The Effect of a Decision-Support mHealth Application on Maternal and Neonatal Outcomes in Two District Hospitals in Rwanda: Quasi-Experimental Study

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Abstract

Background: Globally, mobile health (mHealth) applications are known for their potential to improve healthcare providers' access to relevant and reliable health information. Besides, electronic decision support tools, such as the Safe Delivery mHealth Application (SDA), help to reduce clinical errors and to ensure quality care at the point of service delivery. The current study assessed the effects of the SDA on basic emergency obstetric and newborn care (BEmONC) outcomes for the most frequent complications in Rwanda; post-partum haemorrhage (PPH) and newborn asphyxia and its complications.

Methods: The study adopted a quasi-experimental design. A pre-intervention record review of the BEmONC outcomes: Apgar score and PPH progressions, was conducted. The intervention took place in two district hospitals in Rwanda and entails the implementation of the SDA for six months. Six months' post-intervention, the effect of the SDA on BEmONC outcomes was evaluated. The study included 327 participants (114 cases of PPH and 213 cases of neonatal complications). The analysis compared the outcome variables between the baseline and the endline data. Fisher's exact test was used to compare the proportions and test between-group differences and significance level set at $p<0.05$.

Results: Unstable newborn outcome following neonatal resuscitation was recorded in 61.90% and 27.59% newborns cases at baseline and endline respectively, P-value = 0.000. Unstable maternal outcome following PPH management was recorded in 19.40 % and 6.38% maternal cases at baseline and endline respectively, P-value = 0.048. There was a significant association between the SDA intervention and newborns' and maternal' outcomes following neonatal resuscitation and PPH management, 6 months after baseline.

Conclusion: The use of the SDA supported nurses and midwives in the management of PPH and neonatal resuscitation thus improved maternal and neonatal outcomes after 6 months of the SDA intervention.

Background

Mhealth refers to the practice of medicine and public health, supported by mobile devices (mobile phones, smartphones, tablets, smartwatches) [1]. Evidence suggests that mHealth applications are innovative approaches to improve the delivery of health care services [2]. Further, mhealth tools can help to reduce clinical errors and ensure quality care at the point of service delivery. There is growing evidence of the effectiveness of mHealth interventions in maternal and newborn health programs in low and middle-income countries (LMICs), particularly to improve adherence to treatment, meeting appointments, facilitate data collection, and the development of supportive networks for health professionals[3–6].

Among the many interventions currently being implemented to support maternal and newborn healthcare services, mHealth applications have been widely used in low-resources settings [7, 8] as a potential solution to maximize health providers' efficiency, health outcomes[9, 10, 11] and improve service utilization[12]. Common areas of application of mHealth tools include point-of-care decision-making support; provider-to-provider communication; and data collection[13, 14]. Though mHealth interventions are well received by healthcare providers[6, 16] information about their effectiveness with regards to patient outcomes is limited[5, 7, 17].

Many interventions on the use of mHealth for improving maternal and newborns' health outcomes in sub-Saharan Africa mainly focused on timely access to health facilities including reminders for antenatal appointments and referrals of mothers[18]. Few mHealth applications are addressing quality service delivery with the main focus on

clinical decision support in order to improve maternal and newborns outcomes[19]. The Safe Delivery mHealth Application (SDA) is one of the recent mHealth applications (loaded in smartphones) which avails BEmONC clinical guidelines to support nurses and midwives' clinical decisions[20].

Rwanda, a sub-Saharan African country, reports high maternal and neonatal deaths. In 2015, Rwanda's maternal mortality was estimated at 290 deaths per 100000 live births and its neonatal mortality rate was 20 deaths per 1000 live births, respectively[21] despite 89,8% of deliveries taking place in healthcare facilities attended by health professionals [20, 21]. Common causes of these deaths are preventable including postpartum hemorrhage (71.6%) and newborn asphyxia and its complications (36.7%)[24]. Challenges faced by healthcare providers include poor access to clinical guidelines and the lack of timely response to pregnancy complications during delivery care[25]. It is in this context that a mHealth application - a clinical decision support tool (SDA) to facilitate easy access to maternal and neonatal guidelines for routine and emergency obstetric and neonatal care in Rwanda was introduced. This study assessed the effects of the SDA on basic emergency obstetric and newborn care (BEmONC) outcomes for the most frequent delivery-related complications of postpartum haemorrhage (PPH) and newborn asphyxia in Rwanda.

Methods

Study design

This was a quasi-experimental study done over a 14-month period. The study was conducted in three phases. The first phase was the pre-SDA intervention baseline study over a period of six months (February 2019 - July 2019). During this phase, a cross-sectional study was conducted, using a record review, to document maternal and neonatal outcomes; PPH and Apgar score progressions. The second phase, the SDA intervention (August 2019 - September 2019) comprised of the capacity building of nurses and midwives on the usage of the SDA; the SDA provision; the SDA piloting, and the launch of the SDA which marked the start of the SDA implementation. The last phase was the six months of post-SDA intervention (October 2019- March 2020). Phase three encompassed the implementation of the SDA and a cross-sectional study, using a record review to document maternal and neonatal outcomes; PPH and Apgar score progressions at endline.

Study Setting

The study was conducted in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and Nyamata hospital located in the eastern rural province[23]. The two hospitals were selected out of 12 district hospitals in the two provinces because both had a high number of deliveries per year[21]. Compared to other rural-based district hospitals, Nyamata reported the highest maternal and neonatal mortality rates[25].

Study Participants

The study participants included nurses and midwives who used the SDA in both Masaka and Nyamata district hospitals. The inclusion criteria for nurses and midwives were set as follows: having a work experience of at least 6 months in obstetric care and willing to participate in the study. The study sample also included records on neonatal complication cases and PPH cases. The inclusion criteria for the cases of neonatal complications were set as babies born with asphyxia (Apgar score ≤ 7) and were subject to neonatal resuscitation. We excluded preterm births (≤ 36 completed weeks of gestation) and births with major congenital malformations because prematurity and congenital complications other than the newborn asphyxia could influence the newborn outcome after resuscitation[26]. We have also excluded records with missing data on Apgar scores and neonatal outcome. On the

other hand, the inclusion criteria for PPH cases were set as women who had a recorded amount of blood loss more than or equal to 500 mls and were subjected to PPH management. The records with missing data on PPH progression and maternal outcomes were also excluded. The study was conducted in three phases. Phase one, pre-intervention, included 126 cases of newborns asphyxia and 67 cases of PPH. Phase two, intervention, involved 33 midwives and 21 nurses from both Masaka and Nyamata district hospitals. Phase three, post-intervention, comprised 87 cases of newborns asphyxia and 47 cases of PPH. The flowchart in Fig. 1 shows the number of neonatal complication cases and PPH cases considered in the baseline group (before the introduction of SDA) and the endline group (after SDA).

Description of the intervention: Implementation of the Safe Delivery mhealth Application (SDA)

The SDA is a smartphone application developed by the Maternity Foundation, Copenhagen University, and the University of Southern Denmark. It is designed to support nurses and midwives in clinical decision making, by providing them with instant access to evidence-based BEmONC clinical guidelines and a selection of essential preventive protocols in a user-friendly format. The content of the SDA is primarily based on WHO clinical BEmONC guidelines and has been validated by an international group of global health experts[27]. The SDA contains easy to understand animated instruction videos, action cards, essential drugs lists with their indications, practical procedures guidelines, and a learning platform[28]. All features and functions in the SDA are designed for low-literacy and low-income settings and work offline once downloaded. It can thus, be adapted to local contexts and policies. The SDA can be downloaded free of charge for iPhone at https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en.

Each of the study hospitals (Masaka and Nyamata) was allocated three smartphones, with pre-installed English and French versions of the SDA. The nurses and midwives in both hospitals received an explanation of the nature and purpose of the research and half-day training session on the use of the SDA. The majority of participants have downloaded the SDA on their personal smartphones during the intervention. The training session encompassed: an introduction to the research project; an overview of the SDA development and global outreach; description of the SDA features and modules; and hands-on practice on using the SDA as a job-aid and as a learning tool. This was followed by the six months' intervention period, during which nurses and midwives provided BEmONC services with the assistance of the SDA installed on their personal smartphones or the smartphones provided by the researcher. During this period, the provided six smartphones were made available to the team on duty at all times for use as a backup in case the participants experienced problems with their own smartphones. Nurses and midwives were expected to use the SDA as often as they wished. The intervention also entailed two visits per week by two research assistants to each of the study hospitals. During the visits, the research assistants monitored the SDA use by nurses and midwives.

Data collection

Data extraction forms were used to retrieve information on all cases of PPH and neonatal complications recorded in delivery registers. These were extracted and reviewed six months' pre-SDA intervention and six months' post-SDA intervention. The delivery registers contain information on obstetric and neonatal care including the Apgar scores and PPH progressions following neonatal resuscitation and PPH management. Newborn deaths or admission to the neonatal intensive care unit (NICU) or to neonatologist's service due to an unstable outcome (Apgar score < 7) after neonatal resuscitation was used as the primary outcome measure to determine the failure of neonatal resuscitation.

The mothers' referral to a higher-level facility (referral hospital) following an unstable outcome (persistent bleeding) after PPH management was considered as the primary outcome to measure the failure of PPH management at the district hospital. On the newborn side, we obtained data on Apgar scores progression and neonatal outcome following 10 minutes' neonatal resuscitation before and after the use of the SDA. While on the mother's side, we obtained data on maternal outcomes following PPH management before and after the use of the SDA.

Ethics approval

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Permission has been granted by the hospitals.

Statistical analysis

The data were checked for errors and exported from Microsoft Excel (Microsoft Corporation) to Stata version 16 (StataCorp LLC) for cleaning and analysis. Descriptive summary statistics were computed on data including the hospital, age of the mother at childbirth, the weight of the newborn at birth, sex of the newborn, mode of delivery, the leading clinician during delivery, Apgar scores at 1, 5 and 10 minutes and the resuscitation action taken for the newborns. For the maternal outcome, descriptive statistics included the hospital, age of the mother at delivery, gestational age in weeks, Mode of delivery, the leading clinician during delivery, Blood loss in milliliters, causes of PPH, the resuscitation action taken, mother outcome and cause of maternal death if dead. Further, the neonatal outcomes and maternal outcomes were compared at baseline and endline using Fisher's exact test. significance level was set at $p < 0.05$.

Results

Background Characteristics

Cases of newborns asphyxia

The analysis included 126 cases of newborns asphyxia in the baseline and 87 in endline groups over the study period. Table 1 shows that the majority of cases were from Masaka district hospital in the baseline group (54.76%) while in the endline group more cases were from Nyamata district hospital (56.32%). There were more male newborns for the baseline group (n = 79, 62.70%) and the endline group (n = 54, 62.07%). The most frequent mode of delivery was the spontaneous vaginal delivery in both the baseline group (n = 77, 61.11%) and the endline groups (n = 45, 51.72%). The leading clinicians during delivery, also in charge of neonatal resuscitation were mainly midwives (n = 71, 56.35%) in the baseline group and (n = 44, 50.57%) in the endline group. The average age of the mother was similar, 28 years and 27 years in the baseline and endline groups, respectively. The average weight of the newborn was similar, 2900 grams, and 2800 grams in the baseline and endline groups, respectively. The average Apgar score at birth was the same, 6/10 in both the baseline and endline groups. However, the average Apgar score after 10 minutes of resuscitation was lower in the baseline group (8/10) than the endline group (9/10). The resuscitation actions taken were mostly dominated by aspiration and ventilation with Ambu bag in both groups, baseline (81.74%), and endline (79.30%). The endline group had higher numbers of newborns with stable outcome after resuscitation (n = 64, 73. 56%) than the baseline group (n = 40, 31. 75%). Overall, the endline group had fewer newborns transferred to NICU or neonatology service (n = 24, 27.59%) than the baseline group (n = 78, 61.90%).

Table 1
Characteristics of study Participants_ Cases of newborns asphyxia (N = 213)

	Baseline n (%)	Endline n (%)
Hospital Affiliation		
Masaka District Hospital	69 (54.76)	38 (43.68)
Nyamata District Hospital	57 (45.24)	49 (56.32)
Gender		
Male	79 (62.70)	54 (62.07)
Female	47 (37.30)	38 (37.97)
Mode of Delivery		
Caesarean Section	49 (38.89)	42 (48.28)
Spontaneous Vaginal Delivery	77 (61.11)	45 (51.72)
Leading Clinician of the Delivery		
Doctor	49 (38.89)	42 (48.28)
Midwife	71 (56.35)	44 (50.57)
Nurse	6 (4.76)	1 (1.15)
Resuscitation Actions		
Aspiration, Ventilation with Ambu bag	103 (81.74)	69 (79.30)
Aspiration, Ventilation, Oxgenotherapy	12 (9.52)	6 (6.90)
CPR, Ventilation, Oxygenation	11 (8.73)	12 (13.80)
Outcome after 10 minutes Resuscitation		
Transferred to NICU or Neonatology Service	78 (61.90)	24 (27.59)
Skin to skin bonding with mother	39 (30.95)	63 (72.41)
Dead	9 (7.14)	0 (0)
Weight of the newborn, grams, Median (IQR)	2900(880)	2800(800)
Mother's age, years, Median (IQR)	28(7)	27(7)
Apgar Scores, Median (IQR)		
At 1 minute	6(2)	6(2)
At 5 minutes	7(2)	7(1)
At 10 minutes	8(2)	9(2)
Abbreviations: %: Weighted percent, IQR: Interquartile range		

Cases of Postpartum haemorrhage (PPH)

The analysis included 114 cases of Post-partum haemorrhage(PPH): 67 in baseline and 47 in endline groups for both Masaka and Nyamata district hospitals over the study period. Table 2 shows that the majority of cases were from Masaka district hospital in the baseline group (53.73%) while in the endline group more cases were from Nyamata district hospital (55.32%). The most frequent mode of delivery was the spontaneous vaginal delivery in both the baseline group (n = 47, 70.15%) and the endline groups (n = 34, 72.34%). The leading clinicians of the delivery, also in charge of PPH management were mainly midwives (n = 36, 53.73%) in the baseline group and (n = 25, 53.19%) in the endline group. The average age of the mother was similar, 28 years in the baseline and endline groups, respectively. The average gestational age was similar, 39 weeks in the baseline and endline groups, respectively. The mean estimated amount of blood loss was 1167.16mls in the baseline group and 1178.72 mls in the endline group. The most frequent cause of PPH was the uterine atony in both the baseline (71.64%) and the endline group (70.21%). The resuscitation actions taken were mostly dominated by administering oxytocin, IV fluids, and blood transfusion in both groups, baseline (37.31%), and endline (55.32%). The endline group had higher numbers of women with stable outcomes after PPH management (n = 44, 93.62%) than the baseline group (n = 55, 77. 61%).Overall, the endline group had less women transferred to referral hospitals after PPH management (n = 3.6, 38%) than the baseline group (n = 13,19.40%).

Table 2
Characteristics of study Participants_ Cases of Post - Partum Haemorrhage (N = 114)

	Baseline n (%)	Endline n (%)
Hospital Affiliation		
Masaka District Hospital	36 (53.73)	21 (44.68)
Nyamata District Hospital	31 (46.27)	26 (55.32)
Mode of Delivery		
Caesarean Section	20 (29.85)	13 (27.66)
Spontaneous Vaginal Delivery	47 (70.15)	34 (72.34)
Leading Clinicians of the Delivery		
Doctor	20 (29.85)	13 (27.66)
Midwife	36 (53.73)	25 (53.19)
Nurse	11 (16.42)	9 (19.15)
Causes of PPH		
Uterine atony	48 (71.64)	33 (70.21)
Cervical tear	11 (16.42)	7 (14.89)
Retention of Placenta	8 (11.94)	7 (14.89)
Resuscitation Actions		
Oxytocin, IV fluids	23 (34.33)	7 (14.89)
Oxytocin, IV fluids, Transfusion	25 (37.31)	26 (55.32)
Repair of tear, IV fluids	11 (16.42)	7 (14.89)
Removal of Placenta, IV fluids	8 (11.94)	7 (14.89)
Maternal outcome after PPH Management		
Transferred to Referral Hospital	13 (19.40)	3 (6.38)
Stable	52 (77.61)	44 (93.62)
Dead	2 (2.99)	0 (0)
Mother's age, years, Median(IQR)	28(5)	28(5)
Gestational age, weeks, Median(IQR)	39(0)	39(0)
Blood loss in Mls, Mean (SD)	1167.16 (276.55)	1178.72 (257.02)
Abbreviations: % : Weighted percent, IQR: Interquartile range, SD: Standard deviation		

Pre-Post Differences in Newborns outcomes following neonatal resuscitation

We found a statistically significant association between the SDA intervention and newborns' outcomes following neonatal resuscitation, 6 months after baseline (Table 3). Among 213 cases of newborns complications who were included in the study, stable outcome following neonatal resuscitation was recorded in 30.95% and 72.41% at baseline and endline respectively. Transferred (unstable) newborns were 61.90% and 27.59% at baseline and endline respectively. While death following neonatal resuscitation appeared in 7.14% for the baseline group only. No death was recorded in the endline group. There were significant differences in the proportions values of the three categories of newborns' outcomes (stable, transferred, and dead) following neonatal resuscitation at baseline, and at endline, the Fisher's exact test p-value was 0.000.

Table 3

Newborns Outcomes following neonatal Resuscitation (N=213)

	Before SDA (N = 126), n(Wt.%)	After SDA(N = 87), n(Wt.%)	P-Value (Fisher' exact test)
Newborns Outcome			
Stable	39 (30.95)	63 (72.41%)	P(Fisher) = 0.000
Unstable(Transferred)	78 (61.90)	24 (27.59)	
Dead	9 (7.14)	0 (0.00)	
Abbreviations: Wt.%: Weighted percent			

Pre-Post Differences in Maternal outcomes following PPH Management

We found a statistically significant association between the SDA intervention and maternal' outcomes following PPH management, 6 months after baseline (Table 4). Among 114 cases of PPH who took part in the study, stable outcome following PPH management was recorded in 77.61% and 93.62% at baseline and endline respectively. Transferred (unstable) women were 19.40% and 6.38% at baseline and endline respectively. While death attributed to PPH appeared in 2.99% women for the baseline group only. No death was recorded in the endline group. There were slight differences in the proportions values of the three categories of maternal' outcomes (stable, transferred, and dead) following PPH management at baseline, and at endline, the Fisher's exact test p-value was 0.048.

Table 4

Maternal Outcomes following PPH Management (N=114)

	Before SDA (N = 67), n(Wt.%)	After SDA(N = 47), n(Wt.%)	P-Value (Fisher' exact test)
Maternal outcome			
Stable	52 (77.61)	44 (93.62)	P(Fisher) = 0.048
Unstable(Transferred)	13(19.40)	3 (6.38)	
Dead	2 (2.99)	0 (0.00)	
Abbreviations: Wt.%: Weighted percent			

Discussion

Main findings

The current study assessed the effects of the SDA intervention on basic emergency obstetric and newborn care (BEmONC) outcomes for the most frequent complications in Rwanda; post-partum haemorrhage(PPH) and newborn asphyxia and its complications. Apgar scores and PPH progressions were considered in the investigation of newborn and maternal outcomes following neonatal resuscitation and PPH management.

Our study showed that the 6-month long 'SDA intervention' had beneficial effects particularly for supporting nurses and midwives' decisions for neonatal resuscitation and PPH management in both Masaka and Nyamata district hospitals. The use of the SDA was significantly associated with positive maternal and newborns' outcomes following PPH management and neonatal resuscitation, 6 months after baseline. The after intervention groups had a considerably lower occurrence of referrals for both the newborns and the mothers. There were more stable newborn outcomes following neonatal resuscitation and more stable maternal outcomes following PPH management in the after intervention groups compared with the before intervention groups. Also, the few deaths following neonatal resuscitation and PPH management were only recorded in the before intervention groups.

Comparison with other studies

As was noted in the present study, Lund et al.[28, 29] also reported a significant effect of the use of mhealth technologies and the SDA particularly on skilled birth attendants in terms of significantly increased knowledge and skill scores in neonatal resuscitation in Ethiopia[28]. And, a significant reduction in perinatal mortality in Zanzibar[29]. Also, Tamrat et al.[30] in his systematic review which analysed mHealth interventions in maternal and newborn Health Programs and their outcomes around the world reported that the integration of mobile health for prenatal and newborn health services has demonstrated positive outcomes [30]. This could be explained by the fact that mhealth applications have the potentiality to put relevant and reliable healthcare information into the hands of healthcare workers thus helping them in the management of neonatal cases. But also, that health professionals need continuous access to updated healthcare information and clinical guidelines to support their decision making during practices. The same opinion was reported in a similar study done by Grol et al(2003) about the effective implementation of mhealth interventions [31].

Maternal outcome following PPH management was another significant predictor in the present study. Our findings are in agreement with previous literature on this topic. A 2017 systematic review on mHealth interventions in low-

income countries to address maternal health demonstrated good promise for the use of mHealth interventions in maternal health[32]. This may be because mHealth interventions have been tested in a variety of health services delivery including decision support and clinical management[33–35]. These studies showed promising findings for the mhealth technology in general and for maternal healthcare services in particular. A similar review which identified 51 RCTs, documented that more than half (n = 29) of these studies had positive results supporting the effectiveness of mHealth interventions[36]. However, there was still a need for more evidence and higher-quality research in this field. The current study adds to much-needed evidence as to how a mHealth-based clinical decision support tool functioned in a low-resource setting and its linkage with maternal' and neonatal' outcomes.

Limitations

Though our study documents important patterns of use of a mHealth to inform clinical decisions, the kind and quantity of information accessed for the care of individual patients are undetermined in the current study. Also, nurses and midwives may have consulted other sources rather than the SDA to inform their decision-making during the intervention. Although this limitation is inherent in the design of the study, the current study provides much-needed insights as to how a mHealth-based clinical decision support tool functioned in a low-resource setting.

Conclusion

The use of the SDA supported nurses and midwives in the management of PPH and neonatal resuscitation thus improved maternal and neonatal outcomes, six months after baseline. mHealth interventions that focus on the clinical decision support process in obstetric and newborn care may contribute to improved services delivery and should be considered by policymakers in resource-limited settings, like Rwanda. Overall, there is limited evidence on the effects of mHealth interventions on a large scale and further researches are necessary to draw holistic conclusions, particularly for developing countries within the field of maternal and newborn care.

List Of Abbreviations

BEmONC: Basic Emergency Obstetric and Newborn Care; LMICs: Low- and middle-income countries; mHealth: Mobile Health, SDA: Safe Delivery mhealth Application; PPH: Post-Partum Hemorrhage, NR: Neonatal Resuscitation; SBA: Skilled Birth Attendants, WHO: World Health Organisation; UNICEF: United Nations International Children's Emergency Fund; UNFPA: United Nations Population Fund.

Declarations

Authors' contributions

AN, LI, MN, and DNC were involved in the conception and design of the study. AN drafted the manuscript. LI, MN, and DNC reviewed the manuscript. All authors read and approved the final manuscript.

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Competing interests

None declared.

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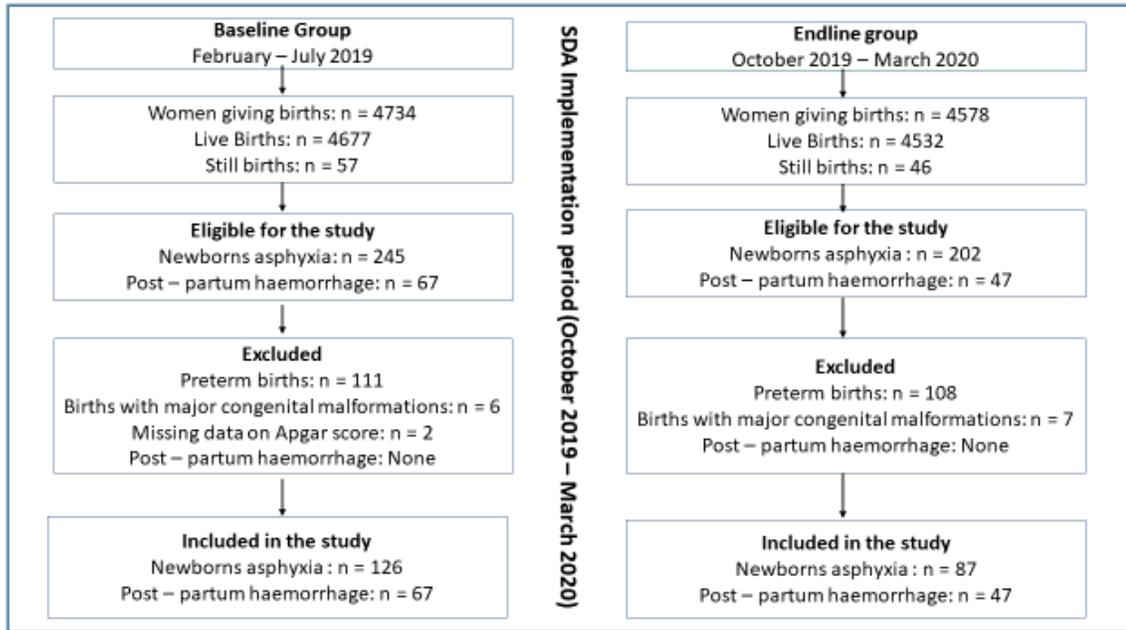
Figures

Figure 1

Records review flow chart