.

However, the interventions in Table 1 are successful only if they can be applied immediately during the event in which they are required, such as in the delivery room or home within seconds after the birth of a newborn, Thus, the reality reflects the need for better access and delivery of neonatal resuscitation equipment and its correct usage by the birth attendants. In the majority of the countries where newborn deaths are attributed to birth asphyxia, delivering interventions for effective reduction of asphyxia-related neonatal deaths are hindered by inadequate resuscitation training of health workers who interface with women during labor and delivery; insufficient resuscitation equipment to

TABLE 1
Three categories of resuscitation interventions that can prevent birth asphyxia [5]

Immediate assessment and stimulation of the newborn baby	Immediate assessment, warming, drying and tactile stimulation (rubbing with the drying cloth, rubbing the back or flicking the feet) of the newborn at the time of birth
Basic Newborn Resuscitation	Airway clearing (suctioning if required), head positioning, and positive pressure ventilation with bag and mask
Advanced Newborn Resuscitation	Basic neonatal resuscitation (as above) plus endotracheal intubation, supplemental oxygen, chest compressions, and medications

health facilities with maternity wards; and low levels of health workers who are able to deliver care to women during home deliveries [6]. Improving these conditions requires enabling ingredients within the environment, such as national attention towards essential neonatal care, governmental promotion of health workers who support home births, and better data on vital registrations [6,7]. Additionally, neonatal resuscitation guidelines should be tailored for resource-limited settings, since they are designed for health providers with assumed extensive training and appropriate technology [8].

As part of the *Every Woman, Every Child* effort, the UN Commission on Life-saving Commodities (UNCoLSC) was formed to get affordable, effective medicines and simple health commodities to the women and children who need them most. The UNCoLSC has identified 13 essential commodities which can save women and children who are dying from preventable causes [9]. Neonatal resuscitation equipment and devices are included on this list, which have the estimated potential to save 200,000 newborn lives per year [10]. To achieve the delivery of neonatal resuscitation equipment and devices, the UNCoLSC's Neonatal Resuscitation Technical Working Group (TWG)[b] was formed to systematically identify best practices for scaling up interventions, identifying barriers in current implementation and gaps in knowledge, and addressing other issues related to reducing neonatal mortality through the development of technical standards.

The TWG is keen to explore the use of mHealth to track the availability and maintenance of resuscitation equipment, to increase health worker training and the appropriate utilization of the resuscitation equipment, and to monitor and evaluate facility-level data. As a first step to understanding the potential of mHealth in neonatal resuscitation, this paper describes existing mHealth approaches and tools to support access to neonatal resuscitation equipment and devices.

[b] The lead convener of the TWG is USAID, and partners include AAP/IPA, MCHIP, the mHealth Alliance, PATH, Save the Children / Saving Newborn Lives, UNFPA, UNICEF, URC, SIAPS, and WHO [46].

A METHOD WAS DEVELOPED TO CATEGORIZE PROGRAMS WHERE mHEALTH AND/OR OTHER ICT WAS USED WITHIN THE CONTEXT OF A NEONATAL RESUSCITATION PROGRAM

3

Methodology

To achieve the objective of this paper, a landscape scan of mHealth and the use of information and communications technology (ICT) for neonatal resuscitation, literature review, and interviews with identified key informants who are involved in neonatal resuscitation work were conducted. This included reviewing the UNCoLSC Report and Implementation Plan, along with documents and recommended literature describing existing mHealth tools and programs. A review of peer-reviewed and grey literature addressing mHealth and neonatal resuscitation was conducted in PubMed, Google Scholar, PLOS, in addition to searches on Google.com. Established search terms for the literature review included: "mHealth", "newborn resuscitation", "neonatal resuscitation", "ICT", "mobile", "newborn", and "neonatal". The search was combined by a review of mHealth case studies and program descriptions from knowledge management portals, such as K4Health, the mHealth Alliance website, and other websites recommended by the TWG and key informants. Relevant white papers, articles, theses, and reports were also reviewed.

Extracted information from the stated sources above was identified and synthesized if it had relevance to neonatal resuscitation activities, including reducing barriers to both implementation and the scale up of existing programs, as well as filling gaps in knowledge. Existing case studies and best practices for mHealth in neonatal resuscitation were identified and reviewed by TWG members. A method was developed to categorize programs where mHealth and/or other ICT was used within the context of a neonatal resuscitation program. Categories focused on, but were not limited to, the use of mHealth in supporting:

- **Supply and maintenance of newborn resuscitation commodities**
- **Training of skilled birth attendants, including nurses and midwives trained on neonatal resuscitation**
- **Monitoring and evaluation of neonatal resuscitation programs**

The three categories above were identified as possible and promising areas of intervention or opportunities for mHealth. The objective was to address issues and challenges for neonatal resuscitation, as identified by the experts and members of the TWG.

For the interviews, key informants were selected from a random convenience sample with input from the TWG. Appendix A is a list of the individuals interviewed. The main questions that guided the interviews included:

- **Do you know of any current programs utilizing mobile technology to support neonatal resuscitation?**
- **What documented or published resources do you know of regarding mobile technology and neonatal resuscitation?**
- **Taking a step back, where do you think are the gaps and barriers in neonatal resuscitation programs?**
- **Do you have any other suggestions for documented or published resources for review with respect to gaps and barriers in neonatal resuscitation?**
- **Do you have any suggestions for other individuals with whom to speak on the topic of neonatal resuscitation and/or related ICT innovations?**

The information collected was reviewed and synthesized. TWG members reviewed and provided feedback to initial drafts of this paper.

mHEALTH IS BEING MOST COMMONLY APPLIED AS A TOOL FOR HEALTH WORKERS WHO ARE THE POINT OF CONTACT FOR NEWBORNS AND WOMEN DURING DELIVERY

4

mHealth Opportunities in Neonatal Resuscitation

Generally, the utility of mHealth has been in improving access to and quality of health. Given the experience and successes of mHealth pilots in addressing existing gaps and barriers within maternal, neonatal, and child health, as well as the potential to take mHealth to scale with the near ubiquity of mobile technologies, donors, implementers, and governments are enthusiastic about scaling up mHealth [11]. Although mHealth is nascent and large-scale implementation of mHealth projects has been limited to date, there is some evidence demonstrating how mHealth can be effectively applied to support interventions along the reproductive, maternal, neonatal, and child health (RMNCH) continuum of care. More specifically for neonatal health, mHealth is being most commonly applied as a tool for health workers who are the point of contact for newborns and women during delivery [12,13], but at the time of writing this paper, a systematic review of mHealth applied to neonatal resuscitation has not yet been conducted. Most recently though, USAID, Dimagi, Inc., and CORE Group have developed an mHealth Field Guide for Newborn Health [14].

While there is a lack of experience in integrating mHealth into neonatal resuscitation activities, the use of mHealth to reduce the incidence of birth asphyxia with effective resuscitation interventions, if well-planned and implemented in the context of existing efforts and programs, could potentially address some of the barriers in implementing interventions that reduce the number of asphyxia-related neonatal deaths. Labrique, et al. (2013) recently published a framework of 12 common mHealth applications (see Table 1) used as health system strengthening tools across the RMNCH continuum of care [11]. This framework is useful for conceptualizing opportunities for using mHealth to support neonatal resuscitation [12,13].

Labrique, et al. (2013) presented definitions for each of the 12 applications, which can be useful in finding opportunities where mHealth can be leveraged during the delivery of neonatal resuscitation interventions. Illustrative examples of the relevant applications are described below in the context

of neonatal resuscitation. Examples include mHealth strategies that are currently being implemented, as well as potential areas in which mHealth could be leveraged, which were conceptualized using the framework.

A Client education and behavior change and communication

Neonatal resuscitation programs generally focus on the supply side of health services, such as the capacity of health care workers as they are the ones responsible for recognizing danger signs and acting quickly to administer neonatal resuscitation when needed. One of the biggest challenges to successful neonatal resuscitation, from a broader level, is the need for skilled health personnel. Delivering at a health facility rather than at home can ensure the presence of skilled health personnel during delivery. However, to encourage delivering at a health facility, effective messaging must be developed for the clients as well, such as for pregnant women, who can tend to the traditional practice of delivering at home. Behavior change programs that encourage institutional delivery can be challenging since the change requires a shift in what may be a cultural norm. Below are two examples of mHealth being used for behavior change and communication around delivery practices. While these programs may not fully change cultural norms and practices, they may be a step in the right direction towards encouraging delivery in health facilities.

Wired Mothers

The Wired Mothers program in Zanzibar contained two components. The first used SMS and supplied mothers with registered phones and unidirectional text messaging. The second used a mobile phone voucher system and provided two-way communication between 'wired mothers' and their primary healthcare providers. The program also provided health messages based on gestational age through pregnancy and six weeks after delivery as well as appointment reminders. While the program identified constraints, such as who owned the phone in the family and where the family resided, there was an increase in skilled attendance at delivery for the Wired Mothers group compared to the control group (60% vs. 47%) [15].

MAMA

The Mobile Alliance for Maternal Action (MAMA) program provides gestational-age-appropriate health information to the mobile phones of pregnant women. As the due date for childbirth nears, the messages become more frequent and focus on preparing for delivery, including where it will occur [11].

The Neonatal Resuscitation Devices Case Study prepared by Coffey, et al. (2013), highlights that pregnant women and the community may not be aware that asphyxiated babies could be saved by appropriate resuscitation equipment and skills [7]. Having this awareness could empower pregnant women and communities to demand that providers be prepared to resuscitate their babies should the need arise, which in turn, could motivate pregnant women to deliver at the health facilities equipped for such emergencies [7]. Messages targeting the community and pregnant women, in particular, around the value and use of resuscitation equipment could be included in messaging packages similar to those developed in the Wired Mothers and MAMA programs.

B Sensors and point-of-care diagnostics

Given the split-second response time required for birth asphyxia, use of mHealth-supported point-of-care diagnostics for decision-making would not be ideal. Reaction time for providers is within one minute after birth, requiring all actions to have a quick response. Providers need to be adequately trained ahead of time and not rely on this sort of technology at the point of care.

TABLE 3
Twelve common mHealth applications for health systems strengthening [11]

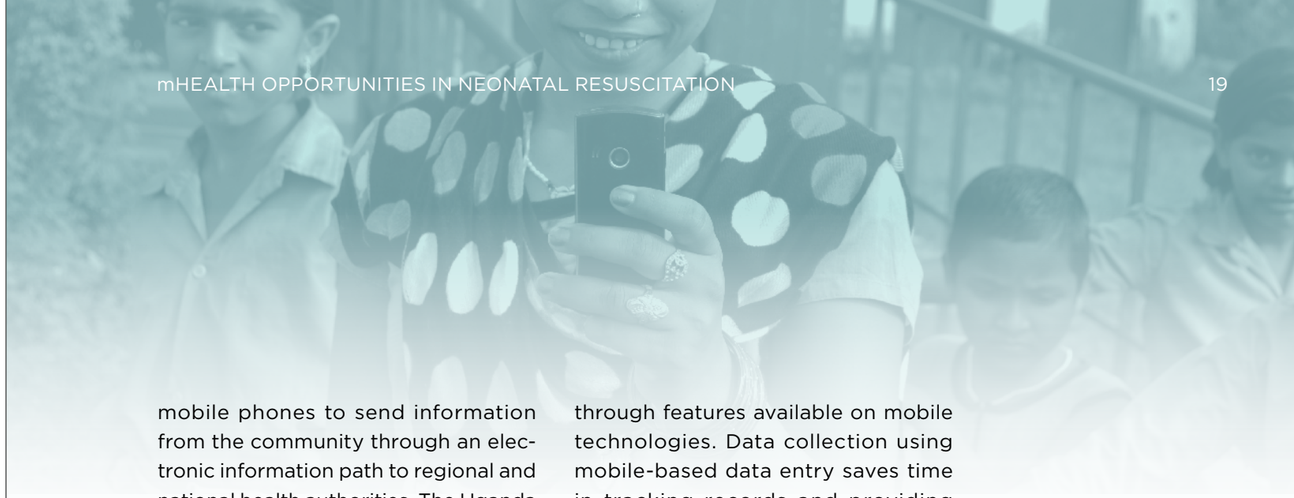
1	Client education and behavior change communication
2	Sensors and point of care diagnostics
3	Registries/vital events tracking
4	Data collection and reporting
5	Electronic health records
6	Electronic decision support-information, protocols, algorithms, checklist
7	Provider to provider communication and user group consultation
8	Provider work planning and scheduling
9	Provider training and education
10	Human resource management
11	Supply chain management
12	Financial transactions and incentives

C Birth registries and vital events tracking

The majority of stillbirths and neonatal deaths happen in countries that have very little data that can guide relevant programs [6]. Without vital registration (VR), not only is information on the cause of death missing, but also the lack of vital registries prevents the monitoring and tracking of events when: (1) neonatal resuscitation was required, but not given, or (2) it was given, but had an adverse outcome. The reporting of cases requiring neonatal resuscitation should ideally track adverse events and the steps taken to mitigate complications. End users of this information would be policymakers, particularly since the information provides evidence supporting an audit of causes of death and facilitates the case management of mothers for service providers. An audit additionally helps policymakers and health authorities in determining the skills of providers and availability of equipment. This sort of information can help in planning and directing capacity support and resources for neonatal resuscitation.

With regard to the policy context, the Global Strategy for Women's and Children's Health and the Every Newborn: An Action Plan to End Newborn Deaths (ENAP) within the Every Woman, Every Child effort focus attention on newborn health and identify actions for improving survival, health, and development. One of the strategic objectives of the ENAP is to count every newborn [16]. The registration of births, along with the registration of deaths, is a component of a nation's civil registration and vital statistics (CRVS) system. Birth registration establishes legal identity for a child and serves to facilitate access to essential services, as well as protect against child trafficking [17]. While birth registration is important from child protection and public health perspectives, death registration is just as important from a public health perspective. In the case of neonatal resuscitation, death registration of babies provides information to public health authorities so that they can begin constructing the appropriate public health responses to address the prevalence of certain health conditions or issues. While there are efforts to improve death registration in LMICs, those efforts lag in comparison with global efforts to promote birth registration.

UNICEF has been supporting the use of RapidSMS, a mobile phone application, to register births, issue birth certificates and maintain a database of new births in countries such as Uganda [11,18]. The information collected using mobile phones is then relayed, using SMS and web-based technology to district, regional, and national health and civil registration authorities. In Nigeria, RapidSMS was developed as a monitoring tool to identify in real-time, center-by-center birth registration disparities [18]. RapidSMS can then prompt and facilitate appropriate action. In the same way it is used for birth registration, tools like RapidSMS can be used to register deaths, using



mobile phones to send information from the community through an electronic information path to regional and national health authorities. The Uganda system, called MobileVRS, will begin registering deaths in early 2014, and the registration of deaths including deaths occurring during the neonatal period can provide information on the number of deaths attributed to birth asphyxia or the number of babies who could not be resuscitated.

D Data collection, reporting, and electronic health records

This section combines electronic data collection and reporting with electronic health records, particularly because of the functionalities in common among the three areas with recordkeeping. This section overlaps conceptually with the previous section describing birth and death registration systems; however, for the purpose of describing the applications, the main importance in keeping registration and data collection as two distinct applications in this report is that birth and death registration data are relatively non-existent in LMICs. Using mHealth for data collection strategies, on the other hand, often involves turning existing paper-based processes into automated ones through features available on mobile technologies. Data collection using mobile-based data entry saves time in tracking records and providing quick informational feedback loops [19]. Examples below include specific experiences with technologies and platforms typically used for mobile-based data collection in the context of neonatal resuscitation, as well as in other contexts that can be adapted for neonatal resuscitation.

mHBB (mobile Health Babies Breathe) pilot in Kenya

The most relevant example of data collection for neonatal resuscitation utilizing mHealth is the mHBB pilot currently being conducted and reviewed in Kenya. A group from the University of Indiana launched the mHBB pilot to look at M&E efforts that support the rollout of the Helping Babies Breathe (HBB) program, which works to ensure all babies are born in the presence of a skilled birth attendant through neonatal resuscitation curricula tailored to low-resource settings [20]. HBB has rolled out widely; however, data collection has not kept pace with the scale of its roll out. The mHBB program being piloted includes both web-based and mobile-based systems using an open-source ICT solution. Using Open Data Kit (ODK), the mHBB pilot collects data on training and implementation of HBB. Information collected fall into three categories:

- **Training-related data, including initial and refresher training registrations and course information**
- **M&E, such as learner-centered evaluations**
- **Quality improvement, including resuscitation debriefings and perinatal death audits**

The facilities involved in the pilot represent varying levels of volume for delivery, network coverage and experience with ICT solutions among health workers. When possible, the program collects data both manually on paper and electronically to allow for comparison. The schematic below presents the functionality of the mHBB system being tested.

Based on initial qualitative feedback, the mobile tool was well received by health care workers. Time savings from using the mobile tool relative to the paper tools were quickly recognized. This response seemed to cut across gender, age, and experience with devices. Some of the challenges faced were that the pilot was meant to test both web-based and mobile-based tools; however, the web connections were unexpectedly very poor. This required more rapid development of the mobile tool, which led to problems with the format in which data were received. Several iterations of the data collection forms had to be piloted [21].

This activity is still in the pilot stage with results expected during the spring of 2014. Figure 1 highlights the many potential reporting domains based on the success and scale-up of the mHBB pilot [12,21,22]. In the long term, mHBB may capture additional M&E data that relate to the RMNCH continuum through other efforts such as *Helping Mothers Survive, Helping Babies Survive* and the Survive and Thrive Global Development Alliance.

MCHIP Maternal and Newborn Quality of Care Survey

MCHIP (Maternal and Child Health Integrated Program) has developed a toolkit of Maternal and Newborn Quality of Care surveys with various assessment capabilities. Relevant parts within this toolkit include surveys in the following areas:

1. **Clinical practice observation of ANC**
2. **Clinical practice observation of Labor and Delivery**
3. **Facility inventory**
4. **Health worker interview and knowledge test**

When these surveys were initially developed, smartphones with Windows operating system were used. However, the size of the device seemed to make a difference in the ability to conduct the survey effectively. A larger viewing screen offers the ability to see more questions on the observation checklists than devices with smaller

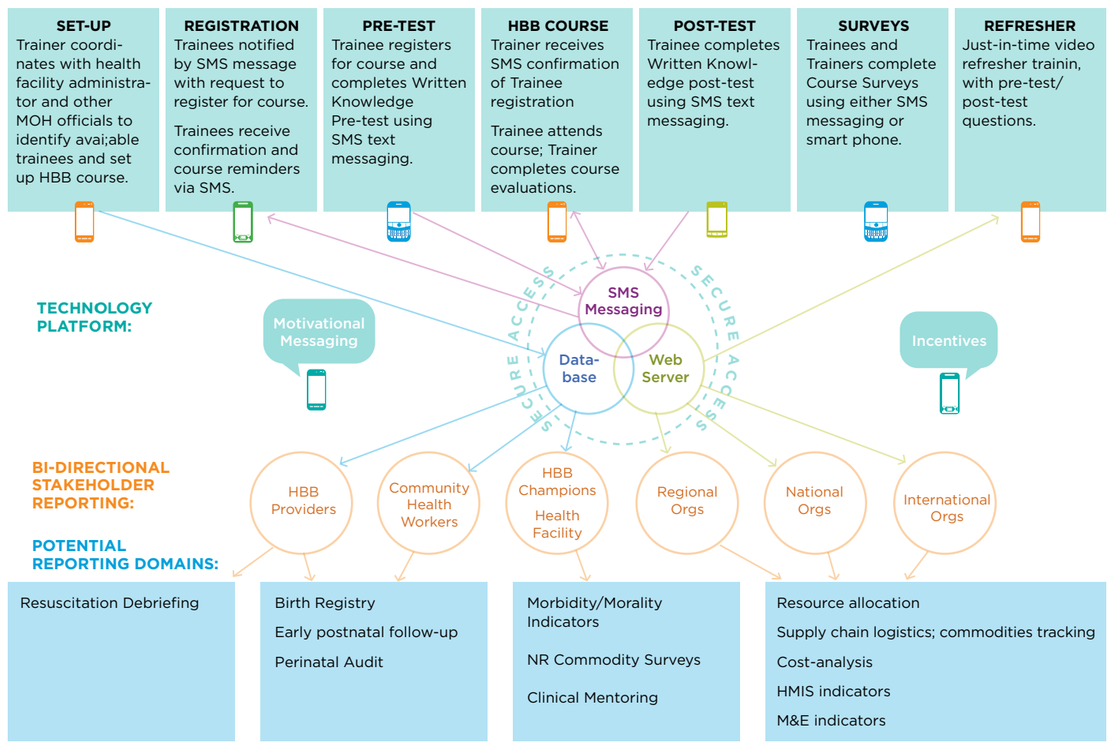


FIGURE 1. mHBB data collection and reporting system. Credit: Sherri Bucher, University of Indiana.

viewing screens. Based on feedback from MCHIP, the ideal device for the survey was found to be a 7-inch tablet and the surveys can now be used on Android, iPhone, iPad and Windows mobile devices [23].

Two of the tools developed have specific questions related to neonatal resuscitation and can be conducted at different types of health facilities. The Labor and Delivery observation assessment is conducted by trained medical staff observers and includes the following neonatal resuscitation checks:

- **Preparation for delivery – review of equipment and supplies that should be set out in preparation for delivery**
- **Immediate care – review of neonatal resuscitation checklist which is included as a part of the complications checklists**
- **Clean-up after neonatal resuscitation – review of partograph and/or chart for completeness**

If neonatal resuscitation is not observed, providers may be asked knowledge questions to capture their preparation for neonatal resuscitation. The Health Worker Interview and Knowledge Test ask about professional and refresher training in neonatal resuscitation. Both of these relevant tools are available upon request [23].

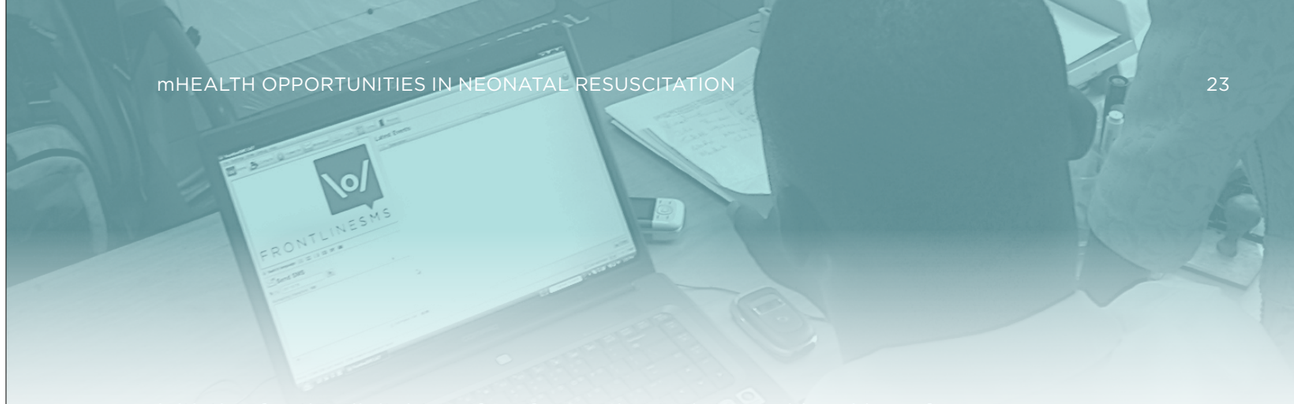
Various mHealth data collection tools exist insofar as data collection was one of the first applications for which mHealth was used. The ease in translating paper-based systems to electronic systems lent itself well to mHealth applications. With respect to neonatal resuscitation, any ICT could help in accurate and timely reporting of cases and outcomes related to neonatal resuscitation, but the data desired vary. Data can include information on training, availability of equipment, frequency of services, as well as outcomes. The type and forms of data being collected can dictate the type of data collection tool used. Below are details of additional options.

Formhub makes basic Excel forms instantly accessible on an Android phone or the web. The data can then be aggregated, shared, and visualized to allow for greater understanding of information [11,24].

ODK, as mentioned earlier in reference to the mHBB activity, is an open-source suite of tools that helps organizations author, field, and manage mobile data collection solutions. Authors design a form, setup a server, and connect the device to that server [11,25].

FrontlineSMS requires a computer running on Windows, MacOS or Linux. The FrontlineSMS application needs to be downloaded and a compatible mobile phone with sufficient credit for sending and receiving text messages is required [11,26]. Commercial systems such as DataDyne have developed Magpi for users to develop mobile questionnaires and provide real-time maps and data visualization [11,27].

In Uganda, through **RapidSMS**, **mTrac** was developed as a government-led



initiative for the digital transfer of Health Management Information System (HMIS) data via mobile phones. mTrac provides a mechanism for community members to report on service delivery challenges, and empower District Health Teams by providing timely information for action [28]. One of the key functions of mTrac is in supply-chain management of medical commodities.

CommCare Mobile allows for data to be sent over standard phone networks for real-time inspection on the web. In Zambia, for example, rural clinics are connected to a central server, but community health workers also have access to patient data through their mobile phone to help them conduct follow-up [29].

E Electronic decision support – information, protocols, algorithms, checklists

Given that the time from decision to administration of neonatal resuscitation is typically within the first minute after birth, mobile-focused decision support tools at point of care are not an ideal option in improving neonatal resuscitation services. As part of preparing for neonatal resuscitation, mobile phone applications with checklists could be used as tools to provide guidance for selecting, cleaning, assessing, and replacing equipment.

F Provider-to-provider communication and user group consultation

Mobile devices also facilitate communication between and among health workers. For instance, if a mother were transferred to a higher-level facility after her baby received neonatal resuscitation, there may be a need for additional communication between health workers at the health facilities where she was seen. This can be facilitated in a timely manner through the mobile technologies.

Other opportunities may exist in providing training and supervision between health care workers at different facilities. Similar to telemedicine, health care workers can provide support to one another via mobile devices regarding neonatal resuscitation. While point-of-care support during delivery may not be the most ideal time to refer to a mobile device, a health care worker could contact a colleague when she or he suspects neonatal resuscitation may be required at delivery based on having observed risk factors or danger signs from a pregnant mother. There may also be benefits from contacting another health care worker at another

facility for post-procedure support to ensure proper follow-up.

G Provider work planning and scheduling

While mHealth applications can be used for time management, such as planning work and organizing schedules, they are not prioritized for directly supporting neonatal resuscitation services at this time. However, it is important to ensure the presence of a health provider properly trained in neonatal resuscitation in health facilities at all times.

H Provider training and education

Adequate training is imperative for supporting timely and effective neonatal resuscitation services. "In order to maintain provider skills and ability to manage birth asphyxia, birth attendants require quality pre- and in-service training, with routine refresher trainings" [30].

The **MCHIP Quality of Care toolkit** helps to identify levels of both pre- and in-service training that health workers have with respect to neonatal resuscitation. Once training schedules are in place for in-service training, programs like RapidSMS can be used to send reminders for trainings by SMS [18]. Other uses of SMS include requesting and monitoring trainings for new or inexperienced staff. Knowledge quizzes could also be received and transmitted by SMS.

eMOCHA is an open-source mHealth application that can provide point-of-care interactive multimedia training & education, among other tools. There is currently an application available for download on the Google Play store called "TB Detect" that provides up-to-date TB-related education [11,31].

The non-profit, **eHealth villages**, presented an example in Kenya when a patient was admitted and the baby was at risk of prenatal asphyxia (sic). The provider had on-demand delivery of medical information on an iPad and was able to research resuscitation. When the baby was born not breathing, the provider performed neonatal resuscitation. This provider now conducts further training for other staff [32].

Depending on the availability of devices, health workers could stream videos for continuing education on neonatal resuscitation. Viewing videos for continuing education in between trainings may prove valuable in ensuring readiness for these workers. As resuscitation equipment becomes more available in facilities, guidance on disassembling and cleaning will be needed. Mobile devices could also be used to help stream videos on cleaning and storing resuscitation equipment. Additionally, mobile phones or tablets could provide access to reference materials, such as that of Helping Babies Breathe, for independent review by health care workers.

I Human resource management

Human resource management mHealth applications were not identified as an area that would directly support neonatal resuscitation services. As mentioned before, however, it is important to ensure the presence of a neonatal resuscitation-trained provider in the health facility at all times.

J Supply chain management

Most of the commodities presented in the UNCoLSC's report of 13 life-saving commodities are single-use medicines, which require constant updates on stock-outs or orders to replenish. Neonatal resuscitation equipment, however, is a different type of commodity and should accordingly be handled differently when it comes to supply chain management. Unlike single-use commodities such as medicines, neonatal resuscitation equipment is generally used multiple times (with the exception of suction bulbs, in some cases). Stock-outs and "restocking" requests therefore function differently. One way to look at the equipment is to relate it to cold chain equipment for vaccines, such as refrigerators, cold rooms, and cold boxes [33,34]. These are items that are also purchased for a facility and have to be maintained until they no longer function properly, at which time, they will need to be replaced.

PATH has developed a **Cold Chain Equipment Manager (CCEM) software tool** which is a Microsoft-Access-based application [35]. The tool has three main functions:

- **A geographic database of health facilities**
- **A data entry system targeting low-resource environments**
- **A modeling engine for generating cold chain equipment forecasts**

This tool is more of an eHealth tool. However, there may be strong potential for incorporating an mHealth component.

Through its **"Health Tech" workplan**, PATH plans to conduct a durability and cleaning assessment of neonatal resuscitation equipment in the field

during the spring of 2014. This assessment should give a better indication of the lifespan of neonatal resuscitation devices. The development of quantification tools and forecasting guidelines are also underway. These tools and guidelines will also help identify how many pieces of equipment are needed in a facility. Based on this information, mHealth applications can be used to provide reminders to conduct checks on the stock status of equipment and potentially put in requests to replace equipment. Ideally, the mHealth solution would connect directly into the country's LMIS system [36–38].

While more involved than likely necessary in the case of neonatal resuscitation, **SMS for Life** uses mobile phones, SMS messaging and electronic mapping to track stock levels of essential malaria medicines on a weekly basis [39].

K Financial transactions and incentives

Mobile is also starting to play a role in transferring money or credit over wireless networks, which can be leveraged in health interventions that use financial transactions and incentives. **Wired Mothers** offers mobile phone vouchers for two-way communication between mothers participating in the program and primary health providers. Mothers can use the vouchers to access advice and if necessary, call for ambulance service [15]. An evaluation of the Wired Mothers program indicated that women who received phones with vouchers were incentivized to contact health care providers [15]. Given that many births occur at home, this may be an additional strategy for encouraging facility delivery.

To provide an example of how vouchers can be transferred through mobile-based systems, **mPesa**, which is a mobile money transfer program being implemented in several countries, can provide another perspective; however, it should be strongly noted that conditional cash transfers should not be provided to incentivize neonatal resuscitation. In the case of Kenya and the use of mobile phones for SMS reminders and conditional cash transfers to improve immunization, mothers who received reminders completed the follow-up survey and then received funds through mPesa [40].

5

Gaps in Knowledge and Barriers to Adoption

A number of barriers and challenges can potentially undermine the integration of mobile technology into not only neonatal resuscitation interventions, but also any health intervention (see Appendix B). This is the case for mobile technology used by communities, as well as the health sector. First, the effective use of mHealth is obviously dependent upon the availability of phones. At the household level, mobile phones in LMICs are typically owned by, or under the control of men [41]. On the health service delivery side, women, who constitute most of the community health workers, often use phones that are shared with household members or with other members of the community. Second, depending upon the location, network coverage and the inability to charge phones are omnipresent issues in most rural areas in LMICs. Third, low literacy in communities may limit the ability to use certain phone features such as SMS [42]. Accordingly, strategizing the use of mHealth must consider the availability of phones among community health workers, gender dynamics, network coverage, availability of electricity, and literacy rates. When mobile devices are not readily available, project planning and budget considerations would need to factor in the funding required to obtain mobile devices, access a working network and energy sources, and build the capacity of health workers who would be responsible for using the phones.

The lack of a large body of evidence demonstrating the attributive impact connected to mHealth has been problematic. There is, however, well-established evidence that supports data collection using PDAs, the earlier form of mobile technology used in LMICs. An increasing number of studies are evaluating the impact of mobile phone technology in data collection and other areas outlined under the framework outlined above. Yet, even as the body of evidence grows, there is a need for evaluation research to keep pace with the advancement of mobile technology [43].

The tendency to create parallel independent mHealth implementation systems constitutes a major operational concern, particularly considering the number of pilots operating in a country. These systems often work in silos, creating

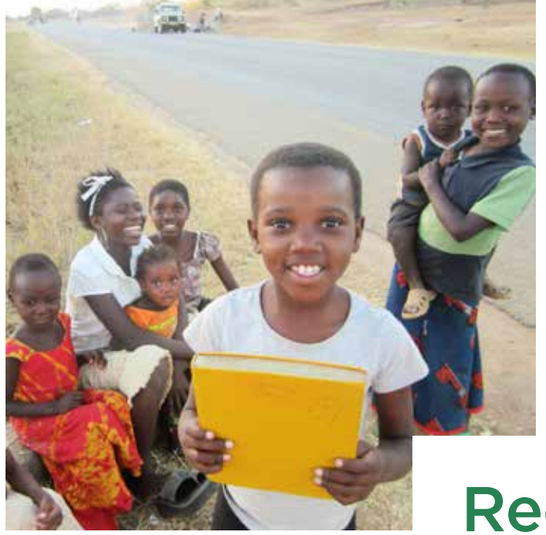
few opportunities for collaboration and efficient use of resources. Instead of creating independent, parallel systems, efforts need to leverage existing initiatives into one interoperable system to both maximize effectiveness and streamline processes [43].

There is a need to address barriers to scale and sustainability of mHealth (which is connected to the transition from pilots [19,43]. mHealth projects require wide availability of mobile devices, consistent sources of credit for phone time, trained legions of health workers and ongoing management of the servers and other equipment connected to using mobile and web-based technology. These are just some of the factors that need to be considered when planning to go to scale.

Applications related to mLearning (the use of mobile technology for educational or learning purposes, such as health worker training) have not been widely studied as of yet. There are several promising ideas but a look at the effectiveness might also be a valuable endeavor [43].

Policy barriers also play a role in mHealth. Some examples of policy barriers include network coverage, national health priorities, information systems architecture and interoperability issues and the existence of standards. These barriers can be addressed at the country-level by presenting more substantial evidence of the benefits of mHealth interventions and by helping to establish global and national level strategies and guidelines for mHealth implementation and integration into existing policies [43]. Country Ministries of Health would need to take an active role for mHealth applications to be successful, achieve scale, and be sustainable. This requires continued advocacy for countries to adopt policies related to mHealth or eHealth [44]. Ministries of Health are already very stretched for resources and while pilot programs may be encouraging, their ability to take on ownership may be limited.

Also, until standard neonatal resuscitation equipment is available globally, there will be significant variations throughout countries in implementing mHealth programs to support neonatal resuscitation services. Currently, there is no consistent guidance on the lifespan of equipment, and there are inconsistencies in the quantity required in a particular health facility, current stock levels of the equipment, and the best methods for cleaning the equipment.



6

Recommendations for Saving Lives

As we think through the opportunities for applying mHealth to neonatal resuscitation, the best strategic direction would be to target areas with the potential for the most direct impact that can be achieved practically in the short term, and to build upon existing experience. Using this strategy, recommendations for using mHealth in the area of neonatal resuscitation include focusing how mHealth can be operationalized for client awareness and education, data collection, provider training, and supply management based on the information received on existing mHealth applications, gaps and barriers, as analyzed under sections 4 and 5 above.

Client awareness and education

Improving client awareness and education on neonatal resuscitation is an important component for improving neonatal resuscitation activities in appropriate situations. Although mHealth strategies have not been applied directly for supporting neonatal resuscitation, several efforts have been implemented where pregnant women are able to receive mobile-based health messages corresponding to how advanced their pregnancy is all the way until the postnatal period. Incorporating information related to birth asphyxia or neonatal resuscitation in these messages would be relevant to include in the existing mHealth programs for maternal health. Additionally, these messages could also serve as a way to monitor and register birth outcomes, since they already register pregnant women.

Birth Registration and Data collection

Developing birth and death registration systems can capture the number of births occurring as well as identify the causes of deaths among babies, and data collection for neonatal resuscitation includes a focus on tracking numbers of health care workers trained, frequency of resuscitation, and the quality of care provided. Targeting resources (e.g. supplies and training resources) to locations which experience a disproportionate number of preventable neonatal deaths related to lack of resuscitation capacity will require linking all

mHEALTH IS BEING MOST COMMONLY APPLIED AS A TOOL FOR HEALTH WORKERS WHO ARE THE POINT OF CONTACT FOR NEWBORNS AND WOMEN DURING DELIVERY

these data points to outcomes in order to track progress over time. There are several mHealth data collection tools in existence that could be applied in tracking neonatal outcomes as they relate to neonatal resuscitation efforts. The mHBB pilot, for instance, is currently tracking provider training through mobile technology, but if supported, this effort could link to morbidity and mortality indicators. The MCHIP Quality of Care survey provides tools to monitor providers when conducting neonatal resuscitation.

Collecting relevant information can help in pinpointing other gaps in providing adequate neonatal resuscitation services. Just as data collection over time has helped to indicate the need for improved resuscitation services, it can also help to identify whether or not gaps are occurring related to training, equipment, or elsewhere. Lessons can be drawn from the various projects that have already integrated mobile technology for data collection.

Provider training

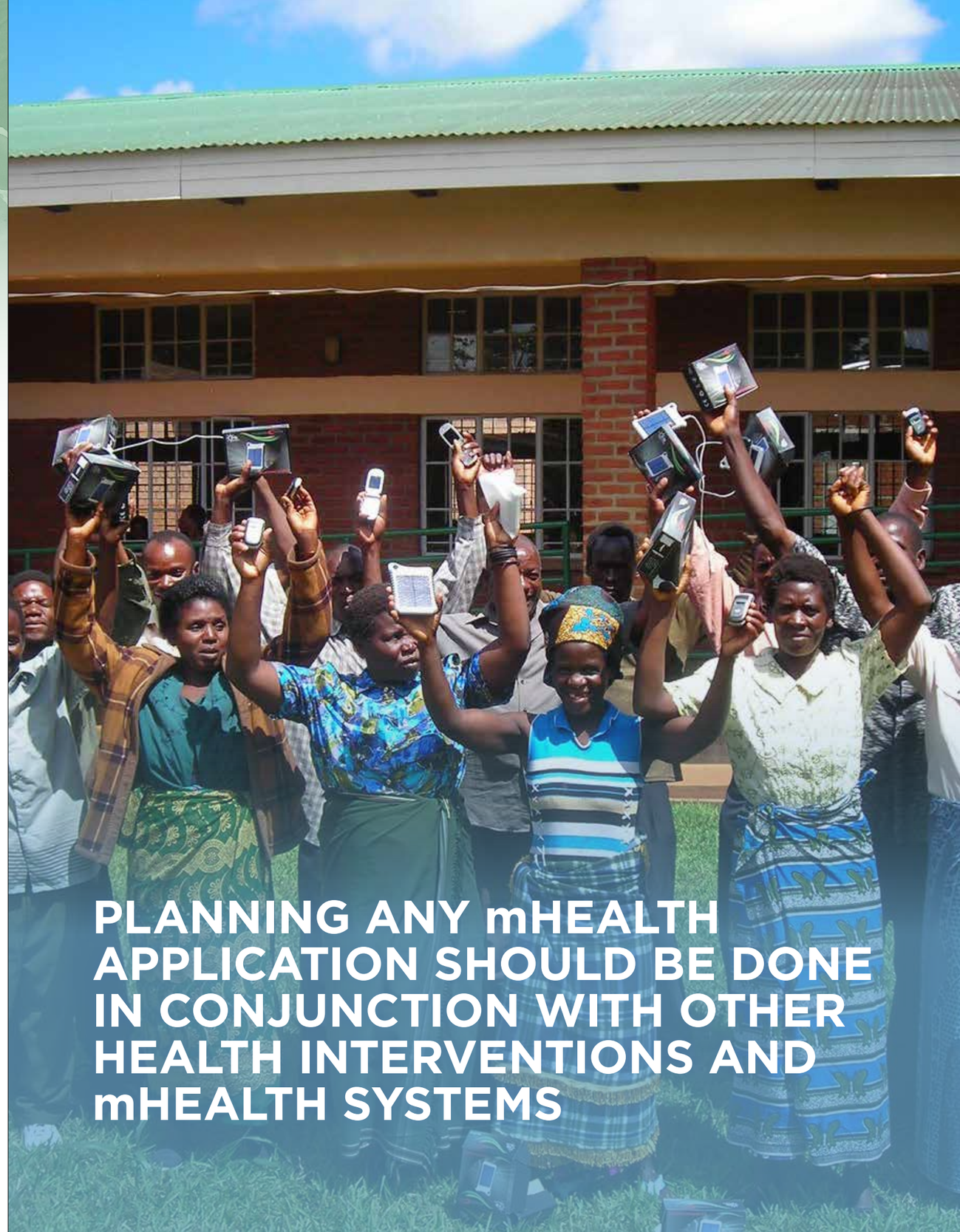
Crucial to the success of neonatal resuscitation is the training of providers. In many facilities, the provision of neonatal resuscitation services may be infrequent. Training is often only provided during pre-service yet there may be a need for more frequent in-service or refresher trainings to reinforce skills and improve recall of resuscitation knowledge, especially for those who do not need to conduct resuscitation on a frequent basis. This is an area where mHealth can provide some innovation.

Support from mHealth for training could occur at multiple levels. Specific applications could be developed or added to existing interventions to include:

- **Reminders for refresher trainings**
- **Requests for trainings for new staff**
- **Providing videos to be used as continuing education in between in-person trainings. Videos could be focused on performing resuscitation and proper handling of equipment when not in use, such as disassembling, cleaning, and storing**
- **Conducting knowledge checks through text messages for health care staff, particularly those who may not be performing neonatal resuscitation regularly**

Supply Management

Also critical to the provision of neonatal resuscitation is the availability and status of the equipment. mHealth support for supply management could include reminders to check equipment as well as a link to the central LMIS to request new equipment. The Cold Chain Equipment Manager tool adapted for mobile devices may be a good example for managing neonatal resuscitation equipment. The critical aspect of this would be that inventory management of neonatal resuscitation equipment would need to be distinguished from inventory management of medical commodities that are used once.



PLANNING ANY mHEALTH APPLICATION SHOULD BE DONE IN CONJUNCTION WITH OTHER HEALTH INTERVENTIONS AND mHEALTH SYSTEMS

7

Conclusions

mHealth has not been leveraged fully for reducing neonatal mortality rates related to birth asphyxia; however, many opportunities exist for improving access and delivery of effective interventions, such as neonatal resuscitation. This paper has used the framework presented by Labrique et al. (2013) to identify opportunities for mHealth within the context of neonatal resuscitation. Using this framework, mHealth examples have been provided for client education and behavior change and communication, sensors and point-of-care diagnostics; birth registries and vital events tracking; data collection, reporting, and electronic health records; electronic decision support for information, protocols, algorithms, and checklists; provider-to-provider communication and user group consultation; provider time management; provider training and education; human resource management; supply chain management; and financial transactions and incentives. Specific recommendations for where mHealth can have the largest health impact from neonatal resuscitation and thus reduce the number of birth-asphyxia-related deaths have been identified. These areas include data collection, provider training, and supply management. Recommendations have been drawn from existing strategies that leverage mHealth and applied to the needs for better newborn health data, such as vital registration, to inform decision making; inadequate training for health workers that interact with women during labor and delivery both at health facilities and households; and poor supply of necessary neonatal resuscitation equipment and devices at the moment when birth asphyxia complications occur.

Planning any mHealth application should be done in conjunction with other health interventions and mHealth systems. Investing in mHealth interventions purely focused on neonatal resuscitation would likely not be as cost-effective, especially if the mHealth intervention is designed and implemented as stand-alone and not integrated into the larger efforts of the health system. In addition, it seems premature to look into the development of these types of applications until there is more consistent guidance on the care and longevity of the equipment. At this time, there does not appear to be any specific mHealth support that can be provided that would strengthen systems where equipment is not available. Where it is available, the above suggestions could be taken to create pilots to be used for learning and scaled as we learn more.

Appendix A

List of key informants for interviews

Emily Bancroft, VillageReach
Sherri Bucher, University of Indiana
Natalie Campbell, MSH
David Cantor, MCHIP
Patricia Coffey, PATH
Madhu Deshmukh, CARE
Maria Freytsis, Independent consultant
Craig Friderichs, GSMA
Lily Kak, USAID
Bill Keenan, AAP
Steve Ollis, D-Tree
Bill Philbrick, mHealth Alliance/UNICEF
Manjari Quintanar-Solares, PATH
Sandhya Rao (email), departing USAID
Olivia Velez, MCHIP
Fay Venegas, PATH
Donna Vivio, USAID
Beth Yaeger, MSH

Appendix B

Examples of barriers to high-quality resuscitation services for newborns born without the ability to breathe

Credit: USAID Assist [45]

Service Delivery Barrier Category	Common Barriers
Organization & Processes of Care	• Lack of recognition and systematic referral and transport of high-risk pregnancies or abnormal labor to referral level facilities. • No designated area & process for emergency resuscitation (ready table with functional clean equipment and designated competent providers available all maternity shifts) • Poor adherence with evidence-based resuscitation standards, including failure to promptly recognize newborn asphyxia • Lack of clear staff roles and organization of post-partum care to support immediate effective teamwork in the event of an adverse event
Provider & Staff Support	• Lack of initial and regular refresher clinical training in evidence-based basic neonatal resuscitation • Lack of supportive supervision to oversee provider and staff competency and performance • Lack of quality improvement and basic data management skills
Basic Infrastructure & Commodities	• No designated and equipped “newborn corner” resuscitation space in delivery room • No functional, sterilized resuscitation commodities (bag and mask) available 24/7 in delivery areas • Non-functional and/or unclean equipment due to poor maintenance • No routine quality assurance processes related to equipment maintenance (e.g. checklists for essential procedures with designated responsible staff and routine supervision checks) • Difficulties and delays in anticipating commodities needs and procuring replacements for malfunctioning commodities
Monitoring & Improving Outcomes	• Facility medical records and registers do not systematically measure intra- and post-partum adverse events, timeliness of recognition of adverse event, quality of clinical interventions and associated health outcomes • Facility providers/managers do not collect, manage and analyze available facility data for continuous improvement of health care services; national/regional and district managers do not analyze routine health information data to continuously strengthen essential supporting health system functions • Facilities do not monitor and audit maternal and perinatal adverse events using standardized procedures and documentation forms

Appendix B

(continued)

Health System (National, Regional & District Management)	Common Upstream Barriers to Effective Delivery of Resuscitation Services
National Policy & Leadership	• Weak national leadership and governance (e.g. assigned national newborn point person, steering committee, comprehensive action plan) • Inadequate designated funding for newborn health and resuscitation • Lack of operational strategy to translate policy into practice and monitor progress • Out-of-date resuscitation standards • Lack of clear policy regarding specific provider cadres authorized to provide resuscitation services and lack of certification protocols • Lack of national policy and guidelines on commodities procurement, distribution and maintenance • No required accreditation, licensing and re-accreditation and licensing procedures (facility and provider level)
Human Resources Support	• Weak and no regulation of pre- and in-service competency-based training, refresher training, and continuous supportive supervision to help maintain provider clinical competence • Poor manager skills to effectively manage commodities procurement, distribution and maintenance • Inadequate professional development opportunities for manager and provider cadres • Low pay and lack of incentives to maintain provider and staff engagement, performance and competence • Lack of oversight and accountability mechanisms
Commodities and Logistics Support	• Weak standardization of effective commodities forecasting and procurement, distribution and tracking systems (national, regional/ district); market shaping (global and local) • Poor oversight of product quality and technical specifications • Weak regulatory efficiency for sustaining demand/supply, inventory monitoring of resuscitation commodities
Routine Health Information Systems	• No vital registries • Weak or no data collection related to facility and/or population incidence of intra-partum adverse events, services provided, and neonatal outcomes as part of routine health information systems • Poor quality of available data • No routine analysis and use of available data • Weak data management skills among providers, managers and facilities

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