Essential Care for Every Baby: Neonatal Clinical Decision Support Tool

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Abstract. Unacceptably high rates of neonatal mortality are an urgent global health challenge. Consistent application of Essential Newborn Care (ENC) interventions reduce newborn mortality. However, ENC has failed to scale-up in low-middle income countries, where the bulk of neonatal deaths occur. The American Academy of Pediatrics designed an evidence-based, simplified training and educational curriculum called Essential Care for Every Baby (ECEB), which includes a clinical practice guideline for the time of delivery through 24 hours after birth. However, the scale-up of ECEB has been hampered by the need to provide a wide variety of time-sensitive ECEB interventions to numerous mother-baby pairs. This incurs significant cognitive load among providers who perform varied tasks every few minutes for each baby. In this high-load, stressful situation, there are often profound gaps in the delivery of crucial ECEB strategies. We propose an innovative, scalable, clinical decision support mobile app which prioritizes recognition over recall and addresses existing challenges.

Keywords: Neonatal Health · Clinical Decision Support · Pediatric Care · Mobile Applications · Cognitive Load · Essential Care

1 Description of the Challenge and Why It's Important to Address:

Globally, rates of neonatal mortality (NMR) are unacceptably high. An estimated 2.5 million children die every year during the first month of life (0 - 28 days postnatal), with about 1 million of these deaths on the first day. Most of the burden of newborn mortality is shouldered by low and middle-income countries (LMICs) [1], where access to skilled and trained health care providers, well-equipped health facilities, and robust health system infrastructure is often lacking. Within this context, nearly half of all mothers and newborns do not receive skilled care during and immediately after birth. It is estimated that if all mother-baby dyads had consistent access to skilled delivery and immediate postpartum care, we could prevent nearly two-thirds of maternal and neonatal deaths [2]. Essential Newborn Care (ENC) is an evidence-based package of preventative, monitoring, and management interventions that are recommended by global health partners, including the World Health Organization [3]. These

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recommendations are supposed to be delivered to every baby, everywhere, around the world, from shortly after delivery through the first month of life. Essential Newborn Care interventions include, but are not limited to, those associated with timely and exclusive breastfeeding, hand hygiene, umbilical cord care, immunizations, and routine monitoring of key vital signs such as the baby's breathing, heart rate, and body temperature. Several key ENC activities are recommended to be delivered on the first day of life, from immediately after delivery and onward.

A key structural barrier to the consistent delivery of crucial, lifesaving ENC interventions in LMICs is a chronic and profound shortage of health care workers (nurses, midwives, physicians, nursing assistants). This is a particularly acute problem in regards to newborn care [4]. Lack of health worker capacity, in turn, impacts the ability of new educational, training, and health service delivery packages to be disseminated and implemented sustainably. Also, the lack of human capacity can lead to cognitive overload and burden among the few health workers who do serve mothers and infants [5]. It may be difficult for in-service health care workers to leave their clinical service duties to attend multi-day training courses. Currently, the WHO ENC training curriculum is a 5-day course. In response to these challenges, the American Academy of Pediatrics (AAP), in collaboration with key partners such as USAID and the World Health Organization, has responded by creating a simplified, evidence-based clinical practice education and training program called *Essential Care for Every Baby* (ECEB) [6].

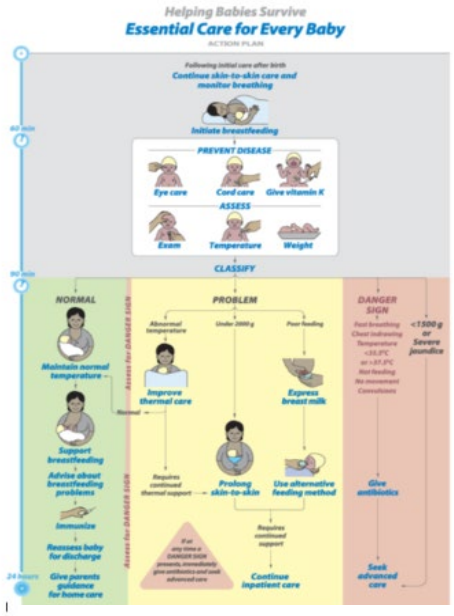

Fig. 1. ECEB action plan [6].

The ECEB curriculum is designed to be delivered in 1.5 to 2 days and is composed of three main educational and training aids for healthcare providers. These include Facilitator Flip Chart, Provider's Guide, and Action Plan. Our efforts in this project focus on developing a dynamic digitized ECEB Action Plan for mobile devices. The ECEB Action Plan (Figure 1) constitutes a series of decision support actions and a list of time-sensitive tasks that play a critical role in preventing, recognizing, and managing common problems experienced by newborns within the first 24 hours after delivery. The first few days at and around the time of birth are most dangerous for newborns; the risk for death is highest. Thus, equipping healthcare providers with the knowledge, skills, and competencies for essential newborn care directly contributes to improved survival of the neonate within the first 24 hours. Based on the ECEB Action Plan, assessments made in the first 90 minutes after birth assist the health care workers to classify newborns under their care into categories of Normal, Problem, and High Risk. These categories further denote various degrees of monitoring and support that

newborns subsequently receive. One key feature of ECEB is a color-coded risk and monitoring assessment schema, in which green denotes "normal," yellow denotes "problem," and red denotes "emergency/urgent care. Drawing upon lessons learned from challenges related to the implementation of other MNCH initiatives (e.g., identification of sick newborns, implementation of KMC) within LMICs, we know that barriers, bottlenecks, and gaps, related to shortages of healthcare providers and high levels of cognitive load and stress among frontline health workers, also confront the ECEB program. This could be one of the reasons that ECEB has not scaled as broadly as originally anticipated when launched in 2015. Also, the current paper-based ECEB Action Plan serves as a static job aid, often mounted on a wall as a poster, provides some ability to guide clinical decision making. However, it does not provide automated, easy access to the tracking of deliveries and mother-infant dyads within high-pressure situations like labor and postnatal wards, where there is an urgent need to better equip harried nurses with the ability to continuously monitor and track the location of babies within multiple wards and across various nursing shifts.

2 Description of the Proposed Solution & Design:

The proposed solution is the development of an Android-based mobile Clinical Decision Support Tool (CDST). The solution aims to address the myriad challenges faced by health care providers in LMICs, to equip them to more effectively provide complete essential newborn care for every baby under their purview. This includes the ability to efficiently track and be reminded, of time-sensitive ECEB tasks that are required for each baby, according to each infant's time of delivery. Thus, we designed the ECEB Digital Action Plan to run on a 24-hour timer analogous to the ECEB chart, with the same suggested assessments or interventions delivered at specific time points, while maintaining the paper-based clinical decision support tool's suggested sequence of events and branching logic. We have built a solution to have has a threefold functionality beginning with the elimination of the cognitive load resulting from the paper-based system. Secondly, the ECEB Digital Action Plan provides access to data (location, time, the status of the newborn, assessments administered) at the fingertips of the health care workers, at the time of each baby's need. We have also ensured security through password protection.

Thirdly, like all well-designed clinical decision support tools, the ECEB Digital Action Plan sends notifications reminding healthcare providers when a baby needs to receive specific care interventions. In addition, automated algorithms determine, based on information that the health worker adds about key parameters such as birth weight and vital signs, whether the baby is immediate danger and/or requires urgent care. Tapping the alert directs the user to the appropriate phase. Additionally, the mobile application supports automated functionality for ECEB-recommended algorithms and classification schemes for infants as normal, problem, and high risk. The classification is based on information entered by the healthcare providers, and automated, thus reducing the cognitive load for the nurses.

Because The ECEB Digital Action Plan CDST is designed to be deployed and functional within poorly resourced settings, the tool supports an offline push notification system and does not require internet access. This is proposed as a mobile

application and not a web application because a preponderance of the evidence has shown that although clinical decision support systems (CDSS) are able to improve the effectiveness of care [7-9], the vast majority of evaluations have been conducted in high-income countries [10-12]. Given the vastly different health systems and infrastructure, the effectiveness of CDSS in LMIC settings is unclear [13]. To maximize the potential for success of the implementation of clinical decision support tools in facilities with infrastructure limitations, it is advisable to build accessible and affordable mobile device-based platforms with reliable offline functionality [14]. More so, mobile apps also provide personalization and notification benefits that make them more useable than desktop interfaces [15].

2.1 Discussion of the Design Steps:

The first iteration of the CDST was developed in alignment with the principles of human-centered design to maximize adoption potential. A critical examination of the design and functionality was performed by doing heuristic evaluations and system usability tests in 40 participatory design sessions at 3 different facility sites in Kenya. Analysis of this qualitative and quantitative data from a critical realism [16] epistemological frame of reference has also informed our proposed design. The research and empathize steps for our design process are similar in both the iterations. The steps combined included problem identification, followed by an intensive in-depth literature review on varying topics like essential newborn care, mHealth applications, cognitive load, medical bias, automation, and color stimulation in a hospital setting. Generative methods were used like affinity mapping, user personas, and user journey mapping to understand the user. It was absolutely important to understand the user involved in the design process of the solution. Deep penetration, and adoption of, clinical decision-support tools (CDST) requires aggressively seeking a better understanding of what the right information is and when and how it should be delivered to the right person, at the right time, as well as a critical examination of the unintended consequences of CDST implementation [17]. Enhancements needed around usability and functionality were identified. Detailed documentation along with the think-aloud comments in these testing sessions and engagements rounds were performed, primarily focusing on user experience and ability to follow and complete the given tasks. The evaluation phase of the first iteration included usability testing and the nelson's heuristic evaluation.

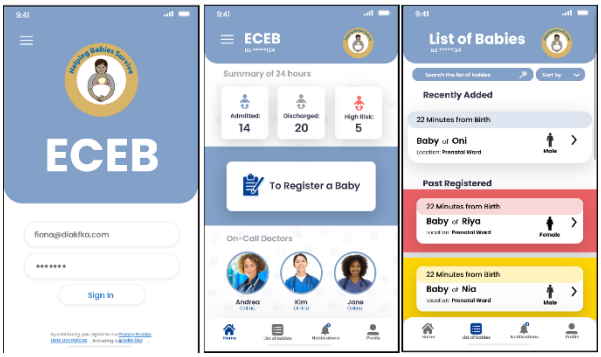

Fig 2. Mockup showing different colors to denote different levels of emergency, thus reducing cognitive load and promoting recognition rather than recall.

Table 1: Changes in design between the field-testing iterations

	Function	**First Iteration**	**Proposed Design Changes**
1	Workflow	Users were not able to differentiate between the primary & secondary function of registering a child and access the list of babies	The primary function is now a part of dashboard highlighted. The other functions are now designed as a part of the tool bar.
1.1		Users were not able to switch between the phases of multiple children and lost thread of the workflow	The proposed design has now been re sequenced so as that all the phases of the child is in a collapsible list. A simple workflow and branching logic were established to promote detectability of tasks.
1.2		Location of the newborn changes in the first 24 hours, this was not captured in the first iteration	The second iteration the location of the newborn can be updated on multiple occasions
1.3		Weight, skin color & multi organ assessments were not a part of the first iteration.	All the mentioned components are a part of the proposed design.
2	Word Usage	The word "DANGER" coupled with the color red instilled panic among healthcare workers thus increasing cognitive load.	The word DANGER in now replaced with "HIGH RISK"
2.1		Generic button design was being used like "NEXT" or "SAVE".	In the proposed design the Action button labels are being used. Ed: "SAVE & MOVE TO PHASE 2"
3	User Interface Design	The users were observed to have problems in the visibility of Icons, use of colors, labeling and navigation	The proposed design now has clarity, consistency, legibility, and comprehensibility.
3.1		The user could not differentiate between the radio buttons and checklists	The new proposed design is consistent, and uniform and we have now removed the options radio buttons.

The proposed design is heavily influenced by the review of the collected data and discussions were held to achieve a group consensus with research and technical team members. Meetings were held with domain and content experts in the fields of Pediatrics and Bio-Health Informatics to further inform the technology team of the health landscape, use cases, as well as discuss technology constraints related to app development for low power, low resource settings [18] along with brainstorming individually and as a group to allow emergence and articulation of the design criteria. Understanding that this tool would be used in high-pressure situations, the basic proposed theme is light blue and white, thus eliciting a calm and kind response from users. However, the tool that follows the ECEB algorithm classifies the child into different phases is color-coded and saved, propelling the feature of recognition vs recall health care worker. A convergence of ideas led to the identification of core features, including the need to establish a link between the mobile Helping Babies Survive powered by DHIS2 app (mHBS/DHIS2; [19]) and ECEB Digital Action Plan.

Strengths & Weakness of the Design. The design is simple and graphical to comprehend and use, with bold displays and large lettering. The texts and graphics have been arranged in different sizes of the importance of the information conveyed. Dynamic buttons that change colors on touch have been provided to give a confirmation of the option being active. The majority of the options are also accessible in multiple ways. The Clinical Decision Tool aims at classifying, as well as organizing the tasks based on a timestamp. These are converted as alerts and reminders and provided to the health workers. Features such as offline alerts and live locations help tremendously to reduce the cognitive load and helps multiple health workers to perform activities on the same baby even if the location is changed. The weakness of the design includes Multiple information display, lack of flexibility, reductant options and lack of universal accessibility.

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